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# AN INTEGRATED KNOWLEDGE FRAMEWORK FOR INDUSTRIAL PRODUCT-COSTING

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# An Integrated Knowledge Framework for Industrial Product-Costing

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# Abstract

Product-costing is recognised as being erroneous. This thesis examined the background to this inaccuracy through the undertaking of case studies in a range of industrial contexts, in particular the automotive and aerospace industries. Initial research and analysis of the costing literature identified distinctive engineering and economic perspectives underpinning the process. The thesis argues partly that it is the emphasis on these positions and the inadequate attention to human and cultural factors, such as communication, that have contributed to deficient costing processes. To address this a second phase of research was undertaken along side an analysis of human factors literature, to establish where and how qualitative changes might be made to improve organisational product-costing.

Social and environmental issues were observed as being ubiquitous to the costing process generically; and subsequently needed to be considered on an interdependent basis alongside the physical, explicit components. The thesis presents an integrated cost-knowledge framework (ICKF), derived from the combined findings of industrial examinations, coupled with cost and cultural literatures. The research phases originally produced six main themes, which referred to the primary concerns correlated to the process, both physically and humanistically; they included issues surrounding: Resource, Data / Information, Comprehension and Training needs. These cost-themes directly related to the cost-knowledge framework. The latter comprises of eight identified knowledge types, recognised to be essential in compiling a cost; all of which are interlinked, incorporating: Costing Process knowledge; knowledge of Design, Materials, Risk, the Product, and Manufacturing Process, all in juxtaposition with Communication and Organisational Cultural knowledge.

Hence the themes and knowledge framework focused on an amalgamated costing perception, of both the implicit and explicit aspects of the process. This lead to a question of the lateral dissemination of this Industrial Integrated Cost-Knowledge Framework, ICKF, via proposed cost-focused training. In order to develop costing in this broader, inclusive context the training was designed to tackle softer, 'social' and 'human issues' by incorporating them within the programme, fused with the tangible, technical components of the cost-process. With research participation constituting 25 international organisations, the industrial implementation of the ICKF via targeted, specifically formulated training will assist in addressing the challenges currently experienced within the process of product-costing.

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***….But I survived it!***

# Author Publications

Mishra, K., Roy, R., Souchouorkov, P., Taratoukhine, V.,
*"Knowledge Reuse: CE$^2$-Focused Training""*
4th International Conference on Practical Aspects of Knowledge Management,
PAKM, Vol. 4, 2-3 Dec. 2002, Vienna, Austria; PAKM 2002, Springer,
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Mishra, K., Roy, R., Souchouorkov, P., Taratoukhine, V.,
*Knowledge in the Commercial and Engineering Activities within Cost* Estimating
Concurrent Engineering 2002, CE2002 July 28th -31st 2002,
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Roy, R., Mishra, K., Souchouorkov, P.
*'Interface Between Commercial and Engineering Activities in Cost Estimating: Industry Practice'*
Third Joint Annual ISPA / SCEA International Conference, Vol. 3; 12th
June - 15th June 2001, USA.

Souchouorkov, P., Roy, R., Mishra, K.
*"Data and Information in Cost Estimating",*
Conference of The Society of Cost Estimating & Analysis, Scottsdale, Arizona,
June 11-14, pp. 44-45, 2002.

# List of Acronyms

| | |
|---|---|
| 9 / 11 | -Denotes a terrorist attack which took place in New York, America, on 11th September 2001; consequently impacting on global economics. |
| AACE | -The Association for the Advancement of Cost Engineering International |
| (AACE) | -American Association of Cost Engineers) |
| ABC | -Activity Based Costing |
| ABS | -Affordable Business Structure |
| AIP | -Affordable Integrated Program |
| AS-IS | -Examination /description of a current process: - How, or AS it IS done, now, at the time of enquiry. |
| ASTD | -American Society for Training and Development |
| BAE | -British Aerospace (formerly BAe Systems) |
| BOF | -Bought Out Finish |
| BOI | -Bought Out Items |
| BoM | -Bill of Material |
| BoP | -Bought out Parts |
| BoW | -Body in White |
| BTT | -Bid To Tender |
| B2B | -Business-to-Business |
| CAL | -Computer-Aided Learning |
| CAPE | -Computer Aided Parts Estimating |
| CBR | -Case Based Reasoning |
| CBT | -Computer Based Training tool |
| CCRT | -Commodity Cost Reduction Team |
| CDS | -Conceptual Design Stage |
| CE | -Cost Estimating / Cost Engineering |
| (CE | -Concurrent Engineering) |
| CER | -Cost Estimating Relationships |
| CFB | -Customer Focused Business |
| C.I. | -Cognitive Interview |
| CM | -Cost Management |
| CP | -Costing Practitioner / Costing Process |
| CT | -Costing Themes |
| CT&D | -Corporate Training and Development |
| DASA | -Defence Analytical Services and Advice Association |
| DFM | -Design For Manufacture |
| DIF | -Difficulty, Importance, Frequency analysis |
| DoD | -Department of Defence |
| DTC | -Design To Cost |
| EDP | -Electronic Data Processing |
| E-Commerce | -Electronic Commerce |
| ERF | -Estimate Request Form |

| | |
|---|---|
| (ERF | -Exchange Rate Forecast) |
| ETS | -European Turnaround structure (ford) |
| EVCS | -European Vehicle Costing System |
| FBC | -Feature based costing |
| FEP | -Field Engineering Programme |
| FIR | -Finance Information Request |
| FPDT | -Ford Product Development Team |
| FPDS | -Ford Product Development System |
| GRIMM | -Global Rate and Information for Machines and Materials |
| H.F. | -Human Factors |
| 5WH | -5W's and H is the KC i.e. How, Why, Where, When Who, What |
| ICE | -Independent Cost Estimates |
| ICKF | -Industrial (Integrated) Cost-Knowledge Framework |
| IDV | -Individualism |
| IPT | -Integrated Product Team |
| IRF | -Information Request Form |
| ISD | -Instructional Systems development |
| ISPA | -International Society for Parametric Analysis |
| IT | -Information Technology |
| ITT | -Invitation To Tender |
| JIT | -Just In Time |
| JLR | -Jaguar Land Rover |
| KA | -Knowledge Acquisition |
| KB | -Knowledge Bases |
| KBS | -Knowledge Based System |
| KARL | -Knowledge Acquisition and Representation Language |
| KC | -Knowledge Category |
| KE | -Knowledge Elicitation |
| KIF | -Knowledge Interchange Format |
| KM | -Knowledge Management |
| KTs | -Knowledge Types |
| LCC | -Life Cycle Costing |
| LOE | -Level of Effort |
| LSD | -Learning Systems development |
| LTO | -Long Term Orientation |
| MAS | -Masculinity |
| MOD | -Ministry of Defence |
| MP | -Manufacturing Process |
| MVC | -Model View Controller |
| NDPC | -Non design Purchasing Commitment |
| NDPE | -Non-design Purchasing Equipment |
| NTC | -Nissan Technical Centre |
| OEM | -Original Equipment Manufacturer |

| | |
|---|---|
| OL | -Organisational Learning |
| P1 | -Phase 1 of research |
| P2 | -Phase 2 of research |
| p.a. | -Per Annum |
| PC | -Product-Costing |
| (PC | -Parametric Costing) |
| PCE | -Parametric Cost Estimating |
| PDI | -Power Distance Index |
| PSM | -Problem Solving Methods |
| PST | -Product-Supplier Team |
| PVT's | -Product Vehicle Teams |
| QA | -Quality Assurance |
| QAF | -Quotation Analysis Form |
| QCLDM | -Quality, Cost Logistic, Development, Management |
| QMF | -Query Manage Form |
| R&D | -Research and Development |
| RFI | -Request For Information form |
| RFP | -Request For Proposal |
| RFQ | -Request for Quotation |
| ROI | -Return On Investment |
| ROM | -Rough Order of Magnitude |
| ROT | -Rule Of Thumb |
| SC | -Subcontract |
| SCEA | -Society for Cost Estimating and Analysis. |
| SECI | -Socialisation, Externalisation, Combination and Internalisation |
| SG&A | -Scrap, General and Administration |
| SME | -Small and Medium Enterprises |
| SoP | -Start of Production |
| SoW | -Statement of Work |
| SPS | -Special Procurement Service |
| SSI | -Semi-Structured Interviews |
| SWN | -Sitting With Nellie (observation / training technique) |
| T5 | -Terminal 5, BAA |
| T& D | -Training and Development |
| TINA | -Truth in Negotiations Act |
| TNA | -Training Needs Analysis |
| TOT | -Transfer of Training |
| UAI | -Uncertainty Avoidance Index |
| U.K. | -United Kingdom; also UK |
| U.S.A. | -United States of America; also U.S. |
| VEVA | -Value Engineering, Value Analysis |
| VFM | -Value for Money |
| WBS | -Work Breakdown Structure |

# List of Contents

## Chapter 8: Implementation of the Industrial Cost-Knowledge Framework ..283

# List Of Figures

# List Of Tables

# Chapter 1:

## The Context & Challenges of Industrial Product-Costing

*".. cost estimating is the act of predetermining the realistic cost of an item or activity that ensures a normal profit.…an integral part of any business. By asking the question "What will it cost me?" the estimator is attempting to determine the worth of the product or the amount of outlay the company must incur ..to develop or produce it"*

[Stewart et al., 1995, Cost Estimators Reference Manual, p648]

Cost assessment is performed in peoples' lives routinely, undertaken through tasks such as domestic, household budgeting and the determination of available income for activities such as shopping. Thus the process of costing on a fundamental level involves having an awareness of the potential cost of products considered for acquisition, against knowing the limit of funds accessible for expenditure. Similarly such a process is required in order to estimate the cost of products on an industrial level.

Within industry every project requires a form of costing both prior to commencement, and throughout product-lifecycle, refer to Figure 1.1. This costing assessment can be of various complexities, from a top level expert evaluation, ROM (rough order of magnitude) to a thorough dissection of each perceived task with all related costs identified and accounted for in the estimated cost e.g. detailed costing, which produces results with high-levels of confidence; see chapter 3 for techniques of costing. Either way, whether ballpark or detailed approach an idea of the costs involved for each activity as well as the estimated cost-total needs to be established in order to ascertain the feasibility of success for embarking on the project. In other words, the pre-cost exercises establish whether the organisation can afford to embark on, or have the capability of producing the goods in question, make changes, and / or upgrade models [Stewart et al, 1995]. Though the need for this information may seem evident, it is required to various levels of accuracy or confidence, depending on the product, the phase and/or intent for cost assessment, the industry, and so forth. Due to the potential range of application of the cost e.g. it may be used for bid compilation, VFM (value for money) / supplier cost checks, change-management exercises; there are a number of techniques which may be performed to derive them. These are dependant on the information available, time and resource constraints, required levels of confidence, and applications, (see chapter 3).

## 1.1 Research Terminology

There are major inconsistencies of terminology in the costing process, which often cause confusion. This applies across industries, within industries and even occasionally within organisations. The lack of standardisation is also apparent at a very high level, namely the title by which the practitioners are referred to. Cost-experts across industries and organisations hold ambiguous, contrasting titles, often for fulfilling the same or similar roles: These titles can also be contradictory. For example it has been observed that experts under the title of 'cost estimator' often work primarily within engineering domains. Similarly, the 'cost engineer' title is also misleading, as many of the experts examined for this study were involved with extensive commercial, fiscal issues within the costing process: See chapters 3 and 4 for further observation (literature and industrial-based, respectively) on cost-terminology.

The research observed in its early phases that there is not one standard title for the costing process and practitioners across industries and organisations. Therefore throughout this thesis, the role of the expert performing any costing activity and process will be referred to as the cost-practitioner, where such a generic term is applicable. If the reference is more specific, either to specialisation (leaning more towards economic or purchase) or organisational–specific then the appropriate term will be applied i.e. (cost) estimator, engineer or manager. Similarly the commercial and engineering activities within costing will be referred to as the costing or cost process / product-costing throughout this thesis. This term will generically cover all the cost-related functions within each organisation examined throughout the research.

## 1.2 Application of Industrial Costing:

Figure 1.1 illustrates a typical lifecycle of an industrial project for a manufactured product; it highlights the phases involved across LCC (life-cycle costing), from the conceptual-design stage, to in-life service / maintenance, and disposal / recycle stages. Hence within aerospace and automotive manufacturing industries lengthy, complex projects often need product-costing at various stages and for a range of purposes; for example:

- General change management: Redesign / modification for 'refresher' models; e.g. for upgraded or new vehicles, commonly advanced products are based on an established, existing design.
- Assessment of supplier quotation: Used in supplier-selection. Mainly to check the validity of cost-quotes / invoices once integrative working has commenced, determining where 'top-loading' may occur, e.g. such as effectively charging twice for the same labour in some subtle way; increasing labour hours or material-costs. General cost-cutting through the identification of supplier 'tricks,' covertly incorporated within the quotes; see chapters 6 for industrial cost examination and themes; chapter 7 for identified cost-knowledge, and Figure 7.10.
- Bid compilation: The derivation of the costs involved to produce a product, compiled for submission to potential customer (when attempting to win contracts). Within large organisations as in the aerospace industry this can be a major undertaking, with numerous areas of costs to compile.

- Conceptual-design stage costing: Project budgets are often set by the costs derived at the early phases, make / buy options are considered, and even decisions as to the feasibility of embarking on the project at all are based on such cost-results.

With regards to the final point, conceptual-phase costing, in order to do this the overall artefact in conjunction with each component which comprises the product, needs to be accounted for and assessed. Within large manufacturing industries this tends to be a complex activity as products, for instance in aerospace, are vast with multiple areas of consideration within the cost analysis. Therefore it is preferable to have knowledge of the product on commencement of this process, as a level of engineering-knowledge related to manufacturing, design, and production is invaluable in assessing the cost of items. Derivation of costs however, additionally involves knowledge of economic functions, application of which is essential (see chapter 7 for discussion on the essential knowledge types within costing). This amalgamation of expertise, both commercial and technical, is not just applicable to conceptual design costs but throughout the cost-process, as Figure 1.1 illustrates.

Within the industries examined (predominantly automotive and aeronautic), product-costing has been described as something of a 'black art'. Though this reference implies a level of tacit-knowledge application, it is still predominantly perceived as an explicit, technical activity tending to be classified within either the engineering or financial company functions. Costing is fundamentally composed of historical data applied with implicit judgements, expertise and informed predictions compiled to formulate the estimated future costs. The principal knowledge requirements thought to be implemented within the process are therefore that of engineering / technical, and financial / commercial. A major question which this thesis addresses is whether these perspectives on costing are adequate.

## 1.3 Problem Domain:

Product-costing is a knowledge-rich process; with the contributions towards the development of cost being derived from two fundamentally different disciplines: Commercial (or economic) and Engineering, [Roy et. al., 2001]. The cost aspects of these two areas need to be used concurrently to produce a cost estimate. This is due to the necessity of the costing-practitioner being able to evaluate the cost of a product. The former highlights two words: 'Cost' and 'product'. This implies that the practitioner requires knowledge that allows cost to be assessed from every angle including direct engineering product-knowledge and to the indirect more commercial (or economic) costs, [Mishra et. al., 2002a].

An initial approach towards this research was via these tangible explicit domains: The two disciplines are required to work in an integrated manner in order to disseminate a lateral transfer of costing knowledge and information. However it was noted within industry that product-costing was not being performed as effectively as it could be i.e. within some of the large manufacturing corporations in particular, projects were running years over schedule and excessively over budget. The perception was that this situation was caused by a lack of integrated working between the relevant contributors towards the cost, namely the monetary areas and the technical ones.

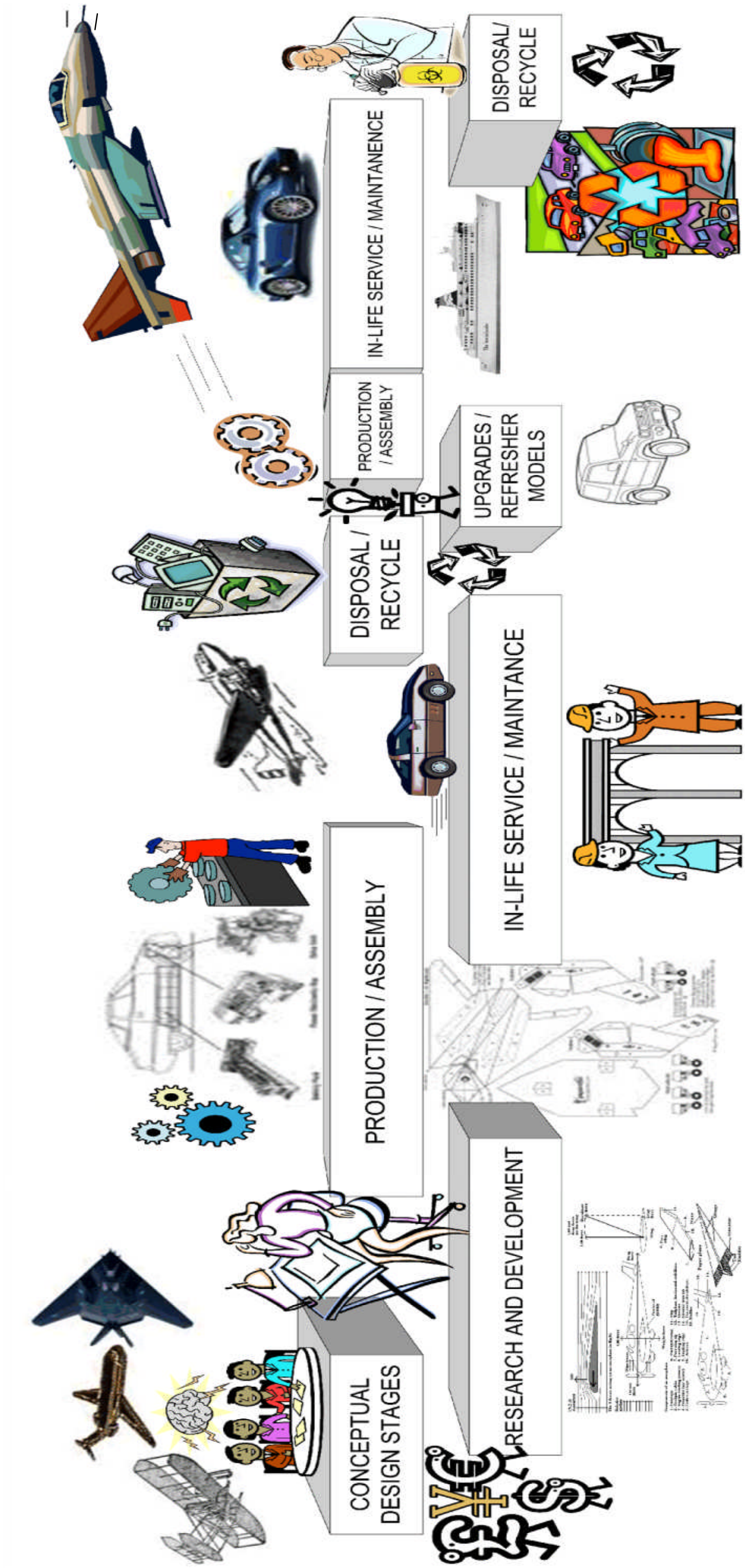



Figure 1.1: A Guide to the Phases of Industrial Projects

In addition to the knowledge-transfer challenges were the issues related to a misunderstanding of cross-disciplinary roles. The perception of industrial-costing has been observed as being a combination of technical activities, plus a 'black art'. This indicates that although it is partly compiled via physical (measurable) inputs, it has significant intangible elements which contribute towards the output. The fact that costing is referred to as an unknown process to a degree implies that the implicit elements are recognised as a substantial contributor, at least to external observers (such as the interacting disciplines, i.e. purchase, and the engineering functions), and in a technical environment can result in a perceived lack of credibility. As intangible elements can be dismissed, the situation may arise where the value of the costing process is diminished due to the perception that it is formulated via indefinable means. With this belief, interacting departments may not transfer the data and information that costing requires; they may not even value the output of the costing process. Formalisation of the process will result in greater visibility of how the costs are derived; therefore confidence levels will increase.

When the intangible elements relating to costing are not acknowledged and addressed the process cannot be effectively formalised, structured and improved. Enhancements to the process can only be made when the complete system is tackled, addressing any challenges within the current process, along with the manner in which the contributing disciplines input into it: This will enhance the integrative working process. An exploratory study of the costing practices within a number of industries was undertaken in order to establish what the current cost-processes were within organisations, and subsequently to identify any difficulties experienced with regards to them, (presented in chapter 4). This thesis will argue that an increase in the quality of costing can only be made when issues such as communication, which are involved in improving the lateral transfer of knowledge are tackled, alongside the pragmatic, technical attributes, such as the use of formalised cost-models as a possible costing-aid. Recognition of the common aspects of the process can be standardised across industries, with the aim of establishing best practice which can be trained and applied across the board (see chapter 8 for cost-training assessments).

### *1.3.1 Integrated Working Practice:*

Industrial product-costing, by nature is a highly interactive activity. In order to cost a product or component, cost data and information needs to be obtained about it; this has to be relayed from the various areas in question, whether this is:

- From the Purchase department (or Buyer /Procurement) regarding supplier information;
- Directly from the contractor / supplier-company;
- Occasionally cost information may need to be procured from an OEM /material producer or vendor;
- Financial information to compile a bid or risk assessment may be required from the commercial (economic) functions.
- Input from one of the engineering specialities:
    - Including any of the product-specific focuses such as: Engine (specific types per vehicle range); exterior / interior trim; avionics /hydraulics /electrics: One-off product line focus; repeat lines, etc;
    - Design (including change-management, for interactive development);
    - Research and development (prototype /designer drawing, etc);
    - Tear-down (or any other organisation /industry-dependent related function).

Evidently for costs to be successfully derived, a high level of integrated working is required from an array of internal disciplines and even external bodies, (see chapter 3 for the literary discussion of the costing process, and chapter 4 for the industrial overview). However, even the culture between different departments within the same organisations can differ, hindering the necessary interaction between them; let alone interacting companies as suppliers; global differences, etc. When collaborative working and interaction is required within such areas, confusion is prevalent; from the terminology and language each discipline uses (see Section 1.1 and chapters 3 and 4), through to the lack of understanding as to why the others role is of importance / how it affects the overall product-costing process. For instance finance and engineering are widely accepted as disparate practices, with different cultures that are not always complimentary: Though the knowledge and information used within both areas contributes to costing the product. In order for such integrated working to be successful, adequate communication is crucial between the functions with a knowledge-base relevant to the cost-process. Updated information being communicated by each department throughout the life-cycle of the project is essential, as it impacts for instance, on the total quoted figures used to establish the costs presented to potential customers for bid compilation.

To avoid miscommunication between the different disciplines that contribute to the costs, effective systems of interaction need to be implemented. Personal interactions are often effective but may be impractical in the present-day operating environment of globalised markets. Consideration from a systemic view of the costing process can establish effective alternative communicative techniques, which need to be addressed. In other words, an examination of the whole system, both of costing, and the environment in which it is performed will identify contributors and reveal linkages between the working departments.

With consideration paid to these requirements the process of industrial costing has been observed as not utilising its expertise to capacity. Unacceptably low confidence levels have resulted in overruns in budget and time. Despite product-costing being traditionally perceived as technically-based, compiled of figures structured through expert-judgment and factual historical-data, the difficulties were not resultant from any tangible cause. On the contrary, as highlighted the challenges were derived from a lack of integrated working practice, which on closer examination (see chapters 4 and 6) seemed to be based on the intangible or 'softer' issues within the process (discussed theoretically within chapter 5). These were principally a lack of fluid communication, fuelled by inadequate understanding between the corresponding functions, primarily that of economic and engineering. The environment in which the costing process was being conducted impacted heavily on the outcome, and if not considered, the results could be deficient. For instance, if the culture was oriented towards autonomous working practices then a lack of interaction could result with the subsequent procurement of information being problematic. If diverse cultures are working concurrently, with an insufficient knowledge / understanding of each others' function, then an isolated or 'over-the-wall' type mentality may be adopted by the workforce. This results in a lack of trust, limited interaction and general clash of cultures: When aspects of product-costing relies on integrated activity, and the quality of the cost has been said to only be as accurate as the data inputted to it, such stifled transactions are clearly detrimental for the resultant costs.

The following are key points of consideration within the costing domain, that underpin the need for the research within this area:

- A fundamental challenge of costing lies in the inadequacy of examining the physical process in isolation: The interaction between the contributors, i.e. the functions that inputted information and data, of which the costs were essentially compiled from, need to be addressed and the context in which costing was performed considered more comprehensively.

- The process of costing needs to be effective within an ever expanding global market. Though the issues of internal culture and communications are pressing, the external factors which can impact on the process also require attention. For instance within an international corporation, many decisions regarding costing may be made outside the country, let alone the local branch-levels. If costing is not understood or appreciated by the decision-makers, the effect of their uninformed guidelines and regulations may greatly influence how the process may be performed. Consideration towards overseas practices, other branches of the same company, or external interactions and their priorities and modes of conduct, is essential.

A proportion of the research presented in this thesis is based on data collected from within an industrial research-project which focused on the conceptual design phases of products. However as costing has been shown to be performed more or less throughout the lifecycle of a project and for a variety of reasons (see Figure 1.1) this research examines the process holistically. From the early phases, to change management, product disposal (particularly with environmental factors influencing the ways in which this should be carried out) as well as design, development, productivity and in-life service.

The phases leading up to the development of the cost-knowledge framework were part of an industrially funded project to improve the accuracy of product-costing, and decrease the time it took to produce results with high levels of confidence. The project focused on the aerospace and automotive industries, as it had four industrial sponsors: BAE SYSTEMS, Ford Motor Company, Price Systems, XR Training and Consultancy. The authors role within the project was to identify the costing knowledge-types, KTs (see chapter 6, Tables 6.4 - 6.9 and chapter 7, Figures 7.5, 7.6 and 7.7;  and Table 7.4.), and to explore how these KTs could be more effectively assimilated into the costing process, see chapter 8.

## *1.4 Research:*

The research focused on the manufacturing sectors, principally aerospace and automotive, although a wider range of contexts are also examined to determine how the costing process is conducted generically. This included ascertaining the practices specific to each industry or company observed, and importantly what the similarities were (see chapter 6 for contributor details, listed in Table 6.2). In other words what are the individual elements of industrial product-costing (either industry or organisation-specific) and the commonalities of the process. The latter will establish process norms, with the potential for the foundation of costing standardisation along with the identification and dissemination of best practice; see chapter 8 for the practical implementation of the costing framework developed.

### *1.4.1 Research Aim:*

With regards to the previously described context-domain, in summary, the research aim is:

To develop an integrated knowledge framework for industrial product-costing.

Given the challenges within the costing process, a lack of integrative working between the relevant disciplines and subsequently the lack of a lateral transfer of costing knowledge, the research aims to identify the knowledge that is required in order to integrate the entities which should be interacting throughout the process. This is initiated by identifying the current process, and issues from both a theoretical and practitioner perspective.

The thesis looks at the cost-process as it is currently performed within the exploratory research, i.e. the AS-IS phase, presented within chapter 4. This is undertaken having examined the costing literature (chapter 3). The potential methodologies, along with the most appropriate ones for use throughout this research are discussed in chapter 2, and highlighted in terms of research activity in chapters 4 and 6. The latter presents a more in-depth examination into more targeted areas of costing, leading to a discussion of dissemination of the research findings, for instance via industrial training development, in order to advance the costing-process, (detailed within chapter 8). These are supported by the essential cost knowledge types developed out of the analysis of both field work phases and presented in chapter 7. Figure 1.2 illustrates the structure and flow of the thesis, showing the primary links between each chapter. The aim is met by the implementation of the research objectives, outlined as follows.

### *1.4.2 Research Objectives:*

The way in which the research-aim was achieved is through establishing and undertaking a number of objectives, which were to:

- ✓ Critique theoretical literature and undertake an exploratory study related to current costing practice:
- ✓ Identify the themes within the costing challenges, through cross-industrial organisation examination:
- ✓ Establish a knowledge framework for costing from the juxtaposition of literature surveys with a combination of the exploratory and an in-depth examination of costing behaviour, within a range of industrial contexts:
- ✓ Consider the industrial implementation of the cost-knowledge framework; and consideration of the training implications arising from it and how that may be applied throughout product-costing.

The structure of the thesis that has been introduced in this chapter is presented in Figure 1.2. The next chapter will examine the methodological options for undertaking a study of knowledge in product-costing and will explain why the adopted approach was decided upon.

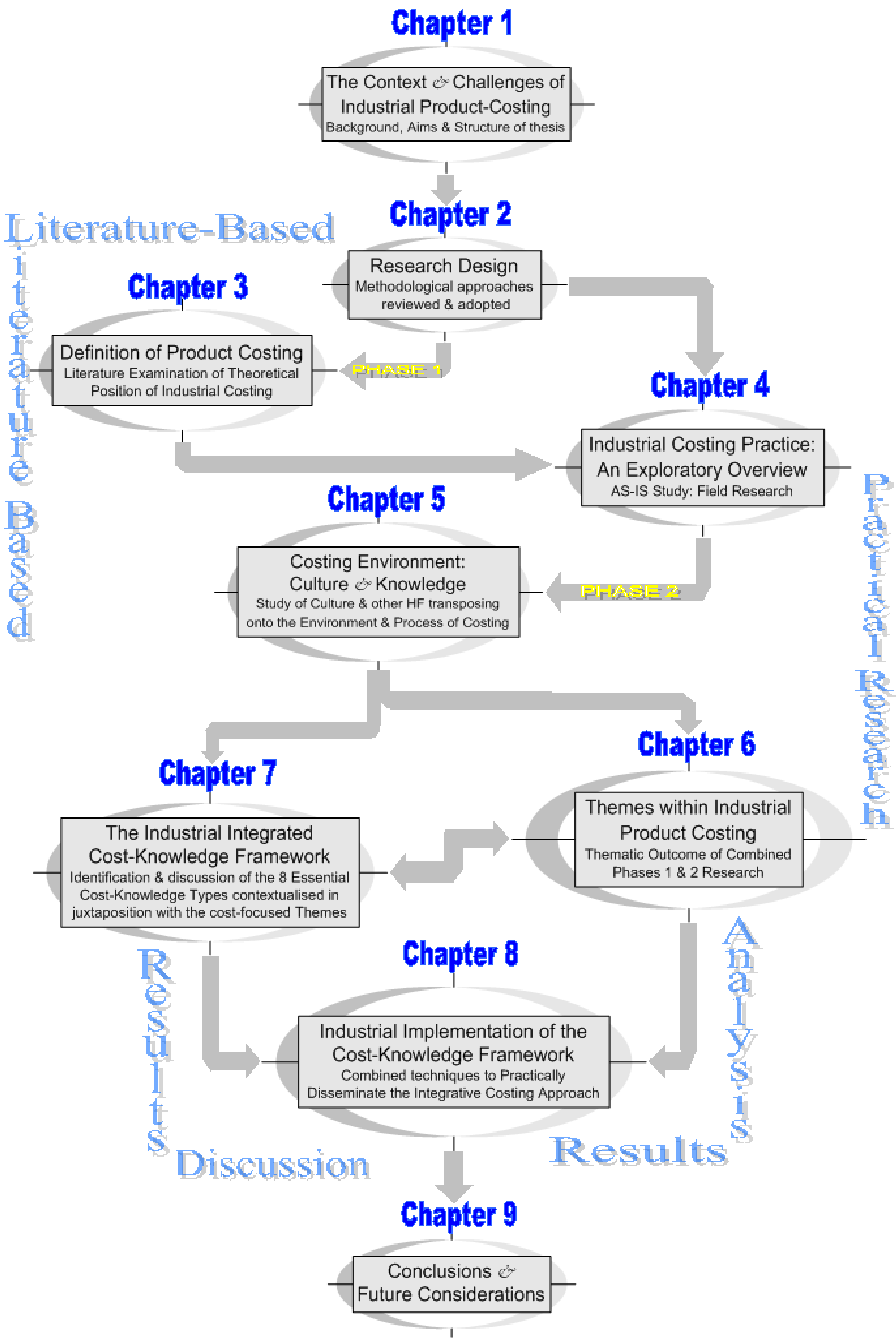
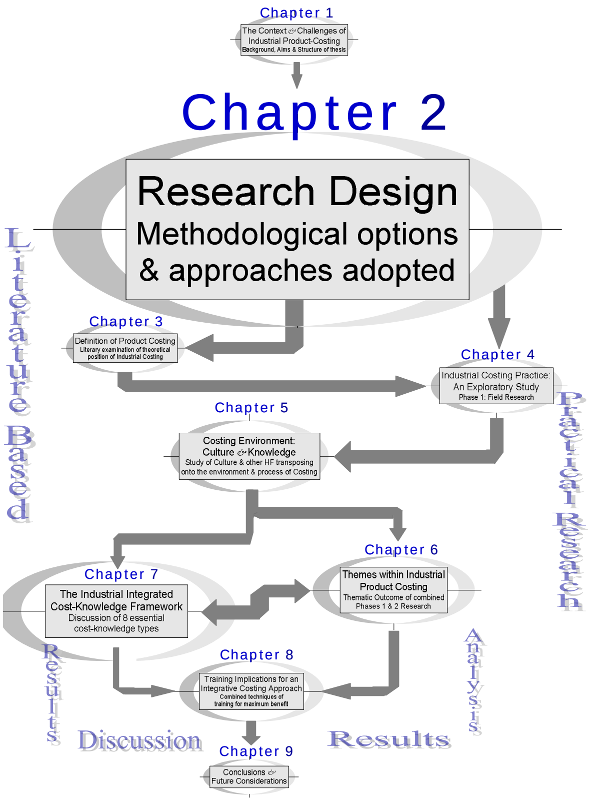



Figure 1.2: Structure of the Thesis

# Chapter 2:
## Research Design




*"If the If the facts don't fit the theory, change the facts"*

[Albert Einstein –Attributed]

The previous chapter introduced the area of product-costing, discussing it generically; whilst touching on aspects of the process which are specific to the different industries examined within this research. The principal question related to this line of pursuit has been outlined as:

Industrial product-costing is currently not producing as accurate results within the required time frames as the level of expertise held within the domain indicates it could.
Why is this?

This chapter presents the methodology used to address this fundamental research question, and the appropriate techniques utilised within the research approach adopted. The methodological options available, and the various techniques which may be used to conduct the methodology are highlighted, within the context of discussion as to which are suitable, and so were used; and which were not, and why.

The practitioner-interaction between and within departments, (and companies), required thorough examination in order to establish best-practice. In order to fulfil these requirements, the methodology had to be able to incorporate industrially interactive activity, to expose the practical, technical issues involved in product-costing. The previous question draws attention to how the integrated working practices of the contributory workforce, as well as tacit, mental workings of the costing practitioners themselves need to be considered when designing this research. Thus, in addition to the pragmatic, explicit areas, there needed to be concurrent investigation into the human integrative techniques applied to the costing process; responses to communicational and comprehension issues, along with investigation into the organisational culture, which often dictated many of the human factors and issues observed.

Although the process of costing is necessarily present in some form or other within every organisation, there is a low volume of documented research regarding the factors (explicit /externally identifiable and tacit /internally implemented) which contribute to the quality of its overall results. The reason for this can be largely explained as being due to the internalised approach in which costing is performed. These elements are often overlooked within a perceived pragmatic domain. Consequently this research needs to be designed to enable it to address the more tacit, subtle contributions towards product-costing, taking into account the informal, unstructured way in which people think. This needs to be considered concurrently with the more structured and overt processes which are loosely applied to this field, the determination of which is less ambiguous then intangible aspects involved in the costing process. Subsequently the type of methodology employed needs to be designed with consideration of sufficient coverage of all the issues involved in examining this domain. This research broadly requires social enquiry into the real world; examining the actual environment of industrial product-costing in order to elicit and address the issues within. It is over simplistic to look at costing purely from a technical perspective; hence within this research has been identified a set of additional factors that influence costing, and provide insights for improvement.

## *2.1 Methodological Options*

There is much written about the type of methodologies that can be adopted for undertaking the many areas of research, which can potentially be diverse, wide in scope and variety. However to simplify this, the approaches can be classified into two very broad categories (see Table 2.1):

- Qualitative
  - Inductive
  - Phenomenology
  - Flexible Design
  - Grounded Theory
  - Real World

- Quantitative
  - Deductive
  - Positivism
  - Fixed (Inflexible) Design
  - Experimental

Quantitative research is generally based on predetermined theory as to what the research is about and follows established procedures, in simulated conditions. The data analysed is largely numerical [Robson, 2002]. A Quantitative methodology is a strictly implemented, fixed, iterative experimental procedure. As mentioned, this results fundamentally in the generation of figures, e.g. percentage-change, chemical reactions, composition-metamorphis / -analysis, and other often physical, unequivocally measurable modifications, derived under known conditions.

Qualitative methodology often involves social interaction undergone within real-world research; in other words, derived with use of direct dealings with the actual subject domain, as opposed to a simulated environment. It focuses on raising awareness of the roles played by the stakeholders, i.e. those who have prominence within the area. For instance, in this research the stakeholders are the industrial cost-practitioners. Definite measurements of human aspects arguably cannot be derived, particularly through calculations; but are assessed through meticulous analysis of the data.

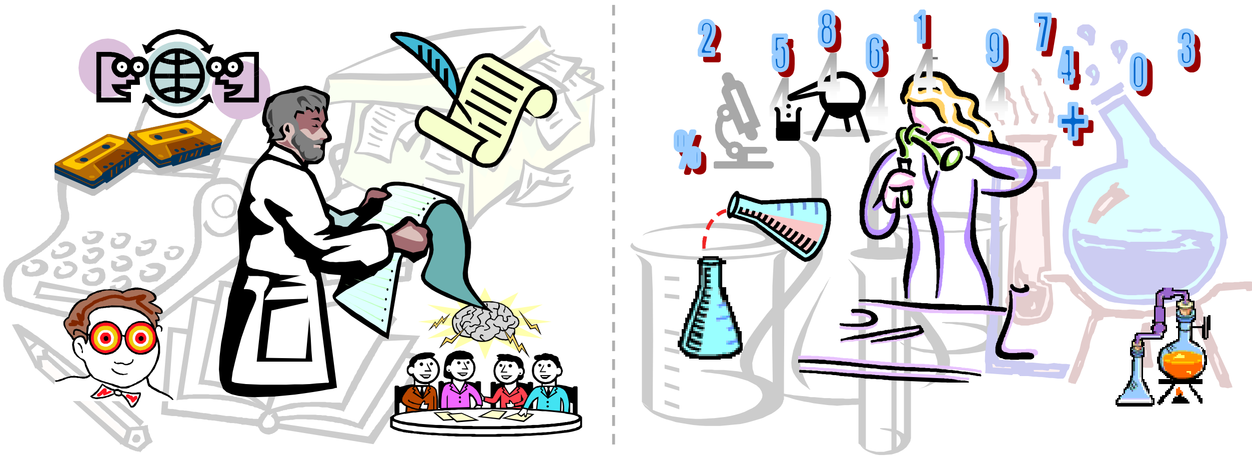



Figure 2.1: Stereotypical Perceptions of Quantitative and Qualitative Research Methodologies.

Figure 2.1 illustrates the traditional view of these two methodologies: It highlights the rigid stereotype which is commonly embraced when initially referring to either a scientific and / or engineering-type study, against a social enquiry-based one. Loosely speaking, quantitative research tends to be perceived as having relevance within pure scientific, technical and engineering domains. Whilst qualitative, tends to be associated with psychological and sociological areas. Further investigation often proves these strong perceptions as inaccurate, in the sense that their application is not exclusive to the areas stipulated. For the basic characteristics of these methodologies, refer to Tables 2.1 and 2.2.

This research was essentially a qualitative study, as it involved examination of the roles played by and perceptions of the stakeholders: And looked at the individuals working within a discipline, their interactions and the environment in which costing was undertaken.

### *2.1.1 Inductive Research:*

Inductive research is when theory is generated or induced from raw data, which has been collected without assumptions, preconceived ideas and free from levels of importance placed on any aspects examined. This means that facts (raw data) are observed & documented without supposition as to their relative value. Therefore with a deliberate absence of any predetermined hypotheses, these facts are analysed and generalisations are inductively drawn, regarding their impact and relations between them. Subsequently patterns and evident themes emerge from which theories can be derived from a non-bias viewpoint, as far as is possible. This analysis shapes resultant hypothesis, which can then be further tested. Figure 2.2. illustrates how the potential masses of raw data, signified at the lower end of the triangle, can then via meticulous analysis be consolidated into theory: This reduction is shown through the gradual upwards slope, to the peak of the figure.

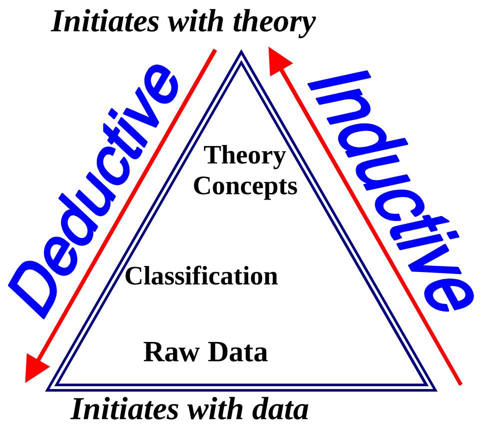



Figure 2.2: The Nature of Inductive and Deductive Research.

The subsequent testing of theory developed from raw data brings a deductive aspect to the research, naturally leading on from the hypotheses development i.e. from the initial, primary inductive phases. Data (often derived from social interaction / real world research) builds theory, leading the research from specific cases, to general theory which summarises an overview of the research findings: The theory generated describes the essence or that which is central to the data.

This research commenced with a broad research-question, to ascertain why product-costing is not performing to capacity, despite its contained expertise; but not with a specific theory to disprove. Therefore the philosophy or general methodological approach to this research is broadly inductive. When the research undergone is of an inductive nature, data-collection continues until saturation is reached, i.e. when the data collected ceases to contribute anything new or additional to the findings or what has already been established through the study. Although inductive research allows an in-depth and complete view of the subject under examination, establishing the saturation point of data-collection can be difficult to assess (see summary in Table 2.1. and Grounded Theory, Section 2.1.5).

### *2.1.2 Deductive Research*

Deductive research adopts a classical scientific approach. The starting point of the research is with a theory that can be tested, and applied to the specific area of examination, (see Figure 2.2). Hypothesis is generated, which forms theory; and where they apply, conclusion(s) are deduced. These theories (conclusions) can be further tested, or validated, by continuously gathering data; if this data fits the theory, then the theory is supported, until the next tests [Lemon, 1999]. Basically deductive research is based around proving or more accurately disproving the initiating theory.

Table 2.1: Inductive / Grounded and Deductive / Quantitative Research

| SOCIAL ENQUIRY / REAL WORLD RESEARCH | | | | |
|---|---|---|---|---|
| TYPE<br>& Other Terms of Reference: | Description | Tools | Benefits | Disadvantages |
| INDUCTIVE<br>➢ Grounded<br>➢ Phenomenology<br>➢ Qualitative<br>➢ Flexible Design | Theory Building through analysis of raw data collected objectively. | Naturalistic Methodological Procedures:<br>▪ Case study<br>▪ Interview (approx. 20-30, to saturate)<br>▪ Ethnography<br>▪ Observation<br>▪ Open survey<br>▪ Document-analysis | Can provide specialist invaluable knowledge, otherwise difficult to access.<br><br>Gives systemic view, looking broadly at domain context / surrounding influences. | • The absence of preconceived ideas prior to research commencement is unrealistic.<br>• Language can be very specialised and therefore hold both inconsistencies on comparison and challenges to decipher<br>• Can be difficult to asses when reached saturation of data. |
| TRADITIONAL SCIENTIFIC APPROACH / CONTROLLED CONDITIONS | | | | |
| DEDUCTIVE<br>➢ Positivism<br>➢ Quantitative<br>➢ Empiricism<br>➢ Fixed Design | Deducing hypothesis from a theory.<br><br>Analytical approach to data; main format of which is numerical.<br><br>Researcher is external to the proceedings | Meticulous, structured testing & observation: Controlled experiments; Closed questionnaires; Iterative, measurements & comparisons. Thorough planning prior to main data-collection stage, hence 'Fixed design' | Straightforward, Unambiguous results;<br>able to make direct , clear comparisons;<br><br>Less room for speculation, misinterpretation, & bias | • Experimental conditions may not strictly reflect real-life environment.<br>• Less lightly to acknowledge and interpret associated influence of human factors:<br>• Too much emphasis is placed on quantitative measurement, which is ineffective in establishing social behaviour.<br>• Study can be narrow /too focused; thus difficult to cater for the exploration of unpredicted occurrences. |

Adapted from [Johnson & Harris, 2002; Robson, 2002; Blaikie, 1995; Gilbert 1995]

Deductive (categorised here with Quantitative research) is more of a traditionally pure scientific type, with experiments often conducted under pre-determined, specified, laboratory or controlled conditions; and data largely collected in numerical form. Figure 2.2 illustrates how the Inductive approach examines raw data and from this derives theor(ies); whilst Deductive starts with a theory and explores data in relation to the theory.

As this research does not commence with a predetermined theory, it is not deductive. An example of how a deductive concept could be applied to this study would be to deduce from the available literature and industrial observations, a hypothesis such as:
'The results of industrial product-costing are currently poor, due to the lack of female practitioners within this domain'. The research then would set about disproving this hypothesis: Consequently the angle of investigation would be clear and very specific.

### *2.1.3 Inter-related Methodological Concepts:*

The type of methodological approach adopted moulds the nature of the research and must be selected from an informed perspective, as it will invariably influence the type of data that can be collected [Bailey, 2003]. A key factor of this choice, and within the debate of scientific validity, lies in the distinction between deductive and inductive approaches. Levels of abstraction from raw data / facts, systematically through to concepts / hypotheses development; and vice versa, i.e. from consideration of theory through to raw data, are fundamentally what inductive and deductive methods of research are, respectively (see Figure 2.2).

Due to the nature of inductive and deductive research, it is argued that it is not feasible to undertake both types concurrently. However, when the fundamentals of each are examined it seems that the continued sole use of either, may be detrimental. This is because there are a number of crucial factors which are unknown at the start of research, such as what the issues, are caused by, the identification of the stakeholders themselves, and what views and perceptions they may have. For example:

? Are the primary stakeholders within this research exclusively the costing practitioners, or are other disciplines, such as engineering and finance, just as relevant?
? In addition, do the more experienced practitioners hold different viewpoints or perceptions to those of lesser experience;
  ? If so how significant are these differing views,
  ? And does it relate to resultant working practices e.g. utilisation of costing aids (tools / softwares), or not?
? Plus, determination of research points i.e. What is the current state of affairs in costing?
  ? For instance: Is the literature accurate in its conveyance of the process; or is it out-of-date, too generalistic /specific, or unreliable in some manner?

Without such knowledge, it is premature to formulate a theoretical position by which the resultant research is conducted against. Conversely, if data are collected without developing a degree of focus, this could result in it being unproductive, with irrelevant, futile lines of investigation, and a consequent waste of time and resource.

Induction and deduction inter-related within this research; consequently it was both:

- ✓ Deductive: In the sense that there were guidelines given from a project plan which was agreed with industrial sponsors. The latter mentioned were collaborating partners in an initial data-collection phase of research; these included representatives from: Aerospace, automotive, software development / vendor, and management training and consultancy: All of which were able to collectively contribute to the research without having conflicting interests.

- ✓ Inductive: As the research progressed and the information was collected, a number of themes and patterns emerged. The primary themes to emerge was not wholly predicted, i.e. the prominent influence of human factors.

Therefore it is reasonable to conduct phases of inductive then deductive research consecutively, with one leading into the other in a cyclical manner. Hence this research does have deductive aspects within it, generally derived from the practicality of testing / reinforcement and validation of theories induced; and stemming from the inductive phases, which are primary.

### *2.1.4 Divergent / Convergent Research:*

The type of knowledge and information elicited within this research was at two levels: That which bestowed a broad overview and that which examined specific cases closely, providing a greater level of detail.

The research commenced broadly, exploring and questioning whether the anticipated results were relevant, how they were perceived and identifying other focal issues. Subsequently it needed to converge to focus and examine the findings, prior to diverging, in order to revaluate the outcomes and test against further data: This broadening and deepening continued in an iterative manner until judgment and resources brought the process to a conclusion.

This type of research activity can be related to the inductive and deductive phase: In the sense that data are initially collected, and subsequently theory emerges (i.e. inductively). Once generated, the hypothesis is tested (deductively): More data is then collected, which results in further theory, or validation of initial concept (discussed earlier in this section).

### *2.1.5 Grounded Theory:*

Inductive research is similar to grounded theory, in which theory is generated from data collected from the field in question, i.e. the theory is grounded in the data. The main data-collection tool used within this methodological approach is interview-based [Young, 2003]. Data are also collected in the form of narrative, derived from observations, interview, and other forms of social interaction within the area of interest. Case studies often follow a grounded, inductive approach, again where data are largely collected and analysed in narrative form. For instance within this research the grounded theory approach is to develop a hypothesis related to product -costing which is derived from data from within the costing field. The origins of this approach are sociological, as it centres on examination of the environment. With regards to specifics of data-collection, the number of interviews suggested as being enough to have reached saturation, is between 20-30 [Robson, 2002] and this was taken as a basic guideline within this research. The data analysis for this type of results can be selective conditional coding, which was conducted throughout this study, and is discussed in Section 2.5 Types of Analysis.

It must be noted that the narrative used tends to be theory or theoretical, partly derived from literature: This is why narrative alone was not the only means of data-collection, within this, what was intended as an industrially interactive study. Section 2.3. (2.3.1), discuss the multi-method 'real-world approach' adopted, including observation. Additionally on-site interviews were dominant, to allow an element of first-hand experience of the stakeholders' environment, as well as keeping them within the domain which would promote the maximum memory retrieval. Group interviews and workshops also allowed stimulation from interaction with other practitioners; all of which were designed to collectively produce the most rounded and formative results.

Thus the characteristics of grounded theory include:

- Theory that is developed from data collected in the field of research:
- It is widely adaptable to suit a variety of phenomena:
- Data-collection is commonly interview-based, with 20-30 interviews being stated as enough to saturate the quest for data and information:
- Provides flexibility within a systematic strategy:
- Produces detailed results, for hypothesis derivation:
- Analysis can be performed through various states of coding also known as constant comparison method: [Pidgeon & Henwood, 1996; Robson 2002].

## *2.1.6 Philosophical Positions: Positivism versus Phenomenology:*

Due to difficulties in clarifying and establishing absolute categories, and to an extent definitions, for social science and 'hard' (traditional or pure) science, philosophical positions have emerged. These are widely accepted as contributions towards the mass of literature which discusses research. The following categories of positivism and phenomenology can loosely fall into the wider classifications of deduction and induction, respectively (see Table 2.1). Both perspectives are based on an acceptance of the value of experience, but from opposing angles: One, from direct observation being related to affecting events, e.g. water changing state under freezing temperatures (-and effects of) from the positivist view. Conversely, for an individual phenomenon to be explained via particular experience of subject-matter from the phenomenological angle.

### 2.1.6.1 Positivism*:*

Positivism has been used to discuss meanings of the term 'scientific' by Robson who mentioned that it is derived from the essence of the word progressive and is also referred to by the broader term 'empiricism': Being tentatively described as a 'standard view of science'. This includes its stance as being logical, value-free and based largely on quantitative data. It has been observed as focusing on *"..the existence of a constant relationship between events, or in the language of experimentation, between two variables."* [Robson, 2002 p21], stating that *"..if you can relate an event, observation or other phenomenon to a general law, ..then you have explained it"* [Outhwaite 1987 p7 (in Robson, 2002 p20) ]. In other words if one event can be observed and related to another, then it can be explained as such. This view has been criticised as having many limitations and for fundamentally being too simplistic to serve as an effective explanation, particularly within social sciences.

### 2.1.6.2 Phenomenology:

Research from a Phenomenological viewpoint examines participant experience, taking it at face value. It can have very specific language and terms of reference, relevant to that particular experience, and may therefore be inconsistent with comparative subjects. However it may also provide specialised insight into otherwise complex areas which may hold difficulties for non-experts to comprehend or even access [Young, 2003].

Examination of practitioner's experience proved to be an important aspect within product costing. This is due to the fact that the majority of practitioners encountered stated that costing was a highly individualistic process, insisting that they each had their own effective and unique technique of performing. This uniqueness-of-practice was said to be derived from each individual's experience. Therefore phenomenological philosophies hold significance for this research, (see Table 2.2 for comparisons).

## 2.2 Application of Approaches:

The way in which the selected methodology is approached depends on the research area, and angle of investigation. For instance, as this is primarily Inductive research, the most appropriate approach will be from an exploratory angle, as predetermined theory is not central to its development.

### *2.2.1 Research Rationale: Exploratory, Explanatory, Descriptive:*

This research adopts a combined strategy, with aspects of exploratory, descriptive, and explanatory. The purpose of each section changes in accordance with the phase of work. For instance during the early stages such as the AS-IS, research was exploratory (Chapter 3), as it was probing the manner in which costing was performed within industry. The results section can be deemed as descriptive, as it describes the findings of the exploratory phase. Whilst the discussion and analysis has explanatory elements, as it is here that the results (descriptive) derived from the exploratory stages, are deciphered, expanded-upon, and explained. However this combined strategy is encompassed within an overall rationale of research which is exploratory.

### *2.2.2 Flexible / Inflexible (Fixed) Approaches:*

A core characteristic of the research methodologies and different approaches towards them is flexibility.  A simplistic view would be to state that quantitative research methodology tends to be fixed; and qualitative, flexible. This has been stated due to the traditional characteristics of each research type, for instance when a quantitative study involves scientific experiments. Here the tests are generally designed prior to the commencement of the measurements / data-collection, and with a fairly specific focus of investigation in mind. For example, a rig may be designed to run experiments which measure the effects on a material, from a turbine disc (within a jet engine). This implementation of experiments would involve a number of pre-specified, fixed functions, e.g. the temperature of the heat applied, (requiring continuous monitoring, to ensure consistency): Plus checks of the general set-up, to manage elements such as the heat being applied to the correct area, and evenly. In addition, of course the primary focus of investigation, which would be the wear of the material under question (e.g. authentic stainless steel), to monitor and log its stability, and gradual progress throughout the duration of the experiment (during regular, recorded intervals). The essence of this study also does not allow flexibility from the principal aim, i.e. to determine the length of time the specific material can be used for purpose, under the prior established (and recreated) simulated conditions. At the very least, the rig would need to be redesigned if any other aspect of the domain were to be tested, or the focus changed. Plus consistency is required in order to obtain reliable, useable, valid results, e.g. the correct specification of heat applied constantly, to the (same) area of material, to test wear of regular use, under those conditions. In addition, such replicable process also enables validation by others. Although this may seem like rigidly fixed research, there are ways in which it could be expanded and therefore incorporate flexibility, into both the tests, and the results. This could be done, for example, by running the tests for a known level of time, under one condition, e.g. a constant degree of heat: This degree could then be either increased or decreased (according to potential variations within the actual application) giving this element of flexibility. Additionally the levels of time of the heat-exposure could be varied: Thus giving a range of results for that experiment. These changes could be in response to the initial results, showing that contextual flexibility from the original test-composition is possible, even within seemingly fixed-design research.

Conversely there are fixed aspects within seemingly flexible research design. For instance, a consistent line of questioning may be applied throughout semi-structured interviews, within every interview conducted; in order to ensure both a degree of comparative analysis, and that the primary aspects of focus were always addressed.

Questionnaires tend to be used more within qualitative research, as it is often related to the procurement of some aspect of social response. However, though they are implemented in this type of research, flexibility issues are not certain, as semi-structured questionnaires / interviews are more flexible than highly structured ones.

Table 2.2: Summary of Methodological Approaches

| | |
|---|---|
| Quantitative: Explicit dealings e.g. figures (temperatures, weights, other units of measure and observed changes), explicitly measurable; clearly comparable; regularly definable | Qualitative: Examination of less tangible aspects, e.g. interviews, individuals opinions /perspectives; assessments (rather then explicit measurements); data-familiarisation enables comparison |
| Deductive : Start with Theory<br>Positivism: Externally measurable<br>Fixed /Inflexible: Degree of pre-specified rigidity<br>Areas applied to: Scientific<br>Use in this research: Limited | Inductive / Grounded Theory: Start with data<br>Phenomenology: Understanding occurrences and situations<br>Flexible: Level of adaptability allowed<br>Areas Applied to: Social<br>Application to research: Primary |

The other thing to consider with regard to flexibility is the concept of triangulation whereby a range of tools, techniques, respondents, etc. provide a more flexible approach than research which focuses on one or two techniques. For example, when questionnaire, interviews, and observation are used to collect data, a wider range will be obtained; in comparison to applying a questionnaire response alone. The former three approaches mentioned can be classified as 'triangulation', and validate the result by obtaining varied perspectives towards it. However with regards to case study, a single one allows in-depth observation of activities, enabling thorough research; and therefore can be extremely revealing [Kazdin, 1982].

### *2.2.3 Methodology for this Research:*

The research within this project was broadly Inductive / Grounded. This was due to the fact that it was initiated with an area of focus, as prior stated but without any specific theory created to disprove or base the research implicitly on. The research-hypothesis gradually emerged from analysis of data and facts, derived from exploration of the focus-domain. Subsequently the research purpose was principally exploratory, with iterative aspects of descriptive and explanatory undertaken in parts. It is a Phenomenological study, as it focuses on cost-practitioner experiences, perceptions and opinions: Plus the theory generated are via qualitative / grounded methodology, as surrounding influences are key; with it concentrating on social research and implicit aspects of costing, in addition to the explicit side to the process.

**The research methodology was broadly an Inductive / Grounded –Theory approach: Undergone with use of multiple Case Studies and combined data-collection techniques; compiling predominantly Qualitative data.**

### *2.2.4 Real World Research and Social Enquiry:*

This research is directed at and conducted within actual industrial costing environments, inclusive of all unexpected, unknown and established day-to-day activities; as opposed to an experimental, artificial laboratory setting. Therefore the type of research detailed in this thesis is said to be real world research, as the term would suggest, due to it being set in a real situation, and not a simulated environment. The nature and substance of the work focuses on the practitioners and their interactions, communication and resulting challenges, among other areas. This would additionally evoke the term social enquiry being linked to this investigation, as the subject-matters' social interactions and the effects of, are being pursued. This is as opposed to a scientific experiment where matter (e.g. materials, metals), chemical reactions and other explicit tests are being compared and documented. Social enquiry can equate to real world research (qualitative), in the way that it is not conducted within laboratory or experimental conditions, but within the context of the research actual environment; for instance, the workplace.

The aim of qualitative research is to highlight the roles played by the stakeholders, who are in this case the costing practitioners, as discussed in the previous Section, 2.1. There are different qualitative techniques which may be used, as information available will vary between contributors (stakeholders). Perception, with respect to issues will also differ between practitioners, as well as change through time; plus ability and willingness to respond will fluctuate. Information may also be acquired via observation, as opposed to direct participant contributions; this is why a variety of qualitative research techniques may be necessary, in order to cater for different situations.

Social enquiry is based on needing to understand the participants' perspective, which in this research is that of the cost -and associated- industrial contributors. It places responses (actions and meanings) in the relevant social context; uses a natural setting rather then a simulated one i.e. everyday, real context rather then experimental conditions. Additionally it can adopt a range of data-collecting techniques, see Triangulation, Section 2.2.2 for expansion on the latter mentioned.

## *2.2.5 The Significance of Perception:*

Regardless of the techniques and methodological approach selected, certain aspects need to be accounted for when accessing any form of research, and in particular inductive, qualitative types. Gauging perception is often key to successful research; and is said to be the act or manner of the process people go through to gain awareness. Individuals behave and respond to the world as they see it, which may differ to the researchers' response. Not only will different people see their surroundings and environment in differing ways, but the same people will change their view over time, for instance with increased knowledge, experiences, and modified environment. The researcher must identify the subject-matters' perception accurately, as only through establishing their viewpoint can it be subsequently analysed and understood.

Understanding perception is crucial in mediating between technical factors and human issues: Often it is the technical aspects alone that are recognised and addressed, which is insufficient. For example a costing process may have very good systems and supporting software in place but if they are not utilised by the workforce the results produced will not reflect the potential, given the range of technological advancements bestowed to support the outcome. In such a situation determination of the practitioners' perception with regards to the technological features and aids available to them, would assist in solving the challenge of why they were not utilising them in order to maximise the quality of the results. Thus, it is over simplistic to look at costing purely from a technical stance: An understanding of the stakeholders' perspective can identify sets of other factors that influence the way in which costing is performed; and subsequently provide insight for improvement. The inductive and qualitative nature of this research ensures that participant perception is accounted for, both in the structure of data-collection and within the type of analysis undertaken.

## *2.2.6 Systems Thinking Cycle:*

Systemic interaction has been described as complex, uncertain, subject to multiple interpretations, and dynamic: From these perspectives it can be applied to the costing domain. Costing complexity, where systems affect other systems, can be seen in the interactions of the different areas which need to work integratedly. Within industrial product-costing, these include the presence and working practices of supplier; the impact of purchase, economic functions, and design decisions on the process; and even from the choice to use software or manually generate results (where such choice is available). New qualitative issues result from such interactions. Similarly uncertainty arises from the fact that it is not feasible to definitely assess future states, as unpredictable occurrences will formulate an unknown future. To an extent this is accounted for, often being referred to as 'risk assessment' within costing, see Chapters 4, and 7: However the impact on the dynamic interaction and affects on the stakeholders, (in this case the many facets of practitioner towards costing, whose fused input results in the final cost), is often difficult to asses. The importance of this interaction (or the affect on the practitioners) often goes unrecognised, and subsequently unaccounted for. Multiple interpretations such as modifications imposed by the customer on the product; an unexpected choice of supplier by the Purchase department; management budget-cuts, or company merges, creates a changing environment in which all systems need to be synchronised and updated, in order to obtain and maintain a successful cost-process. This dynamic element can be further seen, in the sense that costing interactions are modified through time and space. This is evident in long-term projects, for instance as conducted within the aerospace industry from where a senior manager observed that aspects of costing are changed as carried through each phase of the product life-cycle.

In order to understand costing in systemic terms, the different aspects of costing and expertise which contribute to it need to be identified and understood. Therefore the systems thinking cycle has been described by Lemon and Longhurst [1996], and is basically where the challenge is established via the parties concerned. To elaborate, the stakeholders as previously stated, are the main people involved and have a vested interest in the situation: i.e. the cost-practitioners: They can articulate the system of interest, or problem context. These identified challenges can then be mapped-out to highlight their scope and assist in determination of the measures required to solve them, i.e. identify options that emerge from diagnosis.

**Soft systems involve human behaviour which is dynamic, unpredictable & complex: Unlike hard systems, made by humans which are defined and relatively predictable**

Through the implementation of this straightforward systems thinking process, complex issues between people and situations can be resolved. For instance points and processes of intervention can be identified e.g. where in the costing process are the points of challenge. These are not necessarily where they may have been anticipated. Within the costing domain, the perceived challenges were in the lack of fluid communication and understanding. Resultantly an aspect of the solutions were initially perceived as creating an increased awareness via the improvement of IT systems to enhance channels of communication, with the notion that this will address the need for a lateral transfer of costing knowledge. Additionally to train on the tangible elements of each others role, to improve understanding.

A systems thinking cycle involves the examination of the whole, (including interactions / relationships / connections) within the overall area, rather then looking at specific explicit aspects alone. For instance many different disciplines contribute to costing: The manner in which they interact, respond to, and co-operate with each other affects the final estimate. These many functions need to be identified and accounted for: The systemic approach reveals that challenges in costing are related to soft–systems, as well as the physical areas.

## 2.3 Research Techniques:

There are a number of strategies which can be employed for research, but as it has been established that this work is broadly qualitative, the literature indicates that the suitable choice is consequently narrowed. The main research strategies implemented within inductive, qualitative research are case study, ethnography, survey, experimental. As there was a substantial level of industrial contributors (see Chapter 6, Table 6.2 for list), there were multiple case study consideration within this research.

## *2.3.1 Case Study:*

A case study delivers the research as a story, description or assertion, and develops in-depth analysis e.g. looking at specific cases of product-costing, and analysing the content. In the area of costing the practitioner may be describing the variations of a process, and use several examples to convey how different situations can occur. This communication could be verbal or otherwise. For instance it may be procured via an informal conversation; an open question where the interviewee responds by providing such narrative perhaps as an example of their response, or confirm the type of situation that they have experienced. It can even be a written account; in the case of costing this would be obtained when a practitioner has documented their actions and causes of them, usually only applicable where audits may result in personal liability. The latter tends to occur within military / defence domains, i.e. the MOD; see the results chapters for further information on such procedure. Data-collection for case study can be multiple, including observation and interviews (as with grounded theory), document-analysis / archival records; In this research such data came from the companies examined. Analysis of case studies tends to be accomplished via researcher over-familiarity with data, followed by coding or thematic analysis.

### 2.3.1.1 Ethnography:

Ethnography is where the researcher is immersed within the research environment. It is the fullest form of participant research, where the investigator can take on a role in order to wholly observe and experience the domain as fully as is possible for an impartial outsider. This is performed to various degrees, e.g. differing lengths of time, and with a wide level of preconceptions or predetermined focuses of exploration. However, ideally this is commenced with a totally ‘clean slate’. This is where the researcher will not have any preconceived ideas, and will observe and absorb their surroundings without prejudice, leaving the theory to emerge from the results which were ideally collected without bias.

In reality this type of ethnography is not deemed possible, as there are issues about the realistic achievable levels of impartiality of the observer. Additionally there are concerns as to the affect or influence that an external presence within any domain, (regardless of how discrete or integrated they may manage to become), would have on their surroundings / working practices, of the observer on the observed. This and other potential influences of participant research are discussed in greater detail later in the chapter.

### 2.3.1.2 Experimental (Tangible Testing):

Experimental data-collection strategy is where structured tests are undertaken within a controlled research environment. This tends to be fixed design with the subject matter focusing around facts, figures, and other definitive measures, e.g. weight, molecular structures, chemical reactions, melting points, strengths [tensile / shear] and other physical properties or elements. The tests will be designed for consistency, repeatability, and tend to incorporate equipment. The fact that apparatus are generally employed to produce explicit outputs means that the experimental strategy tends to be perceived as accurate and reliable. This type of research has credibility due to the results being repeatable and having consistency.

An experimental strategy tends to be linked primarily with quantitative research. However, it can be used within qualitative research: As a number of psychological tests have been run in which the response (response-times), basic reaction and so forth, are measured. For example the effect of ergonomics on the user, and their subconscious reaction to it can be observed and measured, partly with the use of explicit experiments. This would be in addition to a number of implicit considerations that may be factored into the final results in order to assess a human reaction to certain types of ergonomics. For example the reaction-time towards a signal; constant signal used, with the time measured of the reactions for a number of different subjects. This is just one example where experimental strategy may be utilised within a dominantly qualitative study.

#### 2.3.1.3 Research Techniques: Selection for Research:

Due to the prior-discussed nature of qualitative, inductive research, the strategies available for employment within it are reduced to ethnography, case study and survey. Case studies were selected as the most suitable strategy to approach this investigation, and have been dominant throughout. A primary and immediate positive tendency towards case study selection was the fact that this PhD was initiated from an industrially-funded project, (see Chapters 1 and 4). Therefore it was known from the conceptual stages that a wide range of case study contributions would be readily accessible for incorporation into the research.

Product-costing has reasonable visibility within the organisations observed: Given this perception of the process under examination, such intense and concentrated industrial emersion as ethnography was deemed unnecessary for this research. In addition, as the study focused on organisational and social interactions, no set experiments were necessary. However, survey / questionnaires were used, not in isolation but in conjunction with both group and one-to-one interviews; along with observation, document-analysis and workshops.

## *2.4 Data-Collection Techniques:*

The way in which the appropriate methodology can be conducted is with use of the most effective data-collection, and analysis. This section discusses the options of data-collection, and the most suitable for use within the selected methodology.

### *2.4.1 Questionnaire / Survey:*

Research may be designed where the use of surveys are the main strategy for eliciting the required knowledge and information. The surveys or questionnaires will be carefully structured in order to acquire the maximum information, from as minimal a level of questions as possible. Analysis for such strategy tends to be familiarisation of data, coupled with comparison; see Chapters 4 and 6 for data analysis within this research.

As discussed earlier, questionnaires may either shape the research, or act as a collective part of the data-collection process. During the familiarisation stages of the research, questionnaires were effective in allowing the researcher to gain an awareness of the general area. The questions posed in this research were progressed by a variety of interviews, including one-to-one and group.

The initial surveys were developed with limited reference to questionnaire-design texts, such as Fear [1978]. The main reason for this limited usage was due to time restrictions, particularly within the earlier data-collection phases. However questionnaires were designed and used throughout each phase of research: Principally the exploratory or AS-IS phase; and throughout the industrial implementation of the cost-knowledge framework, see Chapter 8. This included potential training requisite determination which incorporated the development of the materials handbook; and prominently within DIF analysis, detailed within Chapter 8. Examples of the questions and discussion of the responses are all provided within the relevant sections of thesis; and copies of the questionnaires developed are included in Appendices 1 and 4.

### *2.4.2 Interview / Workshops:*

The aim of interviews in general is to elicit more then a basic external behaviour and process, which can be acquired via observation or analysis of documentation. Interviews strive to study the underlying cognitive influences behind the practitioners' behaviour; how processes are undergone, and why they are conducted in certain ways.

There are various techniques of interview, that cater for different types of knowledge elicitation. These vary between two aspects: One is through the type of interview itself, and the other via the way in which it is conducted. The former comprises of: Structured interview, semi-structured, and unstructured. These, particularly the first two techniques may be encompassed within the context of the Cognitive Interview (C.I.) [Moody et al,1996]. The technique of C.I. allows the broadening of interviewer-perception of the physical and mental environment of the practitioner. C.I. principally aims to promote maximum memory retrieval throughout the interview via the way in which it is conducted [Fisher and Chandler, 1984], for instance in how the questions are formulated. This involves aspects such as creative repetition i.e. asking the same question in different ways, in order to obtain additional information -about the same subject- within each response [Roediger and Payne, 1982]. Other factors of C.I. that tend to be overlooked on an explicit level, but can enhance the quality of the results, include consideration of the placement / surroundings in which the interview takes place [Best, 1989]. For instance whether it is conducted within the participants usual work environment, which may encompass distractions but conversely will stimulate maximum memory retrieval due to placement. Alternately if it is held externally, this may enable elimination of interruptions such as phone calls, colleagues-interactions, etc; but is also removing the contributor from the very environment which is being examined.

In addition to the type of interview embarked upon, is the consideration of the way in which the interview is conducted. This encompasses whether it is a personal (face-to-face), or a telephone interview; with single or multiple respondents, e.g. a group interview (workshops can loosely fall into this category) or one-to-one. Such aspects tend to be linked to issues such as availability and time: However multiple, interactive viewpoints that are for instance captured during workshops, need to be planned with the contributors and are often highly structured. In semi-structured interviews (SSI) it is the role of the interviewer to elicit appropriate knowledge and keep the interview focused, whilst allowing adequate flexibility for diversion into relevant aspects of the subject. Direct (or closed) interviews are designed to leave little room for deviation from the focal point, specified within each direct question. The types of interviews are elaborated upon within the following section.

### 2.4.3 Interviews: Structured / Semi-Structured / Unstructured:

Direct interview, Indirect and Pattern or Evaluation interview have been highlighted within the literature [Fear, 1978]. Direct interview, otherwise known as the 'questions and answers approach' is basically where direct questions are asked to the respondent. The factual answers allow a large amount of pragmatic data and information to be gathered within a short time frame. This technique does not allow for any relevant information other then the succinct answer to be provided. Direct interviewing has been likened to the barrage of questions between a prosecuting lawyer and a witness within a courtroom setting, where deviation from direct answers tend to be discouraged.

Whereas indirect, is more similar to the interaction between a psychiatrist and client where conversational responses are sought [Fear, 1978]. The contributor may feel like they are being 'drilled' by the interviewer in direct interviewing, which may stifle the creation of trust between them and limit the answers they give to what they perceive as the 'correct' response, as opposed to the real situation. Within the domain of costing it was felt that it was more likely to result in bestowing official answers to questions, rather then disclosing a true state of events as they occurred in practical situations. Conversely, indirect interviewing allows more room for elaboration from the contributor.

Evaluation interview compares the previous work of interviewee, and bases potential performance or answers on those responses [Fear, 1978]. Prediction of actions was not a focal part of this research, with any such speculation of performance being conducted with the input of the practitioner themselves. The key types of interview are assessed in Table 2.3, with the positive and negative aspects of each technique being listed to enable comparison, and measure of suitability for specific requirements.

### 2.4.4 Interview Focus and Contributors:

The individual interview is an established and effective method of obtaining thorough responses regarding knowledge, attitudes and opinions. However it is quite important to cover a wide range of respondents: Different ages, levels of experience, nationalities, gender and economic situations will often have different experiences to convey. Therefore capturing a representative cross-section of the relevant subject-range is beneficial; hence the sample group needs to be diverse.

A key informant can have broad or specific knowledge depending on the type of information required. They do not necessarily need to be the most qualified, or 'leaders' in the field; and can be external to the group, but with knowledge of the activities and relationships within it; or internal and intrinsic to the area under investigation [Mikkelson, 2005]. For instance the former could be a software provider for tools of the costing process; whilst the latter will be the cost-practitioners within the examined industries

The majority of interviews within this research were with individuals; though a significant proportion were conducted with multiple respondents, either in formal / informal group interviews; and within workshops. Sources were sought throughout each phase of work, e.g. initially a manager viewpoint was of interest, in order to understand the background and overview of the area, including that of official procedures and formalities. Following this, the actual practitioners were interviewed to gain insight into the intricacies of the process; they were then joined with the interacting domains, to determine the chief challenges, (such as lack of integrated working), and to establish the knowledge types required throughout the costing process. Practitioners of all experience-levels, along with those who work with product-costing were consulted when addressing the industrial implementation of the findings and training-implications phase of work, detailed in Chapter 8. The large majority of the interviews were also audio-taped, in order to support the notes taken throughout the sessions

Table 2.3: Interview Characteristics

| Interview Technique | Pro's | Con's |
|---|---|---|
| Structured<br>(-Direct)<br>(-Closed Quantitative interviews)<br>Similarities with:<br>Standardised open-ended interview<br>Closed quantitative interviews | Enables large amount of factual information to be accumulated, within short a short time frame.<br>Easier to analyse and compare then other methods. | Rigidity of questions results in unelaborated answers; therefore important additional information may be missed if not directly linked to the question asked.<br>Interviewer has to ask relevant questions which will provide thorough answers; which means they need to be very clear of issues in question. Therefore is more suitable for experienced interviewers, with knowledgeable of domain under examination, then for novices. |
| Semi-Structured<br>(-Patterned / Evaluation)<br>(-Interview guide approach) | Gains trust of expert therefore additional, practical information obtained, when good rapport is created; whilst can still keep interview structured / focused. | Interviewer requires skill in order to control its direction i.e. not restrict it, whilst not allowing it to be too broad.<br>Allow boundaries to be flexible enough to enable relevant data, whilst not too flexible, to allow time to be taken on irrelevant data. |
| Unstructured<br>(-Indirect)<br>(-Informal conversational interview) | Allows for relevant areas of interest to be addressed which are not directly linked to original questions.<br>Gives a thorough, comprehensive and full coverage of domain.<br>Expert-knowledge can be elicited by relative novices in the area. | Can be time consuming, and ultimately may not cover all required issues.<br>Analysis is not as straightforward as other methods: And may be more time consuming, due to identification and eradication of irrelevant material.<br>Comparison between respondents is not as clear as with other methods. |
| Cognitive | Conditions allows maximum level of memory retrieval during interview. | Is not a widely established method of interviewing; needs further validation of theory involved. |

References: [Mikkelson, 2005; Fear, 1978; Moody et al, 1996]

## *2.4.5. Observation:*

Observation of the subject matter can be revealing, particularly when the area in question is new and therefore largely unknown to the observer; this can help to formulate a fundamental understanding of it. With this said, the observer does not have to be a novice, as observation can act to broaden current knowledge. For instance, if an automotive cost-practitioner gained access to observe cost-practices within another industry, e.g. aerospace, this would give the opportunity to assess best-practice of the overall process i.e. across domains; and possibly obtain or stimulate ideas, which if applicable to their area could result in improvements.

Within this study the observation of cost-practitioners within their workplace during their daily routines, bestowed a sense of the function, activities and depth of work, more then basic interviews alone would give. Observation was effective in establishing work routines and other details which may be difficult to articulate. However, this level of observation is not akin to ethnography, where the knowledge engineer actually attempts to blend in with the studied environment: It can be undergone for varying time-spans, i.e. minutes to any longer period, whereas ethnography requires substantially longer time intervals within the domain in order to become part of it. When conducted within interview and case-study, (as this research used), observation is a highly effective means of collecting particularly tacit, implicit information.

Observation within the industrial domain of the majority of participants was used within this research, as most industrial interaction occurred on-site of the participating companies. Although the researcher was initially inexperienced within the costing domain, this observation aided to the rapid acquisition of knowledge. Once a reasonable level of comprehension had been reached, the observation across companies and industries could assist in deciphering costing best-practice. This allowed the determination of whether the most positive points of each practice were interchangeable, ultimately helping to access and subsequently promote the highest quality costing processes, with greater aspects of standardisation across the board. Chapter 8 explores channels by which the research-developed cost-knowledge framework can be assimilated into the costing community.

### *2.4.6. Company Document-Analysis / Website / Literature Review:*

Organisational document-analysis is fundamentally the analysis of any material imparted by the organisation. The examination of official documentation tends to bestow concise instruction regarding the ideal manner in which procedures may be embarked upon; and more significantly the way in which specific company dealings are expected to be conducted. The latter is important because it can reveal a degree of the company–culture, how it wishes to portray itself and how 'things', i.e. actions, process, procedures are intended to be executed. For this research document-analysis can provide a core background into the companies being examined and the cost-processes. Company documents can generally provide a map of the structure of the organisation, hierarchies, and interrelated departments. This is important for researchers both in the sense of gaining an understanding of the areas and how they are related; and practically, to know who it would be beneficial to speak with, and their positioning within the organisation. Background knowledge, official positions and best-practice process, are the main areas in which such document-analysis are of use.

Analysis of websites are also useful for gathering basics about the domain and background knowledge / preparation for further investigations. A thorough, (if basic) knowledge of the area, and being in possession of all information which is openly available is an effective way to prepare the researcher to conduct more in-depth enquiries. Company websites are an ideal way to gather a general feel of the type of organisation, e.g. through 'mission statements, and the likes; the image it wishes to portray; market it is aimed at; history; often its aspirations; and importantly the fundamentals of its products.

The literature review is crucial for similar reasons as the above; but it is often more in-depth then web-site searches, less specific then company document-analysis, and far broader then both. The dominating literature used within the reviews tends to be of an academic nature, where research has been undergone and documented. This is how it contrasts with the other areas of literature, such as company documentation analysis / websites, and so fourth, because it is designed to be more objective, factual, and often imparts generalised representations of the domains, as opposed to the subjectivity of the other types of reviewed material. The following Chapter, 3, discusses this type of technical costing literature: The areas covered will not only include the main domain, but also the major general area which the subject is within, and the related areas. For instance, with product-costing, related disciplines such as engineering and financial literature will be reviewed, as well as industrial and company specific information. This will provide a comprehensive, thorough representation of the area, as well as the environment in which it is situated within.

These literature-based data-collection techniques can give the researcher a good fundamental knowledge of the area under investigation, prior to their entering it perhaps physically, where they can conduct more in-depth research. Familiarisation and assessment of all the aforementioned types of literature is an important research stage, as a certain degree of pre-requisite knowledge is required when entering a research domain. This is in order to maximise the data-collection techniques employed, and to avoid time-wasting, e.g. via repetitions of information which could have been obtained via website, prior to on-site visits.

### *2.4.7 Physical Tests / Experiments:*

Data may be collected via experimental means, generally when fixed-design research is appropriate; and consistency and structure is required. Experiments may be designed to test for all types of practical elements, e.g. from the reaction of a pilots' response to a signal; to the heat resistance and durability of material from a jet-plane turbine disc. In these cases very specific conditions will be set to enable each cycle of the experiment to be measured, contrasted and analysed. The latter example has referred to physical, inanimate objects, though requires a degree of human judgement to predict and assess all possible conditions which the disc may be subject to, in order to evaluate the material suitability for purpose / safety. The former, though still taking a definite measure, is examining the capacity of a more intrinsic response or reaction, overtly involving human factors, as it is assessing individuals' response-times, acknowledging that reaction-times may vary per person, due to different (often tacit) reasons. Either way, experimental data-collection, whether scientifically or social-science driven, tend to incorporate some degree of rigidity in order to attain reproducible results, which may be compared. Additionally the experiments may be run repeatedly, often under slightly modified conditions, or with varied subject-matter, i.e. different people responding to same experimental situation. Physical experiments were not used within this research as it was grounded theory, a socially and environmentally-founded study, based heavily on practitioner in-put.

### 2.4.8 Data-Collection Techniques: Selection for Research:

In social enquiry, inductive / grounded research, using case study, a combination of data-collection techniques was deemed suitable, as discussed throughout Section 2.1 each data-collection technique within inductive enquiry has merits which differ and compliment each other. Therefore a combination of multiple techniques were employed, see Figure 2.3.

Questionnaires were used throughout, primarily as preparation for the main knowledge elicitation technique, which was interviews. Generally these were semi-structured, individual with a significant minority of group-interviews; all based on the cognitive interview hypothesis. Observation was conducted where possible, given time, accessibility, confidentiality and other practical considerations. Additionally a thorough literature review was undergone prior to company interaction, as well as throughout; along with organisational documentation analysis, including website. A large majority of the interviews was taped, in order to allow in-depth analysis, where necessary. A minority of interviews was transcribed, primarily due to time limitations, though also as deemed unnecessary, given the level of overall interviews conducted. See Chapter 6, Table 6.2 for participants, and detailed information regarding data-collection statistics. The taped material was used as a measure to re-enforce the primary notes taken throughout each encounter. The following section discusses the options and appropriate analysis for the data collected.

## 2.5 Types of Analysis:

The type of research methodology selected can direct the data-collection techniques, to a degree, towards those most suitable for use; and in turn the type of data collected tends to indicate a more tailored range of analysis, most appropriate for the form of data obtained. This section presents data-analysis techniques, and concludes with the most suitable ones for this research.

### 2.5.1 Comparative Analysis:

Having collected the data, when studying and assessing questionnaire response and interview-notes / transcriptions (deemed necessary for only a minority of them, due to the volume of interviews undertaken), it seems that comparisons of results against each other can highlight a number of issues. These include identification of differences, as well as similarities, which may be important if for example it is regarding a similar subject matter, perhaps within difference domains, e.g. comparisons of product-costing within large, multi-national automotive organisations. Here, the industry is the same with parallels in the nature of product, plus similar-sized organisations will have been selected. However there may be differences in practice, when examined. Identification of these differences, the reasons that they occur, and what their outcome / effect is, are areas of interest. These are the types of observations which may be drawn from comparative analysis.

### *2.5.2 Statistical Analysis:*

Traditionally statistics tend to deal with figures, categorising them into frequencies and other values. However the following quote states how statistics is now used in a broader, more insightful way:

*"…statistics is a reliable means of describing accurately the values of economic, political, social, psychological, biological, and physical data and serves as a tool to correlate and analyse such data. The work of the statistician is no longer confined to gathering and tabulating data, but is chiefly a process of interpreting the information"*

[Encarta encyclopaedia, 2006]

Thus even though tabulated information about a domain can be useful when requiring direct comparison, or cross-tabulations of a large amount of facts and figures, statistical analysis can go deeper then this. Trends and patterns can rapidly emerge when information is structured and represented in relevant ways. With such structuring, any unusual or unpredicted occurrences may be easily identified, and therefore allow further investigation and analysis into the targeted areas of interest.

### *2.5.3 Familiarisation of Data:*

Familiarisation of data is part of the analytical process, when the researcher or knowledge engineer becomes familiar with the results to the highest degree, so that each response can be assessed with total familiarity towards it. In other words, the data becomes 'second nature' to the analyst so knowledge and understanding of the issues may be obtained at multiple levels.

This technique of analysis can be undergone in a deliberate, structured manner, where findings are noted as they emerge and further analysis techniques are continued, e.g. thematic and colour coding / other types of classification of points. However, often such knowledge of data is acquired naturally or automatically through the systemic analysis of results as and when they are obtained, or when simply checking through on a regular basis for consistency. The latter mentioned can be related to quantitative / experimental research, even though an initial perception of the structured technique of over-familiarisation tends to be linked with qualitative work. Thus, on reflection over-familiarisation is clearly used, widely within all methods of research.

The way that such familiarisation, comprehension and confidence is achieved, tends to be through the reading and re-reading of data a number of times. The result is often that themes within the data become apparent; as often each time it is examined, and tacitly and explicitly processed, more is understood about it. Patterns and structure will thus transpire, to a familiarised examiner of the data; to a less knowledgeable / more casual observer, the same data may seem haphazard, unstructured and to have little – no common themes. For examples of specific data analysis within this research refer to Chapter 6, Section 6.2 Thematic Analysis, and examples of which are illustrated in Figures 6.3, 6.5; and discussed in theory within the following section.

### *2.5.4 Thematic–Coding:*

As stated in the previous section, themes can be identified from data, through the process of familiarisation. Here, as more elements of the data are compared, the commonalities in the results can be grouped together and classified in various modes from which point statistical structuring and analysis is beneficial. Therefore as a result of all analysis-types discussed within this section, to various degrees themes or trends can be identified within the research domain.

Thematic coding of the data is a valuable technique of structuring and assessing large amounts of data. It is a particularly effective way of deciphering or managing vast quantities of narrative collected. Such narration will require dissection and analysis, and as this is undergone, certain repetitions of points become prominent. These can be classified into themes, which will have sub-themes, which can be inter-related across each other, see Chapter 6, Table 6.3 for a specific research example. Thematic coding classifies the main points raised, allowing them to then be arranged into whichever areas of area of interest is prominent within the research domain. For example the main challenges within costing as conveyed by the practitioners, once thematically coded, may be evaluated from the point of view of:

- Industry;
  - Specific to each: -aerospace, automotive, defence, softwares / IT, other
- Experience of practitioner:
  - And / or background-knowledge / experience:
  - E.g. industrial or academic; economic or engineering; etc
- Geographic location;
  - E.g. affects of co-location against separate working sites
  - Communication between interacting national and international sites
- Size of company:
  - To highlight possible effects of varying levels of resource available; among other points;

Whichever area is of interest can be examined, once the themes have been established from within the data: Thus it is a beneficial technique of analysis.

### 2.5.5 *Analysis: Selection for Research*:

Due to the type of methodology, the research strategy, and the techniques of data-collection selected, the results were generally obtained in the form of narrative. Resultantly there was a substantial quantity of such data to analyse; therefore the most suitable type of analysis was that of over-familiarisation, supported by thematic-coding. As the data was familiarised, it can generally be deduced that themes would be identified. These themes could then be sub-categorised and examined from various angles.

However given the options of techniques for analysis, it can be accepted that a general aim of analysis appears to be in the identification of commonalities and exceptions, themes and patterns from the data elicited. Such results have been described throughout this chapter for all the discussed techniques, to various degrees. Thus it must be stated that the analysis options mentioned within this section have all been utilised to various levels of prominence, within this study; though at least one, statistical analysis, was only briefly employed. Nonetheless, for the areas in which it was deployed, it served its purpose of identifying trends and leading to further, often deeper investigations for areas which it identified as being of interest, e.g. via producing less predicable results. Refer to Chapters 4, thematic coding / knowledge categories; and 6 which detailed the cost knowledge-types, (KTs) for statistical package analysis. I.e. SPSS representation of data, including mapped frequencies of industrial-relevant trends, thematic coding, KTs and classification.

## 2.6 Research Considerations

Although the research methodology and the techniques selected to conduct it are key to the research, there are practical aspects related to the research types which need consideration prior to, and throughout the study. This section highlights the pragmatic elements linked generally to industrial research as well as specifically in relation to this work, and discusses the most appropriate ways to address them.

It is worth noting that this chapter discusses the research considerations from a theoretical stance; whereas the proceeding chapters discuss the actual challenges encountered throughout the industrial research, and how they were overcome. For instance the following section and sub-sections all outline issues related to accessibility, in the context of contemplating the research design. Whereas Chapter 4, Section 4.3.3 discusses industrial accessibility from an in-depth, practical position, as it affected the real world costing research that was undertaken, detailing the challenges experienced directly with the various organisations encountered, and how they were addressed.

### *2.6.1 Accessibility:*

A primary concern whenever academic research crosses into industrial examination is that of accessibility. What is meant by the term 'accessibility' within this work, spans across all aspects, from gaining access into the organisations and the relevant expertise to how much useful, reliable knowledge and information is imparted by the practitioners. For instance the former may give physical access to the areas under investigation, namely the companies / departments themselves. Whilst the latter allows access to the knowledgeable elements generally beyond the level of physical access, linked to social access; see proceeding sections for detail.

#### 2.6.1.1 Availability:

The number of industrial contributors was principally dependent on availability of the experts, as was the length of time per interview. As the first phase of research was intended to be an overview, the amount of time committed by the participant was flexible, ranging from between a few hours and three days (see Chapters 4 and 6). The degree of participation was determined by each industrial collaborator. A sole limitation of their availability was the need for them to be able to fall into the time scale set for this phase of research, which was in total extended to approximately sixteen weeks for all interviews to be completed within.

The second phase is split into three sections: The more in-depth study; overseas observations; and the implementation / validation / training-development stages, see Chapter 8 regarding the latter mentioned. These varied in length, but Phase Two-A, (as illustrated in Figure 4.1, Chapter 4) invariably consisted of more lengthy industrial interactions then the previous phase. Refer to Chapters 4 and 6 for more detail.

#### 2.6.1.2 Gatekeepers

In order to access an organisation the use of gatekeepers tended to be required. A gatekeeper, as the title suggests is a way to get access to the area of interest / a person who could provide it. This was often in the form of one who could introduce the researcher into the environment of research, in this case into the companies for examination. Not only was the basic physical entrance into an organisation an issue, but gatekeepers encompass deeper levels of accessibility. This includes acceptance by the practitioners possessing the knowledge, in order to gain their ready co-operation, as opposed to being suspicious or averse in other ways, regarding interacting with an external element. With this said, gatekeepers can either hinder or help access, due to their position. For instance if practitioners perceive an external academic interview focusing on their working practices and environment as an imposition enforced by management, this may create resentment / mistrust, resulting in their bestowing guarded responses, ultimately imparting minimal information: Also see Section 2.6.1.6 detailing social access. Alternatively, if communication was clear by all parties and the participant firstly knew why the research was being undertaken and what their contribution was required for: Secondly had a degree of choice about participation, the interaction is likely to be more successful.

#### 2.6.1.3 Contributor Incentive (Gaining Access):

Although gatekeepers tend to be perceived as person(s) of whom can clear the way for physical access and introduce into the environment; another method that was greatly used throughout this research was in the form of incentives for company participation. The incentive usually offered was reports, detailing and discussing company feedback, inclusive of assessment and analysis of all the other contributors. E.g. every industrial contact conducted was guaranteed two things:

A) Total confidentiality and discretion with regards to their contribution;
B) A copy of the report produced for that section of research.

Therefore the feedback was a practical incentive for the contributor, acting as a direct productive output for the time and expertise they input into the research. Hence the value of such independent academic-industrial feedback was highlighted to every potential participant. This objective documented feedback- incentive, of not only their organisation but others, often tended to open-doors, presenting opportunities for industrial collaboration due to the offer, and delivery, of mutually beneficial gains. Therefore the guarantee of confidentiality was a common requirement to the vast majority of industrial contributors; the assurance of receiving feedback from the study allowed access into desired domains, throughout the research.

#### 2.6.1.4 Gaining Access:

The research budget was adequate to cover costs of up to a few days per organisation, within the UK. Therefore there was limited imposition on the companies regarding participation. Due to the time constraints of the research organisations who were potentially problematic to access, (generally due to the fact that more time then was available was required to go through security checks and clearances), were ruled out early on. Such organisations, primarily within defence / military were not contacted for participation. Other then the aforementioned, the majority of organisations gave permission to allow the on-site research to move freely within the cost-department, approaching experts as and when they became available. They also arranged for additional departmental contribution, where deemed relevant for examination, i.e. engineering and financial areas; including a tour of products and showing plants and production processes. Generally speaking within companies, the practitioners approached were willing to give varying lengths of time to discuss costing issues openly and with the aid of accompanying documentation / examples, where possible. This was more prominent during the later phases of research, (Phase 2, following the exploratory phases), when greater periods of time were scheduled for the field studies; however it was true to a lesser degree in the early stages too. Throughout the secondary research phase more organisations with limited access were explored, having by then had more time to establish contact, clear security checks, and so forth; this is discussed further throughout the thesis.

#### 2.6.1.5 Physical Access:

In order to gain access to the industrial expertise, with use of both questionnaire dissemination and on-site practitioner interviews, three main techniques were used: Academic –industrial links; Project sponsor contacts; and novel relations with industrial communities formed via meetings and exhibitions. The main way of gaining access was through the industrial-project sponsors, BAE SYSTEMS and Ford Motor Company. Physical access was obtained through contacts or gatekeepers within these companies; and additional industrial links were formed via these participants. The companies sponsoring the research had a vested interest in its success, which was partly achieved via extensive industrial in-put. Therefore assisting in adding to the repertoire of contributing expertise was well within the scope of their commitment levels and continued support. The links between Cranfield University, (from where the research was based) and their associated industrial contacts were utilised for further access to corporations. Often if companies had previously worked with or had some connections to the university they would be prepared to extend their expertise to other areas of research as this one, where feasible. Subsequently access was gained via these historic relations between academic institute and industry. A minority of industrial contacts were created from industrial meetings / exhibitions / conferences, during which the opportunity was taken to raise interest in the research and the need for participation.

These industrial relations allowed the research to commence in the sense of providing physical access: However other barriers can occur once entrance to the workplace has been established. Thus although gatekeepers in the form, for instance of the sponsor-company managers, would have created the opportunity to access the site and personnel, developing social access once among the practitioners is a more subtle issue.

#### 2.6.1.6 Social Access:

The primary manner in which social access to the required information was attained was through the development of a rapport with the participant. The combined techniques utilised in the interviews aided in this pursuit, where the semi-structured interview (SSI) style would allow the practitioner to verbalise issues as they were able to comfortably decipher them psychologically. This was without having too rigid guidelines to follow; but with some structure to assist them in relaying the knowledge. The interview designed to maximise mental stimulus, C.I. was used concurrently with the SSI, (see Sections 2.4.2 and 2.4.3), subsequently encouraging maximum extraction of information partly via enhanced memory retrieval, helping the respondent to answer fully, (see Chapter 4 for further discussion). However before even reaching this stage, implicit acceptance of the knowledge elicitation process has to be agreed upon by the participating practitioner, in order to gain the full support, and maximise the outcome of the interaction. In gaining a rapport with the interviewee, use of language is important, which means interacting with them in a manner which is both comprehensible and familiar. Highly academic terminology of which they may be unfamiliar with, is inappropriate, and can create a lack of understanding and therefore hostility, or a ‘mental-barrier’, which will ultimately minimise their response. The latter also occurs if the respondent feels they do not understand what is required of them, again caused by inappropriate communication such as an ineffective use of language; and by lack of clarity. Alternately a lack of knowledge on a basic level as to what is being examined by the interviewer also posses a challenge, as the contributor may have difficulty in determining the level at which to begin interactions at. They may also feel a lack of appreciation of their practices by the interviewer, if unawareness is displayed at even basic levels. This was addressed by using terminology even if limited, learnt from the associated literature available, and /or industrial documentation including marketing material and websites, to communicate with the practitioners. This type of preparation was key prior to company-interaction, on general and specific levels, in order to acquire a basic degree of knowledge for novices, which often added to the extent of acceptance and participation gained. Where aspects of work were unknown to the researcher, it was important to admit this to the participant, acknowledge them as the expert within the area, and seek an explanation into the unfamiliar domain. It was often observed that a recognized appreciation of the practitioner’s skills would put them at ease, and assist in their developing an open attitude towards the aims of the research. This was seemingly primarily due to an understanding that the knowledge and information sought was related to what they already know, their opinions and perceptions; and was not some form of test or assessment. A thorough description into the research and how the practitioner’s contributions fitted into it helped greatly in their understanding of why the work was being conducted. This reasoning, behind the knowledge elicitation, assisted in gaining trust which consequently helped acquire social access into the desired domain. Gaining the trust of the practitioners was key in achieving a workable situation for the interviewer; conveying the fact that confidentiality was always adhered to on many levels was crucial in securing their trust. Issues of trust are referred to throughout the following chapters, specifically in Chapter 5, Section 5.8.

### *2.6.2 Pre-Requisitional Knowledge of Techniques:*

Although the research involved a degree of learning, there was a limitation to the amount of basic training which could be undergone, primarily due to time restraints. Therefore, unavoidable limitation of knowledge naturally influenced the selection of technique applied throughout the research, as the familiar routes were bound to take precedence over the unknown. With this said it must be noted that the research commenced with a review of the potential research techniques and methodology for the project, both novel and known, so that the most appropriate choice could be made for application. As a result, if a specific technique that was previously unknown was identified as suitable during these early stages, there was thus the means to familiarise with, and employ it for implementation within the research.

#### 2.6.2.1 Knowledge Categories: Five Ws and H:

The research was designed in order to answer key questions within the costing domain. In order to populate the questionnaires and interviews appropriately an information-extraction technique was used to formulate data-generating questions during the conceptual phases of research, referred to as Five W's and H [Collison and Parcell, 2001; 2008]. The following questions are derived from the primary research focus and are based around this straightforward 'data probing' technique. This creates data / information-generating questions concerning the research focus, with use of natural prompts from within the generally used language. The probes used are simply: How? Why? Who? When? Where? What? This template is discussed in greater depth in Chapters 6 and 7, the cost-themes and cost-knowledge chapters. As this concept is widely accepted, it has been used within the formulation of other research-based paradigms. Therefore later within this study there is a significant section of data-analysis based around knowledge categories: These consist of knowing how, why, when, where and who [Collison and Parcell, 2001; 2008]. It is thus evident that part of the data-analysis has been guided by analogous theory for which the data-collection has been based.

The following questions and sub-questions help define the type of methodology and techniques which were used for this research: They are derived from the main research question, serving to break the issues down into areas of focus. The questions are relevant across various stages of the work; thus it was important to have identified and them at the research design phases, being adapted continually, throughout to ensure that they were able to be addressed properly. For instance they probe into the differences between the documented process of costing and the industrial reality; about who within the organisations are responsible for cost-compilation, about the challenges encountered, and the training required. These are all areas which span this research:

- What do the cost publications state about the costing process?
- How is industrial costing performed within industry?
- Why is it performed in this manner?
- How does this compare to the published literature on the subject?
- How does the process of costing differ in reality from the documentation?
    - And if it is different, Why it this?
- How can the costing process differ between industries, organisations and even between individual practitioners?
- Who is responsible for compiling the costs?
    - Which experts: -Including finance, engineers, suppliers, purchase, a combination?
- What contribution do they make
    - E.g. What information and knowledge do they have?
- Where do their contributions fit into the overall process?
    - Engineering, economic or other? Conceptual phases, data-collection, etc.
- Where are these contributing experts?
    - Internal or external to department / organisation?
    - How can they be contacted / Where are they located?
    - What medium do they use to contribute to product costing, and is it effective? E.g. verbal / meetings; drawings (designer); documents; emails; telephone- calls, etc.

- Which areas of costing are in need of development?
    - How can these deficient areas be identified?
- How can the human issues that contribute to the challenges gain recognition?
    - I.e. How can they be identified and accepted as serious issues?
- How can these areas be addressed?
- What is the common terminology within costing, if there is any?
- What effect does a lack of standardisation have on the costing results?
- What knowledge is necessary for costing?
- Who owns this knowledge?
- How can it be classified / what categories does the knowledge fall into?
- What areas are in need of this knowledge?
- How can it be disseminated to the relevant areas in need?
- What is required to make these areas work in a more integrated manner?
- How can these modifications be realistically implemented industrially?
- Will they be relevant for the costing process across industries or even organisations?
- What training is lacking in product-costing?

The above questions are related to the problem domain and are addressed throughout the thesis. A number of these questions are also dealt with via systems thinking which presents a framework highlighting the issues at stake, the individuals affected, and potential outcomes; see Section 2.2.6 earlier within this chapter.

### *2.6.3 Restrictions of Research Design Application:*

Having designed the research to suit the area under investigation and address the research question, the suitability of application required consideration. In other words, issues that would inevitably restrict the research needed to be evaluated. Regarding limitations, there are the issues that cannot easily be predicted but will occur throughout the study and be addressed as and when they arise. Additionally, there are the type of restrictions which can be identified after deliberation of the area, and hence become apparent in the design stages. The two primary aspects which were readily predetermined as a limitation of the research scope were time and funds. The research drawbacks are discussed further in the proceeding chapters, including the final Chapter 9; however, the following briefly outlines some of the predicted potential challenges which were factored into the research design.

#### 2.6.3.1 Costs:

A large contribution of the data collected for this research was derived from an industrially funded project, with four contributing collaborators, see Chapter 1. Subsequently, high levels of funds were available, in comparison with the average research project, i.e. purely academic-based and / or funded, often with comparably limited resource. However, although this funding supported the large majority of the initial data-collection, there were limitations to its application. These primarily applied to the examination of overseas conglomerates; with the exception of the U.S.A. where a degree of research activity was possible. As many of the industrial contributors were UK branches of international corporations, a degree of cultural awareness was raised throughout the investigations. Therefore although personal interaction with overseas contributors was limited, the research did benefit from a level of cultural observation. See Chapters 4, 6 and 7 for further discussion of cultural awareness and the effects on organisational cost practices.

### 2.6.3.2 Time:

As expected, time served as a necessary restraint to the way in which the research project was conducted as a whole. Understandably the amount of data collected and analysed needed to be limited to that which was suitable to the time scales of the research duration. Therefore the project was scoped appropriately, to fit the time allocated, as opposed to what might be ideal.

The bulk of all data-collection was initially designed to be completed within 24 months, and no more then thirty. However this time span of data-collection and analysis was approximately doubled when the original research scope and focus was broadened to incorporate further examination of certain areas, (see Chapter 5); encompassing a more full, comprehensive study within product-costing: Hence all associated aspects of the research were modified accordingly. This essentially enabled the initial industrial project focus on which the research had been broadly conceptualised upon, to be greatly expanded. The extended time frame therefore allowed for a basic assessment of the effects that human factors, H.F., and sociological issues had on the process of product-costing, PC. Refer to Chapter 5 for an introductory review of the fundamental association between areas based within H.F., and the principal research domain of industrial PC. Resultantly a small portion of the extreme latter stages of industrial contributions within phase 2 was therefore conducted in order to validate the original phase 1 data; thus ensuring its up-to-date status, whilst concurrently reinforcing these original findings.

With this in mind, all aspects of data-collection were necessarily limited to set periods, including the final investigations; as were the phases of analysis. Refer to earlier sections within this chapter, and to Chapter 4 for specifics and clarification of times spans, and levels of required and assembled data collected.

#### *2.6.3.2.i Time Considerations Regarding the Levels of Data-Collection:*

Although a satisfactory amount of data was able to be collected within the time limitations, allowances were required for the analysis. The time taken to assess and examine each section of data needed to be accounted for when planning the knowledge elicitation stages. Earlier sections within this chapter, (see 2.1 - 2.4), have discussed the levels of data which have been deemed appropriate, or 'enough' to draw accurate research conclusions from. In accordance with these guidelines, a more common challenge within research projects tends to be around the issue of insufficient levels of data-collection; associated with this is the lack of full industrial participation and difficulties in securing the on-going, sustained interactions required to address the research needs in totality. Conversely it would be futile to collect excessive material, when there would not be enough time to adequately analyse it. This research was more probable of falling within the latter category. Therefore the constraints of time needed to be assessed realistically and updated throughout the project.

#### *2.6.3.2.ii Time Considerations Regarding the Industrial Contributors:*

Given the schedules with regards to data-collection and analysis, limitations towards the diversity of the industrial sectors examined were necessary, as well as the time spent within each one. One of the drawbacks from this aspect was related towards gaining access for organisations with high security clearances. This tended to be the companies related to military / defence, such as the MOD and DoD; and aerospace, such as BAE SYSTEMS: Refer to Chapter 4 for full industrial participation listings; and for the methods by which accessibility issues were overcome, Chapter 4, Section 4.3. In theory, the time taken to access and examine such contributors meant that their inclusion within the research was less likely, principally due to the time frames involved in obtaining researcher full security clearance, see previous Section 2.6.1. and sub-sections. However in the vast majority of cases, knowledge elicitation was possible to various degrees such as interviews, either personal or telephone. Plus any documented material deemed confidentially non-sensitive was made readily available for review; and often on-site visits, where practical, see Chapter 4, Section 4.3. The proceeding chapters detail the data-collection, analysis and conclusions from all participants.

#### *2.6.3.2.iii Time Considerations Regarding the Research Funding*

The research design and continued monitoring if and as required meant that the former mentioned data requirements were continually met throughout this research; thus ensuring that levels of data were not particularly hindered by the time constraints. With this said, funding was still a large factor towards the research contributors. Basically, the time scale expansion was not matched with equivalent funding. This situation predictably had an effect on the research methodology employed within this phase. The fundamental consequence was simply that the areas of H.F. that were considered within a product-costing domain, were marginally more literature based then the previous sections, though did also benefit via a range of industrial in-put, see Chapters 5, 6, 7, and 8. Chapter 8 had a substantial amount of industrial practitioner interaction, as interest was created due to the potential range in which the research findings may be disseminated throughout the costing community. This included how the knowledge- framework might be implemented, including prospective custom developed training materials, specifically for PC, refer to Chapter 8 for detail.

## *2.7 Summary:*

To clarify what is meant when referring to the research design terms:

- The methodology of research describes the general approach adopted towards the overall research project.
- The specific techniques utilised refer to the tools used to implement the appropriate methodology selected for the type of research being conducted.

Thus the techniques impart a more detailed view of the research, whilst the methodology portrays an overview or generalised framework of which will be populated by the techniques (tools and analysis) deemed necessary. In summary this research utilised:

- Qualitative methodology:
- Including: Inductive / grounded-theory; with phenomenological, flexible research;
- With philosophy of real world research, social enquiry, and systemic thinking.
- Primary data consisted of multiple industrial case studies;
- Using a combined strategy of data-collection techniques.
- Qualitative data was collected (company documentation / descriptive narrative);
- Using multi-analysis techniques;
- Principally: Over-familiarisation; followed by thematic coding and clustering techniques.

- Themes emerged which were then classified into similar groups, allowing areas of importance to be revealed.

Figure 2.1 shows methodology, techniques and analysis-type utilised within the research: The levels of abstraction within the research, from the main methodology adopted, to the techniques and analysis undergone throughout each phase of research.

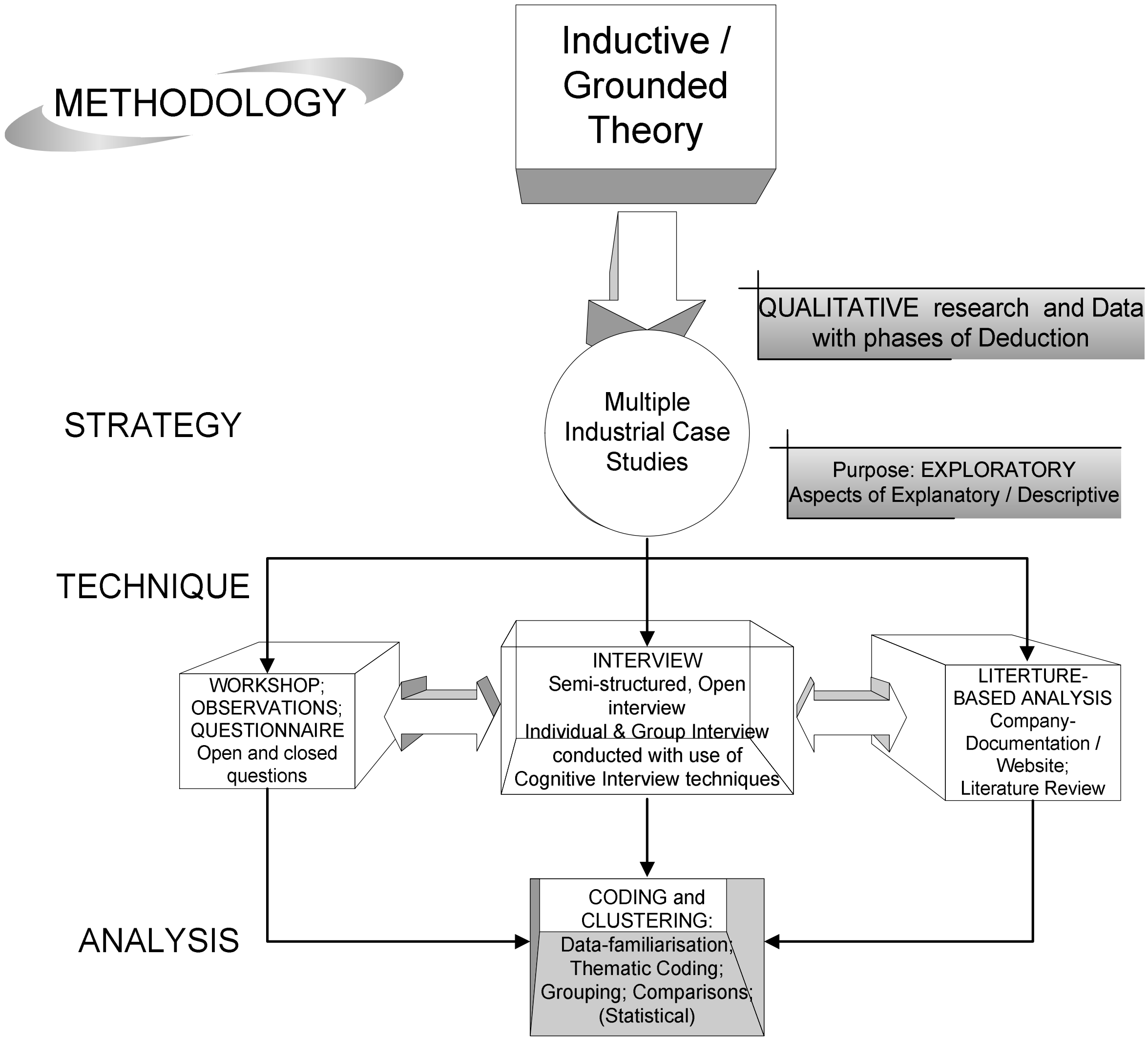
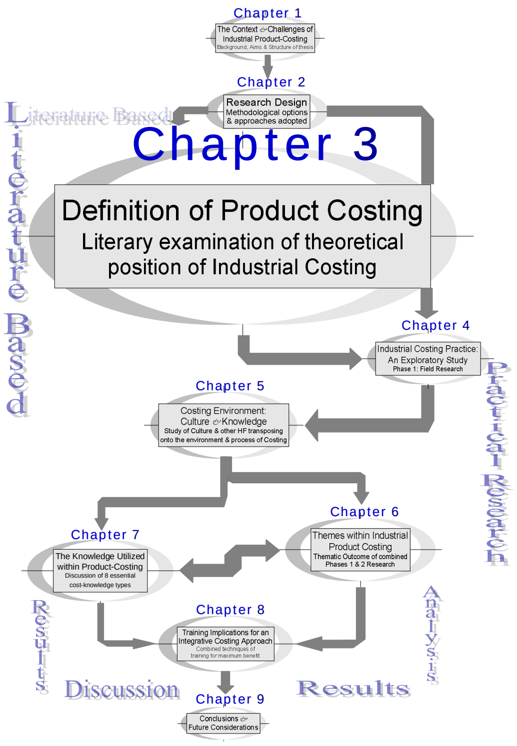



Figure 2.3: Research Methodology and Techniques

The following chapter presents the primary type of cost literature-based research, see Figure 3.2. This incorporates a critique of principally academic publications, directly related to product-costing. Included in this review are both theoretical suppositions behind the process, as well as pragmatic industrial-related documentation analysis. For example when assessing the different techniques which are used to cost a product, the juxtaposition of theoretical examination of the techniques, integrated with a practical discussion of situational-suitability are concurrently addressed. In addition to a targeted review of the costing field, the environmental factors, external to costing though still influential on it, are within the documented examination of product-costing: See Figure 3.1 in the following chapter, which presents the main steps involved in the process of costing.

# Chapter 3:

# Definition of Product-Costing




*"..Cost estimating is essentially an intuitive process which attempts to predict the final outcome of a future capital expenditure program even though not all parameters and conditions concerning a project are known or not fully defined when the cost estimate is prepared."*

[Jelen and Black, 1983 p322-323]

This chapter presents descriptive analysis of costing; giving an outline of different types of estimating techniques used, including parametric cost estimating (PCE), feature based costing (FBC), the Delphi process, and activity based cost estimating (ABC). The merits and drawbacks of each method described are discussed, and comparatively analysed i.e. highlighting various applications and detailing what type of costing is beneficial in each case. Therefore the suitability of the techniques within different contexts is highlighted, along with the contributing activities within product-costing. An account of the techniques selected for use within a range of industries is given, focusing on aerospace and automotive.

## *3.1 What Is Product-Costing*

The cost estimator is said to use the same natural reasoning, common sense and bargaining instinct as every person regularly engaged in purchasing situations. However, in addition to these more intuitive assessments, there are often models, techniques and tools to perform a structured cost appraisal with. Regardless of the particular industry in question, the estimator attempts to establish how much a product is worth, or going to cost to develop [Stewart et al, 1995].

A product cost-estimate calculates potential costs by predicting the manner in which a project will be undertaken; this is planned out on a progressive basis from conceptual to the final stages and all that is in-between, including the design, production and in-life service support, see 1.1, Chapter 1. The opening quote highlights the use of tacit, intuitive aspects to form a cost, whilst insinuating its fusion with prior knowledge about the item being costed. Such background product-information assists in the process of 'filling the gaps', when elements that contribute to the cost are unknown.

Within industry the cost per unit is estimated and allocated to each specific area which when collated results in the total predicted cost [Clark and Lorenzoni, 1985]. Predictions of how much will be paid per item plus when it will be procured (to account for any escalations), and from where, i.e. world market source, are calculated to various degrees of detail. The depth of which depends on a number of factors, including the estimating technique employed and the stage at which the costing exercise is being derived at. Both of the former mentioned are expanded on later in the chapter, refer to sections 3.3 and 3.4. However the primary considerations that determine what level of estimate-complexity is achieved is said to hinge on the time allowed to produce it, and the quality i.e. the accuracy and amount of information available to the expert, on which to base the estimated costs [Clark and Lorenzoni, 1985].

Prior to discussing the subject of product-costing any further, the issue of cost terminology should be addressed. Throughout the reported literature, and observed industrial practice, 'cost engineer' and 'cost estimator' are both regularly referred to. Subsequently standardised definitions and distinctions if indeed there are any, should be made clear between these commonly referenced terms to avoid possible confusion throughout the documented research. The following section discusses the cost definitions used throughout the literature.

### *3.1.1 Terminology within Costing: Literature Definitions:*

The way in which the titles of cost engineer and cost estimator were used, rapidly emerged as unclear and undefined within the proceeding industrial research. These compounded observations are expanded on in Chapter 4 which details the exploratory study of industrial interactions. Although the cost-titles used were occasionally defined within individual organisations, they were by no means standardised to any other degree within, or across, the industries examined. This research found that the role of Cost-Estimator and Cost-Engineer tended to draw many parallels, and were often indistinguishable when the actual activities of the experts from different companies were compared. Consequently the terms appeared to be used interchangeably across the organisations examined [Mishra et al, 2002a].

The observations derived from the surveyed literature correspond to the above industrial findings. There are, however a number of documented definitions stating what both cost estimation and cost engineering amount to, although the most frequently cited reference with regards to cost engineering is produced by the AACE International: The Association for the Advancement of Cost Engineering, International, formally known as: American Association of Cost Engineers [aacei.org, last referenced Oct. 2008]. Nonetheless despite the existence of these apparent guidelines, even within the literature it can be seen that the most commonly quoted definitions are all encompassing, and therefore unspecific; particularly the widely quoted AACE one. As a result they are unclear, which again merges the two costing activities into a fairly indistinct and interchangeable format when viewed as a whole. This results in a general lack of clarity between them as further exposed within the next section.

The following section explains the range of literature-defined meanings and various uses of cost estimating, cost engineering and other terms encountered. Subsequently assumptions can be made and parallels drawn which will establish the most appropriate, single term of reference for common usage throughout this research.

#### 3.1.1.1 Cost Estimating

*"Typically an estimate is an assessment, based on specific facts and assumptions, of the final cost of a project, program, product or process"*

[Westney, 1997, p2].

Cost estimating has been described as the process in which the cost of a work activity or output is forecast or predicted [Stewart et al, 1995]. Future cost-concerns are dealt with by use of current and / or historical data. The Society for Cost Estimating and Analysis (SCEA) describes cost estimating as an 'art' of roughly determining an items' worth or cost, with use of whatever information is accessible. It goes on to state:

"*The art of predetermining the lowest realistic cost and price of an item or activity which assure a normal profit.*"

[SCEA website, http://www.sceaonline.org/prof_dev/glossary-c.cfm,
within main website, http://www.sceaonline.net/ last accessed Oct. 2008]

SCEA also defines the resultant cost estimate, produced by the act of cost estimating; stating the experts 'judgment' or 'opinion' is used to calculate a required cost, [Rush, 2002]. A monetary value is derived in order to establish guidelines for the amount a specified task, or the procurement of a required object will be; therefore the calculated costs may comprise of more then one. The results will encompass all the activities necessary to successfully complete the desired outcome; this will include material, labour hours / skill-levels, and logistics, among the predicted costs [SCEAOnline.org, last accessed Oct. 2008].

Cost estimating is completed concurrently and with the aid of other cost activities, including cost analysis. Cost analysis is said to be a *"…view into the past, with an eye towards the future"* so works essentially with cost estimating whose focus is future prevalence [Stewart et al, 1995]. These aspects are briefly discussed later in the chapter, see Associated Functions, Section 3.2.6.

To summarise, the literature relays that a cost estimate is an expert-assessment of the overall costs, in addition to a breakdown of those costs which compose the final figure; to develop a product or undergo a project / provide a service. The art of cost estimating is that which is performed in order to produce the resultant cost estimate. This includes an expert-appraisal of the cost-factors that comprise the project and / or product. The components of costing are illustrated in Figure 3.1. The areas of estimating e.g. engineering activities, overheads, and so forth are discussed later in this chapter; in addition to the relevance of the stages at which the estimate is required e.g. at conceptual design phase, or further into the project.

### 3.1.1.2 Cost Engineering: Multiple Functions:

The AACE definition states:

*"Cost Engineering is defined as the area of engineering practice where engineering judgment and experience are used in the application of scientific principles and techniques to problems of cost estimating, cost control, business planning and management science, profitability analysis, project management, and planning and scheduling."*

[AACE website, http://www.aacei.org/, last accessed Oct. 2008]

This characterisation brings scientific and technical issues together with management and financial concerns. These two areas are very broad, thus there can be a number of subsections within the AACE cost engineering description. The classification clearly requires skill and expertise from many disciplines, including management, research, economics; as well as engineering and other technical specialisations [Jelen and Black, 1983].

In conjunction with the commonly adopted AACE guideline, the literature tends to support this portrayal of the cost engineering domain as wide and often vague in its description, encompassing many cost-activities. The included activities can vary from source to source, as the interpretations of the dominant definition are modified to suit the user. However cost estimating is an area which reoccurs within the function of cost engineering in many of the referenced documents [Humphreys and Wellman, 1996; Stewart et al, 1995; Jelen and Black 1983]. In addition to cost estimating, the type of cost activities incorporated into cost engineering are included in a comprehensive list by Jelen and Black [1983]; a selection of which are presented in Tables 3.1 -3.4:

The subheading content in the tables differ according to the source referenced. For instance depreciation and depletion does not fall under the specific section of Taxes in other accounts [Westney, 1997]: These cost factors can potentially be filed under manufacturing / equipment concerns, or more generally, within economic factors. When examined under more of an accountancy light, the tax implications are clear; for instance associated time frame e.g. to completely fall within one years budget or depreciate over longer (tax rules recognize depreciation). Tables 3.1 - 3.4 have been adapted by Jelen and Black [1983] from the AACE study guide recommendation for the assessment of cost engineers: Thus it is another example of how interpretation, perspective and use of all aspects affecting cost can be adapted, per user. This is because cost incorporates wide-reaching issues, which spread over many areas; affecting the whole business in some or other manner: From engineering budgets and technical concerns; to tax and insurances, affecting finance and accountants. Therefore cost issues are modified not only according to individual expert-opinion; but on an extended scale, in relation to the focus or area of the costs.

Therefore the conclusion deduced from the reviewed documented material is that:

- Cost estimating is seen as the manner in which an approximate evaluation of the costs required are derived;
- Cost engineering is documented as a wide range of organisational costing activities.

Under close examination the activities involved in cost engineering can also be seen to be as valid within the cost estimating domain. For instance cost control and profitability, both which are mentioned in the prior stated AACE definition, can also be within the scope of cost estimating. Cost control, with regards to the examination of future occurrences to predict costs for estimation: Business planning in relation to expenditure determined by the planned out costs and values in estimating, primarily in machinery procured and alternative consideration. Plus profits need to be predetermined and accounted for towards the inclusion into overall calculations of cost; and these are just a few of the transposable terms of description. The examination of different literatures alludes to the similarities of these activities, again reinforcing an interchangeable view of these two cost terms.

The definitions of both cost estimating and cost engineering have highlighted three areas of expertise:

- Expert judgement, knowledge and assessment applied: To predict future costs with use of very little data; to overcome challenges incurred using expertise and experience.
- Economic aspects of business: To determine costs as inflation, tax, interest (overheads); and to assign costs to the technical process and materials, and so forth.
- Technical level of competence requisition: Fundamental necessity when assessing the costs of an engineering product.

Table 3.1: A Selection of Cost Engineering Activities: General Cost Considerations

| | |
|---|---|
| Equivalence and cost comparisons<br>Comparing methods and alternative materials, with equivalent products, with the view of lowering current costs. | |
| Life Cycle Costing; (LCC)<br>This is when consideration is given to the total costs associated directly and indirectly with a product. This not only includes conceptual design, development and production, but also aspects as in-service costs, (the support provided while the product is in use, particularly for products such as aerospace); maintenance; and more increasingly disposal, as government regulation stipulate manufacturer responsibility.<br>LLC is often used to evaluate potential alternatives. | |
| Time value of money:<br>Can be described in terms of the 'compound interest laws', and time-value conversion relationships.<br>Investments increase with time, and these increases also grow over time. | |
| Cost-benefit ratio:<br>The benefit of direct cost-savings against other modifications i.e. time reductions; material substitution. | |
| Detailed comparisons of alterations:<br>Changes to product; whether design, engineering, (manufacturing processes and / or materials used) in order to upgrade / refresh the models / reduce costs (even modify as per customer specification). | |
| Taxes | |
| Depreciation:<br>Decreasing value of investment over time. For example, a machine may cost £100K and be in service for 10 years. The cost of the machine will be amorphised over the length of machine-usage, not accounted for within one years' budget, but for the expected time in use. | |
| Depletion:<br>The way in which aspects which have no value once used for purpose get accounted for e.g. oil, gases, etc. This is unlike depreciation where the original 'new' value can be taken from the decreased worth; (also accounted for when assessing the costs). | |
| Inflation and cost escalation | Learning curve and productivity |
| Profitability | Risk analysis |

Table 3.2: A Selection of Cost Engineering Activities: Structure and Specification of Costs

| |
|---|
| Topics of cost: Areas which can be costed; the components which make-up the cost estimate |
| Labour: Number of labour hours required; types of expertise; pay-rates of skill type; Are skills in-house or subcontractor requirements, etc. |
| Materials: Types of material utilised; weights; suppliers |

| |
|---|
| Transportation / logistics: Transportation of materials; overseas or local; is plant split between many sites; and so forth |
| Construction, Manufacturing and Operating costs |
| Planning |
| Scheduling |

Table 3.3: A Selection of Cost Engineering Activities: Associated Cost Domains

| |
|---|
| Cost accounting |
| Indirect and direct costs |
| Design considerations e.g. value engineering |
| Forecasting<br>Long term predictions or estimates of factors usually affecting profits. Considerations include potential competition & effects of; volume of sales; variations in cost of raw materials; effects of legislation, taxes' and production costs. |

Table 3.4: A Selection of Cost Engineering Activities: Managerial Issues

| |
|---|
| Government legislation: Changes in regulation can effect industrial practice e.g. pollution control in the form of product production and maintenance. When responsibility for issues as disposal is legislated as being the industrys', this effects LLC for automotive companies. |
| Ethical considerations: The regulation / prohibition of sales to unfriendly governments in industries as defence / aerospace; Plus should production be relocated if other countries have lower wages / reduced costs for company. |
| Personnel or Human Resources, H.R. and administration |
| Budgeting: Adequate allocation of funds and resources; to cater for risk and other unexpected expenditure without going over-budget; also without wasting funds. |
| Bidding; Legal considerations |

Adapted from [Jelen and Black, 1983]

Despite cost engineering having been described as a broader domain, the fact that all three prior stated areas are involved in both cost estimating and engineering, links them together. In addition to these linkages, although literature-based definitions have been found it can be noted that most refers to one or the other as the prime cost function. Where cost engineering is primarily used, cost estimating is subsequently referred to as a costing activity within part of the wider costing process, of cost engineering. If the principle reference is cost estimation then cost engineering as an independent domain is often omitted completely, with breakdowns and estimates of engineering activities being examined but no other reference to engineering within the costing scope. With these considerations, it seems to return to the point of where either engineering costs or estimating costs are used, with regards to predetermining required costs within industrial projects.

#### 3.1.1.3 Inconsistent Industrial Terminology

When discussing the cost estimating discipline as a profession, Stewart et al [1995] stated that the expert produces estimates in order to support the decision-making process which will in time maximise resource and increase revenue and competitiveness; describing them as *"..a cost estimator, cost analyst or cost engineer."* [Stewart et al, 1995]. The literature in this instance seems to clarify that costing activities tend to be known by multiple-terms. However this is a minor acknowledgement of what was widely observed throughout the practical field-work, where many more titles and terms were used for the roll of the cost estimator / cost engineer. Refer to Chapter 4 for more detail about inconsistent cost terminology, particularly regarding practitioner title and their designation within organisations e.g. an engineering function or financial.

The literature definitions can also be seen to overlap, as explained towards the end of the previous cost engineering section. It stands to reason that if the described content of the functions are interchangeable, so too will the functions themselves, i.e. cost engineering activities fall into cost estimating, in some of the reported narrative.

The unspecific definitions and lack of standardisation with regards to primary references throughout the literature expose the potential for confusion within industry. This fundamental terminology-inconsistency aids the inadequate comprehension and communication between the costing domains and other external disciplines associated with the cost process. This section reveals that the role of the 'cost estimator' and 'cost engineer' and the act of cost estimating and cost engineering, (among other terms of reference) are not standardised. This unclear state which can be identified within the literature was substantiated further through the practical observations. Therefore in order to avoid confusion in the terminology outlined above, the terms costing process / product-costing and cost-practitioner will be used throughout this thesis.

## *3.2 The Process of Costing:*

Estimates are performed at different stages of project and for different reasons. It is commonly accepted that approximately 80% of costs are determined at the conceptual design stage, including the budget allocations; when there is little actual data to base these important results on. Further into the project more detailed estimates can be performed as more reliable data becomes available; having actual product-data to work with clearly allows for improved degrees of accuracy [Clark and Lorenzoni, 1985]. Thus the different project-phases often require different costing techniques; a variety of which are currently utilised across industry. The various procedures are based on different levels of data; some can produce an estimate with less data available, and others will incorporate various aspects of the increasing information. All techniques seem to differ depending on the quality of information; time allowances and the requirements e.g. is a detailed or top-level estimate sufficient. The following section discusses the different purposes of product-costing; and a number of related estimating techniques are described in Section 3.4.

### *3.2.1 Regions of Costing:*

Stewart et al explained: *"Cost estimating is inextricably entwined with the detailed definition of the product or service to be provided.."* [Stewart et al, 1995, p2]. Subsequently estimates are performed for each area of the project, such as engineering and design costs; operation and manufacturing costs; for fixed and variable costs; overhead and support activities [Humphreys, 1999]. The compilations of such estimates are in-depth with many considerations, and much is written on engineering estimates and their composition alone [Westney, 1997; Stewart et al, 1995; Clark and Lorenzoni, 1985].

Jelen and Black [1983] argue that there are two major aspects of cost estimating: Direct cost and indirect costs. Direct costs comprise of all the features that affect the cost of the actual product which include elements as material cost, labour hours, material type, skill level, rate per hour of labour-skill type. Indirect costs encompass all aspects not directly linked to the production of product. This includes start-up costs; insurances and government legislative effects and overheads i.e. administration, consultants, floor space per unit, management, lighting, and so forth [Jelen and Black, 1983].

Additionally the compilation of each individual quote will greatly depend on the industry and organisation examined. For instance, the calculation of depreciation differs from company to company, as does what is and is not included in overheads. How current and accurate the information used or supplied to the estimator also affects the outcome. For instance a practitioner may obtain cost-data from computer-aided costing software. However if the database of this software has not been maintained, i.e. kept updated with the latest figures, the resultant cost will clearly reflect this inaccuracy. Here the experience of the expert particularly with regards to escalation and historical data will play a major part in whether the predicted cost is recognised as being outdated, or taken at face value; see Chapters 7 and 8 for further discussion. Costing a product or project is part of the wider project management process, and the costing process itself is comprised of a series of interlinked steps [Westney, 1997]. The costing of a large project such as within aerospace, can be a mammoth undertaking with numerous aspects for consideration. Therefore a systematic series of steps is necessary in order to account for every aspect of the project, to ensure adequate representation of all costs in the final estimate.

### *3.2.2 Costing Compilation:*

The costing literature contains more then one version of the stages involved to compile an estimate. Three of the more widely quoted literatures on product-costing list incremental accounts of the process, which when compared have similarities [Stewart et al, 1995; Humphreys, 1999; SCEA website, last accessed, Oct. 2008]. Stages of the costing process are often reported as being sequential; however further examination indicates that such rigidity is not strictly necessary. This variability is depicted in the literature when different accounts can be observed as not having followed the same pattern of events as each other; showing flexibility is allowable, according to the manner of interpretation of the process, refer to Figure 3.1. There are many routes to developing an estimated cost, with considerations as the amount of data both available and required, how it is found; and the perspective and experience of the individual completing the cost-process [Humpreys, 1999]. This section highlights the steps which are most frequently cited throughout the related publications.

Figure 3.1 illustrates the array of steps involved in the cost process, whilst deliberately displaying the lack of sequencing. The required activities can be performed in a different order; depending on the particular industry, organisation, product, or as the individual practitioners' preferred series of structure. An overview of order is logical, i.e. the background and preparational work in the early / planning stages; the more detailed compilation to proceed. However these broad areas can clearly entail a number of aspects which will hold varying degrees of relevance for each different project. The process from this respect can be very fluid and certainly difficult to classify sequentially, to a medium or high level of detail for general usage. Thus Figure 3.1 gives a selection of the stages of estimating, whilst loosely grouping them under wider headings of activities. These stages and headings are not inflexible; on the contrary, are more of a guideline, with a number of the collated aspects being interchangeable and / or linked, and often iterative throughout the process.

### *3.2.3 The Systematic Steps involved in the Costing Process:*

Initially the costing process tends to be developed around a Work Breakdown Structure (WBS). This is where the main components of the project are identified and linked to each other, then subdivided from major into minor tasks; these sectioned tasks are subsequently broken down into subtasks and this structuring continues, cascading to whatever levels are required. WBS can be quite basic in the early project phases, though need to be able to allow expansion and changes as the project continues. They are often derived through collaboration with the owner, design and engineering teams [Humphreys and Wellman, 1996]. Stewart, et al [1995] discusses the WBS in detail examining the hierarchical pyramid styles as the levels descend and expand, caused by the identification and breakdown of requirements; and work element numbering system. These can be divided and listed in such a manner which outlines costs as:

- Product: Including tooling and equipment; tests and inspection; logistics
- Process costs: Including process management; raw materials; utilities
- Project: Including assembly; manufacture; project management
- Service: Including customer-contact; service support; documentation.

[Stewart et al, 1995; Humphreys, 1999].

Westney includes WBS as being within the category of scoping the work; at this stage the functional requirements of the product require definition i.e. design basis. This is closely linked to the detailed scope of work, which highlights how the functional design basis will be met. Categorical breakdowns compliment WBS by categorising subdivisions of the work, for instance into common engineering disciplines; or classifying by comparable physical traits [Westney, 1997].

Code of accounts is where the costs of each aspect of the project are filed into identifiable categories with the associated costs e.g. categories as procurement, engineering and construction. This is done to a high level of detail, and is again hinged around the WBS in the sense that it can be seen as the most detailed (lowest) level of the work breakdown structure. Code of accounting is discussed by Humphreys, who claims that MasterFormat is an industry standard within the USA: It is basically a system which files, retrieves and organises data and information; often used within the construction industry [Humphreys et al, 1996]. End-users formatting requirements ensures that the estimate is structured in a universally comprehensible manner, accounting for software differences, and ensuring that all provided information is comprehensible [Westney, 1997].

Both Stewart and Humphreys discuss the detrimental consequences of a lack of preplanning stage, which is said to be frequently overlooked by estimators [Humphreys, 1999]. The relevant historical data must be located for comparative use throughout the costing-process; and the assumptions made must be established early on [Stewart et al, 1995]. Failure to perform such tasks will result in inaccuracies and wasted time.

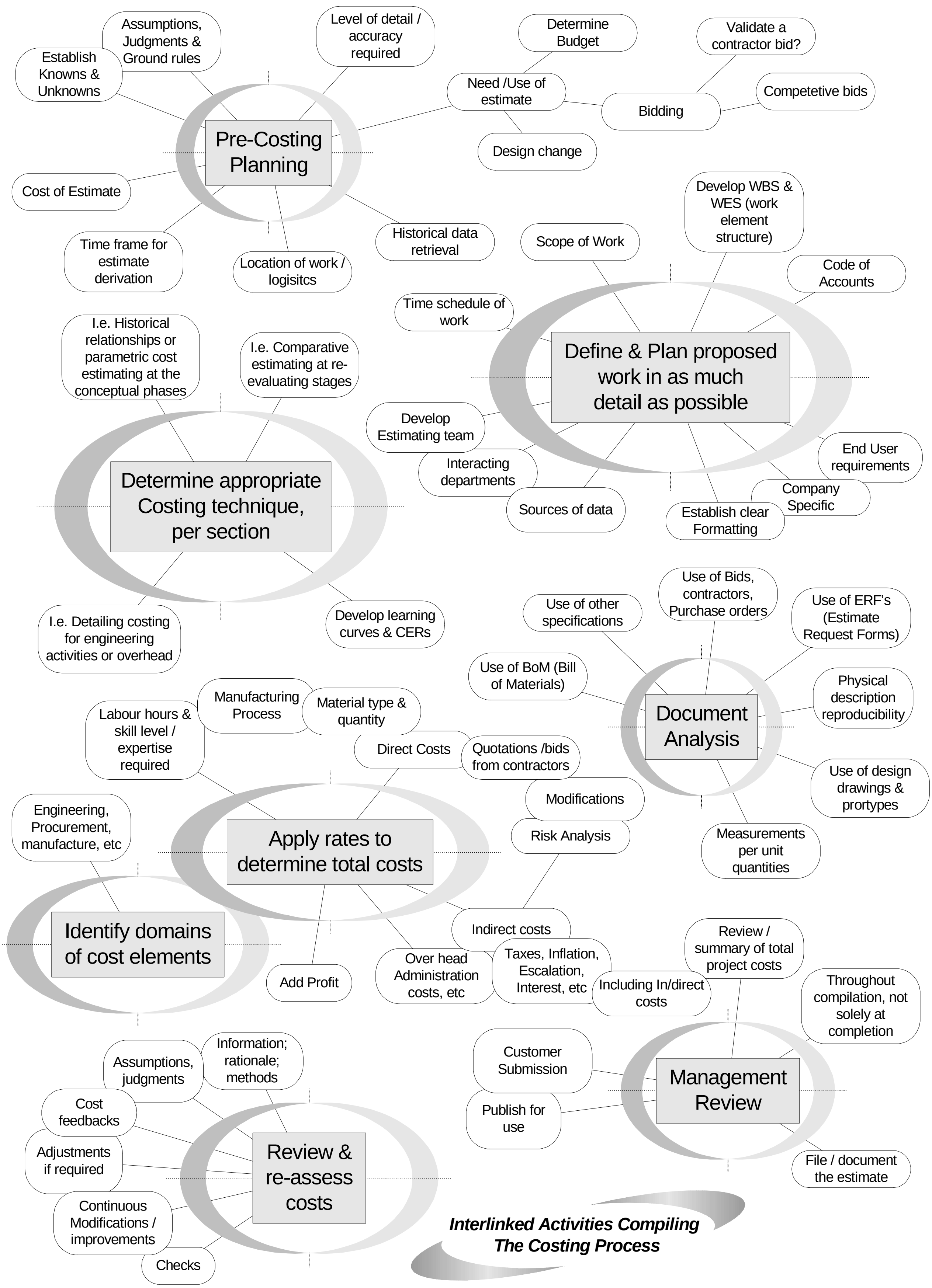



Figure 3.1: Link, Sequential Activities within the Costing Process

Additionally, lists of questions which should be addressed at this stage are documented; these include:

- ✓ Consideration of what the cost-estimate will be used for;
- ✓ The level of estimate accuracy that is required;
- ✓ Establishing the reoccurring and non-reoccurring costs;
- ✓ Completion-date of costing process;
- ✓ Identifying potential contributors for compilation of the costs;
- ✓ Understanding the primary software and hardware -overall deliverables;
- ✓ The estimate-preparation cost itself

[Humpreys, 1991; Stewart et al, 1995].

When the planning and preparation are complete, the actual components of estimate can begin to be established. This entails the use of designs, prototypes if available, ERFs (estimate request forms), purchase orders, and contracts. Basically all information and data available in order to evaluate the product, dissect every aspect involved and to asses associated costs. Issues such as inclusions / exclusions, physical descriptions, and quantities required, will need evaluation and incorporation into the final estimation results. A detailed explanation of how to actually cost aspects as material-used and labour-hours, calculated with use of figures for the average (or actual) rate per hour, rate-of-pay per skill level, number of labour hours required, and so forth, is described in many areas of the literature, including Westney [1997].

With regards to material costs, the cost per unit of weight often varies widely on amount purchased. Other considerations which can greatly influence the cost are the particular specification requisites of delivery; for instance requirements for particular cut-size or a specific shape, as the user may not have necessary equipment to do so. Where being delivered from which is associated to logistical considerations e.g. overseas or inland, and so forth. All these points need to be addressed for consideration into the final costs. Actual supplier quotes and / or bids are more preferable to base costs on than the other methods of data-collection prior mentioned e.g. calculating rate per hour for skills based on averages.

When all costs are collated they are then presented to management. This typically does not consist of a singular figure; instead the format will frequently include summary sheets attached with the final costs. The subcategory summaries will provide overviews of the contributing costs of specific areas e.g. engineering; which can potentially be divided into subdivisions of engineering activity-totals. Other inclusions will be items as overhead, direct and indirect costs and so forth, including manufacture, in-house development, subcontractor work, etc.

### *3.2.4 Perspective of Estimate:*

The issue of perspective is discussed by Westney in relation to whom is producing the cost-estimate, and from what angle they are approaching it from [Westney, 1997]. In the case of 'who', it is stated that the work culture, employer, and experience of the individual will all affect the process selected for use. The viewpoint of the estimate relates more to the owner versus the contractor perspective. The emphasis between them will differ, as the owner will have a differing perspective about issues such as the required accuracy of the costs, business-risks, uses of cost-estimates, and determining the most beneficial level of involvement. More specific considerations, for instance in the early phases of project lie in the consideration of features as potential funding acquisition, new technology types, site-studies, marketing, logistics, and general contributors to costs and risks. Whilst the owners' participation in the initial stages is dominant, the contractor is intricately involved throughout the continuing and concluding project-phases. The contractors' requirements are to meet specifications set by the owner (customer). The concerns regarding risk and costs are more focused e.g. on the specific areas that they are contributing to as opposed to an overall concern for the project as a whole, which the owner will have [Aaron, 1995].

In addition to this business-angle perspective, the type and result of cost produced can differ depending on a number of factors surrounding its derivation. These include: The skill of the performing cost-practitioner, the level of accuracy required, the time given for preparation, how the costs are calculated, e.g. the annual breakdown, what is excluded and included in the final cost, and the amount and quality of data available.

### *3.2.5 The Requisite and Use for Cost Estimates:*

*"…before embarking upon a significant construction project or other endeavors requiring expenditures of large sums of money, those concerned need to know, and therefore, ask how much it will cost."*

[Humphreys and Wellman, 1996, p4]

An estimate can present the potential Buyer with the information to asses whether they want to and / or can afford to purchase the product; and gives the seller an idea of production costs and probable profits [Stewart et al, 1995]. In addition to these types of feasibility studies, estimates are required for other uses, many of which are listed within Table 3.5.

The different types of estimates conducted are not just for the various stages of project, but also to address the differing aspects involved, as stated by Jelen and Black: "*Cost is the glue that binds together a wide variety of components into a single structure*." [Jelen and Black, 1983 p3]. For instance engineering and design activities require costing which differ from that of overhead and support activities, which are often costed separately. It is important to be aware of the costs of different aspects of the project, in order to identify areas of over-expenditure; or to learn for unpredicted costs for future reference. In addition to requiring the separate entities, the components that make up the entire project are brought together into one estimate for uses as competitive bids and to assess initial feasibility of project.

### *3.2.6 Associated Functions*

The associated financial activities which both input into product-costing, and utilise their output were found to be inconsistently referenced; where the same functional characteristics emerged under various guises. This section presents an academic guideline of the main interrelated functions, highlighting their roles. Fundamentals within leading costing literature associate the process of product-costing with cost accounting, and cost management. This is in the context of how cost-estimates should be connected to the actual costs, in order effectively control current business resource; and can be used to predict the future performance of the business including provision of guidelines for the management of resources within the organisation. Subsequently the systemic area of 'cost' is interlinked with these three major functions: Cost estimating, cost accounting, and cost management; which collectively have important business contributions, see Tables 3.3 and 3.4. When the former are utilised in an integrated manner they produce results beneficial to organisational decisions; and are outlined in the following sections [Stewart et al, 1995].

Table 3.5: Requirement and Use for Cost Estimates:

| Utilisation of Cost Estimates |
|---|
| Asses the viability / affordability of the project |
| For risk assessment and to establish reasonable contingency:<br>✓ E.g. cater in budget for unexpected cost-escalation,<br>✓ Excluding changes to product, and natural events as earthquakes, strikes.<br>✓ Includes risks as weather-change effects; unstable / unreliable supplier. |
| To prepare bid proposal preparation. |
| To asses material and facility costs. |
| Appropriation of required finance:<br>✓ Production of a project estimate assists in the procurement of obtaining funds due to the visibility of proposed costs. |
| Bestows information required to produce a project-schedule:<br>✓ E.g. the duration of tasks,<br>✓ Resources required,<br>✓ Types and levels of activities to be undergone, etc. |
| Enables a good planning basis for project:<br>✓ By providing resource requisite such as labour, materials. |
| Determine project budgets and establish cost targets:<br>✓ Bestows time scales.<br>✓ Subsequently aids in the control of costs. |
| Return-on-investment (ROI) evaluation:<br>✓ Indicates revenue,<br>✓ Or often is complied around the predetermined profit margin dictated within larger organisations. |
| For comparative design assessments:<br>✓ E.g. Most cost effective choice from a selection of designs (~design and economic studies);<br>✓ Site-comparisons: Alternate site selection ~most advantageous investment choice;<br>✓ And other cost reduction studies |
| To decide whether to produce in-house or contract-out work:<br>✓ E.g. Make or Buy studies |
| Asses the cost of additional work and / or changes to product / contract modification |
| Provides cost information on potential / new products. |
| To compare and asses supplier bids:<br>✓ If too low the supplier may loose money or even suffer bankruptcy, which would greatly effect costs;<br>✓ Or if too high, they will not secure the bid. |
| Comparative analysis:<br>◊ To validate accuracy of bids from contractors and subcontractors with use of Independent Cost Estimates (ICE). |
| ICE for negotiations with supplier contracts and cost-proposals / estimates:<br>◊ I.e. bid evaluation. |
| Future cost-estimates:<br>◊ Can be used as historical data, if enough detail to allow for updates. |
| Can promote discussion:<br>◊ Via different teams assessing input to cost estimate in early stages and throughout. |

[Stewart et al, 1995; Jelen and Black, 1983; Humphrey, 1991; Westney, 1997; Clark and Lorenzoni 1985; NASA, 2006]

#### 3.2.6.1 Cost Accounting

*"Cost Accounting supports financial systems in their attempt to measure how much to spend on individual resources, how much was spent, and how effectively the finance was spent."*

[Quinlan, 1989 p3]

Unlike product-costing (or industrial cost estimating / cost engineering), cost accounting seems to have a reasonable consensus regarding its literature-definition, with the above quote highlighting a fairly typical characterisation of this activity. Cost accounting helps plan and control organisational activities, by providing financial information; which exposes the financial implications of decisions made [Hussey and Hussey, 1999]. Therefore it can be perceived as a type of checking system of the 'before and after' i.e. costs actually spent, versus the figures that had been estimated [Hyder, 1999]. Included within this associated cost topic are direct and indirect cost, standard costs, joint costs and transfer pricing [Jelen and Black, 1983].

The opening quote to this section was taken from an EDP, (Electronic Data Processing) cost accounting publication. In which the definition of this activity extended to the gathering of principles, procedures and methods used to estimate, measure or analyse the cost of individual data processing services (products), departments, resources, or other segments of an organisation for internal or external purposes. A 'Cost account' has been described as the point where the budgeted costs and actual ones can be assembled and evaluated; allowing the management of costs and planning [SCEA, last accessed Oct. 2008]. Thus if an organisations' cost accounting is of high enough quality, the product-costing function can utilise this historical, comparative data to maximise the cost-results (or estimates) produced: It is therefore clearly an important corresponding cost activity.

#### 3.2.6.2 Management Accounting:

Management accounting can be closely associated with cost accounting, though has been differentiated within some literature, were its function has been utilised as:

*"Management Accounting is concerned with providing financial information to managers and other persons inside the organisation"*

[Morse et al, 2003, p17]

This activity is similar to cost accountancy but on a wider scale, with its intent being focused ultimately towards a different application: It may be perceived as an activity which assists managerial decision-making, providing a spectrum of financial information [Williamson, 1996]. The difference between cost accounting and management accounting has been acknowledged as, the former being a way to identify the actual costs through the compilation and structure of localised or domain-data and information. Whereas management accounting incorporates and expands upon this function, extending it to the organisational level as opposed to more targeted focus, e.g. project-based data-collection and analysis. As the designation suggests, it is intended to contribute towards managerial considerations, e.g. influencing corporate policy, and so forth [Hussey and Hussey, 1999]. Therefore this costing function has considerable influence within companies, with regards to their prior financial tracking and future decisions.

#### 3.2.6.3 Cost Management:

Although cost management (CM) is currently a widely used term within business, there does not seem to be a clear, consistent definition that standardises it [Cost_ Management, last accessed, Oct. 2008]. With regards to product-costing, there are a number of technical activities which directly impact it, and are prominently discussed throughout the thesis. Additionally there are the financial areas which tend to influence the costing process more indirectly, including cost management. Therefore it is necessary to clarify its meaning in a judicious manner, appropriate for this research; as the following definition conveys:

*"..cost management is based on the requirements of oversight and reporting of information needed to financially control the business process."*

[Stewart et al, 1995 p2]

Though the initial impression of the above quote may be generalistic, it holds significance ultimately because it states that the management of costs takes whatever route is relevant (per application) to assist financial decisions on a corporate scale. Cost management is approached via a systemic route, tracking the major cost-components involved on an organisational level aiding financial and competitive gains [Grundy, 1996], as mentioned in the previous section. The monitored costs include labour, material and overheads: The management of which should precede cost accounting and product-costing (estimating), the three functions having been described as almost cyclically interlinked. An example of cost management can be seen in design-to-cost projects, which stipulate the cost of the product prior to its development; as opposed to establishing the stages involved, and deriving the cost based on a compilation of the steps. This type of activity which has tended to be perceived as falling within the realm of cost management, can now be commonly placed within product-costing, as the industrial studies undertaken for this thesis reinforced [Stewart et al, 1995].

#### 3.2.6.4 Cost Analysis

Cost analysis has been described as being closely associated with product-costing, where costing looks to the future; and cost analysis spans across the spectrum of previous and future costs, assessing and structuring them [Steward et al, 1995]. A definition of cost analysis is given as:

*"The accumulation and analysis of Actual Costs, statistical Data, and other information on current and completed Contracts or groups of contracts or programs. Cost analysis also includes the manipulation of Cost Data, comparisons and analyses of these data, and cost extrapolations of data for future projections of cost."*

[SCEA website, http://www.sceaonline.net/ last accessed April 2009]

The quote conveys the range of analysis process which can be undergone on previous costs, in order to apply them to the establishment of future predictions. Within organisations the associated functions described within this section were often observed as falling within the industrial product-costing function: The previous account of cost analysis is a typical example of this. Many companies within the industries examined classified them as general costing activities which can be categorised within the function of product-costing. Therefore the activities were undertaken sometimes simultaneously, by essentially costing practitioners; whose expertise covered a range of costing-related disciplines; which industrially could often been seen to fall within one activity, see the following Chapter, 4 detailing the exploratory industrial research.

The literature tended to differentiate between them, making them distinctly separate, though generally dependent on each other. Thus revealing what is perhaps not unexpected which is, that in theory these activities can be distinguishable as specific activities, but when costing activities and the financial associations are practiced in reality, many of them including product-costing and cost analysis, fall into the same domain, and are dealt with by the same practitioners.

### *3.2.7. Supplier Interactions:*

A branch of product-costing which is essentially external to the organisation is that of supplier interaction. Although comparatively little has been documented about the direct relationship between product-costing and supplier, it is a subject which occurred within the industrial research seemingly playing a significant role within the activities of product-costing. Refer to Chapters 4, 6, 7 and 8 for details about the industrial finding and further discussion regarding supply chain interactions.

The supply chain has been described as incorporating manufacturers, distributors, retailers along with suppliers [Beamon, 1998] in order to interactively provide *"..vital business process"* [Ramudhin et al, 2008, p71]. The latter incorporates everything from dealing with the raw materials, production, and enhancements, to sales and after-sales care [Min and Zhou, 2002]. The resultant implication is that supply chain consists not only of the interaction between supplier and industrial buyer; but includes logistics, vendors, as well as the end-users of the product. From this perspective the supply chain basically constitutes every phase that leads to the development of product for the customer, inclusive of costumer requirements such as training and / or in-life service and maintenance; until overall customer satisfaction is achieved [Chopra and Meindl, 2001; Cakravastia et al, 2002]. Zuckerman [2002] discusses such aspects of supply chain theory, whilst providing ten steps to implement it successfully within actual business environments. These steps include maintaining quality; which in turn assists the perpetuation of JIT (Just-In-Time); managing change is essential for the continuation of supply chain; as is identifying with new roles across organisations. Here business-to-business (B2B) interface was recognized as an essential part of those changes; along side appropriate technological considerations. This linked into development of a supply network; whilst working within a web environment; and creating a web presence within an ever increasing electronic commerce (e-commerce), globally interactive domain [Zuckerman, 2002].

The supply chain fundamentally balances the issues of cost and quality throughout the product life-cycle [Ramudhin et al, 2008]. This perspective has seen to be mirrored in the industrial activities between supplier and costing; as the supplier is often involved throughout the project from conceptual design stages onwards, and was occasionally even based within the buyer-domain for the duration of the project. See Chapters 4, 6, 7 for details of these results, specifically Section 7.2.3.3 Knowledge of Supplier–Process: 'Tricks' and Trust Issues, and Figure 7.10; plus Chapter 8 for discussion about improvements to these collaborative working agreements. The type of cost utilised depended on the stage at which it was being performed; as was the level of interdisciplinary contribution: Whether supplier, engineering, purchase, management or all were involved, the costing technique used tended to have an impact on what level of input was required from the various contributors. The following sections discuss cost types and techniques, which include the various economic implications of adopting different approaches to costing, as industry or organisational specific.

## 3.3 Types of Costing:

Whilst product-costing can be performed via a range of techniques, each one requires an assessment of the overall job plus analysis of the work involved within the task. The degree of detail necessary regarding the work-activity breakdown will vary between an overview, to intricate details; either way a degree of information in this domain is required for the process of each estimating technique, [SCEA website, last accessed Oct. 2008]. Although there are a number of estimating techniques, which are discussed later in this chapter, classifications can be made regarding the general areas in which they can be grouped. These are focused around the project phases; from early stages through to development, production and use; see Figure 1.1 within Chapter 1.

### *3.3.1 General Classification:*

The costing texts give a range of general classifications; these span from between two and five main groupings, depending on the material referenced. Generally three major categories of project-phase emerge from the literature in which specific estimating types are performed, as relevant to the stage; see Table 3.6. These were Conceptual, Preliminary, and Definitive Estimates, though are also referred to by other names, refer to Table 3.6, and the following sections.

#### 3.3.1.1. Conceptual Estimates

Conceptual costing, see Table 3.6 for terms otherwise known as, is performed at the early evaluation, preparation and conceptual stages of the project. Therefore the amount of actual data available on which to base the costs on is low, with only loosely defined programmes, plans and rules. The work scope and hence statement of work (SoW), schedules, logistics, equipment and labour requisites are largely unspecified; essentially requiring generalisations to be made and informed predictions. Risk is an important factor at this stage, with the lack of definition and other uncertainties. Therefore a substantial allowance for risk is often incorporated into conceptual estimates [Humphreys and Wellman, 1996; Clark and Lorenzoni, 1985].

Consequently the confidence level of such estimates are low therefore they are primarily used to provide information or top-level 'go / no-go' decisions, early on in the programme; as opposed to forming the basis of firm commitments [SCEA website, last accessed April 2009]. The estimating techniques which fall into this category are given in Table 3.7 and described in Section 3.4.

#### 3.3.1.2 Preliminary Estimates

Studied cost-estimates, see Table 3.6, are conducted after the major project-concepts have been agreed but whilst still within the initial design stages. A minority of the documented sources have integrated conceptual and preliminary estimates: For instance Jelen and Black [1983] places them both under the category of preliminary; stating that they are used in the early, conceptual stages where there is little verifiable data or information to evaluate the project [Jelen and Black, 1983]. More commonly though they were distinguished between, and classed independently; with preliminary estimates being developed with use of conceptual organisational costing. They are derived with greater quality or higher definition of data, rules and with more product detail; and are subsequently more reliable then conceptual estimates. However there is again the requirement for risk allowances, and insufficient actual data means they are still not adequate to base formal commitments upon. The main use for these types of estimate is in procurement, funding and other financial evaluations [Westney, 1997].

Table 3.6: Characteristics of Project-Phase Costing-Types:

| PROJECT PHASE | ALTERNATIVE REFERENCE | DESCRIPTION |
|---|---|---|
| Conceptual Estimates | ○ Rough Order of Magnitude (ROM)<br>○ Ratio Estimate<br>○ Screening Estimates<br>○ Rule-of-Thumb<br>○ Top-Down estimate<br>○ Ball Park figure<br>○ Planning Estimates | These estimates are essentially derived with little –no actual data, so cannot provide much detail.<br>They can be used as a guideline, as the level of accuracy expected relays (see Section 3.1.1); to make 'go /no-go' top-level decisions. |
| Preliminary Estimates | ○ Budget Estimates<br>○ Feasibility estimates<br>○ Top-Down estimate<br>○ Studied estimate<br>○ Factored Estimates | Can be used for financial and supplier evaluation; these costs still tend to lack in detail, as the typical range of %-accuracy level reveals (see following section). Though are good cost indications in the preliminary stages. |
| Definitive Estimates | ○ Detailed estimates<br>○ Project Control Estimate<br>○ Defined estimate<br>○ Final estimate<br>○ Official estimate<br>○ Firm Cost estimates<br>○ Budget estimates<br>○ Check estimate<br>○ Bottom-Up Estimating | Often derived further into the project (i.e. 40% into), with use of more actual data to base the figures on. Therefore firm costs can be deduced, which have high levels of confidence. The results can act as binding commitments for the parties involved. |

Reference: [AACE, 2009; Jelen and Black, 1983; SCEA, last accessed April 2009; Westney, 1997; Humphreys and Wellman, 1996; Clark and Lorenzoni, 1985]

### 3.3.1.3 Definitive Estimates

Definitive product-costing methods, see Table 3.6, are derived from quantitative information with use of a high level of detail and often undergone with a lot of planning. This is due to the fact that they are created after the determination of the initial scoping of project, and because there is more actual data to base the costs on. Definitive cost estimating tends to be based on factual data and mathematical modelling, though techniques vary depending on the industry. Refer to Section 3.4 and Table 3.7 for specific techniques used in this phase. These estimates are approximated as being +/-10% accuracy, see following section for more detail; however the specific accuracies depend on the level and quality of information available as well as the time allowed to produce it [Jelen and Black, 1993; Westney, 1997].

Detailed estimates can be derived when the consumer has placed a definite request for work among its other uses, including to support contracts and negotiations; bid-proposals and bid-evaluations; establishment of budgets; changes to contract / extra-work orders; and to assist in the procurement of funding. The costs derived from these methods are usually used as binding commitments for the organisations, namely the supplier or customer involved [SCEA Online, April 2009; Clark and Lorenzoni, 1985].

#### 3.3.1.4 Project-Phase Estimation Accuracy

The accuracy of each of the project-phase types has been approximated as:

- Order of magnitude (ratio estimate) -30 -+50%
- Preliminary (budget authorization estimate) -15 -+30%
- Definitive (project control estimate) -5 -+15%

[Jelen and Black, 1983 p 323]

During the preliminary stages of the project where little verifiable data is available the costing techniques which centre on expert judgement / experience, historical data, rule-of-thumb and simple mathematical equations are used to derive the estimates required. The approximate accuracy of these estimates, which are relatively low in cost to produce, is as stated above. However ultimately the accuracy depends on the amount of time allowed for the creation of estimate, in order to gather, validate and incorporate as high a level of product- data as possible; and subsequently the level and quality of information available [Jelen and Black, 1983].

Definitive costs are generally conducted at the engineering / production stages of the project and though have greater accuracy than at earlier project-phases, are more time-consuming to prepare. As they require so much actual product data, if their derivation is delayed until enough high quality data is secured from the development of the evolving project, the results can be attained at too late a stage to be of proper project cost-control use [Clark and Lorenzoni, 1985]. More detailed accounts of costing-accuracy are explained in the documented literature [Westney, 1997]. The accuracy required for the end-use should fit the type of estimate performed, i.e. A high level of detail with marginal accuracy-increase can be sacrificed if an overview, ball-park estimate is needed, very quickly and early-on in the project.

For budgeting, planning or firm company commitment, another costing-type may be employed, namely Not Less Than (NLT) or Not To Exceed (NTE) estimates. The figures produced by these methods can be passed onto a supplier, when a maximum allowance is specified for work to be done; or when purchasing items. It can also be used to secure minimum payments for contracts. SCEA, an influential international costing body, has stated:

*"The amount of contingency of NTE / NLT allowance added is strictly an estimator or management judgment factor"*

[SCEA, website http://www.sceaonline.org/, last accessed April 2009]

As stated previously there are different accounts of the phases of cost estimating, i.e. some of the literature places phases one and two together; whilst others situate aspects of group two into group three; and so forth. The given account is derived from summarising the majority of the costing publications.

## 3.4 Cost Estimating Techniques:

There are a number of techniques from which an estimate can be derived. The purpose of the estimate, time allocation, and available information all determine the costing-technique which will be used: Estimates vary widely in accordance with these parameters [Jelen and Black, 1983]. Additionally, the perspective and experience of the estimator [Zhang, 1996], the type of calculation utilised and the project-phase can all affect the resultant estimate, e.g. whether it is being derived for conceptual, or production / construction stages. In other words the type of costing-technique used depends at what stage of product life-cycle the process is being performed for, see Figure 1.1, Chapter 1; with different types being suitable for different stages [Farineau, 2001].

Table 3.7 highlights the phase of project against the most appropriate technique of costing. These consist loosely of the early, conceptual phase; intermediate or development / design; and the final stages i.e. production / construction / in-life service / support, as discussed in the previous section, and refer to Table 3.6. Estimates are also required for VEVA (Value Engineering, Value Analysis) and change management, which can occur throughout.

The literature provides adequate information with regards to cost estimating techniques. Therefore to avoid reiteration this section gives a brief summary of the main types, their uses, and phases employed; whilst attempting to bring together any inconsistencies in the published work. For instance it often appears that a type of estimation is known by more then one name; this coupled with the differing descriptive narrative can obscure the fact that some of the methods are similar, or the same. To avoid confusion such techniques have been compared, assessed and are summarised throughout the following section. Table 3.7 lists the different names which in essence describe the same costing technique, or are close enough to be grouped within the same reference. Further into the research it was noted that these differences in terms, for what was essentially the same technique, was a universal one i.e. observed both within the literature and industrial encounters: The reference or name used per technique differed depending on organisation, etc. This is why it was important to provide the main range of costing-technique titles referred to, as well as the description of process attached to these labels, where appropriate.

### *3.4.1. Traditional Cost Estimating*

Traditional cost estimating is derived by focusing primarily on raw material, subsequent related activities and overhead. The technique equates the level of activity to the amount of raw material used, with the latter directly affecting the former. For instance if the amount of raw material used is low, the estimate will link this to the level of activity, which will therefore also be assumed as low. Similarly, if the raw material used is high, the associated activity will be presumed as high; with the cost calculated accordingly. Within traditional costing a particular pre-established amount, usually 15%, of the estimate is classified as overhead costs.

All three of the above points related to overhead, activity, and raw material are gross approximations, and not necessarily the most valid assumptions. Although 15% may be a reasonable deduction for the overhead costs, they will almost certainly differ between projects. With regards to the level of activity being proportional to the utilised raw material, lower material quantities might require a vast amount of intricate activity, for example in specialist areas such as avionics. This subsequently higher activity demand will incur larger costs, which will be overlooked by the traditional product-costing technique [Griggs et al., 2001]. Therefore, although in theory the raised activity in accordance with greater material requisites can be applied; in reality the relationship will too often differ from this equation:

Traditional Estimate = overhead (15%) + material (x level) + activity (x level)

The traditional costing equation does not account for: The higher costs associated with specialist labour, though the amount of this labour may be relatively lower. A smaller amount of a more expensive material may be required: For example the cost for a relatively small quantity of the higher value or quality material, may equal the cost of the lower value, high quantity material. The different types of machinery used for these materials will not be accounted for or considered individually, and may simply be generalised within the overhead %-costs. High / low level of raw material does not necessarily equate to a high / low level of associated activity.

To summarise, for a low confidence, rapidly produced estimate traditional costing may be effective in providing a non-committal idea of the potential costs involved at the beginning of project when little actual data is available. However it is not a suitable technique for basing firmer costs, necessarily making many assumptions and generalising information, [Cost Estimating short course, 2000].

#### 3.4.1.1 Merits & Drawbacks of Traditional cost-estimating:

Traditional costing is a quick method of procuring an overview cost which can be obtained in the early phases of project; thus able to be derived with use of little data. Guidelines used to base costs on can be as reasonable an assumption as any, given the low level of actual data available on which to derive the estimate from.

The traditional costing technique may overlook overt escalated costs due to the basic relationship between material and activity. Additionally it omits the examination to any degree of detail regarding many influencing aspects towards cost, including labour and varied effect of material level upon activity required: Subsequently the confidence factor is low. Template assumptions on which costs are based can be seen as outdated, given that contemporary products are vastly more sophisticated, in comparison with much older models. For example aerospace and automotive vehicles have lower mass, often due to intricate detail towards the electronics, as well as a lower quantity of relatively novel light-weight materials used, e.g. carbon fibers / composites / ceramics, selected over metal usage.

### *3.4.2 Detailed Cost Estimating*

Unlike a number of the other costing techniques which focus on certain aspects of the costing process i.e. the activities, ~parameters, ~features and / or ~material quantities, and base the bulk of the costs on these areas, detailed costing is more of an all-encompassing technique, deriving costs with use of as many product details as possible. This ranges from the incorporation of basic labour-hour estimates to the overheads, material costs and specific manufacturing-process associated costs [Stewart, et al 1995]. This has been relayed by the costing body, SCEA (Society for Cost Estimating and Analysis):

*"A method of Cost Estimating characterized by a thorough, detailed Analysis of all tasks, Components, processes, and assemblies. Requirements for labor, tooling, and material items are produced by this type of Estimating. The application of labor rates, material prices and overhead to the calculated requirements translates the Estimate into dollars. This type of estimating is further characterized by the presence of complete calculations, records, and quotations that are available for future use."*

[SCEA, http://www.sceaonline.org/ last accessed April 2009]

Within such a detailed process, each area of cost can be broken down to further sub-costs within the domain. For instance labour-hour estimates of every level of skill required to complete the job will be combined with the appropriate labour pay-rates, from basic low-level skills to the experts utilised for specialist activities. The range of expertise involved could be wide, including engineers, (junior and senior engineers), designers, draftsmen, their assistants, manned machinery, and so on. A compilation of all these rates and skill levels will produce the labour-cost estimates. A detailed break-down of the labour costs derived for the estimation of labour hours worked, are typically procured from an average of the rates paid to the type of skill level in question, referred to as 'composite' labour rate [Stewart et al 1995]. The composite labour rate is calculated by multiplying the labour-rate per hour by the number of hours that skill will be utilised in order to accomplish the task at hand.

The manner in which overheads are deduced per organisation needs to be overtly known for detailed costing; this allows subsequent specific estimates of each individual aspect of the overhead to be compiled, which can be extensive particularly for large projects in major organisations. The overheads can include general administrative costs as well as aspects as floor space per unit, travel and logistics, electricity, indirect labour, i.e. cleaning staff, management, consultants, training, and so forth.  Thus a summary of the detailed costing technique is:

*"Detailed estimating requires the understanding of and the distinction between initial acquisition costs; fixed and variable costs; reoccurring and nonrecurring and direct and indirect costs".*

[Steward et al, 1995, p197]

Though thorough guidelines with regards to the specific calculation of aspects as labour, breakdowns of engineering activity, and overhead costs are provided in a number of the costing texts, the results from a detailed costing process depends largely on the expertise and experience of the practitioner performing the process [Zhang, 1996].  The overall estimate is concluded by adding the fee or profit being made from the product. The final estimate on a project / product is said to be detailed: Given the lack of data at the beginning of projects, this is a logical deduction of detailed costing [AACE, last accessed Oct. 2008; Humphreys and Wellman, 1996].

An estimate which seemed to have similar characteristics of detailed, but was referred to by a different name, was that of the grass roots estimate. The similarities of grass roots to detailed, is that it starts from the bottom-up (also known as this; see Table 3.7 for name listings), and gathers as much actual data as possible to compile the costs from. Though the latter mentioned is true of all estimates, the thoroughness of this technique tends to ensure greater accuracy. A characteristic of grass roots costing is that though it collects data and information from all interacting functions and contributors, it will then utilise whatever amalgamation of costing techniques are fitting, given the accumulated input, for the most accurate output possible. Regarding the other references which can broadly be categorised within detailed costing: A sum of the detailed cost estimates was referred to as the engineering cost estimate, generally produced by supplier bodies and / or financial functions [SCEA, last accessed Oct. 2008]. Refer to Table 3.7 for a list of other terms for this technique, and all others discussed.

#### 3.4.2.1 Merits & Drawbacks of Detailed cost-estimating:

Detailed cost estimating is as the title suggests very good for obtaining a detailed comprehensive breakdown of every aspect and level of the project being estimated. Therefore a merit of such estimates is the high level of confidence that can be placed in the results, due to the extensive detail included within them. This is important in areas where the degree of accuracy of costs are under public scrutiny such as within government funded corporations.

Although detailed costing tends to be perceived as a time consuming process, an experienced practitioner can complete a grass-roots cost-process within a relatively faster time then a less experienced one. Therefore there are instances when it is not as lengthy a pursuit as it is perceived to be. Plus the results produced are often claimed to be more accurate then any other process, including those which use computerised softwares' specifically designed to aid the product-costing. For details of the former mentioned refer to Section 3.4.12 Computer-Based Cost Models, and Table 3.8.

A major drawback of detailed estimating is that it largely does tend to be time consuming; subsequently the industrial application can be limited, as the production of costs are often derived under tight time pressures e.g. for use in change management, bidding, and so forth. This estimating technique is also resource consuming: The result of which is that companies may not have the time and available labour to undergo such thorough estimates, needing to suffice with less resource-intensive techniques.

The other primary limitation is in the very nature of detailed estimating, which is its prerequisite for a high level of actual product-data; the main consequence of which is that it can only be used further into a project, when more of the required information has become available. Additionally the results for such highly detailed costs, lie less within the technique used, and more in the quality of the data used [Briand, et al, 1998]. Therefore if the data is inaccurate this will result in a low quality output, for even the more complex costing processes.

The nature of costing can be very expert-dependent, as typically there is not enough data at the beginning of a project to enable such detailed estimates; although paradoxically this is often when the majority of important costs need to be established. Many budgets, and other cost-decisions are necessarily defined at these early stages. This results in the implementation of techniques as top-down costing being performed by established practitioners as a way to secure as high a level of confidence as possible in the output of such techniques, which are essentially low confidence processes; and are discussed as follows.

### *3.4.3. Top-Down Estimating:*

The level of resource required to produce an estimate depends on the type of estimating method used. ROM (Rough Order of Magnitude), 'Rule-of-Thumb' or 'top-down' costing can be produced with relatively low resource, and under pressured time frames. Table 3.7 lists more titles by which, what is basically the same technique has been referred to [Jelen and Black, 1983]; but a fundamental characteristic of ROM-costs is that they may be produced with use of little actual data. This makes it an ideal costing process for the conceptual stages of a project where ballpark figures are required. However the demands made on these rule-of-thumb costs are heavy, due to the necessity of scoping projects, setting budgets, establishing time frames and so forth, all required at the early project phases [Humphreys and Wellman, 1996]. While the results tend to be more intuitively derived figures [Rush, 2003], rather then considered, meticulous costs compilations, capital costs may be used for a variety of purposes, including: Procurement of investment; create the foundations of contract, proposal or bid. Plus guidelines by which further, more detailed costs may be based on; and for comparative analysis against other derived costs [Westney, 1997].

This type of cost can be described as being on the opposite side of the spectrum to detailed costs or bottom-up, which tends to be performed in the later, definitive stage of the project lifecycle with the use of more actual costs, which are known by then. With this said they are both commonly executed costing techniques, with detailed costs obviously being required once the required level of data has been attained. Conversely not only do top-level, ROM costs need to be established in order to base fundamental goals and project objectives on [SCEA, last accessed April 2009], but they were at times stated as being the primary costing procedure, principally due to low resource i.e. time-constraints and low funding / insufficient labour, [Cost practitioner, Automotive industry, 2002; 2005]. In such companies full costing processes were frequently bypassed, over capital cost estimates; described as follows:

*"Capital Cost Estimating is essentially an intuitive process which attempts to predict the final outcome of a future capital expenditure program even though not all parameters and conditions concerning a project are known or not fully defined when the cost estimate is prepared."*

[Jelen and Black, 1983 p323]

Hence due to the significance of these costs they are also known as Expert-Judgment; as although they are performed at the early stages, the costs are still adequate to base decisions on. Research undergone by Rush [2003], shows that these types of processes rely heavily on the assumptions and rationale of the practitioner [Rush, 2003]. Such tacit contributions could often not be explicitly recognised, in order to verbalise it by the practitioners themselves [Vigder and Kark, 1994]. This leads to the presumption that though ROM is a straightforward technique, it is better applied by practitioners who have substantial experience within the field in question, whether aerospace, automotive, white goods, etc., to produce the highest confidence levels of cost-estimates.

#### 3.4.3.1 Merits & Drawbacks of Top-Down Estimating:

Costs can be derived early in project lifecycle: This technique requires little actual data in order to base a feasibility cost on, which conceptual-phase decisions can subsequently be founded upon. The process is relatively fast compared to more detailed techniques, and requires less resource i.e. time and expense, to perform. The lack of detail within the ballpark figure may result in the costs being up to 50% inaccurate [Jelen and Black, 1983]. This lack of confidence is compounded by the necessity of the costs, i.e. the need for rapidly produced result. Additionally, it is due to assumptions necessarily based on things other then actual data from factual project-outputs; whereas instead the costs are based on aspects such as historical data / past-project; simulated models; practitioner experience / prior knowledge of product.

Related to this point, the most effective rule-of-thumb costs will be produced by experienced, knowledgeable practitioners; so it stands to reason that novices to the domain and /or less experienced performers will produce even lower confidence-level results [Vigder and Kark, 1994]. This coupled with the observation that expert-judgment costs are dominated by implicit suppositions [Rush, 2002], which are difficult to explicitly convey signifies that the wide application of ROM may be leading to challenges across the costing community. The latter mentioned currently claims to have a depleting knowledge source as stipulated by a number of industrial contributors, including Ford Motor Company practitioners, [2002; 2003] and JLR [2003; 2005]. These results are expanded on in later in the thesis within Chapters 4, 6, 7 and 8.

### *3.4.4. Parametric Costing*

The parametric technique of estimating costs can be described as assigning cost to a function of specific parameters. As the costs are related to variables they are also known as Cost Estimating Relationships, CERs, [DOD, 1999]; which have been described as:

*"..A mathematical expression defining Cost as the dependent Variable to one or more independent cost driving variables. .."*

[SCEA, www.sceaonline.org, last accessed April 2009]

*"A Cost Estimating Methodology, using statistical relationships between Historical Costs and other program variables such as system physical or performance Characteristics, contractor output measures, and manpower loading, etc. 2) An Estimating technique which employs one or more Cost Estimating Relationships for the measurement of Costs associated with the Development, manufacture, and/or modification of a specified End Item based on its technical, physical, or other characteristics."*

[SCEA website, www.sceaonline.org, last accessed April 2009]

The most straightforward way to describe this concept is by a basic example in the case of determining conceptual costs towards the building of a house:

Cost =Function of specific parameters *
(parameters can be dependent / independent variables)

This equates to a simplistic equation:

$$y = ax$$

Where y = cost; a = price per $m^2$; x = number of $m^2$

The number of meters-squared (x) will depend on the preferred size of house, so in this sense can be a variable; though once established, is a fixed parameter: Such subjectivity in CERs has been discussed [Gray et al 1999], with the need for expert-judgment requirements strongly emerging [Beltramo, 1988]. The cost per meter (a) is dependent on a number of things, e.g. location of house, the general real-estate market, and so forth; therefore it is an independent variable: Which subsequently leads to the cost (y) being a function, in this case of these two parameters. Costs can be based on similar products; this is because equations that define the relationship between independent variables and cost, are usually based on historical information [Bashir and Thompson, 2001; Roy, et al 2001a].

More sophisticated versions of this type of equation may apply to other areas, e.g. aerospace product-development, where mass is commonly used as a cost parameter* [Scanlan et al 2000]. When a number of variables are involved, CERs will use more complicated mathematical equations to address them [Valerdi, 2006], e.g. multiple linear and non-linear regression. When the complexity increases further, the former mentioned become insufficient for developing solutions; subsequently cost algorithms and parametric models are applied [DOD, 1999]. *Parametric modeling operates via similar concept to parametric estimating but it can substitute for instance efficiency for cost, in the initial equation.

Parametric costs are more rapidly executed than the more detailed methods, as CER's usually link costs to top-level measurements of capacity or performance-information that is available in conceptual or preliminary stages. This technique does not rely on detailed information, instead it relates the cost to the main cost-drivers or cost descriptive variables per project. As parametric costing relies on statistical equations that relate cost to some other variable(s) it is also referred to as statistical estimating, see Table 3.7 which lists what the techniques of costing are also known as. Within a few of the reported literatures CER's, statistical, and parametric costing were described individually, alluding to their being classified separately [SCEA, last accessed Oct. 2008]. However, on examination of the majority of the main costing techniques, this research deems them as similar enough to be placed within the same category, see Table 3.7 for classification of the cost techniques.

#### 3.4.4.1 Merits & Drawbacks of Parametric Costing:

Parametric costing can be performed at the conceptual stages of project even before the full product definition has been finalised. This is due to this techniques' characteristic of focusing attention on the main cost-drivers, and producing costs based largely on the relationships between them. Due to the statistics involved, the results can be produced relatively rapidly and in a straightforward manner e.g. non-labour / resource consuming. Plus, tend to be more adaptable for computerization, making them fast and undemanding to perform.

CERs relies on the use of parameters which means that generalisations are made for the 'missing' parameters, or for those considered less important. Statistical analysis does not show specifics: Subsequently it can be challenging to retrace the constituents which compile the resultant costs, produced by this technique [Durverlie and Castelain, 1999]. The CER's can occasionally lead to oversimplification; for instance where mass is a primary factor in this technique for an aerospace product [Scanlan et al., 2000]; if the target was to reduce it, the CER would assess that production costs increase, as weight does [Rush, 2003]. This does not tend to be the case: With mass as a parameter, although its reduction equals use of less material, cost would inevitably increase. This is due to the requisite of complex advancements, e.g. intricate electronics /avionics / even redesign / lightweight materials tests, etc, to produce the reduced mass sought. Therefore in aerospace, the cost effectively increases as the weight goes down. Hence the continued need for practitioner judgment into such model-outputs [Beltramo, 1988].

## *3.4.5. Feature Based Costing (FBC):*

FBC maps the costs to the physical attributes, e.g. assigning costs to geometric features. Loosely speaking this technique can be associated with parametric costing, where the features are signified as parameters; and can be derived with use of cost model databases. Feature Based Cost Estimation in design focuses on decisions such as whether or not the inclusion or omission of features from a product design will affect the costs, to the point where it eventually leads to an impact on overall life cycle cost of product [Sivaloganathan and Shahin, 1999; Bailey, 2003]. An AI-based programme has been developed to estimate the costs of these feature-based design modifications, [Kekre et al, 2002]. With the amalgamation of design, planning and other cost-data, feature based cost-frameworks have been explored [Weirda, 1991; Ou-Yang and Lin, 1997].

However, before such costing can occur, the issue of what comprises of a 'feature' needs to be addressed. Although a minority of corporations appeared to have their own feature definition, a standardised version proved challenging to obtain [Rush and Roy, 2000]. This is because an aerospace product, for instance, can have many levels of features, which ultimately will need to be classified into subsections. The initial features, e.g. skin, wings, frame, avionics, interior, etc, clearly have a number of descending levels to the basic components. Therefore a fictitious feature based cost model could calibrate a number of detailed, lower level data, derived from: Concept classification; Design Feature; Product definition; Manufacturing definition; In-life service features i.e. spare parts /add-on's [Taylor, 1998; Bronsvoort, 1994; Catania, 1991; Pahl, G, et al, 1984]. This results in FBC being a thorough but highly complex, intricate undertaking for larger projects such as those conducted within BAE Systems, Rolls Royce and other large manufacturing domains.

### 3.4.5.1 Merits & Drawbacks of Feature-Based Costing:

A benefit of this technique it that with practitioner-input assessments [Beltramo, 1988], and the use of parametric modeling tools, FBC can derive reasonable conceptual estimates, requiring little product data. Therefore FBC appears to be a straightforward and applicable concept due to its theoretical simplicity. However a major drawback is that the ambiguity regarding what a specific product feature actually is, indicates that this technique can be ineffective. This will be due to the inability or difficulties incurred through attempting to establish, and collect the fundamental data required for this process, namely the features themselves.

## *3.4.6. Activity Based Costing (ABC):*

Activity Based Costing as the title suggests, bases costs on a breakdown of the activities involved in the production of a product / component. Related-product and non-product costs are both accounted for e.g. direct labour; direct materials; other direct costs, etc: As well as the non-product associated costs, e.g. R&D; marketing; sales; logistics; administration. Activities within an organisation will be identified, then allocated to various projects, products or other direct categories. The ones which cannot be classified into the direct sections will be attributed to the indirect sections. Fundamentally ABC is based on the recognition of the activities which comprise the product / project [Innes, 1994]. This approach directly influences overhead allocation [Hussey and Hussey, 1999]: In this sense it is an accurate indicator of costs, more so than even detailed costing, since a characteristic of ABC is that it attempts to apportion the activities to the products in an appropriate manner [Innes 1994; Dale and Plunkett, 1995]. This is compared to simply amortizing them across the projects, which other techniques with more generalistic templates tend to result in doing, i.e. like traditional costings' bias towards basing costs around raw material quantity, see Section 3.4.1. Traditional Cost Estimating.

ABC appears to be an accepted, regularly used cost-technique with a number of documented accounts attributed to it. For instance it was implemented on a shuttle project within NASA, to derive a method of tracking direct and indirect costs associated with activities in launch vehicle processing. This was done by integrating the ABC format with their current simulation structure [NASA , last accessed April 2009].

#### 3.4.6.1 Merits & Drawbacks of ABC:

The contributions and advantages of utilising ABC within organisations have been discussed [Maisel and Morrissey, 1994; Brimson 1991], and includes: Ability to monitor logistical and support operations; maximize manufacturing processes, through performance comparisons; observe product profit and loss status, to check the successes, and identify the challenging areas. With this said, there are limitations to ABC, which include: Activities may be difficult to define as they can be ambiguous, unstructured and informalised. This makes the compilation of cost-data required for this technique resource-consuming with regards to the costs used to implement it, and the time taken to carry out the process [Eldridge and Dale, 1989]. The procurement of detailed information may prove problematic, as cost-practitioners are often provided with cost-summaries, not detailed breakdowns of activities; and adequate historical data may not have been catalogued [Zhang, 1996].

### *3.4.7. Absorption Costing*

Absorption costing is a comparatively straightforward way of estimating, when compared to techniques as ABC (Activity Based Costing). The costs become absorbed within the given project / product, through a process of blanketed distribution of the overheads across the more defined costs [SCEA website, last accessed Oct. 2008]. The technique has been described in the literature within the context of organisation overhead distribution, as:

*"The system of applying overhead… …is known as absorption costing because the direct, fixed, and variable costs are absorbed by the work in process and in turn become part of the inventory"*

[Jelen and Black, 1983, p447]

The quote is in relation to the discussion of the cost performance in association with the quantity or amount(s) of product. On a basic level, absorption costing incorporates the overall costs against the overall number involved; and creates an estimate with these two factors. An oversimplified example may be: If 100 items are produced; then all 100 are subsequently sold in total for £200, an approximation can be deduced that the costs are £2 per item. Initially this is may appear to be a logical enough assumption; though it does not take into account the situation that each item might have a totally different cost associated to it; because the 'whole' have comprised the estimated cost in totality.

It can be noted that such a sweeping technique does not account for the differing businesses, hence product; and the conflicting concerns associated within them. For example if 20,000 cars are sold then saving 40 pence per car is a relevant, and in total significant saving. However if the product changed, and the significance was altered, i.e. it was compared to 100 houses, then a minimal saving per house, e.g. £40 would not be a significant saving overall, and potentially not worth the cost of making the £40 reduction. These types of cost-saving issues would need to be assessed by the practitioners, dependent on the specific situation; and has been discussed in detail within the results and analysis chapters later in the thesis.

#### 3.4.7.1 Merits and Drawbacks of Absorption Costing:

Absorption costing can be a relatively clear-cut technique given its approach towards overhead allocation, as the calculation of which tends to otherwise prove challenging. It can produce seemingly logical results with regards to its simplistic relation between quantity and cost / price. However as described above it can be too indiscriminating a process, resulting in the loss of potentially useful business-information related to cost assessment of product including item detail.

### *3.4.8. Level of Effort Costing (LOE):*

Level of Effort is classified as the sustained amount of activity or labour-hours for a known period of time. An LOE-cost tends to be used when the output or deliverables of the area being costed is difficult to determine. Therefore an LOE-cost may be produced for R&D work and services that specifically may be included within overhead costs such as management, administration, supervision, and indirect support staff [Westney, 1997]. LOE has been summarised within the Cost Estimator's Reference Manual as:

*".. a constant number of personnel assigned to a given job for a specified period of time"*

[Stewart et al, 1995 p690]

Therefore with LOE-costing much seems to depend on having firmly established time frames for the impending assessed area so it can subsequently allocate resource accordingly. For example the tasks, labour hours, etc; with the various costs being associated to each area [SCEA Online, Oct. 2008].

#### 3.4.8.1 Merits & Drawback of LOEs:

LOE costing is an adequate way to account for costs which are difficult to classify and easy to overlook such as supervisory duties; and can be performed on both direct and indirect labour. However its' characteristic of grouping many other costs within the 'labour' category means that these other activities can be overly generalised so challenging to identify clearly, if required.

### *3.4.9. Analogy Costing:*

Comparative costing is possibly the most important concept within the product-costing approaches: Also known as Analogue Costing (see Table 3.7), the underlying principles are influential across the spectrum of costing techniques to various degrees, (see following quote). When assessing the cost of product / project, an almost automatic reaction to the situation is to compare it with equivalent prior-items. This technique at its most basic levels has simply formalised and structured this automatic, tacit response; classifying it into a recognised process. Therefore the analogical-based ideology for basing costs on is well established within the literature [Hughes, 1996; Sheppard and Schofield, 1997; Cowderoy and Jenkins, 1998; Klein, 1998].

Comparative costing techniques have been described as:

*"Estimating the Cost of an item by comparing the job to be done (or portions of it) to all or parts of a previously completed job for which valid and comparable cost and technical information is available. ..."*
*"…Cost based on the Historical Cost Data of a similar (analog) item and utilizing adjustment factors to account for complexity, technical, or physical differences between the items."*

[SCEA website, http://www.sceaonline.org/prof_dev/glossary-a.cfm, last accessed April 2009]

Due to the characteristic of recall, assessment and comparison of past-project information, a prominent factor within analogical costing are Case Based Reasoning systems, (CBRs). These allow the user to capture, structure, and store expert-procedure directly from the practitioners. Such in-puts are effectively imminent historical cost-cases; thus CBRs are essentially past-project databases [Kadoda et al, 2000]. The former can range from simplistic ROM-type relationships to highly detailed, multi-variable cases; and are essentially developed in order to produce graphs / equations to relate the historical costs to the new projects. Data can be correlated in order to consider prior inaccuracies: Known variables must always be factored into such analogical costing such as inflations indices, labour rate increases, affects of global economy modification-impacts, and so forth [Steward et al., 1995].

Although CBRs are commonly and often effectively utilised [Miranda, 2001], the practitioners still require a repertoire of prior-knowledge expertise, and generally a rounded knowledge of the product being costed [Bashir and Thompson, 2001]. An adequate level of expertise is required to enable them to access the appropriate similar-project / product type, from the onset. This type of memory-recall tends to occur naturally to a degree, where the experience and memory of a practitioner is constantly being referred to, to assess new cost-situations [Vigder and Kark, 1994; Vicinanza et al., 1991]. The following quote from the international cost body SCEA, reinforces this finding:

*"Generally, a proficient cost estimator cannot help but use this method* (Comparative costing) *to some extent, consciously or unconsciously, because experience and natural thought processes force this measurement or Appraisal."*

[SCEA-Online, http://www.sceaonline.org/prof_dev/glossary-c.cfm, last accessed April 2009]

This technique can be applied across a range of work levels, either detailed or generalised; for costing new projects, bids, current products, and so forth [Jelen and Black, 1983].

#### 3.4.9.1 Merits & Drawbacks of Analogy Costing:

A benefit of this method is that it can be utilised within the early stages of project, and to a degree throughout it; though in the definitive phases more actual data is available, so the need for historically-based costs is considerably reduced. The fundamentals of analogy-costing will be naturally applied to an extent: Though the process currently has formalised tools and databases developed to aid it. They include memory support, experience alone, etc; making it an even more effective cost-technique [Sheppard and Cartwright, 2001; Miranda, 2001].

However a drawback of CBR development and subsequently its application is that extracting information which is implicitly used in order to populate a CBR tool can be a challenging task. This is because a trait of such tacit knowledge is that can be difficult to verbalise, even being consciously unknown to the practitioner themselves. Therefore CBR development is said to be subjective; and can be derived via processes which are unrepeatable [Gray et al, 1999]. Consequently the user requires expert-knowledge in order to understand the CBR results, [Mukhopadhyay et al., 1992; Myrteveit and Stensrud, 1999]; creating difficulties for novices / trainees, or less experienced users.

### *3.4.10. Conference Costing:*

Conference costing is where a collection of individuals with experience in similar projects are called upon for their judgment, as a group [Jelen and Black, 1983; Ostwald, 1974]. The final estimate is ideally derived via a consensus of the participants [Colding, et al 1979; Buffalane et al, 1976]. Comparison costing has been evaluated against this technique, as they both involve knowledge and comparisons of previous projects. However comparative estimating was said to be more structured; as it was based on attributes which generally required adjustment factors when updated for a new project; so thus utilised more formal logic then the Conference technique [Jelen and Black, 1983]. However Round-table costing, also known as the Delphi technique, includes a number of different disciplines in an open discussion. The interaction often occurs without any detail of the product; instead relying on the collaborative expertise at hand: This is as opposed to implementing software’s and computerised costing tools [Dalkey and Helmer, 1962; Dalkey et al, 1969].

Although a main characteristic of this system is group interaction / discussion, the Delphi technique in particular highlights the need for individual commitment to an informed opinion of costs, prior to the practitioner-group discussion [SCEA, Oct. 2008]. This individual element is to avoid bias and influential results on each other when in a group; with the collaborative team aspect intentionally proceeding the singular element. This is arranged so that a commitment to a cost can be made; then subsequently when with contemporaries, the cost is more lightly to be defended if there are discrepancies. This is as opposed to if a figure had not been prior procured; in which case a consensus towards a cost may occur which would not have been reached individually. In other words, the practitioner is more lightly to defend their costing position, then to follow majority-opinion once in the group, if they had prior-stated their estimation before hand. If every expert present is compelled to do this, then the final results are lightly to be far more thorough, well thought-out and accurate.

This technique can be observed as having direct links with ROM; as both rely on expert-opinion and as with the analogical comparison, historical data is a prominent feature. However the main differentiating factor is that this approach incorporates multiple judgments and experience. Therefore although the similarities are acknowledged, Conference costing may result in a more considered output due to the high level of discussion surrounding the outcome in comparison to rule–of-thumb type techniques.

#### 3.4.10.1 Merits & Drawbacks of Conference Costing:

A merit of this approach is clearly the high level of expertise which will contribute to the final cost. The suitably selected practitioners will be more likely to debate any discrepancies, until a consensus is reached; consequently there will be more scrutiny and less room for overlooking important cost-aspects. A drawback to this technique is the time taken to organise the group-discussion, especially within the larger establishments. Plus within an industrial environment, given the general occupational time-pressures which the costing personnel experience, the level of practitioners that will be required to contribute towards this approach makes it a challenging technique to realistically, regularly implement.

### *3.4.11. The Importance of the Cost-Techniques Analysis:*

This section presents the principle characteristics of ten categories of costing-technique: The main features of the processes are highlighted along with certain benefits and deficiencies, summarised in Table 3.7. Although a number of publications have to various degrees discussed the approaches, this section of literature analysis was deemed highly significant within the thesis, for a number of reasons. The first of which is that the costing-techniques are constantly referred to within industry, under a number of guises. The preliminary stages of industrial familiarisation unequivocally highlighted this; confirming that the terms need to be understood by any novice or even observer to the domain. On subsequent analysis of the approaches it rapidly became clear that there were similarities between a number of the references, (used across different companies), to the point where they could reasonably be classified within the same heading. Without such categorisation, it was evident that any cost-research within multiple organisations would result in confusion and / or miscommunications. Interestingly a review of the main literatures only confirmed this observation. As stated, a number of the publications had attempted to describe segments of the techniques, however:

- A thorough listing of the approaches was not apparent within any one publication;
- There was a lack of standardisation between a significant proportion of literatures, i.e. equivalent techniques were noted as being described not just independently of each other, but via differing titles.

Table 3.7 presents the primary cost techniques; whilst listing a number of terms by which each may otherwise be known, either within the reported literature or when referred to across industries. This is important as similar techniques may be referenced via different names, causing confusion if there has not been any type of collaborative definition or attempt towards standardisation.

> *This section has summarised the most commonly referenced cost-techniques consolidating the results from a number of the main literatures.*
> *The same or similar approaches have often been referred to by different titles:*
> *For clarity, this research has classified the similarities within main headings, so that comparable techniques can be recognised.*

A further observation, following thorough examination of the theoretical techniques, i.e. independent of any specific application, is the level of experience, judgment and knowledge which is prevalent throughout the costing-process. This becomes apparent regardless of which technique is being performed. A poignant feature of the majority of costing related publications was the fact that little attention had been given to such implicit applications, other then to acknowledge that they were used.

To summarise:

- ✓ An extensive cost-technique review was derived from a combination of prominent costing documentation, some of which were taken directly from industrial bodies / corporate information: See proceeding chapter for specifics of organisational contributors;
- ✓ An observation prior to this review was that there was no consensual complete listing;
- ✓ And many different titles were used, for what was essentially the same technique or at least similar enough to be classified together for the purposes of clarity and standardisation;
- ✓ Direct comparison of each one highlighted the high levels of tacit, implicit knowledge applied throughout the costing domain;
- ✓ There was no breakdown of knowledge contributors; (see Chapter 7 for research results regarding cost-knowledge types).

Despite the undeniable knowledge contributions, it has been stated that practitioner assessment alone can be too subjective and unstructured; thus a combination of techniques should ultimately be used so that cross-validations may be obtained [Pengelly, 1995]. This includes the integration of computerised cost-models into the process.

### *3.4.12 Computer–Based Cost Models:*

*"Dynamic linking of technical, schedule, and cost quantities needed …..is becoming increasingly important and increasingly feasible because of the emerging availability of sophisticated electronic data interchange methods"*

[Stewart, et al, 1995 p2]

The number of commercially available products specifically to assist the product-costing process is increasing, though currently there are just a few main competitors leading the market; companies that develop and supply the softwares include Price Systems, Galoreth and Cognition. Refer to Table 3.8 for a listing of cost softwares. Additionally a number of organisations are in the process of, or have already developed their own tailor-made in-house tools. A number of these are fairly straightforward, developed for instance on an excel-based programme. Whilst the minority of others are complex, extensive products with considerable databases supporting them,

Table 3.7: Descriptive Analysis / Classifications of the Different Costing Techniques

| Techniques of Costing<br>) = Also known as | Product Life -Cycle Position: | Description of Technique<br>Merits / Drawbacks |
|---|---|---|
| Parametric cost estimating<br>(CER's:<br>Cost Estimating Relationships)<br>(Statistical estimating) | Conceptual Design Stages | Looks at main cost drivers, and the relationships between them. Can be compiled at early, developmental stages; without even full product definition: So acts as good conceptual cost indicator; Though lack of defined detail can seem like the technique has a 'black-box' element to it. |
| Detailed costing<br>(Bottom-up)<br>(Final)<br>(Engineering Cost Estimate)<br>(Grass-Roots Estimate)<br>(Defined)<br>(Standard Cost Estimating) | Definitive Costing | A widely used technique: Basically a compilation of all costs –working with as much actual product-data as is available; along with historical data, publications, and any other reliable method of data collection. Due to the need for high actual data, its derivation can be within the preliminary, but mainly definitive stages. Detailed costing is time consuming to produce; but can give very accurate results. |
| Feature Based Costing -FBC | Conceptual Design Stage | Maps the product-features, to the costs. With similarities to parametric costing, it can be performed at the conceptual stages; though it is often difficult to define the actual features. |
| Activity Based Costing -ABC | Preliminary / Definitive | Derives cost with use of both direct and indirect product activities. Perceived as having high confidence levels, due to the more accurate apportioning of the activities per project; though it is said to require comparatively high resource to maintain ABC systems. |
| Conference costing<br>(Delphi)<br>(Expert Opinion)<br>(Round Table costing) | Conceptual / Preliminary stage | Gathers opinions from groups of practitioners, experienced in similar past-projects. Cost is derived ideally via a consensus; though Delphi specifies individual commitment to costs before the group-discussion. Collaborative expertise can provide valuable cost-input; though results are as strong or weak as those who contribute into it. Has reduced feasibility due to time demands it places on a number of required practitioners. |
| Traditional cost estimating | Conceptual Design Stage | The level of activity is directly linked to the amount of raw material utilised i.e. high material, high activity. Overhead is approximated at 15%. Results can be procured rapidly, and at early stages of project: Though tend to have low confidence factor. |
| Absorption costing<br>(Direct costing) | Preliminary stages | Related to the allocation of overheads to the costs. Logical, though Simplistic way of costing, taking the minimal level of factors to produce the cost-estimates, i.e. the cost and the total quantities involved. A theoretically logical technique, with straightforward application; though does not account for the detail of cost allocations. |
| Rough Order of Magnitude -ROM<br>(Top-Down)<br>(Rule-of-Thumb)<br>(Capital Cost Estimate) | Conceptual Design Phase | More rapidly performed then detailed costing techniques and less expensive. Can be derived with little actual data, so can give cost-indications early in project. Estimates may be based on |

| | | |
|---|---|---|
| (Ball Park figure)<br>(Feasibility estimate)<br>(Expert Judgment)<br>(Expert Opinion)<br>(Empirical Cost Estimating) | | historical-data, experience / knowledge of past-products. This technique does not formulate detail, so may miss aspects that subsequently impact on the costs / can have low confidence levels: But is rapid, and straightforward to produce. |
| Analogical Costing<br>(Historic relationships)<br>(Comparison cost estimating)<br>(CBR –Case Based Reasoning)<br>(Pairwise Comparison) | Conceptual / Preliminary Stages | Past-project data is used to base / assess new estimates. The concepts of comparison-costing are widely used throughout the techniques. Historical data needs to be calibrated with relevant cost-adjustment factors (incorporate updated information / account for previous inadequacies): Though much tacit knowledge is applied to the process. CBR's can be subjective / difficult to develop: The collection of historical data can be laborious. |
| Level of Effort costing –LOE<br>(Apportioned Effort Estimating) | Preliminary / Definitive Phases | LOE is related to estimating labour, able to account for all aspects of such, and allocate costs against them, within the given time frame. |

Table 7 references: [Jelen and Black, 1983; Steward et al., 1995; Bashir and Thompson, 2001; Westney 1997; SCEA on-line, last accessed April 2009; Nasa website, last accessed April 2009]

having been created with major expertise and finance. A primary example of the prior mentioned can be found within Ford Motor Company, namely their CAPE system (Computer Aided Parts Estimating); run by database GRIMM (Global Rate and Information for Machines and Materials), [Griggs et al., 2001].

The use of computer technology is now a regular feature in the production of cost estimates, with high investments by organisations into the development of cost estimating programmes [Jelen and Black, 1983]. The reason that such capital, time, and other resource tends to be poured into such computerised cost models is because they are perceived to ultimately enhance the results [Gray et al., 1999], as the following depicts:

*"Computer-aided estimating is a technique used to increase accuracy and to reduce the time and cost of preparing capital-cost estimates."*

[Jelen and Black 1983, p334]

Although the formalised models, particularly the commercial products, have their various focuses and strengths; the generalised form they tend to take is through a series of in-put parameters. The user will in-put variables such as: Project-start-dates, end-date, the materials being used, labour-related data, quantities, and so forth. The results are then calibrated via pre-set equations and cost-information derived from supporting databases which are maintained i.e. regularly updated, particularly for the commercially subscribed model-users.

The subsequent results have had mixed reactions within industry and the literature; from not being trusted, to invaluable contributors to the cost-process as a whole. Though what does seem to have been established is that when practitioners use their expertise in juxtaposition with computerised models, the results are improved [Myrteveit and Stensrud, 1999; Hughes, 1996]. Just a few examples of the type of formalised models described can be found at the locations listed within Table 3.8:

### 3.4.12.1 Merits of Computer-Based Costing models:

A merit of computer-aided costing softwares is that an adequate cost may be generated in theory by a relative novice: If they are able to procure the required parameters which allow the programme to derive an output, the formalised cost-systems will calculate and calibrate the results. As well as novices, practitioners of whom have specific expertise are not limited to producing costs within their specialisation alone. The cost-programmes allow non-experts to derive costs, outside of their known area [Valerdi, 2007]. Formalised cost-model usage is also said to reduce time and costs in the performance of the cost-process, due to the fact that the statistics required are within the programmes' database. Therefore the practitioners do not need to take the time to individually establish for instance the required material costs, various overhead, particular countrys' labour rates, and so forth: Neither will they need to estimate such costs based on similar projects. This is due to the fact that the database will be maintained; hence be capable of readily providing all such information required to input towards the cost derivation. In other words the information within the database in conjunction with the in-putted parameters formulate the cost, the results of which are relevant per project due to the variables, namely the required data provided by the cost practitioner.

Table 3.8: A Selection of Costing Softwares:

| | |
|---|---|
| http://www.pricesystems.com/<br>http://www.estek.co.uk/<br>http://www.tekton-group.com/<br>http://www.arrantsolutions.com/shareware/<br>http://www.winest.com/Pages/default.aspx<br>http://www.ecfc.u-net.com/cost/index.htm | http://www.galorath.com/<br>http://www.leadsoftware.com/<br>www.decimal.ca<br>http://www.aceit.com/<br>http://www.benchmark-estimating.com.au/<br>http://www.cprsoft.com/ |
| http://www.franz.com/success/customer_apps/cad/cognition.php3<br>http://sunset.usc.edu/csse/research/COCOMOII/cocomo_main.html | |

[Nb: Table references: Websites valid as of April 2009]

### 3.4.12.2 Drawbacks of Computer-Based Costing Models:

A drawback of the use of such cost-softwares has been via the unknown equations supporting them. Although work conducted by researchers such as Valerdi et al., [2004] imply that high levels of confidence are placed on the results of these models, this research found scepticism towards them in general. Experienced practitioners in particular have doubted the feasibility of such programmes being suitable enough to continuously provide relevant, accurate outputs; simply because no matter how complex, some degree of generalisation must apply to them. It was suggested by a number of practitioners across the board, (principally from within aerospace and automotive industries) that the databases would be populated by generalisations and averages, with the equations behind the perceived 'black-box' outputs being therefore questionable. In contrast, individually derived costs are more lightly to regularly account for the distinctive or individualised elements of each cost-estimate derived, which the software's will tend to necessarily amortize.

Related to this concern, which has been echoed in literature as well as by the in-house software developers, is the perception that the expertise and skills required to develop these computer-based models will be lost by users over time. If novice cost practitioners continue to base all their findings on the output of software-based estimates, then the judgement and knowledge involved in creating an estimate from first principles will deplete naturally, and / or will be deemed as unnecessary. The overall implication of such a concern is that the level of expertise within the cost-domain will decrease, as new comers to the process rely increasingly on the formalised cost-models.

With relation to over-reliance on such tools, Rush [2003], conducted literature comparative-analysis between practitioner-expert-judgement against formalised cost-models. Although the expert-analysis alone outperformed the cost softwares from the cases examined, the results were not wholly conclusive due to different conditions: Samples sizes, differing application of model, and so forth [Rush, 2002]. The results do signify that the use of computerised cost-models needs some type of regulation or 'back-up' to check the results against; as it has perhaps logically been observed that models merely perform according to the in-putted data [Pengelly, 1995; Velardi et al., 2004]. Thus alluding to the fact that a novice or inexperienced practitioner would be inept in detecting inaccuracies if they did not possess the necessary level of knowledge to understand the outcome of the models. Additionally they would require at least a basic awareness of what the approximate figure should be, in order to be able to recognise a potentially inaccurate output of the system used. Fundamentally, software estimating should be used to reinforce or accompany other expert-estimates and techniques, being used as an aid to their derivation and / or to validate them; as opposed to the results being blindly based on the software results [Jelen and Black, 1983; Rush, 2003].

## *3.5. Observations from the Literature:*

This chapter examined documentation which detailed the domain of industrial-costing. Section 3.1. examined the essence of product-costing; what it is, its' function, including the issue of terminology and reference. The latter was noted as largely not standardised, explaining the potential for confusion when researching multiple organisations within a number of industries. A couple of points to consider:

- The need for clarification of the terminology utilised within this thesis, which highlights the industrial requisite for standardisation from a theoretical stance.
- The following chapter focuses on the real world research so will relay whether this point requires clarification within the actual practices themselves.

However the fact that a much of the reference material was adopted from industrially–based research and by experienced practitioners, alludes to the fact that this inconsistency is present throughout the cost-process.

The process of costing was then relayed within Section 3.2. presenting the typical stages of how it is performed, depicted in 3.1 and see Section 3.2.3 The Systematic Steps involved in the Costing Process. The associated functions which influence the cost-process are also highlighted within Section 3.2.6 and sub-sections.

Section 3.3 examined the types of costing, prior to detailing the cost-technique analysis; as the technique which is selected is overtly linked to project phase, as described in Section 3.3.1. Discussion of the various phases, requirements and perceptions (refer to 3.2.4 for Perspective of estimate), aided the breakdown of the cost-considerations, ultimately helping to portray the process systematically: This explained the various complexities involved, detailing them logically.

Therefore leading suitably into a discussion of the cost-techniques in Section 3.4; the importance of which has been fully explained in subsection 3.4.11 The Importance of the Cost-Techniques Analysis. Table 3.7 whilst summarising the main characteristics of each approach, highlights the unambiguous need for standardisation [Mishra et al., 2002a; Westney, 1997], through the multiple terms used towards the large majority of approaches discussed, refer to both Tables 3.6 and 3.7.

This establishes inference for the continued research throughout the thesis: As the literature inconsistencies have been established to a degree, the industrial ones can be embarked upon; as discussed in the following chapter. The hope of such focal evaluation is to ascertain suitable insights regarding the widespread usage of cost-terminology, which may ultimately assist in leading to proposals for potential solutions towards this ambiguity. Lack of standardisation across the costing domain is subsequently addressed, the results of which are presented within the latter chapters.

### *3.5.1 Implicit Components of Costing:*

Having broken down the outline of this chapters' content, a primary result can be observed: Although the chapter had been essentially grounded in explicit observations, what has clearly emerged is the implicit elements involved throughout the cost-process. The tacit in-put of the practitioners through experience, comparative analysis and knowledge application to each cost performed, is imperative.

With this said, within the body of cost-specific literature there was found to be practically no other reported documentation within the area of tacit elements within the process. Therefore the commencing work has focused on the similarities between other industrial disciplines, mainly design engineering. Design has been selected partly because it is a comparatively established area, i.e. research has already been conducted on the cognitive process of design engineers. Design is also suitable as it is often closely linked with the cost-activities: Thus making it a reasonable area to base the study on. Subsequently these preliminary examinations have, to a degree, transposed the known aspects of implicit design-engineering decision making onto product-costing [Roy et al, 2006; Coley, et al 2007]. However, it has been stated within the publications themselves, that this research is still in its infancy [Houseman et al, 2006].

Much has been documented about product-costing; most of which focuses on the physical or sequential procedures, business positioning of the process, and particularly on the development of and implementation of computerised costing aids [Houseman et al., 2006]. As prior stated, there is little-to-no reported literature regarding the essentially humanistic inputs into costing, with if anything the emphasis on formal models detracting from these contributions, and even questioning the significance of costing-practitioner expertise. Section 3.4.12 implied this, on reiterating the claims surrounding the cost models, that a non-cost expert can produce an expert result. However, the section also mentioned the potential for continued depletion of expert-knowledge, if reliance on software cost-models became the norm.

Furthermore there is research which concludes that despite the various models developed, the role of the cost-practitioner is always going to be necessary [Stensrud and Myrtveit 1998]. Although cost models are sophisticated, and currently theoretically capable of producing high quality costs, such results cannot go unchecked by the actual cost-practitioners [Mukhopadhyay et al, 1992]. The work of Rush [2002], shows the prominence of Expert Judgment within the aerospace systems of costing [Rush, 2002], being ubiquitous across the process regardless of what tools and techniques were used. This school of thought has been substantiated within a number of literatures, and within expanded applications: Subjectivity, practitioner-rationale and considered assumptions are essential cost-process components [Beltramo, 1988; Pengelly, 1995; Stensrud and Myrtveit, 1998].

Resultantly, although this chapter of literature analysis has focused principally on the technical, explicit issues of costing a product, the continued practical research, initiated within the proceeding chapter will extend this argument. As a faction of the literature has alluded to implicit elements holding significance within the costing process, the following industrial-based research will take the opportunity to study the tacit contributions to costing. This will be undergone in the hopes of gauging the overall magnitude of such individualistic expertise, experience, knowledge, and general informalised, implicit input within industrial product-costing.

### *3.5.2 Gap-Analysis:*

The impact of tacit knowledge on costing has been touched upon when describing the techniques, see Section 3.4; though these have not been assessed adequately in the literature. The research which has heavily related to the experts' implicit judgment [Rush, 2002; Beltramo, 1988], partly commenced such recognition and formalisation. However, there is a deeper element or driving force behind the judgments and opinions of practitioners, which is principally the actual knowledge which is used to make such assumptions. With the exception of having been occasionally mentioned, this fundamental basis of the process has not been addressed in any dept throughout the literature; other than within this research [Mishra et al., 2002a; Mishra et al., 2002b].

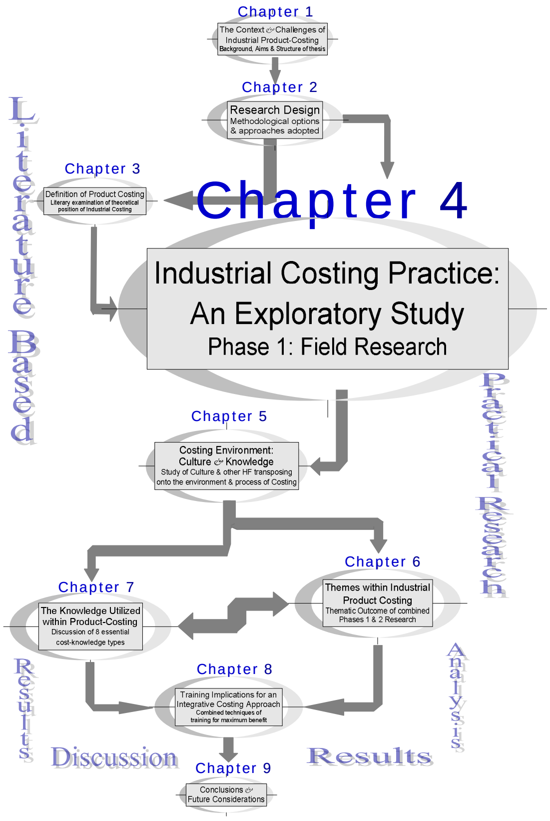
This chapter provided the background to the fieldwork research. The following Chapter, 4 discusses the subsequent industrial studies, showing how it compares with the theory and what the main contributors to product-costing proved to be. This is from a perspective external to the subject domain, as far as researcher subjectivity can occur; see previous Chapter, 2, for Methodological issues. The primary circumstantial contributors to the process will be examined, see Chapter 6 for the main cost themes: In the ultimate effort to integrate the elements of both organisational-costing with regards to the interacting disciplines; and industrial-cost-processes in relation to standardisation.

Given the literary findings plus the aims and objectives of the research, a focus was placed on identification of the contributing knowledge types involved in the process. Results of which are discussed in Chapter 7, which identifies and discusses the principal knowledge-types used within product-costing. Interlinked with identification of the necessary knowledge types used, is the issue of acquisition of such knowledge, once established. Experience, expert-opinion and judgment have been frequently referenced, captured and reused; the latter refers to cost-training, which in this research has been incorporated within Chapter 8 identifying routes of practical implementation and application of the cost-knowledge framework developed. The need to formalise the cost-knowledge and disseminate it to keep it within the costing community are subsequently detailed within Chapters 7 and 8.

To summarise, this chapter has highlighted the gaps in cost-literature, therefore the theoretical deficiencies of the process; which are fundamentally a lack of standardisation of costing terms. Additionally the implicit, tacit or ‘soft’ aspects that contribute towards the cost process have barely been identified, let alone examined. Therefore, against what has been noted as important implicit contributors towards the costing domain, the industrial research will show whether the knowledge-gaps and subsequent implementation, dissemination and / or training-gaps are present in reality within the cost process, as well as the theory.

# Chapter 4

# Industrial Costing Practice: An Exploratory Study




*"The Costing process is composed of: Labour; Material, and Overhead costs"*

[Cost Estimating Manager; Automotive, 2002]

Chapter 3 examined the process of costing from a theoretical, literature viewpoint. Aspects including terminology employed, the techniques used to cost a product, and the required associated functions which support cost activities were highlighted. The intent of this chapter is to provide a practical view of product-costing, to compare against the theoretical one gained from the literature. This is achieved through an exploratory study into the process as it is performed across industry i.e. an AS-IS study. Through the exploration of twelve organisations within five industrial categories, this field-study provided a tangible current perspective into the way practitioners cost a product. The attitudes and approaches to costing, as well as the challenges experienced from an industrial aspect are conveyed; and can be compared to the documented processes as seen in the previous chapter. This chapter fundamentally presents an exploratory-study of industrial costing-practices; the details of how it was conducted; with a brief, introductory discussion into the thematically-coded results that were derived.

## *4.1 The Nature of an Exploratory, Overview Study*

Within research, obtaining a general sense of the area under examination is important in order to acquire a comprehensive understanding and basically to facilitate familiarisation of the overall domain. Therefore an exploratory study was the first phase of the field-research which was undertaken in order to gain broad industrial insights into the actual processes and techniques employed within product-costing. The intent of this initial study was to achieve an idea of the most common, recurring industrial practices currently in use; along with identifying which disciplines interacted with costing, and how these communications occurred. The exploratory observations were deliberately designed to be wide and as far reaching as was practical within the research constraints (explained in later sections), in order to attain a sense of how costing was compiled across a number of industries. Hence phase 1, (P1), was an introductory, broad study carried out in preparation for more in-depth and thorough costing-process examinations; Phase 2, (P2). The latter-mentioned took place within fewer organisations and industries, but was intended to provide more detail, and with concentrated examinations into specific areas, rather than general costing procedure, as in P1. Discussion of P2 is covered from Chapter 6, onwards. In other words, this research-phase deliberately focused on the breath of scope across organisations, whilst P2 was designed to divulge with greater depth into them; see Figure 4.1.

To summarise, an exploratory study is a high level overview of the subject matter under investigation, conducted at a stage of research in order to assess the current situation. The purpose of undergoing the exploratory study in this instance was to gain a broad and comprehensive awareness of industrial product-costing practices, as explained in the following section.

### *4.1.1 Why an Exploratory Study Was Required*

The function of this initial exploratory phase of research was to ascertain the costing processes currently employed across industry, also referred to as an 'AS-IS' study. It was necessary to determine an accurate interpretation of organisational-costing practice in order to establish a reasonable origin from which the rest of the research could be initiated from. Thus the basis of the Phase 1 research was:

- To establish the processes involved within product costing;
- To identify the difference in practice between organisations and industries; and essentially the similarities across them;
- To determine the interaction required both across the costing disciplines:
    - Of engineering (technical) and economic (commercial) practices,
    - Of all associated functions which input into the costing process, in order to develop the cost.
- To gauge:
    - What level of contact is required between them?
    - Observe what level is currently occurring;
- To address the difference between what interaction is deemed necessary against what is actually happening in reality:
    - To identify and examine the causes behind any lack of integrated costing process;
- To finally broaden the approach to product-costing to incorporate factors whose current exclusion is detrimental to the quality of the results:
    - To take into account the application of human factors in addition to tackling any technical constraints.

These prior listed points of conducting P1 are all discussed in greater depth throughout the thesis, and expanded on in the second phase of research. Figure 4.1 illustrates the broader breath of research in phase 1, though with less depth then phase 2. Figure 4.1 highlights the outcome of each phase, i.e. the main cost themes emerged from P1, see Chapter 6; and has sectioned P2 in order to highlight the areas of focus, and contributory inputs.

Phase 1 of the research consisted of the examination of a total of twelve organisations, within five industrial classifications. For an introductory study this was a broad scope; however it was deliberately designed to be a widened level of observation, in order to enable comparisons not only within industries, but across them. This level of industrial contributor allowed the examination of many different cost-practices, bestowing a sense of what is specific to either the industry, or in some cases to individual organisations; whilst determining why such idiosyncrasies may occur. However, given the often generalist and all encompassing description of costing which was observed throughout the literature in Chapter 3, an important aspect of researching several industries lies within the conclusion of any resultant commonalities of process. This can reveal what features of costing are generic, and subsequently could form the basis for some standardisation; which is largely lacking at present. Table 4.1 examines the factors behind company selection; and Table 4.2 gives the range of inconsistent cost-title / role references.

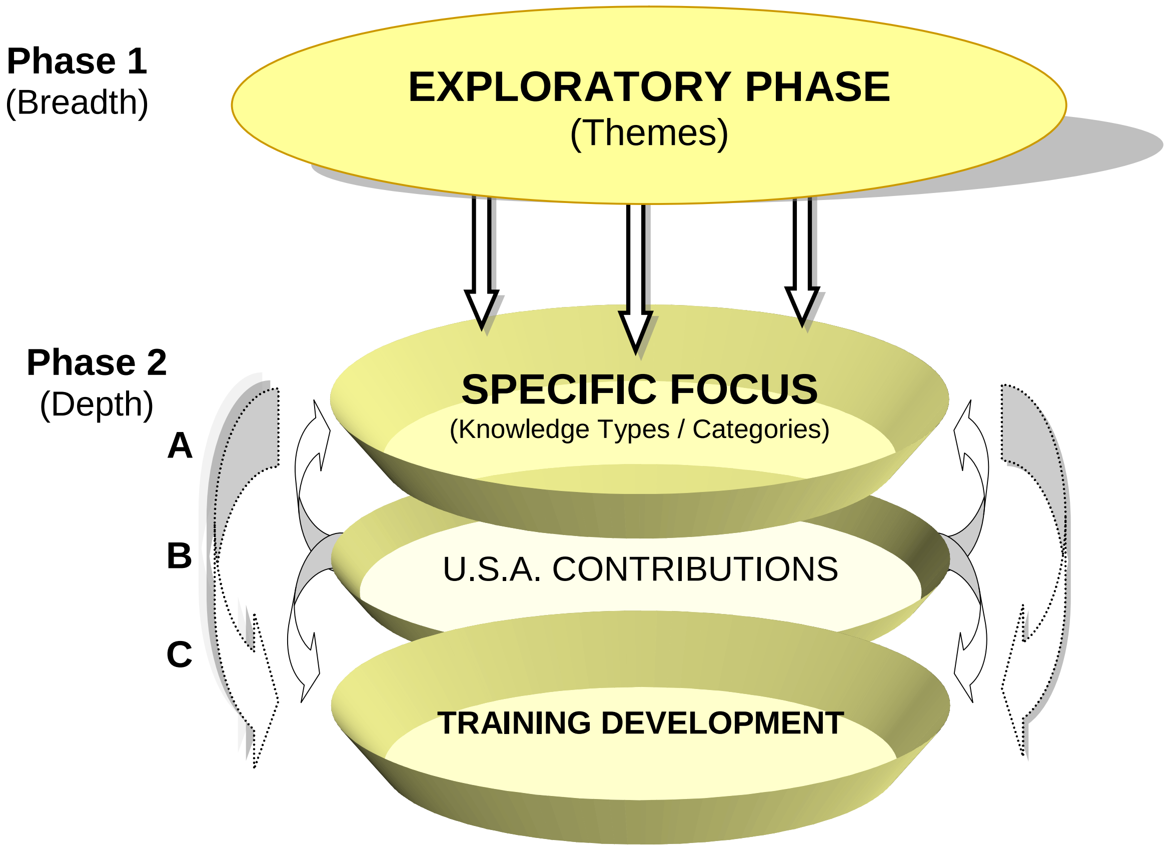



Figure 4.1: The Layers and Depth of Industrial Research Phases.

## *4.2 Designing and Conducting the Study*

Having defined what an exploratory study is and why it was required, this section focuses on the AS-IS studys' design and implementation. In order to get a broad cross-section of industry the first points to determine were:

- ✓ A selection of organisations which were different enough to impart a wide set of practices;
- ✓ Broad enough in number to provide a representative view;
- ✓ But which were accessible within the time frame allocated for phase one of the research.

### *4.2.1 Company Selection*

There were many factors that affected which organisations participated in this initial investigation, Table 4.1 has summarised the main considerations. The range of industries considered suitable for examination spanned from automotive, aerospace and defence to construction, software, and those which were placed within a general 'manufacturing' classification, refer to Table 4.2. The latter mentioned grouped participants within this generalisation in order to assist in the production of comprehensive, straightforward results. The range of industries was intended to allow assessment of the types of cost-practice used, with comparisons against substantially different end-products. Table 4.1 lists the specific choice of industries and companies who participated in this section of research; it can be seen that the focus was on the manufacturing and supporting sectors. There was a fairly broad set of criteria behind the selection of specific companies who did participate in the study. Practical aspects of conducting such direct industrial research were primary concerns in company choice. For instance expert and organisational availability were key factors; along with researcher accessibility to the contributors' place of work; see Chapter 2 for research methodology considerations in these areas.

The budget for this initial exploratory phase allowed a reasonable level of UK industrial on-site visits. Therefore depending on circumstances, the researcher could either invite practitioners, or travel to their organisation for a couple of days where possible and / or necessary, which was for the minority of cases at this stage. However there was insufficient funding for visits outside the UK during phase 1. In this sense the limitations and allowances dictated by the available funding helped shaped the areas of research, in that it was broad and covered an adequate level of companies but was limited to the UK industrial practice. The later stages of research, stages within phase 2 (see Figure 4.1) entailed longer periods of on-site research (up to ten days), within UK and US–based organisations.  The site-location of observed participants is relevant and has cultural implications: This is discussed from Chapter 6 onwards. Whilst an introductory examination of the culture of product-costing and the effects of culture on the process are fundamentally presented in the following Chapter, 5.

As well as the practical factors of company-participant choice, primarily available funding, accessibility, and time, both to complete the research and for expert-availability; there were other issues which needed to be considered. These focused on the desired achievements of the work, and through which organisations would adequately address them. Refer to the following Table 4.1 for a list of reasoning behind the companies that were selected for participation within the research.

In general, large to medium organisations were targeted due to the nature of the issues being investigated, principally a lack of communication / integrated practice. The situation as shown in the one small company examined contrasted significantly with the larger organisations, due to the small environment which allowed regular personal interactions and hence, tended to avoid miscommunication, (see Sections 4.8.2 and 4.8.3). All the companies were established in their field, so in theory their costing procedures were being successfully employed throughout the organisation at the time of observation. The fact that such processes were already developed and in use, enabled an external observer to gain a clearer impression of the systems in place: In reality, the success of the costing processes witnessed across the companies varied widely, as is detailed in later chapters.

Table 4.1: The Considerations and Influences on Phase 1 Company Participation Selection

| FACTORS OF COMPANY SELECTION |
|---|
| WIDER SCOPE FOR INITIAL RESEARCH PHASE: |
| ▪ Desired a more rounded view of costing<br>▪ Therefore wanted as large a selection of industrial practices as possible<br>▪ This was in order to gain a sense of what is common practice, and what is particular:<br>• a) Industry - specific;<br>• b) Company – specific<br>▪ Examination of different industries would reveal best practice; which could ultimately be disseminated through the research, to be utilised in other areas, where possible.<br>▪ Size: Organisations were selected from large to small and medium, in order to compare processes.<br>▪ Initial company-size comparisons could allow for eliminations of irrelevant aspects. For example the results showed that smaller companies did not face the same costing-process challenges as medium–large organisations; resulting in their subsequent exclusion from further examination;<br>▪ Resultantly large-medium companies were focused on, due to the nature of the investigations, i.e. lack of integrated costing procedure.<br>▪ Wide Practice: The organisations were often the UK branch of global corporations; or companies who had international business.<br>▪ Established organisations were preferable with tried and tested processes, which would theoretically allow external observations to be more straightforward.<br>▪ The exploratory phase was conducted in order to get a sense of general industrial practice; therefore was not an in-depth study but more of a broad, quick overview.<br>▪ More thorough examinations were performed in later research stages i.e. throughout phase 2, P2. |
| TIME / FUNDING / ACCESSIBILITY FACTORS: |
| ▪ This exploratory section of research was conducted over a period of no more then five months, inclusive of participant identification, in order to keep the entire research programme on track. Therefore participants were limited to those who could accommodate, within the time allowed.<br>▪ Given the time constraints UK-based participants only, was a reasonable target for Phase 1.<br>▪ The primary contributors, not only for this phase, but throughout the research, were BAE Systems, Ford Motor Company; and across phase two there were additionally Price Systems and JLR*. These participants were industrial collaborators on a research project (with exception of*), from which much of the primary data utilised within this thesis was gathered (see Chapter 1).<br>▪ The former mentioned importantly acted as Gatekeepers for physical access into the organisations stated, as well as additional ones.<br>▪ The other organisations examined tended to be comparatively limited in the level of time they could impart towards the knowledge elicitation / data-collection: With this said their input was still more then adequate for the research intent.<br>▪ The time range within companies for exploratory examination e.g. interviews, observations, etc was between two hours, for lunch-time meetings and two day visits generally within the pre-stated organisations.<br>▪ For the first-phase of research, there was inadequate funding to travel outside the UK in order to asses costing practice abroad; so companies were limited to UK-branches only.<br>▪ Expert - availability and organization - accessibility were key in deciding which companies contributed to the research. |

The contributors were generally either the UK branch of an international corporation, or had global dealings in some form, e.g. with the customer / product-interface or supplier. This was deemed preferable due to the immense level of complexity required, e.g. via procedures and guidelines, to operate a company on such a broad scale; plus in a changing, increasingly-globalized market, such working interfaces were important to examine. The amount of information and communication which is needed would pose great challenges, particularly if detrimental issues which occurred where not recognised or failed to be fully attended to.

## 4.3 Industry Accessibility: Practical Perspective

A primary concern whenever academic research crosses into industrial examination is that of accessibility, as discussed theoretically in Chapter 2, methodological options. Please note: Chapter 2, throughout Section 2.6.1 covered the theoretical pre-empted discussion of accessibility and the assumed related issues. Whereas this section describes and discusses the actual challenges encountered within the real world research conducted, including that of confidentiality, see Section 4.3.4; and the methods that were employed to overcome them.

Accessibility covers all aspects, from the pragmatic consideration of gaining physical access into the organisations and the relevant expertise, to the social issues of how much useful, reliable knowledge and information is imparted by the practitioners. These aspects, of social and physical access are discussed in this section, with the former also addressed within the knowledge elicitation description. The design of interviews and the way they were conducted was an important factor towards the acquisition of social access, see Section 4.6. When it came to both company and practitioner input, assurances of confidentiality were fundamental to the success, examined in Section 4.3.4; as was the basic practicality of their availability, see sub-section 4.3.2. A more surprising influence around the systemic question of accessibility was that of terminology; with the unexpected element being in the form of its prominence. From the onset inconsistencies within the terms implemented throughout the costing sphere created challenges regarding company comprehension of the research and required immediate attention, see Sections 4.4 and 4.7. However once these issues were identified and fluidly tackled, one advantage utilised by the research in relation to access, was that of incentives.

### *4.3.1 Incentive:*

Incentives may be seen as a means to enabling physical access into an organisation. What is meant by an incentive in this case is the offering or exchange of something of perceived use to a company, for access to that company's expertise. Within this section the report compiled for the complete exploratory-phase was used as an incentive for potential participants. This was beneficial to them because it would present the state of costing on an industrial scale, and could subsequently give them an idea of their placing within this; and with the intention of disseminating best practice. In return for the inducement of the report of the overall findings for this section only, companies agreed to contribute to the research. With this said, this agreement was attained via an amalgamation of a number of factors, as discussed in the following sections, including the incentive; which once established relied on the balance of both researcher and practitioner availability.

### *4.3.2 Availability:*

The number of industrial participants was principally dependent on the availability of the practitioners, as was the length of time per interview. As this phase of research was intended to be an overview, the level of time committed by the contributors was variable, and ranged from between a few hours to a couple of days. The degree of participation was determined by each industrial collaborator, with the sole limitation of their availability needing to fall into the time-scale set for this phase of research which was approximately twenty weeks. Generally the researcher was able to accommodate the industrial-participants availability, being flexible to within the pre-set examination schedule. The issue of their availability was influenced by a number of things, including how busy they were and how valuable they perceived the research. Surprisingly it was found that the status held e.g. management, cost-practitioner etc. did not tend to affect their availability, within reason, if they appreciated the research focus. Therefore within the costing realm expert-contribution tended to be given generously; whereas it was generally less forthcoming from the other interacting areas, such as engineering and finance. With this said, adequate participation from these disciplines was gradually secured. Though status was not a barrier to availability, the issue of busyness was. For example if near a launch date (for automotive) or bid (for aerospace), it was difficult to secure interviews until this period had been completed; although time was given, though usually more limited then at other times.

Therefore, as the AS-IS research was conducted within such a tight time frame, occasionally industrial-contributors could not accommodate it. More time to contact the organisations and to conduct the research would have resulted in a higher number of participants. However this was not deemed necessary owing partly to the time required for data-collection analysis, principally conducted by the coding and classification techniques, see Section 4.8.1. This included the questionnaire-response; and interviews, which were taped, but primarily documented via note-form. An extended period was not considered necessary, fundamentally due to the impending second stage of research which would allow more time to address any neglected points anyway; as well as to validate the current findings and / or cover them in greater depth. Prior to any synchronisation of schedules / availability, approval needed to be sought and obtained to access the organisation, and practitioners within it. The issue of gaining access may be described as two tier, with an initial physical accessibility, followed by social access in this case with practitioners, as discussed in the following sections.

### *4.3.3 Gaining Access*

The research budget was adequate to cover costs of up to a few days per industry, within the UK. Therefore there was limited imposition on the organisations regarding participation. Due to the time constraint of research, organisations that were potentially problematic to access generally due to the fact that more time than was available was required to go through security checks and clearances, were ruled out early on. Such organisations primarily defence / military were not contacted for participation, however most experts approached were willing to give varying lengths of time to discuss costing issues. A large minority of organisations gave permission to allow the on-site research to move freely within the department, approaching experts as and when they became available. Plus they occasionally arranged for additional departments, where deemed relevant, to be examined including engineering and management: Often a tour of products, plants and production processes was given. This was much more the case in the later phases of research, proceeding from the exploratory phase when greater periods of time were scheduled for the field studies. In the secondary study more organisations with limited access were explored and this is discussed further, throughout the thesis.

Access to the actual field of industrial costing was quite straightforward, as far as obtaining initial contacts went, because this was both an independent academic study with therefore no perceived organisational bias or 'agenda'. Whilst additionally having had interest at the project-development stage by companies as BAE Systems, and Ford Motor Company; as well as XR Training and Consultancy and later Price Systems. Therefore the research had the input towards contributors from these major organisations, as well as the collaborators which Cranfield University aided in providing.

#### 4.3.3.1. Physical Access

In order to gain access to the industrial expertise, both for questionnaire dissemination and on-site practitioner interviews, four main routes were used:

- ✓ Academic–industrial links;
- ✓ Project sponsor contacts;
- ✓ Meetings and exhibitions with industrial representation: Creating interest in the research
- ✓ Cold-calling; and subsequently establishing interaction

The first two listed above were the main entry points: Physical access was obtained through contacts or 'gatekeepers' (explained in Chapter 2, Section 2.6.1.2.) within the prior mentioned companies; and via existing ties between the university and industry. The companies sponsoring the research-project from which the author collected much of the initial data for this thesis, had a vested interest in its success and assisted by adding to the repertoire of contributing expertise within the scope of their commitment and support. The associations between Cranfield University in which the research was based, and interacting organisational links were utilised for further industrial access. Often if companies had previously worked with, or had some connections to the university they would be prepared to extend their expertise to other areas of research where feasible.

A minority of industrial contacts were created from meetings / exhibitions during which the opportunity was taken to raise interest in the research and the need for industrial-participation. Novel relations within the field were occasionally formed via 'cold calling' companies, and explaining the research and type of interaction sought; refer to the terminology Section 4.4 for particular challenges encountered here. An internal link into the organisation opened more metaphoric doors then the last two routes listed, though interestingly not always, as explained the following section.

These industrial contacts allowed the research to commence in the sense of providing physical access. However other barriers can occur once the physical entrance to the workplace has been established. Thus for this research, although gatekeepers in the form of the managers would have created the opportunity to access the expertise, developing social access once among the practitioners is a more subtle issue.

### 4.3.3.2 Social Access

The issue of social access involves gaining acceptance by the people within the environment in question; in this case, by the participating practitioners within the companies included in the research. Social access was the way in which the sought information would ultimately be accessed, see Chapter 2, Sections 2.4. The primary manner in which this was procured was through the development of a rapport with the participant. The combined techniques utilised in the interviews aided in this pursuit, where the semi-structured style (SSI) would allow the practitioner to verbalise issues, as they were able to comfortably decipher them (tacitly), without having too rigid guidelines to follow: Though with some structure to assist them in relaying the knowledge. There was also consideration when conducting the interviews, to the need to achieve a maximum mental stimuli, see Section 4.6.5. This angle, used concurrently with the SSI encouraged the greatest retrieval of information, helping the respondent to answer fully [Burgess, 2008; Moody 1996].

However before even reaching this stage, implicit acceptance of the knowledge elicitation process has to be agreed upon by the participating practitioner, in order to gain full support and thus maximum outcome of the interaction. In gaining a rapport with the interviewee, use of language is important; this means interacting with them in a manner which is both comprehensible and familiar. Highly academic terminology with which they may be unfamiliar was inappropriate; could create a lack of understanding and therefore hostility or a barrier if the respondent feels they do not understand what is required of them.

Alternately a lack of knowledge by the researcher on a fundamental level of what is being examined, also poses a challenge as the contributor may have difficulty in determining the level at which to interact. They may also feel a lack of appreciation of their practices by the interviewer, if unawareness is displayed at even basic levels. This was addressed by using terminology and information even if limited, derived from the company literature, including company-documents / websites, etc., to communicate with the practitioners. Where aspects of work were unknown to the researcher, it was important to admit this to the participant, acknowledge them as the expert and seek an explanation into the unfamiliar domain. It was frequently observed that a recognition or appreciation of the practitioners' skills would put them at ease, and assist in their developing an open attitude towards the aims of the research. A thorough description into the research and how the practitioner's contributions fitted into it helped greatly in their understanding of why the work was being conducted. This assisted in gaining their trust; as questions into their work and how they perform it could be misconstrued, particularly within an environment of 'fear-culture', (see Section 4.8.3.1).

Therefore social access into the desired domain was helped by:

- ✓ Explaining the reasoning behind the knowledge elicitation;
- ✓ Having a fundamental awareness of the subject area;
- ✓ Creating a rapport: Using neutral, conversational language;
- ✓ Implementing semi-structured style of interview, to assist the informality of the interactions.

Specifics of the contributors are presented in Table 4.2, including industry, organisation and type of expert that contributed to the study, with a total of forty practitioner-interviews within P1.

Gaining the trust of the practitioners was vital in achieving a workable situation for the interviewer: In this matter, conveying the fact that confidentiality was always adhered to on many levels, was crucial.

**Physical and Social access proved to be heavily linked to issues of Confidentiality, of both:**
- ✓ **Specific Organisations**
- ✓ **Individual Contributors**

### *4.3.4 Confidentiality Issues*

Assurances of confidentiality, plus full explanations of the research were key to securing agreements towards participation. It was stressed from the onset that the results of any interactions would be used solely for academic purposes; and the specific raw data i.e. notes taken or audio / visual recordings, were created for use and analysis by the researcher alone, with no other individual needing to make reference to it. For each phase of research the contributing organisations would receive a copy of the report derived from that section of work, often in draft form initially, to allow the opportunity to approve the document or request modification; following which the final version would be disseminated. Declarations were made highlighting the fact that all work within these documents would be presented in a generic format, that company-identity would be protected / contributions presented in indistinguishable narrative which was guaranteed not to compromise any collaborators. This included protecting competitive advantage.

In addition to the company anonymity, assurances were made per practitioner, which meant that any type of information bestowed from a personal viewpoint would be held in the strictest of confidence. It was stressed that the practitioner knowledge elicitation was not undertaken for that organisation, but for independent research into the costing process and affecting domains. This was important, as a number of the questions and issues were related to challenges in communication within their working environment. This could be between the company and a related organisation e.g. supplier; or simply within their organisation across departments; even specifically between practitioners; hence at times potentially highlighting what may be perceived as malpractice. Therefore guarantees were made that there would not be repercussions incurred for divulgence of any potentially sensitive information. This is also linked to the value of clear explanations of the research being conveyed so that the participant understands why they are contributing; that it is part of impartial, external research; which holds no detrimental consequences for the participant whatsoever: But instead will be applied in a systematic and systemic manner, i.e. throughout industrial costing.

Thus confidentially was crucial not only between the individual experts but also to protect commercial company-practice within a competitive environment. This protection extended beyond commercial and into a different level of military-confidentiality in the case of aerospace and defence organisations. One practitioner within a large corporation explained that he was:

*"..am just mindful of relaying answers which could breach confidentiality.. ..without even realising am doing so"*

[Cost Engineer, Aerospace, 2001]

This practitioner felt that through the normal course of conversation and interview, held with a company-outsider, he may reveal something potentially compromising to security. Subsequently although the interviews were on a personal basis so that the practitioners could directly control flow and type of information bestowed, sensitivity to the confidentiality of any information received was still applied. The researcher had also sought and been granted the highest level of security clearance required to interact freely with the practitioners within the relevant organisations. Thus, care was taken to adhere to the conditions of security and avoid exposing within the research reports, publications and / or thesis any information received which could be deemed confidential.

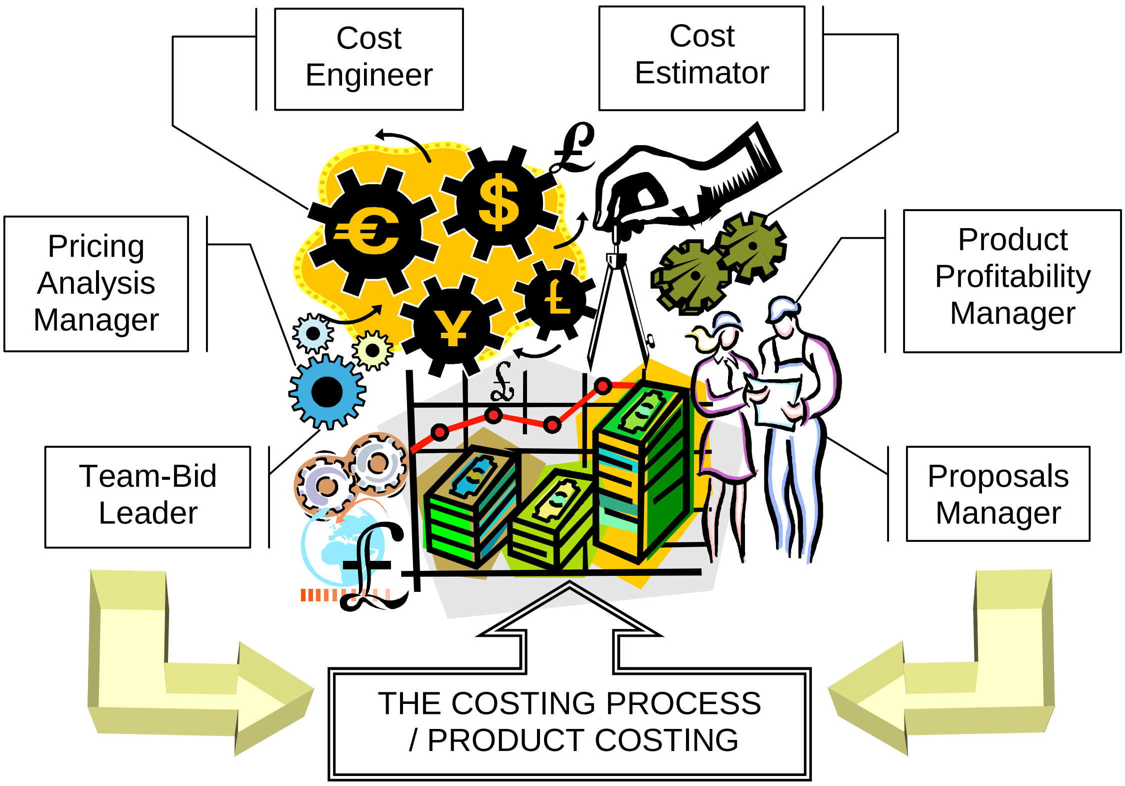



Figure 4.2: A Selection of Industrial Terms Used: Presenting A Research-Standard Reference

Consideration towards the selection and identification of the most appropriate organisations to approach is given within Table 4.1; with the actual contributors listed in Table 4.2. Having acquired physical and social access the next step was to arrange the meetings. In order to organise the researcher-expert liaisons, the first stage of contact tended to be made and / or confirmed, via telephone. Interestingly enough, a significant challenge was immediately experienced with this approach, in the form of inconsistent terminology.

## *4.4 High Level Terminology & Identification Challenges*

Even at this early stage, of making contact with potential research-participants, the lack of consistent terminology with regards to costing posed challenges in the form of identification. The experts within the costing domain and the departments which deal with product-costing were known by different terms in most of the companies approached, a selection of which are presented in Figure 4.2. The Figure, 4.2 also illustrates the diversity of the costing process, amalgamating engineering including manufacture, design, and other technical skills with global monetary and economic considerations. This diversity of role seemed to result in a range of titles and departments with which costing was associated. For instance the spectrum of companies revealed that costing may be included within the engineering activities, or linked with finance, and occasionally it was even placed with procurement.

Due to this lack of standardised reference, which was increasingly noticeable as more establishments were contacted, it quickly became apparent that a request for information from either a cost-estimating or cost-engineering department would not necessarily be understood. Subsequently the only clear way to identify the desired expertise was to describe the actual activity of product-costing. Phrasing the request in this manner would often enable direct communication with the correct area within the organisation for the research needs, i.e. allowed access into the costing field.

The terms encountered for the cost discipline have been listed in Table 4.2, and as can be seen the range of companies examined within this phase presented several different titles: - approximately eight, in reference to the direct cost-practitioners interviewed. Figure 4.2 highlights the role of the cost-practitioners which included economic, commercial activities performed in conjunction with engineering technical ones; whilst indicating a number of the terms encountered to refer to the same or similar cost-role. The specifics for the organisations examined have been given in Table 4.2. These discrepancies directly drew attention to an outcome which was identified at conceptual stages of the real-world or field research, but was valid throughout. This was that inconsistent terminology naturally created complications in communication, and a lack of understanding. These issues feature prominently within the outcome of the fieldwork and the lack of consistency is discussed further in the thesis, primarily with reference to the need for standardisation at least of commonly utilised terms, in order to assist an integrated cost-process. This inconsistency needs to be addressed across the industrial costing community on a global scale, as dictated by the companies examined where currently an international level of interaction within and / or between organisations is increasingly commonplace.

Once identification of the costing domain had been established, the majority of organisations were obliging being happy to input their knowledge into the research. The reason for this willingness was perceived, at least in part, as being due to the fact that research into the cost domain is in its infancy, with there being little reported documentation to date, as discussed in the previous Chapter 3. The practitioners working within the field realise that there are challenges within it, and recognise the need for research to be conducted within the area.

The practitioner-knowledge was elicited primarily through interviews and questionnaires, discussed in detail within Chapter 2. Alongside locating and organizing meetings with potential suitable industrial participants, a questionnaire was developed for use at the data-collection stage. The function of the questionnaire was to support the main knowledge elicitation (KE) technique of expert-interviews. See Figure 4.4 at the conclusion of this chapter for KE techniques employed throughout the research.

Table 4.2: Type of Industry, Organisation, and Contributor Interviewed

| INDUSTRY | ORGANISATION | TYPES OF EXPERT | NUMBER OF INTERVIEWS and INTERVIEWEES Approx. time frames |
|---|---|---|---|
| AEROSPACE / DEFENCE (Military) | BAE SYSTEMS | Cost Estimator<br>Cost Engineer<br>Group Leaders | Five interviews with one or more of five experts, varying time frames between 1 and 4 hours. Plus site tour |
| AUTOMOTIVE | FORD MOTOR COMPANY | Senior Cost Estimator<br>Cost Estimator | 12 cost practitioners, including one supervisor and one senior manager. Interviews varied in time, from between a few hours to a whole day: Total time of visit to site was almost 3 days. |
| AUTOMOTIVE | FORD -Finance | Financial Manager | One interview held with one expert, Approx 3 hours |
| SOFTWARE | TTW | Managing Director | One interview held with one expert; Approx 3 hours |
| AUTOMOTIVE | LOTUS ENGINEERING | Senior Cost engineer<br>Trainee cost engineers | One interview held with 1 manager & 3 trainees: Afternoon-long meeting |
| SOFTWARE | COGNITION | UK Manager | One interview held with one expert – approx 2.5 hours |
| AEROSPACE (Commercial) | TERMINAL 5 –BAA | Development-team members | One interview with Four experts ~Approx. 3 hours |
| MANUFACTURE | ALSTEC | Proposals Manager | One interview held with Two managers<br>PLUS site tour<br>Another interview held with Two manufacturing experts; all day visit to site |
| AEROSPACE / MANUFACTURE | ROLLS ROYCE | Cost Excellence Team | One interview with two cost managers<br>Afternoon visit –approx 3 hours |
| AEROSPACE / MANUFACTURE | GKN WESTLAND HELICOPTERS | Head of Commercial Pricing and Estimating<br>Deputy Pricing Analysis Manager | Two interviews<br>With two: One manager and one senior manager;<br>Approx 4 hours |
| AUTOMOTIVE | NISSAN | Technical Financial Engineers (TFEs) | One interview with two: One manager and one cost practitioners; 3.5 hours |
| AEROSPACE | AIRBUS | Cost Engineers<br>Cost Estimators | One interview with two: manager and one cost practitioner; approx 3.5 hours |
| DEFENCE | MOD | Cost Engineer | One interview with one cost practitioner; approx 2.5 hours |

Nb: The company classifications presented throughout this thesis have been determined via the industrial practitioners in-put in juxtaposition with specific reference to the information provided within each organisations' official website.

## 4.5. Knowledge Elicitation

Having identified suitable contributors, contacted them and secured access, the next most logical issue to tackle is that of gathering the data and information i.e. eliciting knowledge. Chapter 2 discusses the main methods which may be used for data-collection; whilst his section addresses the specific techniques applied here, within P1:

- Questionnaire
- Interview
- Document analysis
- Observation
- Case Study

Figure 4.4 illustrates the research design used throughout, but particularly in this phase. The main difference between phase one and two, (P1 and P2) with regards to knowledge elicitation (KE) was that, due to increased time, workshops were able to be conducted in the second phase, P2 of research. This was not particularly the case within the first phase, P1; though presentations were shown to companies and questionnaires implemented, it cannot be said that the KE was structured into workshop form until the next phase. Although the main reason for this was due to time constraints in P1; with this said the later examinations in P2 were undergone in a more informed manner due to the knowledge and understanding gained from this phase. Hence P2 examinations were generally more focused as P1 was comparatively broad; therefore P2 workshops could be successfully applied.

The first stage of KE was via questionnaires which were specifically designed to gather the exploratory, introductory information; though were also used to prepare the participant for the type of knowledge sought. This would ideally prime them for the type of question that would be asked, whilst concurrently providing them with an understanding of the research.

### *4.5.1 Questionnaire*

A questionnaire was developed to disseminate to the participating companies: It was designed to elicit cost-knowledge and activities, as derived from the costing literature. The questionnaire was piloted within the sponsoring companies mentioned, see Section 4.3.3; prior to being modified, and sent usually by email to the contributors, generally before the interviews.

#### 4.5.1.1 Questionnaire Design: Introduction

The questionnaire had an introductory section which explained the research to the contributing practitioner, briefly highlighting the perceived industrial challenges; this included an explanation of terminology used throughout the interactions and who, i.e. which practitioners it incorporated. It was important to address the issue of terminology at the initial stage of the survey, as the experts requested to participate may be in danger of assuming that it was not relevant to them if it did not address them by their correct title. For instance, if the questionnaires were directed at cost estimators, then any cost-expert who was referred to differently, may conclude that it is not within their area, and therefore fail to respond to it, see Figure 4.2 and Table 4.2 for ranges of title. This was the case when an organisation may have two departments that deal with costing, e.g. one which may be referred to as ‘cost estimating’ and one as ‘cost engineering’, ‘cost analysis’, or something similar, see Figure 4.2. The questionnaire was aimed at all the costing practitioners within each company; it was deliberately designed to be generic, as far as encompassing all aspects involved in product-costing, allowing a spectrum of viewpoints to be incorporated and considered. Thus the survey started with a brief outline of the research, including a definition of expected respondents.

### 4.5.1.2 Questionnaire Sectioning:

The main body of the survey was divided into three parts: Module 1) General Issues; Module 2) Process; Module 3) Interface. The sectioning was created so that all the required costing areas were covered and for ease of the respondent. For instance if the participant is asked for background information these questions are straightforward to answer, thus would ease the respondent into the questionnaire. The questions proceeded to be more thought provoking, related to issues of process and interaction, further into the questionnaire.

Grouping the issues into three also helped structure the survey; with each section incorporated to target specific information. The background of each participant in the first, general issues section along with their experience and current position / activities was important to the research. This was to determine the knowledge gained both in their role, as well as the prerequisite knowledge required to enable an individual to cost a product; and so to identify the caliber and / or what comprised a cost-novice; whether it differed per industry or even between organisations. The latter point was in preparation for the concluding aspects of research where cost-novice training issues are addressed, see Chapter 8 for details. Previous experience could also indicate the way in which the practitioner may tend to cost, e.g. what will be focused on, etc. For instance if one had previously been involved in a project which assessed Risk and Uncertainty of product-development, whilst the other had experience within a technical production domain, the latter may not place high value or refer to potential risks in the development stages when costing; whereas the other would have a high awareness of such. This would also aid in assessing the strengths, and the areas of development required per practitioner, which is examined later in the thesis; reference Chapter 8 for the practical implementations of the research findings. Establishing the current role would serve to substantiate the proceeding survey section, which examined the cost-process. Examples of the questions asked within the first section are as follows:

- How long have you been employed in the company?
- What is your role in the company?
- What is your experience (Academic & Industrial) prior to your current position?

Examples of answers to these questions are as:

- *"I have been working within the MOD, in various roles, for approximately 15 years"*
- *"Currently work in the procurement department."*
  *"..Specialist Procurement Service ..support for Defence Procurement Agency"*
  *"..for 3 ½ years"*
- *"Completed apprenticeship in MOD, Flight Systems (technical role)*
  *Draftsman, approx. 2 years*
  *Systems eng. approx 2 yrs*
  *Work study -8 years →scientific man. services; bonus scheme*
  *time / motion./ method studies*
  *-Procurement, current."*

[Cost Practitioner; Defence Industry, 2001]

From the literature, a theoretical position of product-costing was ascertained. However due to the observed variants in the reported costing documentation, plus the generalised view that was often taken in describing cost-procedures as discussed in the previous Chapter 3, it was evident that the specific process-per-organisation required attention. Therefore the second section of the questionnaire focused on examining the actual processes of costing. Organisations were expected to vary in their cost-approach due to differences in product, organisational culture, and general procedure variants. Therefore a view of how it was done within different organisations was sought, to get an idea of the scope of variance in the way costing was performed, and whether these differences were fundamental or superficial. Later in the chapter the SPSS analysis show trends between different industries and highlight patterns in the outcome, refer to Section 4.8.4. A selection of questions within the second section are as follows:

- What information is required for an estimate?
- How is this information acquired at the various stages of estimating?
- What information is not provided that you require, (if any)?

A sample of the way in which these questions were responded to are as follows:

- *"Labour, material, overhead"*
- *"Designer drawing… .Interaction with designer…"*
  *"Prototypes.."*
  *"..plus …most information required is within the costing software system"*
- *"New materials / processes may occasionally not be added to databases on time"*

[Cost Estimating Manager; Automotive Industry, 2001]

A lack of fluid interaction between the relevant expertise was perceived to be the foundation for many of the challenges experienced within costing. It was important to establish the necessary areas of interface, what information required transferal, and how it was communicated. A combined awareness of these areas would subsequently reveal the 'gaps' within the process. Section three of the survey, the interface, focused on these issues. The type of questions posed were as below:

- What level of contribution towards the estimate comes from other departments?
- Is the data / product-information that is required from other departments easily procured?
- How is all relevant information inter-linked?

An examples of the manner in which these questions were responded to are:

- *"T5 -team (dept.s)*
  *Include → Architects*
  *Client teams –users*
  *-business }*
  *-project –cost plan*
  *Eng.s } work closely with*
  *Mech., Electrical, special eng.*
  *customer / users*
  *BA –team*

*Supplier -1st tier (construction), Cost Disad., Environmental, Management, Admin support, IT"*

- *"Full review at each g/way …" "..if needed …can bring everyone together" "…have good IT"*
- *"Tools and tech.s will differ, though there's Cost Management throughout process: to bring some control + rigour to projects in BA..*
  *Info. links as required. T5 only get to each stage of project when last one's ready; they are not concurrently run"*
  [Cost Planner, Cost / Project Services, Quantity surveyor; Aerospace, commercial Industry, 2001]

Appendix 1 presents a complete copy of the exploratory (AS-IS) phase questionnaire that was utilised.

#### 4.5.1.3 Questionnaire Validation:

A draft version of the questionnaire was developed and piloted within an aerospace and an automotive company, namely BAE Systems and Ford Motor Company. Feedback from these two organisations helped to determine the relevance of the questions within different industries. The main points resulting from the pilot exercise related to the detection of either grammatical errors or incoherence; so modifications were made to the wording of the questions to make them read more clearly. The other suggested change as instructed by the sample experts of the questionnaire, was in relation to perceived repetition; occasionally a question was posed, which though reworded, was in practice reiterating a point which the specialist felt they had already addressed through a previous question.

#### 4.5.1.4 Dissemination of Survey

Once the costing questionnaire had been completed and modified it was ready to be disseminated throughout the participating organisations. This was often done prior to the interviews and emailed to the participants as a form of preparation to the subsequent company visits. This included a covering email, which clarified the visit details, so that it was received at a suitable time in relation to the interview itself. The manner in which the questionnaire was completed varied between respondents. Occasionally it would be filled out and returned prior to the interviews. In a minority of instances it was ready to be addressed at the commencement of the company visit. The most common practice however was for the expert to have familiarised themselves with the type of information being requested via the survey, and for the researcher to go through the questionnaire with the expert during the personal, on-site interviews.

#### 4.5.1.5 Cross-Examination of Results:

The results tended to be cross-checked with practitioner at the time of the interview, with a summary section validating what was discussed and specified. Additionally the interviewer accessed the responses directly following the interview and formalised them into a research-section report which was sent to the participants to validate: If required, modifications were made. Very few changes tended to be requested, although it was a good checking-process, as an example of a modification required was to change the company name used, as they had recently had a merger. Such a correction was important from a participant-identification perspective, though it did not impact directly on the results.

#### 4.5.1.6 Primary Function of Questionnaire

The questionnaire could not achieve, neither was it intended to give, in-depth insight into the issues at hand. The main intent for it was to act as a research-introduction for the contributors, to bestow an awareness of the type of investigation being conducted, and to prepare them for the more exhaustive examination within the subsequent interviews. It essentially acted as a template for the semi-structured interviews, ensuring that the main points were covered, ranging from the initial background, title and role of the contributor, to the perceived challenges of the process. Refer to previous Sections 4.5.1.1. and 4.5.1.2. for examples of questions and participant answers, and see Appendix 1 for the full document. Although the questionnaire helped to introduce the research to the participant, a verbal explanation commencing each interview was always provided, clarifying the aims and purpose of integrating the internal costing practices.

On determination of the process i.e. ideal performance against actual, the challenges within costing can subsequently be identified and in turn, addressed. Recognising whether gaps are inherent throughout the official process e.g. inadequate procedure specified by organisation or whether it was issues as a lack of integrated working practice due to some other reason, such as cultural environment, needed to be established. Even issues such as whether there is a formalised process within the organisation regarding costing; and if so, whether it was adequate; how implemented e.g. whether enforced or not, and so forth, needed examination. The interviews were the primary means of facilitating dialogue which penetrated these issues.

## *4.6 Industrial Expert-Interviews*

The principal method for eliciting the experts' knowledge was via interviews. Personal interviews were held on-site at each of the experts' organisations. This allowed the interviewee to gain an idea of the type of environment in which the work being studied was undergone. The researcher was often showed around the premises during the visit so was able to view a number of the processes employed within the organisation. Such observation not only revealed the product / service which the company delivered, but also assisted in the understanding of the type of environment in which the practitioner worked in.

Interviews were the means by which a large quantity of information was procured about the expertise required for costing, and is especially effective at extracting the tacit knowledge employed. Case studies were gathered through conversational interactions, created within an interview-setting, see Chapter 2 for more detail. This depth of knowledge could not be elicited by the other, supporting techniques used, which are all more formal and involve less personal interaction with the practitioner then interviews allow. However there are various aspects to interviewing which contribute towards the maximisation of the effectiveness of technique, with regards to the research. This includes the type of interview used, the skills and capabilities of the interviewer, and the selection of the most suitable subject-matter to examine, in this case the cost expert.

### 4.6.1 Maximising Efficiency

The first thing to ensure with regards to interviewing was the suitability of the interviewee. In order to maximise the use of time, and avoid the accumulation of data which could ultimately be deemed irrelevant, the candidate selected needed to be appropriate in the sense of choosing practitioners who could provide the most relevant information [Fear, 1978]. Within this research the correct participant was identified either through describing the role / research in advance and being directed to the cost-disciplines. Otherwise via contacts, usually industrial ones who either had prior knowledge, or were in a position to find out who were the appropriate research contributors within organisations. Table 4.3 lists the general attributes of the participants within phase one of research.

The management of time was significant: It was important not to waste either the experts or interviewers time. In relation to the practitioners, a positive attitude towards the research interactions was strived for, in order to maintain the relationship where they would continue to be willing to provide their input into further phases of the research if required. For instance, if perceptions were formed by industrial bodies that their experts have participated in unnecessary or unproductive exchanges, which proved to be an ineffective use of their time, this would be detrimental to the work, not solely for the researchers directly involved, but potentially the collaborating research institute as a whole. Misusing or wasting practitioners' time may be attributed by the contributor to a lack of understanding of the specific requirements for the work on the researchers' part. This may also be associated with a sense of unappreciation of both the expertise at hand, and the value of the time given.

With respect to the interviewer: If irrelevant information is obtained it will be at the expense of time that could have been spent on the elicitation and analysis of appropriate information. The time and therefore amount of quality-data is reduced if such matters as relevance are not addressed thoroughly enough both at the selection stages and throughout the interactions. The interviewer needs to determine the significance of the subject-matter due for investigation thoroughly, and be confident of examination into the correct area preferably prior to, or as early as possible into the commencement of the knowledge elicitation system.

Table 4.3: General Attributes of Practitioner Contributors:

| EXPLORATORY PHASE CONTRIBUTOR ATTRIBUTES: | |
|---|---|
| Type of Experience: | Specialised work on specific project e.g. a specific aerospace model, such as Eurofighter; or specific model of car / engine / classification of car type, e.g. family saloon, executive model, etc |
| Background: | Generally Technical Apprentiship; followed by on-the- job training; often involving placements across the organisation. Various positions held; usually engineering-focused; and often within the same organisation. |
| Current Roles / duties: | Technical-based, e.g. design / design-alternative assessment within primary financial function e.g. research into costs; overhead assessment; annual-cost breakdowns: Supplier cost-checks / bid analysis |
| Gender: | All male contributors |

The research process accounts for a certain learning curve and therefore trial and error type progressions, and acknowledges that not all information gathered will contribute (directly) to the overall findings: Although can still be useful, adding to background and environmental knowledge / information. Given this situation clearly every measure should be taken to ensure time is not utilised on irrelevant work. This can be partly overcome by establishing unambiguous research-standards regarding terminology employed, and widely disseminating it to the selection of potential participants. If such standardisations are introduced concurrently with the research ideologies, this will help align the thinking of the contributors, aiding the effort of procuring data which is comparable. Additionally there were definite similarities in respect to the participants background, as highlighted in Table 4.3. These patterns factored in ensuring that responses were given from the stance of understanding the essence of the research, and thus creating a more universal comprehension towards what was being asked within the interviews. The alignment of respondent-perception towards the research aims and what they were contributing too impacted on the quality of the findings; so it was important to consider these issues.

With regards to the actual process of interviewing itself, there are different aspects and techniques applicable; these have been examined within the previous methodology chapter. The following section discusses the specific techniques utilised through this research, namely a semi-structured style of interview which incorporates elements that maximise mental stimulation, providing guidelines of interaction; see Table 4.4 for the contributory techniques involved in the interviews. The benefits of this combined approach for this type of research are discussed in the following sections.

### *4.6.2 Group Interviews*

Both individual and group interviews were held, though the majority were with more then one practitioner. Group interviews generally enabled the researcher to gather an increased level of information within a smaller time frame then if interviewing one expert at a time. The semi-structured interview, SSI, technique helped promote discussion within the group which would reveal greater depth to the knowledge bestowed; as any information could be directly questioned by the other participants, resulting in the original point being elaborated on. On a practical level within one session where a small group of practitioners (maximum of four) participate in a discussion-type interview, this tended to be more economical with time for the contributors, then conducting individual sessions with each one. However within group-settings where multiple practitioners are collectively contributing, attention needs to be paid to certain situational issues. For instance, the interviewer has to be aware of and stifle any dominating individuals, who may monopolise discussions and either overly influence or generally create an environment which causes the other practitioners to be reluctant to contribute candidly. Additionally, any sensitive or controversial issues which arise from the discussion may not be addressed as fully as if the contributor was responding in isolation, and away from the direct attention of colleagues, [Mikklesen, 2002 p106]. This was potentially the situation, when the issue of challenges in interface / communication across disciplines was embarked on. A degree of fear culture tended to be present in many cases, as discussed in Section 4.8.3.i, and in later chapters; otherwise issues as confidentially occasionally caused contributors to give diplomatic or slightly guarded responses. As opposed to this being the case for the identification of challenges it tended to be more obvious in their opinions regarding why challenges arise and are sustained within the organization; expanded on in the Themes Section, 4.8 and Chapter 6.

### *4.6.3 Individual Interviews*

Therefore although group interviews were an effective way of facilitating group-expert discussions, individual interviews also added value to the knowledge elicitation process. A positive point of one-to-one interactions was in relation to confidentiality, and covering controversial or (organisationally) sensitive topics, which may have created difficulties in being broached within a group setting. This is particularly relevant to the costing domain and this research, as an emphasis was on establishing what process was currently being conducted, against how it should / could be done with respect to making improvements. The inevitable link would be to discuss why costing process is not being performed to capacity, and to determine how it can be, i.e. what changes should be made to enhance current performance. Given this, it can be seen that there are many areas which require caution and sensitivity when examining: For instance the ‘why' question as touched on in the previous section and Chapter 2, Section 2.6.2.1; namely why product costing may not be currently performed to maximum effectiveness, in the practitioners' opinion. The responses to such enquiries may involve perceived criticism of the organisation, management, department, other departments, or even other practitioners, in the way they work, training requirements, understanding, communication and so forth. Therefore within a confidential, individual interview setting it was far easier to frankly examine such issues than it tended to be within group / more open settings; which is why individual interviews, or interactions involving just one or two people were valuable.

As said the interviews were primarily documented via note-taking form and often taped, though this was for precautionary means, if validation of a point was required, etc. Generally the questionnaire format was followed, but not rigidly adhered to if relevant information occurred outside the direct questions posed. As costing is a wide domain and the researcher was not an expert in it, the interviews were deliberately designed to be conversational to allow the practitioner to elaborate on issues which may not have previously been known to the interviewer. However as the technique followed was the semi-structured style of interviewing (SSI), there was still enough structure to allow relevant diversifications, whilst monitoring the points covered, ensuring the required areas of interest were addressed.

### *4.6.4 Semi-Structured Interviews*

The aim of the expert–interview is to capture knowledge and information which could not be fully ascertained by other methods such as document analysis, questionnaires and observation. However all the previous mentioned techniques served to support the main manner of eliciting knowledge, which was from interviews. The type of interview deemed most appropriate for this type of practitioner-interaction was the semi-structured interview, SSI. This is fundamentally due to the fact that SSI are less ridged then closed, structured interviews; but have more control then the unstructured, open-ended approach. The primary reasons for which have been elaborated upon in Chapter 2, Section 2.4.3 stating the characteristics, advantages and disadvantages of the various techniques. The questions can provoke responses which due to the flexibility of the technique are able to lead into areas that subsequently facilitate an understanding of rationale, behaviour, motivation and experiences [Mikklesen, 2002 p105-107].

For example, a section from one of the interviews is as:
*"My background's wholly technical…. did manufacturing engineering apprenticeship in BAE from '85-'91.."*
*"..then completed a design and manufacturing degree at uni.."*
*".. was R&D designer for 2-3 years.."*
*"Then from Feb. '97 went on to do R&D ..for 5 ½ years…"*
*"..have worked in aerospace, manufacture and design, which is good experience for a cost eng …"*
*" You need a lot of all-round manufacturing and technical experience, or will struggle in cost engineering."*

[Cost engineer; Aerospace / Defence industry, 2001]

In this above example the practitioner has had both industrial training in the form of an apprenticeship, which is typically no less then two years, and in this instance 5; as well as an academic qualification in their area of expertise. Often it was noted that practitioners especially within more manufacturing environments did not posses both, but tended to have been trained via the in-house technical apprenticeship route. This proved adequate to base their career in a manufacturing domain upon, which could subsequently lead into product-costing when they had acquired enough experience within other areas, as mentioned above. The quote is extracted from a very conversational SSI, where the contributor was able to present informed opinion and perspective derived from experience. Table 4.3 lists the general attributes of the contributors.

Once with the practitioner the type of questions asked were in general guided by the questionnaire content to begin with. The survey was produced to support the interviews, see Section 4.5.1, so the interviews often commenced with discussion and expansion of those areas targeted in the questionnaire. To start with however there would be an informal greeting with the aim initiating rapport, followed by an explanation into the research as a whole and more specifically into the purpose of the interview, and what type of information was being sought along with the reasoning into why. As many of the participants were unknown to the interviewer the introduction to the research was always given; occasionally accompanied by a presentation, though often the practitioners tended to prefer to pursue their enquiries on a more informal basis. Following this, the main knowledge elicitation would commence with exploration into the background and experience of the practitioner. This gave the opportunity to establish areas such as pre-requisitional knowledge, how they began accumulating their knowledge within the field; why they had begun at this point i.e. their original focus / direction; and sequentially unfolding how they moved into the costing domain. At each point the reasoning as to what work they had done and what type of expertise this had bestowed could be addressed; along with why and how they had progressed or side-stepped into a new / different area. For instance did they start as engineers, moving onto different projects, across different parts of organisation, departments, company, etc: Why did they move; and how did they facilitate their moves. The incremental build-up of knowledge and how experience was gained helped to assist in what became the principle substantive contribution of this research, namely how to implement the research findings pragmatically. Plus additionally, preparing for suggested improvements to industrial cost-training in order to bring novices up to speed a lot more rapidly, see Chapter 8 for details. For each change in their career, they were asked what skills and knowledge they felt they had acquired in their previous role, and what was needed in order to accomplish their new role. This information collectively tracked the expertise gained, and allowed the researcher to asses by how these gains were made; as well as enabling consideration of the practitioners own opinion on these aspects. A quote from a highly experienced automotive practitioner, in respect to their background prior leading up to product-costing is as follows:

*"I was an apprentice toolmaker in Chrysler …for 4 years.."*
*"When was a qualified toolmaker …went to Ford in south Africa for 6 years.."*
*" did Quality for 9 months … (stayed in S.Africa, but company change).."*
*"Went to General Motors as a Procurement Analyst ..evaluating purchases and high level costs"*
*"..to Ford in cost estimating for 2 years.."*
*"..Leyland, vans .. …before Jaguar in 1987,*
*…in Vendor tooling for 5 years .. ..were evaluate or prove tooling costs"*
*" ..used to be separate entity, the price cost and tooling costs"*
*..Evaluate the launch team, PVT (product vehicle teams) x2000 launch…*
*..All estimators have technical backgrounds, …mainly within toolmaking, process engineering or manufacturing"*
*"..Cost estimating used to be more technical… …take 2 weeks to develop an estimate for large components …"*
*…here and now, not able to regularly come up with detailed costs... mainly due to resources and time pressures"*

[Senior Cost Estimator; Automotive Industry, 2001]

The previous quote leads into issues surrounding resource; this is one of the cost themes, namely areas which have been identified within the research as being important factors in the success or otherwise of product costing. These themes are discussed later in the chapter, see Section 4.8; and in detail within Chapter 6, also refer to Figure 6.5 which summarises the themes and the interactions between them. This style of questioning allowed the interview to move into aspects which were not necessarily anticipated. For instance information imparted as to the process of costing within a given organisation, could lead into the typical sequential procedures and associated knowledge to fully perform the process. This could diverge into relaying the necessary areas i.e. departments for liaison, in order to obtain all the required aspects of costing; how the interaction takes place, and the subsequent advantages and inadequacies of the current process. The practitioner was always given the opportunity to state their opinion with regards to what modifications would benefit the processes and how they would create the desired improvements; see below automotive quote:

*"Now there's a lot more commercial involvement then used to be, basically commercial and engineering are mixed… ..target setting are done via ABS (Affordable Business Structure).. where profits are known in advance.. all aspects of vehicle are broken down: -chassis, BoW, etc ..even further sub-section front panel, etc*

*Engineers get suppliers on board ..for instance if a new seat was required, ..assessed with use of historical data and cost estimating… Purchase request supplier to give formal quote, even though ..fluid design, (it changes a lot)*

*PST has rep.s from different teams –includes finance, engineers, purchase, estimating, management, Quality QA –these are the main, …the team plus supplier*
*..early stages are frequent meetings, every 2 weeks to get design more cost efficient ..to lower the costs.*
*..interact via meetings ..also spin-off splinter groups aside from PST*
*…Estimating is used ..FPDS (Ford product development system) …estimator involvement is clearly stated in this document.*
*However often ..not used routinely, more on an "as and when required" basis.*
*For cost checks we should be automatically included throughout the process, ..and from the start.. …ideally right from supplier selection stage"*

[Cost Estimator; Automotive Industry, 2001]

Semi-structured interviews (SSI) are often used with exploratory and participatory techniques: Though when conducting a SSI, the subject and focus to be covered are predetermined. However as described above the order, manner and verbal approach (wording) of the questions will be dictated by the general direction the interviewer pursues. The specific detail of the interview therefore is not planned meticulously, but instead is intended to naturally emerge from the interaction and general rapport gained with the practitioner [Mikklesen, 2002 p102-103]. The following section discusses intricacies of the mental stimulus in more detail, including the environment actively strived for to maximise it.

### *4.6.5. Evoking Maximum Mental Stimuli / Awareness*

A lot of consideration was given to the way in which the interviews were conducted, from a mental, tacit view: In other words, the interview design included evoking the maximum mental alertness when gathering feedback to the questions and general interactions. As industrial visits were limited primarily due to time constraints, it was important to maximize the time spent within the companies, and particularly with the practitioners. To accomplish this, the interviews took into account elements of mental stimulation such as environment focuses, and wording or phrasing of the questions posed.

#### 4.6.5.1 Creative Repetition:

Information was probed for from various angels, i.e. essentially the same question may be repeated, but in different forms. This would usually result in a more rounded and complete response, but would require some resourcefulness by the interviewer, in rephrasing the same query in an interesting, provocative manner. Examples of the questions are:

- "What type of design-information is lacking from the initial feedback?"
- "What additional detail could the designers provide to assist the costing process?"
- "With regards to the product-design stage, what further information would you benefit from receiving?"

Each response to the rephrased question would add to the previous information regarding the subject of interest: Both helping the respondent to trigger their recollection of further detail; and ensuring the point addressed was covered fully. An example of the way the previous questions were actually responded to in an interview:

- *"..could do with always having an actual prototype to cost"*
- *"..most of the information required is contained within the designers drawing that we receive, ..however these are complex…time consuming.. ..More interaction with the designers earlier on would be of benefit, as …potential cost savings can be made.. from our input"*

[Cost Estimator Practitioner; Automotive Industry, 2001]

The cost practitioner highlighted that a prototype was ideal to create a cost from. However in later interviews with a supervisor within the same organisation it was pointed out in response to this oversight that they are simply not always available, particularly at the conceptual stages of project. The latter response though lead into another cost theme, of interaction and communication: If communication between interacting disciplines was enhanced, in this case between product-costing and design, the product could be made more cost–effective from the design stages. See Section 4.8 later in this chapter for an overview of the cost themes; and Chapter 6 for detailed accounts.

#### 4.6.5.2. Decomposing Complexity:

Within the mental considerations was the issue of how information is best elicited from a respondent. For instance points could be discussed sequentially leading on from other activities, in relation to other events as well as in isolation. These probes were used, as different angles of examination activated or further stimulated recollections which were not immediately triggered by one type of query, but which could add to the information imparted. For example:

- An isolated question may be: *"What was your final cost -activity yesterday?"*
- As opposed to a question leading from another event: *"What was your reaction /response on receiving the latest supplier cost-breakdown?"*

There are various activities linked to the receipt of a supplier quotation, e.g. when received the quote needs to be checked by the estimators, who may query whether it is greater than anticipated or even abnormally low, compared to other quotes. Either of these evaluations can prompt a follow-up action, such as requesting justification if the costs appear excessive; or assurance / proof / validation if the costs are too low. Excessively low figures may indicate that quotation was submitted solely to secure the bid or to 'win business', but without real intention to deliver for the quoted costs, potential for 'top-loading' i.e. escalating the costs, further into project. Alternately an unrealistic quote may have been submitted by an unstable supplier, creating high-risk if they are unable to absorb the losses made through excessively low-quoted figures, presented simply to win the contract. It is evident that in a situation as supplier-quote many responses will be created by the situation itself; these can be investigated sequentially and according to circumstance. In the prior example, of supplier quote, the questions posed would serve to break down a large area of costing activity into manageable, assessable information. Hence questions would result in answers which would lead into each other, incrementally explaining a complex process.

Similarly, specific questions may be asked, in conjunction with multiple ones; the latter refers to extensive answers contained in response to one question. For example:

- *"What individual elements are incorporated into the overall budget?"* The response to which requires a breakdown, broad or detailed of all comprising departments and collaborative projects towards the whole.
- Against: *"How is the material cost determined?"* This answer involves explaining how current costs are established from publications among other sources, and how the quantities of material-order affect the price.

### 4.6.5.3. Contextual Importance

The contextualisation of events, both mentally and physically assists with the elicitation of accurate information and knowledge. On a physical level, this was where the opportunity was taken to conduct the interview within the industrial environment whenever possible, as this is were the work under question was carried out; as opposed to conducting the interviews in an external setting that is unfamiliar to the participant. Queries posed about issues encountered on a day-to-day basis were addressed with practitioners on-site, in order to better understand the context within which the costing was undertaken. It was recognised that the tangible environment impacted on the mental engagement and responses of the interviewee. The benefit to the practitioners' recollection was apparent, as they could refer to items / documents, etc which were relevant, regularly giving statements as "*..this is what I was working on yesterday*". For the AS-IS phase, out of 12 organisations that participated, 11 industrial visits were made, with the researcher able to conduct on-site interviews: This ratio was similar for P2 research, see Chapter 6 for detail.

Table 4.4: Components of Industrial Interviewing

| Constituents of the Collaborative Interview Process: | | |
|---|---|---|
| Practical conditions | Group Interviews | Usually a time-saving process<br>Enables a multiple collection of views<br>Via the promotion of expert discussion<br>Dynamic transactions: Tend to lead to otherwise undisclosed opinion / train of thought<br>May stifle controversy or open expression towards sensitive subjects, due to fear culture among other factors |
| | Individual Interviews | Challenging or potentially delicate issues may be addressed openly<br>Privacy increases perception of confidentiality which reduces fear culture; so responses may be more frank / detailed |
| Mental conditions | Semi-Structured Interviews | Flexibility to allow appropriate digressions<br>Whilst keeping overall subject-focus<br>Open-ended questions often used<br>Elicited Case Studies |
| | Maximising Mental Stimuli | Conscious attempts to create the most favourable interviewing conditions<br>Via consideration of most effective mental and physical states<br>Ways of phrasing questions, etc, evoke maximum mental focus, e.g. repetition of enquiries; keeping within the practitioners work-environment, and so forth. |

Workplace interviews also assisted the interviewer through being placed in a position to ask about visual things relating to their surroundings e.g. if the costing practitioners happened to have a prototype or designers drawing to hand. Placing the practitioner and work in context not only addressed the physical process more thoroughly, but also the mental experiences of estimators that ultimately affect their overall performance. For instance, it was revealed that during the lead-time towards a bid deadline, high pressure is on the practitioners to produce a reasonable figure for approval to management and project ‘owners’ within the pre-specified time-frame. The issue of how they feel, whether rushed, anxious, worried; or calm, relaxed and composed can disclose related behaviour and potentially explain higher levels of errors, miscommunications etc. In the case of meeting bid-deadlines, if relevant information is not communicated when required, it is possibly as much due to confusion within a pressured environment and lack of implementation of processes, than from the processes not being stipulated adequately, or at all to begin with. Similarly, it was often the case that deriving full, detailed costs was rare, due to lack of resource, as mentioned in the interview quote within the previous Section 4.6.4. However for the cases in which they are undertaken it is evident that the departments / organisations have sufficient labour, time and information provided to the cost-practitioners to perform detailed costs; though they were often claimed to be performed within pressured environments, and would ideally prefer to work with increase resource. Despite these claims, the fact that some companies have facility for detailed costing, whilst others commonly perform ROM, with little-no formalised cost tools, indicates that the role is valued within the organisation, and tends to point to the expert being more relaxed or comfortable within their work schedule. Thus they will be more likely to carry out procedures fully, and relay to the interviewer what this entails. Hence probing the experts to think about their feelings assists in the information they are able to give, and aided the interviewer in understanding the overall costing process within each particular domain.

As the practitioners were often directly at their desk / in and around office, a certain level of distraction, both physical and mental could not be avoided. For example there were times when the interview may have been diverted by a passing colleague making an enquiry, or very occasionally by the telephone. However it was deemed more beneficial to have these distractions than to remove the participant from their place of work, although interruptions can generally be expected to break a trail of thought, in this case, any distraction would be work-related. Whilst isolation or interactions external to the usual workplace may imply minimal distractions, it was deemed beneficial for the knowledge recollection process to stay within the field of examination, particularly where the atmosphere and stimuli in the work-environment were perceived to act as memory enhancement or stimulus in obtaining the physical, and less straightforward tacit, responses. Another measure taken primarily for validity was that on completion, the interviewer relayed all elicited information back to the respondent in order to ensure that it had been fully understood, and to clarify the points expressed.

#### 4.6.5.4. Influence of the Cognitive Interview

Interviews in general are aimed to elicit more than external behaviour which can be acquired via observation or analysis of documented procedures. In addition, they strive to study the underlying cognitive influences behind the practitioner’s behaviour plus how and why processes are conducted in certain ways. The technique incorporated within these interviews was influenced by the Cognitive Interview (C.I.) theory [Moody et al, 1996] which specifically aims to broaden the interviewer perception of the physical and mental environment of the practitioner. This, practised collectively with the other techniques discussed provided the most insightful interview into product-costing activities. C.I. was developed through a collection of theories related to memory retrieval and enhancement; and focuses on five approaches which aim to maximize the interviewee-recollection process. These processes are: varied retrieval, multiple representations, extensive retrieval, context reinstatement and focused retrieval [Moody et al, 1996]. C.I. principles provide guidelines for the interviewer that assist in the construction of an interview which evokes maximum memory retrieval when the five stated processes are applied, as appropriate.

In semi-structured interviews (SSI) it is the role of the interviewer to elicit appropriate knowledge, and keep the interview focused on the requirements, whilst allowing adequate flexibility for diversion into relevant aspects of the subject. Given the aspirations of C.I., this research placed emphasis on the mental stimulus applied during the SSI, and worked in conjunction with SSI to evoke maximum tacit awareness from each participant, in relation to the investigative domain. Table 4.4 summarises the collaborative aspects incorporated into the industrial interviews.

### *4.6.6. Benefits of Combined Interview Framework:*

Due to the level of judgment and tacit application within costing, the interview process needed to be suitable to elicit knowledge from both the tangible and implicit perspectives involved. The combined interview-framework was designed specifically with this in mind. Table 4.4 highlights the main components used throughout the P1 interactions; with increasing information obtained from the practitioners via the dynamics of group exchanges. Individually and collectively the respondents recalled more information as they responded to the open-ended questions, reacting to the mental stimulation of creative reiteration, within work-focused environment. The semi-structured style, lead partly by their answers, along with being guided by the interviewer; plus reinforced probing, lead to the dissection of processes undergone.

Within costing, the practitioners have many enquiries related to the estimate / costs which they successfully address; it is beneficial to the individual and the development of the profession as a whole if such information were retained or captured, particularly for training purposes. If the situations encountered were documented, as and when they arose in order to ensure maximum detail, a library of costing-data would eventually be developed with live examples, information and valuable case studies: This would greatly assist in the training of new recruits; and provision of historical data records, which benefit all levels of practitioner. This is discussed later in the thesis, see Chapter 8. The researcher noted that the practitioners often found it challenging to list their activities, primarily because they were not used to doing so. An observation was that they usually perceived elements of their skills and knowledge as common sense. This seemed to be due primarily to the fact that it involved tacit decision making or judgement which was such an integral part of their role that they took it for granted; often failing to verbalise the detail unless prompted by the interviewer. A typical, if basic, example can be seen in the following segments taken from an early interview with an experienced cost-estimator within a large automotive company; speaking with reference to a physical prototype at hand:

*"..Take this for instance: When I was sent this prototype, I estimated the cost would be about…"*
Researchers' question: How did you estimate its cost?
Practitioners' response: *"..Well from the manu. process and material used, I then …."*
Further enquiry: How can you tell the manufacturing process used for this prototype?
Practitioners' explanation: *"From looking at the shape of the component; …the cylindrical holes here show.. …and you can see it's been made all in one piece; there are no joints (welds, bolts, etc), you can physically see this… it's been moulded to shape… so from*

*this I can immediately tell the process to make it was… Now this process tends to use* …(grades of polymer); *...and it was manufactured in-house"*

[Senior Cost Estimator; Automotive Industry, 2001].

Continuous enquiries into the explanations given disclosed increasing levels of detail which eventually lead to a record of the complete process that could be followed by a non-costing observer.

## 4.7 Observation: Terminology

As noted earlier within this chapter and within Chapter 3, terminology proved to be a significant factor, when examining cost-process across industries. However although initially recognised via the top-level references used towards practitioners, the depth of terminological inconsistencies was visible throughout the processes.

### *4.7.1. Identification:*

As discussed in Section 4.4 a perceptible challenge experienced from the onset of research was in the form of lack of common terminology. This even hindered the identification of the correct expert or organisational area for examination, let alone the impact it was having on the implementation of the process itself within industry. However, this identification-challenge was quickly overcome by reverting to cost-role / cost-activity description, to locate the relevant expertise required within each company. To elaborate, the search for research–participation did not begin with a direct request for specific practitioners or even department within any given organisation. This was due to an evident lack of standardisation in the terminology referring to the costing domain: Instead a brief portrayal of the cost-process would suffice in communicating which area of work was sought. Due to this lack of standards across the costing-process, establishing who to converse with regarding participation was not as simple as it should have been within the majority of research-subjects. However, once this was clarified, there were few challenges encountered.

### *4.7.2. Literature versus Reality*

On the subject of terminology, the costing-process has multiple terms of reference: Two recognisable expressions are cost engineering and cost estimating. Aspects which have differentiated these terms are drawn together throughout this research and lead to the question whether they can be classed as separate entities as far as practical use within industry is concerned. There are descriptions of both cost engineering and cost estimating found within the literature, see Chapter 3, Section 3.1.1. These definitions can be seen to be vague, and if anything prove the point that the terms can be used interchangeably with ease. Though the costing documentation reports the act of cost estimating to differ to that of cost engineering, there are inconsistencies even within these literary portrayals, as noted within the previous chapter. With this said the general emergent theme of the published work, was that cost estimating was an activity performed within the overall process of cost engineering. This description was not observed throughout the industrial examinations. Generally companies encompassed cost estimators and / or cost engineers, in addition to cost-practitioners or other references, as presented in Table 4.2. Thus P1 found that the cost-process is performed by practitioners, referred to by a number of titles, see Figure 4.2.

### *4.7.3. Research Terminology*

Within the research it is shown that the activities described as cost estimating and cost analysis are often described as being under the same umbrella within the industries examined, seen as general costing activities undergone simultaneously by (numerous) cost experts in question. However Stewart et al, [1995] stress the inseparable relationship between the two functions, stating that they are dependent on each other. In practice product-costing and cost analysis fall into the same domain, and are dealt with by the same experts.

All the aforementioned cost-practitioners, see Table 4.2 for the range of title encountered, worked within the costing domain. Individual companies tended to have developed their own definitions or type of cost-expertise dependent on their needs and organisational structure. For example a large aerospace organisation had distinct, defined roles between cost engineer and cost estimators. However, having a department for each placed them in the minority of company costing-structure; most companies contained one or the other. For instance one large automotive organisation had only one sizeable 'cost estimating' department which covered aspects of both the roles as performed within the previous mentioned aerospace organisation.

Similarities in the work done were noticeable, as well as differences and occasionally complete omissions between them, generally due to the nature of the product. For example the automotive company in question did not bid for projects; whereas a main role of the cost estimators within the aerospace organisation was to compile bids to tender. The role of the cost engineers within aerospace included risk analysis, whereas in this particular automotive organisation risk analysis was not a primary role of the cost estimators although elements of risk were dealt with, as documented later in the thesis, see Chapter 7, Section 7.3.6; Figure 7.11; and within Chapter 8. Therefore inherent differences in the roles reflected the diversity in the costing-structure of the company; which in this case was due to the type of product made and nature of customer. However the fundamental differences, such as those between different industries or products, were not always the reason for dissimilarities in the costing-process, as they were noted within the same industries as well as across different ones.

Other organisations revealed that the use of the terms were interchangeable depending on which company was being examined. An interesting observation was that often practitioners termed 'cost engineers' had roles which were dominated by economic activities, despite the engineer reference in title; this was similar to literature definitions. In contrast the role of 'cost estimator' often dealt with engineering as well as economic elements of cost derivation particularly as the costing practitioners examined within this research were overwhelmingly from an engineering background. Essentially, the processes performed by the cost estimator, cost engineer and other titles frequently appeared to be similar. This reinforced what the thesis has opted to use to refer to all relevant cost activities, as one all encompassing term of the costing-process performed by the cost-practitioner, illustrated in Figure 4.2.

## 4.8 Industrial Cost Themes:

This initial phase of research resulted in a number of prominent observations, from which certain themes could be identified. Figure 4.4 shows the framework of this section, from the knowledge elicitation technique used, to the main findings. Six themes were identified and are presented in Table 4.5 These themes summarise the main issues discussed by the practitioners across the industrial examinations. The concerns varied from quite tangible factors, such as the range of difficulties surrounding data / information transfer, and the impact that a lack of resource has on the process; to the more implicit elements such as communication, understanding and organisational culture. The latter are interesting, as costing tended to be perceived as an explicit process, in the sense that it was compiled though figures, and assumptions based on expert judgments and / or established historical product-data. However, the frequency Table 4.6 highlights the prominence of the intangible considerations in relations to the process.

Chapter 6 discusses each theme in greater depth, and assesses them against the knowledge categories and cost-knowledge types detailed in Chapter 7, which emerge from the later phases of research when combined with Phase 1 findings. However the interviews and questionnaire results were analysed via the thematic coding technique, see Chapter 2, Section 2.5.4. The main points that emerged were grouped together and the frequency that they were referred to were classified within the statistical analysis programme SPSS, see the following sub-section. This could show how often aspects were raised, and hence how prominent they were within the results against the total number of points made. Table 4.6 lists the outcome of P1 findings. The Table represents the 'frequency', how often each of the cost themes occurred; and the percentage that they were mentioned i.e. in relation to all the comments made, how prominent each theme was.

Table 4.5: The Cost-Themes:

| THEMES | CHARACTERISTICS / COST FEATURES |
|---|---|
| RESOURCE | Lack of resource resulted in lack of labour, which impacted on the quality of costing performed. It affected training, including On-the-job, and general levels of maintaining / improving expertise, due to time constraints on practitioners. |
| DATA / INFORMATION | There was lack of process to automatically transfer information to costing, particularly modifications to initial costs assessed. Often inadequate data was provided, and costs are only as accurate as the data used to formulate them. |
| UNDERSTANDING | Lack of comprehension of the costing role; lack of understanding between the interacting disciplines about each others function, priorities and systemic placing;<br>Inconsistent terminology added to the confusion. |
| COMMUNICATION | Poorly integrated working process and practice between interacting disciplines;<br>Impersonal, formalised techniques used, which often overly limited communications. |
| CULTURE OF ORGANISATION | Ingrained work-practices contributed to lack of integrated working / communication.<br>Fear culture created challenges across the board. |
| TRAINING | Concerns over new source of novice i.e. from technical apprenticeships to academic graduates: Training concerns were expressed.<br>Necessity to capture and reuse current expertise and knowledge is essential;<br>Promote understanding between the relevant disciplines, including management. |

### *4.8.1 Thematic Coding and Classification / SPSS:*

The themes were established via a coding and classification system, explained within Chapter 2, Section 2.5.4. Basically this involved an assessment of each interview in detail, to establish the main points discussed within them. This analysis was detailed with each sentence being classified and coded regarding the main point being raised in terms of which theme it was related to. Later in the thesis, (Chapter 6), this data-analysis technique is used to determine what knowledge type and category were being discussed per statement, ascertaining the frequencies and any correlations between them. The main themes were identified soon after each industrial visit through familiarisation with the interviews, refer to Chapter 2, Section 2.5.3, though to summarise it is basically a technique of repeated reading of the transcripts, the physical notes taken and the taped interviews. The emergent themes were then cross-checked as mentioned, with the thematic-coding system per interview. An example of this coding and clustering analysis technique can be found Chapter 6, refer to Figure 6.3 and Table 6.3 for an example of the process. The results were then analysed using the SPSS programme, a statistical analysis package to identify the frequency of each theme. For greater clarity of the concentration, the frequency of the themes has been plotted against the industries, to expose any trends and points of interests, see Figure 4.3, Section 4.8.4.

The Table highlights that on analysis of this preliminary phase the tacitly-based issues hold prominence. Culture of organisation was mentioned slightly more frequently by the costing practitioners across the examined industries, referring to it for 22.1% of the general discussions, as listed in Table 4.6. Cultural aspects are closely followed by communication (21.6%); and then by the issues surrounding comprehension of the costing-role and interacting elements (20.3%). As access to data / information was strongly linked to these other themes it can also be perceived as a highly pragmatic, tangible concern and was dominant in the findings, only slightly below understanding (20.1%). Resource is placed substantially lower than the others, though perhaps naturally very few departments observed were satisfied with the general levels of resource made available to them. The grievances ranged from lack of labour hours, insufficient labour and skill-levels to lack of funds to procure either personnel, software or to make on-site visits to potential suppliers. Although training had not been a focus of this section, it was still notably present within the discussions surrounding costing. Thus although a lower frequency, the fact that it still emerges when it was not central within P1 reinforces its importance within the current cost-domain; see Chapter 8 for further analysis and discussion. All the themes are briefly discussed in the following sections; and elaborated on within Chapter 6.

### *4.8.2. Communicational and Data / Information Transfer Challenges*

The inconsistencies in cost-terminology observed had consequences across the process: Primarily in the way the role was understood or rather not understood; and in the quality of communications. These would naturally be hindered if the interacting parties were unclear about terms of reference, not just with regards to titles but throughout other aspects of the process. It must be noted that the mixture of titles acts as an example to illustrate the inconsistencies and lack of standardisation of terms in general across industrial costing.

Product-costing is derived via the assessment of three major components: labour, material, overhead, the latter is also known as 'burden'. This is in accordance with a large, international automotive company. The information for the first two points tended to need to be compiled in conjunction with the relevant engineering departments; and for the latter, from the financial sectors. Thus adequate interactions and channels of data / information flow were essential in the compilation of product-costs. A lack of communication and understanding of the costing needs hindered the knowledge of where information could be found: The location of such with direct access to it is essential within a high pressured, costing environment. One point which practitioners from every organisation commented on was their perception of the value of personal, verbal communications:

*"..people are emailing across to the next desk, let alone …*
*..need to go down and actually talk to the engineer ..and designers about…*
*..avoid miscommunications and misunderstandings.."*
[Cost Estimating Supervisor; Automotive Industry, 2001]

A general consensus was that one to one interactions would avoid the high level of miscommunications that occur via other more common and impersonal techniques; which include email, telephone, reports / memos. A lack of personal communication was noted as a concern from many experienced practitioners, and as a cause of difficulties / confusion which result in wasted time, i.e. via miscommunications / misunderstandings.

Table 4.6: A guide to the Frequency of the Cost-Themes

| Cost Theme | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Resource | 116 | 7.4 | 9.2 | 9.2 |
| | Data/Information | 254 | 16.2 | 20.1 | 29.3 |
| | Understanding | 257 | 16.4 | 20.3 | 49.6 |
| | Communication | 273 | 17.4 | 21.6 | 71.2 |
| | Culture | 279 | 17.8 | 22.1 | 93.3 |
| | Training | 85 | 5.4 | 6.7 | 100.0 |
| | Total | 1264 | 80.5 | 100.0 | |
| Missing | System | 307 | 19.5 | | |
| Total | | 1571 | 100.0 | | |

Additionally there often appeared to be a lack of process with regards to communicating between departments. This was reported by practitioners across the companies examined to be ad hoc, with cost-disciplines repeatedly stated as being used on an 'as and when required' basis compared with being incorporated into the process automatically, see practitioner quote in previous Section 4.6.4. A result of this almost incidental attitude was that information frequently tended to not be relayed to costing. The lack of enough data and information made available to the costing practitioners was a substantial recurring theme throughout the study and manifested in a number of guises, from it being withheld due to fear culture, and unwanted perceived scrutiny from other departments; to a lack of formalised process to readily transfer information across the organisations. The challenges with communicational issues linked in with the lack of adequate data and information not only lay with unrecognised tacit associations; but in the technical aids which would assist the smooth running of communications / data and information transfer.

#### 4.8.2.1 Technological Impacts

The general feeling towards the ever increasingly used methods of communication such as emails, mobile-phone etc, was that they tended to discourage the personal interactions which were perceived as being vital for adequate propagation of the required information. However, physical communications were not always practical, for instance within organisations which had numerous sites across the region; national and / or international locations. One solution proposed to overcome this was to maximise technology and implement systems such as video links for regular meetings between interacting organisations and colleagues across locations. This solution is becoming increasingly popular within industry.

An observation which was more prominent than expected was related to the lack of adequate IT facilities and compatible software's, as stated within the following quote from an automotive cost manager. The reason that this was unforeseen as a major issue was due to the fact that a significant number of the organisations examined were commercial, with others being government funded: Additionally most were large, established entities. It was often wrongly assumed that the advantages of implementing state-of-the–art technology would be recognised, particularly within the larger bodies, and made available as necessary.

However inadequate IT was not the situation in a large minority of cases which had sufficient tools to aid the cost-developer. Even within these companies though, there were issues regarding the formalised cost-aids such as the inability to update the database which supported the software. For example every grade and slight modification of material which was used could not be preempted, and entered into it ready for use when needed, especially as new types of material were continually added to the repertoire of products available. As a result it was often observed that practitioners were not always using the software costing aids that were provided; giving reasons as:

*"Things change rapidly ..with regards to technological processes ..and materials.. Rates:.. ..changing rates.. …input the data into database… ..but the GRIMM system may not contain the machine rate, .. they might not have costs for that year..*
*..need to know the speeds ..feeds of machine.. ..need raw material costs, say for 1000 tonne machine ..for instance could be 30% glass filled nylon …usually can't find it …as database is not maintained…*
*..system needs to be kept updated."*
*"…but the results are often inaccurate, as half the time the database won't contain the grade of material…*
*I don't use ..programme…"* (for costing a product) *"…is quicker to do it myself"*

[Cost Practitioner; Automotive industry, 2001]

One aspect of this was the lack of attention to the updating of the tools; another was whether it was possible to do this even if adequate facilities were made available. Practitioners mentioned they were able to forward the updated database information to the person responsible for its maintenance but it would still take time for it to be added, and the challenge lay in the fact that it was often required as soon as identified. A small majority of organisations had tools in place to aid costing-development however they were often inadequate. Their shortcomings ranged from being too basic or deficiently written programmes, to lack of adequate IT support facilities (as mentioned in the above quote), and the functional limitations on its usage. For example the software was too specialised and not efficient in a diverse enough range of costing eventualities; it was also unable to incorporate many activities within the cost, as noted in the previous practitioner quote. A number of the organisations did not posses any tools to assist in the product-costing process. As a result practitioners within different companies tended to experience similar challenges with regards to having to deal with insufficient software systems. For example a practitioner within a large aerospace firm commented that there should ideally be a systemically available system in which any changes made on a project which in that organisation all tended to be long term, should be able to be simply inputted into it, and thus everyone involved would automatically have instant access to the modifications. This particular cost estimator commented that currently no change-management facility like that was in place, so as a consequence occasionally vital product changes were not relayed to him and therefore would be omitted, detrimentally from the compilation of costs.

Similarly a cost manager within a large international manufacturing corporation described how such a system would be beneficial as a tracking device, effectively of fluid expertise which contributes towards any given aspect of the project. This was in relation to again long-term ventures where it was common for the practitioners to move, and not stick to one project for its duration. The identification and location of the knowledge inputted towards the product was said to be challenging at present, with much time wasted due to difficulties in locating expertise and / or the familiarisation of work which had been performed by another practitioner, as expressed within the below interview quote. Coupled with such a personnel tracking-system, could be a knowledge and activities database. This could assist any new contributor to the project and act as a learning tool.

*"..there are so many projects running concurrently across Rolls Royce… lengthy projects… ..run over a number of years..*
*..the problem is people move around, from one project to another and leave things midway…*
*…then someone else has to take over their work … ..time wasted, figuring out what was actually done, or redoing so can understand..*
*..could do with a database to track who did what …where they are now …even explain, when necessary…"*

[Cost Manager; Aerospace / Manufacture Industry, 2001]

A cost-manager within a medium-sized automotive company conveyed a more fundamental software networking inadequacy in the form of totally incompatible systems being in place across the company. This ranged from incompatible software to some departments predominantly implementing paper-based systems, as stated in the following quote:

*"..departments don't communicate …the problem is there's a complete lack of compatible systems used between departments*
*...is literally anything from sophisticated software programmes ..to paper-based systems"*

[Cost Manager; Automotive Industry, 2001]

Thus identifying extremes in the systems used, resulting in the lack of interactive working and systemic access. This stifled fluid communications and data / information transfer with detrimental consequences, as discussed in greater detail in Chapter 6 which presents each individual cost theme observed, why they are prominent and how they interlink, also see Figure 6.5 for illustrative description.

### *4.8.3. Resource, Understanding and Training:*

On further discussion it seemed that such deficiencies in general IT facilities were often due to a lack of resource. Where a minority of companies had greatly invested in systems such as computerised cost-models, the principal example being Ford Motor Company, with the CAPE system; others had little to no significant software cost-tools in operation, partly due to lack of funds. The formalised cost-models have been discussed within the previous chapter from a literary stance, see Section 3.4.12; as well as having been referenced within the above previous sections, and are later in the thesis within the results / discussion regarding their role in the cost-process. However a relevant perception in relation to the issue of resource is that the use of such models result in costs being derived rapidly, whilst allowing relatively less experienced practitioners to produce them. This clearly aided the departments which suffered from low resource / personnel.

As well as impacting on the quality and level of software facility, low funding has training implications. For instance, practitioners often stated that training-programme attendance will not take precedence "..over the actual work itself". Therefore if there was insufficient resource and / or the department was in a state of high demand for productivity for instance during bid compilation or product launch, or any other overly extended period, then training courses would be a secondary concern in comparison to the work at hand. Many interviewed perceived their schedules as overloaded, and struggled to justify taking time to attend training courses. Not only was the attendance of such courses for current practitioners affected, including personal-development training e.g. for maintenance and / or updating of skills and knowledge; but a lack of resource had consequences for the provision of training for novices. This was seen through the lack of time / labour put not only into training development, but for the on-the-job personal, interactive training which the research showed was accepted industry-wide as the most reliable technique for cost-novice training, see Chapter 8 for in-depth discussion. Although not dominant within phase 1 as Table 4.4 shows, the issue of training does feature heavily within the overall research as a primary method of addressing the identified challenges. This is fundamentally via developing training which can update practitioners on each others roles; principally for the interacting disciplines, on what product-costing does. Also to propagate standardisation of terms to help avoid miscommunications and misunderstanding, among other uses that customised cost training could entail, see Chapter 8 for detail.

Resource which incorporates budgets, allocated funds and cost targets, could also affect the level of pressure involved, as one automotive practitioner described the company methodology for deriving the costs for the project was:

Price – Profit = Cost

In other words, the cost at which the product will need to be delivered is derived from establishing the price that it will be marketed at, minus the profit the company will make. As the profits tended to be non-negotiable, the product therefore had to be made to fit within the specified budgets; this meant the application of design-to-cost, DTC and could involve the redesign of complete components. For instance if the suppliers product cost £12 per part, and the budget was £10, then the supplier would work together with the user-company, including the cost-practitioners, in order to redesign the entire part to ensure it could be produced within the cost target set, as explained within the below interview:

*"The supplier set the cost of a wire loom at.. … now we went through these costs with them in detail, and they were in fact correct in their estimate.. ….were satisfied that it couldn't be produced any cheaper then the cost they'd given us.*
*However, we still had to knock $2 per part off this cost.. ..the budget had been set, … we had to stick to it… ..so we worked with the supplier to actually redesign the part, to get it for cost.. …design to cost.."*

[Senior Cost Estimator; Automotive Industry, 2001]

Note: This type of practice only tends to occur with large, influential organisations that have at least two tiers of supplier; though it is an example of how the resources allocated impacts on company practice across the board, including the potential dictation of supplier activities.

Clearly insufficient resource had many direct and knock-on effects; though a point which tended to lead to this low-funding situation to begin with was a lack of understanding about the role and therefore value of the product-costing function. Through inadequate communications a lack of comprehension with regards to product-costing was evident. Not only could this be seen in other supposedly interacting disciplines, but also occasionally in management. One automotive practitioner commented that management had allocated substantially low resources to the department due to a fundamental lack of understanding, and therefore appreciation of the costs which the product-costing team tended to save through the cost-process, stating that:

*"Cost estimating has a problem because it has a low profile within the company. Therefore .. ..is not benefiting from this low profile. We've suggested that we go into suppliers, within the automotive industry, such as TRW or Visteon. This would higher our profile within the company; …But management's a key problem; they don't understand were the cost estimators role is in the company and the value we add."*

[Product-Cost Manager; Automotive Industry, 2001]

This general resource deficiency had ripple effects. As the quality of the cost output was reduced the lack of understanding about the role had direct negative impacts on the process as performed within this particular automotive organisation. Coupled with management, interacting disciplines were described as not understanding the function of the costing department, partly due to inconsistent terminology. As a result they (costing) were not involved in projects they should be and / or at the stages where they could productively input to assessing costs. Consequently they were not provided with the necessary information and data. One manager within an automotive organisation explained:

*"…their ethos is basically to keep data and not share it; thus when new people come in to company ..transfer this practice to them, to not share data, so it snow balls …becomes more and more of a problem.*
*So cost estimating basically can't do their job, if they don't have the data.*
*If ..can't do job as cost estimators, due to lack of data, then they end up thinking we're basically of no use to them*

*-They cannot see any use from the cost estimating department ... ..question why are they there?"*

[Cost Estimating Manager; Automotive Industry, 2001]

This lack of interaction was often due to the relevant departments not realising the need to relay the required information to product-costing and was caused chiefly by a lack of understanding of the contribution of costing on a systemic level: Training needs analysis, TNA, addressed these issues, see Chapter 8. This misconception could often result in detrimental working practices, and underpin issues such as a fear culture which is discussed in the following section.

### *4.8.4 Organisational Culture*

The culture of an organisation tends to influence, and be influenced by, the general ideologies adopted, working practices and environment: For instance whether communication was open or what in effect was a blame-culture was in place, creating a more stifled, introverted mode of work. This affected the attitudes towards projects, such as whether departments worked in an integrated manner, or if 'over the wall' type procedures were commonplace, discussed in more depth within the following chapter.

Thus the culture had an impact on:

- The costing prominence, i.e. the level to which they are known about and used by other departments.
- Resource allocation,
- Which in turn dictated the procedure / type of costing to be performed,
    - E.g. Detailed and ROM; see literature Chapter 3, Section 3.4 for cost-techniques.
- The internal promotion of various areas, and education of the workforce towards:
    - A systemic understanding of the organisation,
    - The company aims / needs
    - How the various functions inputted to these needs,
    - Where they were placed within them.
- Alternately it could concentrate on the end product,
    - Giving less attention to the intricacies of how the ends are reached.

Practitioners regularly commented that the interacting departments did not understand the function of costing, and therefore were not as regular 'internal customers' as they should have been. A lack of understanding and appreciation of the cost contribution inevitably created low morale for cost practitioners subjected to this working environment and attitude; as one experienced automotive practitioner of 15 years stated:

*" ..they employ people to do a job that they can't do, …unable to do in this environment ... So they leave. ..Eventually the whole department is weakened, left under-skilled and under-resourced…"*

[Cost Estimating Manager; Automotive Industry, 2001]

Within this particular company, the UK office was branch of the controlling body which was based overseas. A number of issues emerged as a result of this distance; such as the fact that it was felt that the bulk of decisions for the company, and which directly impacted on the costing department, were derived in a country with a vastly different culture to the UK. The perception relayed was that the cultures were too dissimilar to develop working-processes which could be productive when universally applied, and so UK practice should have been addressed independently with the specific purpose of these branches accounted for and differentiated from overseas sites. Additionally the decisions were not consensual, which means that the culture focused around a centrally managed area, quoted as *"dictatorship"* style. Again it was felt that the choices made from a central base, and then disseminated throughout the global organisation ended up being inappropriate for the specific regions it affected.

With regards to inappropriate procedures the cost-practitioners perceived that the costing role had not been understood by the overseas management: This cost-manager, who like most within the UK had a technically based background, perceived that budgets were shaped by financial and accountancy targets and were not technically based as they should be being product-focused prior to profit. Although this was a more extreme example of the effect of geographical cultural challenges i.e. between Asia and the West, the organisational atmosphere and environment had various affects which directly influenced the performance and credibility of the costing process; the attitudes within and external to it, and resultant behaviours.

#### 4.8.4.1 Fear Culture / Trust

A fear culture was an apparent cause of inaccurate costing in many organisations. For instance within one large, international automotive company it was stated that one of the main interfaces of the costing team was with the purchase department who were financially, not technically skilled. It was felt that most of the procurement decisions should be verified by the costing practitioners prior to acceptance. In reality costing were rarely involved in the procurement process and the contributing practitioner perceived that little notice was taken of their recommendations. There was friction between the departments, with the minimum of information being passed from purchase to costing; and quotations were not approved by costing prior to acceptance. In fact parts were costed and this information was passed onto costing, instead of the costing experts being allowed to develop a design-to-cost programme. For example they were told that 'x' part would cost £5. If there was only £4 in budget to cost, then as costing have technical knowledge as well as economic their input could assist in developing a product which was designed so its cost met the budget, see previous Section 4.8.3. for practitioner discussion of DTC and supplier-customer collaborative redesign example. However instead of such integrated DTC the practitioners within this particular automotive organisation felt that work was accepted without having evaluated whether lower costs could have been achieved or not. The reasoning stated behind such withholding of information and exclusion of relevant departments was fundamentally due to fear culture. Targets were often set by management for the purchasing team to meet. These for example, could be three-year target-reductions, meaning that each year of contract with the supplier the costs would have to decrease by a specified amount. As purchase may be unable to guarantee such annual reductions, they would strike a (unofficial) deal with the supplier, where the supplier would lower their costs each year as required; ensuring that the purchase team would meet their goals, and not be held accountable by management for missed targets. This type of practice was clearly detrimental to the company, as instead of the lowest possible costs being obtained from the beginning of the contract and maintained throughout its duration in order to minimise overall costs, arrangements were actually being made which would cost the company more. The lowest price was not negotiated from day one, but instead applied over three years. As for the perpetrators of this practice, they were effectively in fear of 'looking bad' or being perceived as incompetent by management.

The yearly cost reduction targets could be perceived as short-sighted by management too, as this pressure to obtain further reductions when it may not have been feasible to do so clearly created a fear culture which in turn provoked this type of malpractice. It created the type of defensive attitude which stifled interactive working through fear of 'being found out' e.g. by analysis of purchases' supplier choice by the product-costing department, and / or the 'blame culture' if not able to perform to management targets. If product-costing were subsequently involved openly in the selection choice, they may have established that costs could be lower, therefore as far as purchase were concerned, jeopardising their perception of successful results. The practitioner explained:

*"..each purchase department within company has targets to meet each year for cost reduction ..improvement productivity,*
*If cost estimating can do their job, ..will take out targets within the first year; …don't want to have someone to strip all extras out, so can't lower it next year, have nothing to reduce it by, nothing to negotiate with next year, if stripped clean, …want to chip away at the over-estimate, therefore shown to be doing their job;*
*if know over-estimating took place …purchasing would like to avoid this happening by cost estimators …is totally non-profitable, a false economy, …not in interest of company."*

[Cost Estimating Manager; Automotive Industry, 2001]

As a consequence purchase did not co-operate with costing or maximise their input in order, it was stated, to avoid exposure as stated in the above interview quote: All prompted by a fear culture and excessively pressured work environment. It also contributed to the lack of comprehension between disciplines. For example within the same situation, procurement may argue that they have selected the best supplier for the job, as the choice was made not only with reference to costs, but on reliability, quality, reputation and so forth. All of which are important considerations in supplier choice, and which product-costing had not accounted for.

As well as such working practices which detrimentally involved the shunning of the cost-department, evidently creating challenges and stifling costing-process, fear culture was represented in other examples observed. For instance one manager within a large aerospace / manufacturing organisation explained the internal dilemma where the workforce were seemingly systematically overestimating work. This was in order to secure higher budget allocations; so if they specify larger amounts for labour hours, skill-levels, costs needed, etc, then they are much more likely to meet the targets which will be set by management based on their budgets-requests, which were founded on overestimations. Overestimation by the practitioners arose through a lack of trust of the management, which made the workforce feel a sense of vulnerability which they felt they had to safeguard themselves and their jobs against. The manager was concerned about this group-mindset and resultant practise of misquotation; as regular overestimations in the resources stipulated were gradually escalating company-costs to the point were the workforce in this instance were also directly working against the needs of the company. The long term effects of such practice could obviously have devastating impacts on the organisation with project losses leading to a general lack of competitiveness against primary contenders. Although this mindset, defensive attitude from sections of the labour-force was recognised, the manager was finding it challenging to tackle this aspect of the organisations culture effectively: Chapter 6 presents further discussion within this area. The way in which this cultural attitude may be modified would be via addressing issues of communication and comprehension, and making general improvements to them. The importance of making time for cost training programmes must be conveyed, as such enhancements may be done through tailored cost training among other means. See Chapter 8 for further discussion including improved internal networks and greater involvement and interaction between workforce and management. This would be undertaken with the aim to increase the understanding of the benefits of systemic cost-reductions; to create trust and open the horizontal and vertical channels of communication.

### *4.8.5 Industrial significance:*

Whilst Table 4.4 shows the frequency of each theme generically, Figure 4.3 illustrates the prominence of the themes within three categories of industry, namely aerospace, automotive and 'other' which includes software development / vendor and manufacturing, see Table 4.2. Although the results for data / information, understanding, communication and culture were high in all the industrial categories; there are still differences between them, which are of interest. For instance the highest reoccurring theme within automotive, is noticeably that of the culture of organisation. This is as can be expected from the organisational studies, as firstly there was the highest level of international corporations within this industrial category. Additionally a number of mergers and take-overs had occurred within these sectors, which meant the culture within the resultant companies was a noticeable concern. The result of mergers had clearly impacted the culture / environment enough for issues related to it to have been mentioned both subtly and overtly, more frequently than any other point referred to.

Within aerospace, culture was also a prominent theme coming a close second to the levels of data / information-transfer which were most frequently discussed industrially. The other three highest mentioned themes impacted the data / information transference, with a minimal but discernible increase between culture and understanding challenges and communication. Bearing in mind that some of the bodies examined held established, deeply ingrained codes of practice, notably 'over-the-wall' or segregated working practices, it seems evident that the culture influenced the highest mentioned topic of discussion, namely that of data / information.

The concerns surrounding the lack of disseminated data / information seem logical given the cultural, and almost equally prominent reference to communication and need to understand challenges. The levels of these two themes within the automotive domain were equal, which supported the ideology that they were almost directly related. Though more interestingly the data / information concerns were notably lower; this is possibly due to the fact that all automotive companies were private, and thus tended to have a reasonable level of computerised systems in place to interact. With this said, the level is still high and data / information transfer is also a substantial concern within automotive organisations. The primary observation from within the 'other' category (refer to Section 4.2.1 for what category comprises of) was to validate the fact that the three intangible themes also featured prominently, along with data / information transfer, which again reinforces the link between them; and the importance of the human factors or implicit cost elements. Training also occurs, highlighting its ubiquitous value within costing discussion.

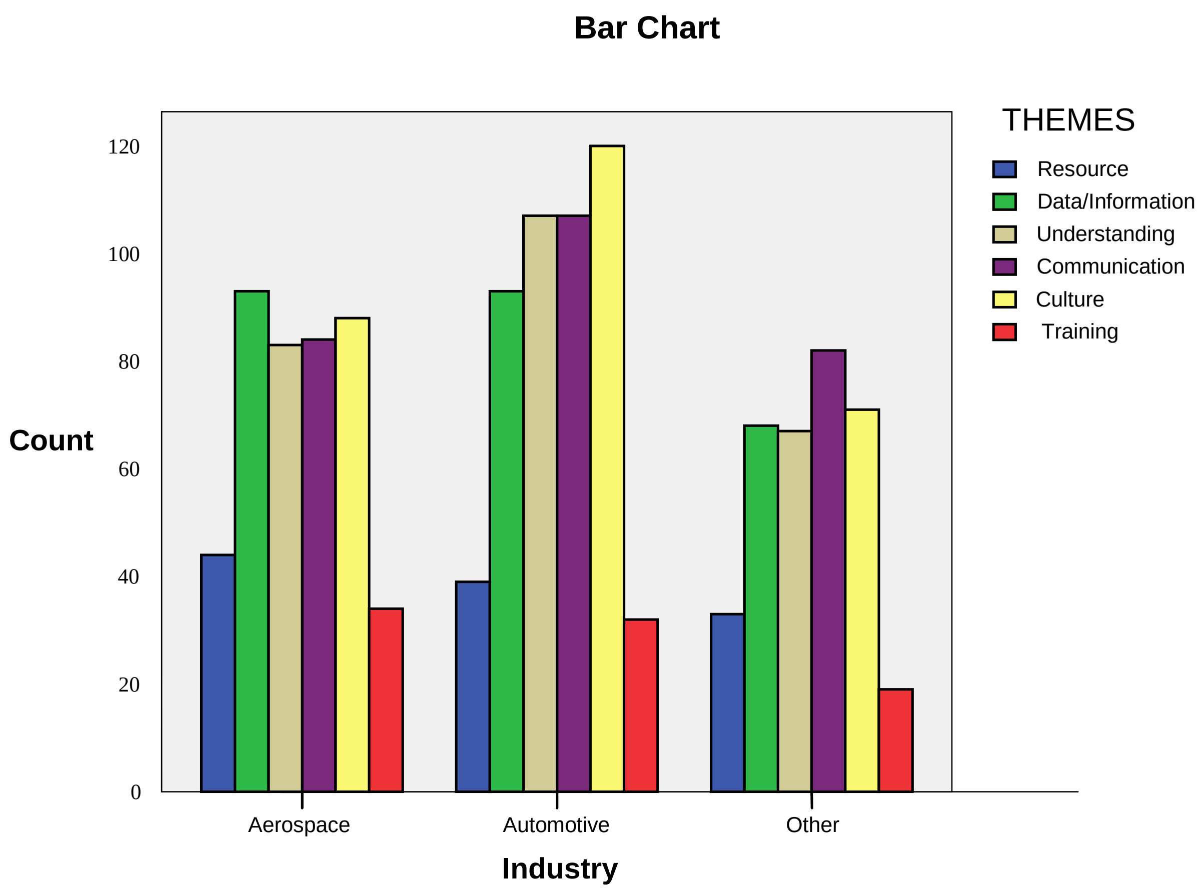



Figure 4.3: The frequency of the themes within the three main industrial categories

### *4.8.6 Industrial Feedback of Research*

On commencement of the exploratory phase, an industrial AS-IS report was produced, and feedback gathered during a meeting with the project sponsors [Roy et al, 2001]. Occasionally experts queried findings which did not relate to their specific organisation. This was explained as the findings presented within the report were an overview of all participating organisations. Subsequently differences in practice were to be expected; so industrial-practice discrepancies were due to specific diversity between process, as opposed to being derived from misinterpretation of any individual company operations. Such enquiries were likely to be raised in relation to challenges experienced in industrially non-transferable cost-activities. For example bid proposal preparation was not experienced by the major automotive participants but was a regular part of the process within aerospace and some manufacturing organisations. With this said there was a high level of similarities in cost-opinion, including:

- The need for more personal communications;
- Concerns regarding this decline;
- Lack of understanding of cost-practice;
- Difficulties in establishing adequate integrated working practices;
- Trepidation regarding depleting cost-expertise;
- Issues around how to replace this expertise, centering on training implications;

- Worries about the calibre and background of upcoming novices; principally due to the decline of technical apprentices who previously produced the majority of costing practitioners.

## 4.9 Summary

This chapter has discussed the results of the first phase of real-world research, having previously embarked on the background and context of costing, see Chapter 1; the methodological research approaches available detailed within Chapter 2; followed by the theoretical position of costing presented within Chapter 3. Through a series of interviews within twelve organisations from five industries, see Table 4.2 a number of prominent themes emerged. Figure 4.4 shows the techniques used to elicit knowledge within a dominantly qualitative methodology, and the data-analysis applied to the results. As the research progressed and the knowledge and information that emerged was examined, a number of themes and patterns emerged. These were not wholly as predicted, e.g. the prominent influences of human factors. Of the six themes it was revealed that three were clearly intangible which heavily impacted on the three more tangible ones. This highlighted the concerns within industry with regards to the costing process, the root of the challenges experienced, and indicated the subsequent areas which need to be addressed in order to improve process and performance.

It was expected from the outset that a lack of integrated working practice was likely to be prominent in the costing challenges. This lack of integration was due to insufficient comprehension about, and communication of, the significance of these human or tacitly related factors that were often not fully appreciated by either the industrial participants or costing researcher. However, the importance of human factors was made clear and with further examination into the subject area (see Chapter 6) it was recognised that a solely technical, physical remedy would not address the areas in need. The answer to the difficulties lay in combining implicit communicative and social elements with technical solutions.

Therefore as the themes revealed the non-physical aspects within costing, and emphasized their importance: -communication, process and issue understanding and organisational culture, the solutions proposed could thus incorporate them, accordingly. However prior to any further continuation into the field-research, the human factors identified need to be understood and the following chapter consequently explores the culture and communicational–based literatures, presents the findings within these areas, and relates them to the costing process.

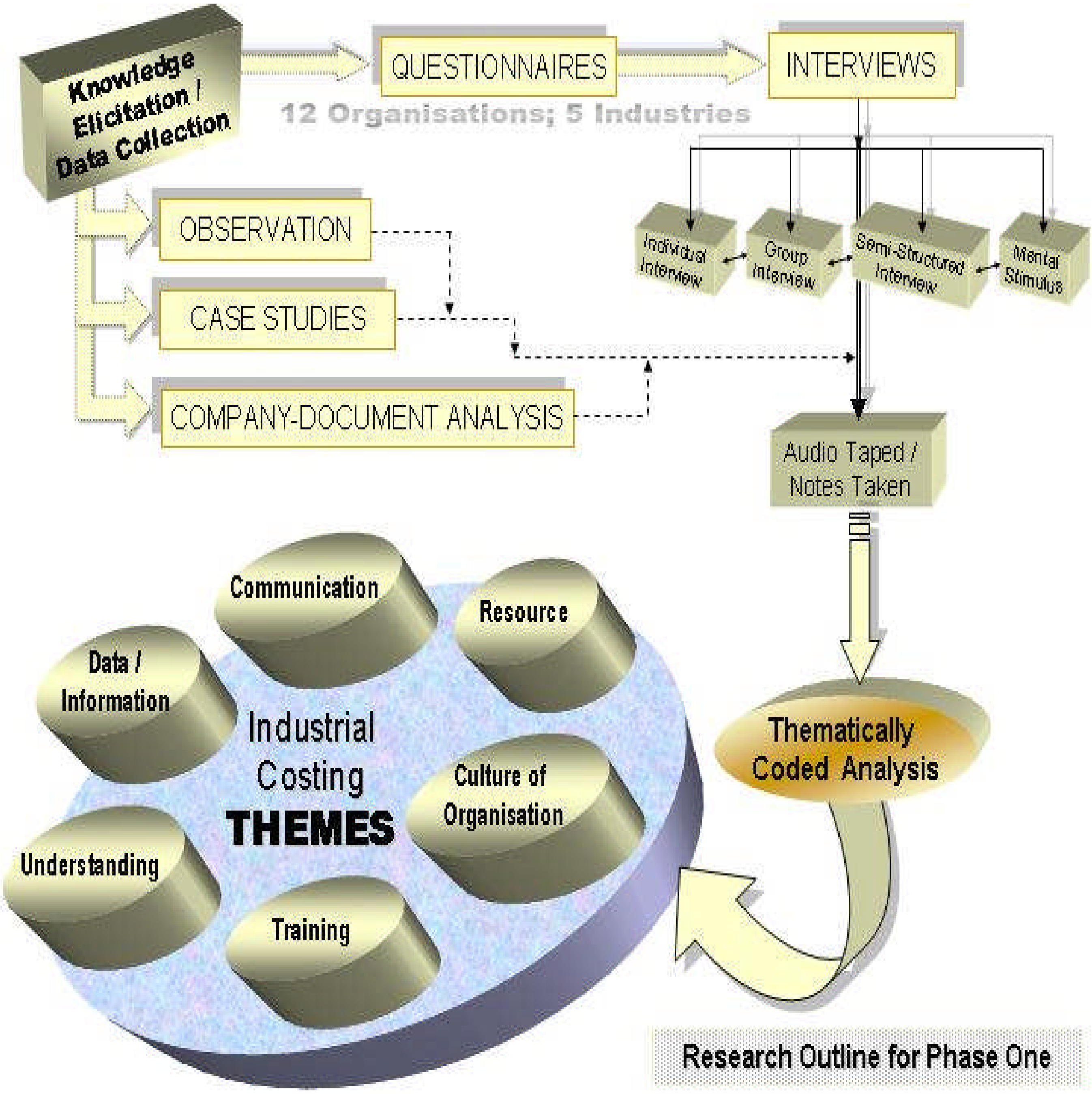
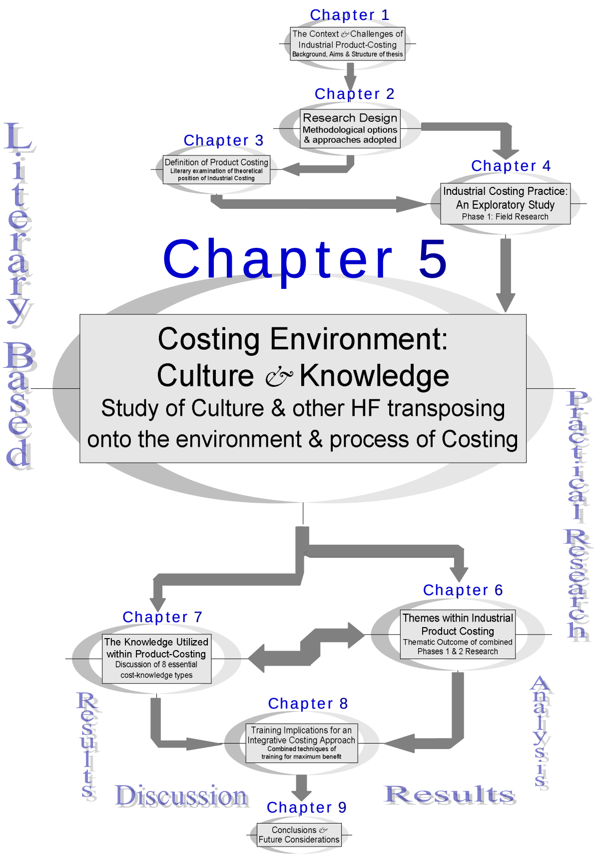



Figure 4.4: The Structure of Phase 1 Research; Highlighting the Resulting Themes

# Chapter 5:

## Human Factors in Costing: Culture and Knowledge




*"Culture is the way in which a group of people solves problems and reconciles dilemmas"*

[Schein, 1985]

This chapter is derived directly from the findings of both preceding chapters: Chapter 3, which addressed documented costing issues and examined aspects of organisational costing; in juxtaposition with the results from the first phase of industrial research. Chapter 4 highlighted the way in which costing is performed within organisations, identifying and examining the current challenges experienced. Although Chapter 3 examined the documented cost-process, which was dominantly discussed from a technical, physical stance, the outcome of Chapter 4 detailed the main themes that were apparent from the real-world research into organisational costing. These cost themes emerged out of research which deliberately focused on examination of the issues within human factors, (HF) which appear to affect product costing. Therefore 50% were based on HF and the other more tangible findings were both affected by, and impacted on the HF themes. There was a low awareness towards the impact of human factors, which was noticeable both within the cost-based literature and the industrial observations. This lack of recognition was despite the influence of tacit elements on product costing.

Consequently this chapter focuses on the aspects of human factors that affect industrial product costing. Literatures are examined that relate to culture and communicational issues as relevant to organisations, the industrial workplace, and which resultantly impact on how costing is performed. It concludes with a summary of how the reported work correlates with the industrial cost-findings, and places the themes against implicitly based frameworks. This is in preparation for the commencement of the second phase(s) of research see Chapter 6 onwards, which continues the examinations of industrial-costing from an approach which fuses the physical contributors with the implicit; giving the appropriate equal consideration to both ends of the spectrum.

## 5.1: The Necessity for Human Factors Investigation and Application

One of the primary and most apparent observations derived from the industrial research P1 discussed in the previous chapter, was the general lack of recognition and attention attributed to the range of 'people issues' which regularly occurred within product costing. Concerns alluding to and stemming from 'human factors' (HF) emerged repeatedly, under different guises such as communicational issues, insufficient interaction between the disciplines and inadequate understanding of associated roles, to mention a few.

Lack of acknowledgement towards the significance of human issues seemed to effectively equate to a neglect of the challenges evident within product-costing. Though the provisional findings were clear about the need to identify and address such concerns it appears, particularly in manufacturing environments, that in practice they are precisely the ones that are routinely either not recognised as being valid or 'real' contributors, or are so low a priority that they tend to remain unaddressed. A continuance in this deficiency or unawareness can accordingly lead to catastrophic consequences when left unrecognised. For example the lateral transfer of cost-knowledge relies on adequate communication: The importance of making improvements in this area was observed industrially as not recognised, due to the perception that communicational issues are intangible. Therefore it seemed to be assumed that they will align themselves against the improvements made from within the tangible domains, such as updating softwares' to aid the enhancement of data and information flow. As this issue was not seen as a challenge in itself, but something that resulted as a consequence of other activities or functions, then little attention had been paid to it, which meant non-technical communication / personal interactions was currently a weak area within costing.

The effective assessment of such a wide subject-domain called for some degree of reduction, in focusing on the specific aspects of HF that were relevant to the industrial cost-process. When focusing on organisational needs recognition of the type of culture within it and having an awareness of the effects of this culture, enables a vivid portrait of the characteristics of the workforce and the reasoning behind behaviour / actions and interactions. Following the first AS-IS phase of industrial examination the next step was to pursue research within organisational culture, knowledge management and organisational learning leading to suggestions about the challenges experienced within industrial product costing.

Gaining an awareness of what the culture is and how it affects the workforce and their output, is the only way to enable effective management of it. An additional consideration is the way knowledge is created, nurtured and managed, which is imperative to an organisations' progress levels, discussed further in the knowledge and knowledge management sections later in chapter. To summarise, this chapter discusses the need for incorporating human factors into costing environment. It compares industrial costing challenges with the documented work on culture, with the aim of providing insights to the 'soft' challenges experienced within the predominantly technical industrial environment.

## *5.2 The Meaning of 'Culture'*

The broad subject of culture has been extensively explored and incorporates descriptive analysis, as well as theories and examination of the affects of certain cultural types on their environment. Such studies include the application of cultural models within organisational contexts, and the following quote from Hofstede provides a concise definition of how culture provides the basis of context:

*"Culture is the means by which people communicate, perpetuate, and develop their knowledge about attitudes towards life. Culture is the fabric of meaning in terms of which human beings interpret their experience and guide their action".*

[Hofstede, 1980]

All people involved in a community contribute to that community's culture; however culture is not comprised solely of human contributions. Additional constituents are involved, which have been referred to as 'artefacts and products', these include the explicit physical aspects, shown in Figure 5.1 which include:

- ✓ Buildings and architecture,
- ✓ The types of foods,
- ✓ The general styles of dress (uniforms),
- ✓ Language used,
- ✓ Mannerisms; including how people greet each other,
- ✓ Observable logos.

On a less physical or tangible level, the 'norms and values' adopted within a group define cultural status. Values define what is acceptable and unacceptable or rather what is perceived as 'good' or 'bad': It dictates behavioural aspirations. Similarly norms are the sense of what is right or wrong and may be explicit and formal in documented rules / laws; or informal expressions of social control. These include for example controlling the actions of children so they queue orderly and are not allowed to impatiently or instinctively move to the front; holding doors open for strangers, and so forth [Trompenaars and Hampden-Turner, 1999].

In other words, values underpin norms which are expressed through 'normative' behaviour; this cultural depth or layering is illustrated in Figure 5.1. Norms, values, beliefs, behaviour and assumptions are what culture is built on from human input, and the previous mentioned hardware (artefacts and products) constitutes its physical and institutional presence.

Organisations are frequently structured and develop within an existing cultural environment the nature of which they have no direct control over e.g. gender-relations, language, custom, religious beliefs, regional attitudes and norms, family relations.

### *5.2.1 Cultural Significance*

As previously explained, culture comprises of a synthesis of the social, physical, natural and structural characteristics that form the organisational environment [Argyris and Schon, 1978].

Within the current global climate, corporations are proving to be increasingly important influences on western culture [Ahmed, 1998]. The Hofstede quote within Section 5.2 makes direct reference to communication [Hofstede, 1980] which has so far proved to be a dominant reoccurring theme throughout this study, of the costing practitioners and those with whom they necessarily interact; see the previous Chapter 4. Who to contact for information, where it is; how the data is conveyed; what is needed and when; along with why it is not being relayed to the relevant domains, was just a selection of the outcome from the industrial observations; refer to Chapter 7 for detailed discussion. Therefore as the issue of communication has been so prevalent, a logical link to cultural studies was concluded in which the costing domain was paralleled in conjunction with the cultural work.

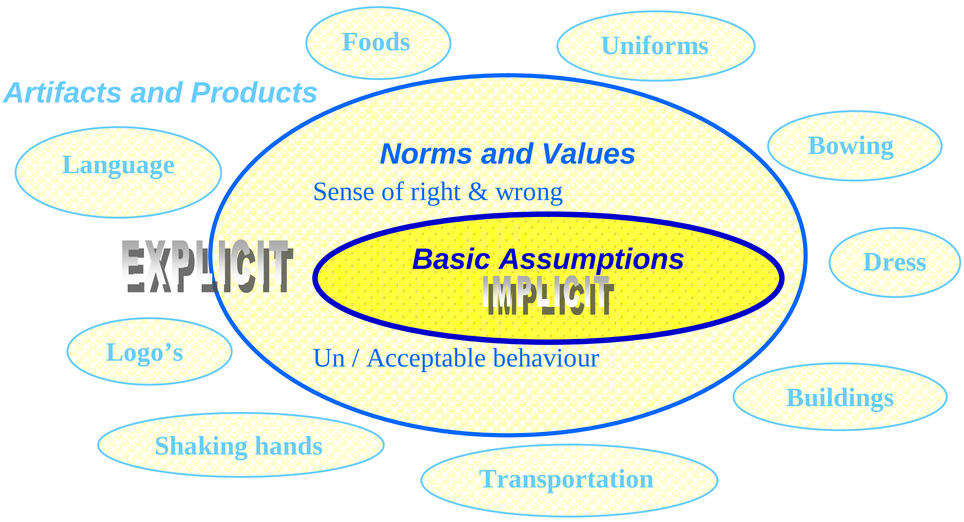



Figure 5.1: Depicts the Inner Core and Outer Layers that Influence Culture [Based on Hofstede, 1980].

Schein broadly discusses culture in relation to 'problem solving and reconciliation of dilemmas' [Schein, 1985], whilst Hofstede makes reference to 'knowledge development' [Hofstede, 1980]. These features are directly relevant to the areas of costing practice examined within this thesis. With regards to knowledge this research identifies cost-knowledge types, what they are and why they are required, detailed within Chapter 7; then establishes which of the types are required for transferral across the interacting disciplines and subsequently how to do this. For knowledge implementation and cost training requisites, see Chapter 8, where the dilemma of determining how to disseminate the function and value of product-costing throughout organisations to promote integrated working; and avoid issues such as fear culture via lack of understanding is explored in depth.

Examination of the cost-process issues clarify that the affects differing cultures can have on business is not limited to international concerns i.e. solely between different countries. To the contrary challenges which stem from cultural roots can occur within the same organisation, between different if complimentary disciplines, e.g. engineering and finance; and / or hierarchies, i.e. management and sections of the workforce. For instance industrial research revealed a distinct disparity in working culture between the engineering, technical communities and the economic, financial ones within medium-large organisations: More specifically between cost engineering and cost estimating in one large aerospace organisation and was palpable between product-costing and purchase in a number of other industries, to differing degrees [Roy et al, 2001a; Roy et al, 2001b]. Though the issues in many ways were institutionally specific, a general observation related to the root of the challenges was that the practitioners held different priorities and perspective with regards to the product. I.e. a senior aerospace cost engineer research participant was focused on a particular area of development dedicated to enhancing a specific aspect of the product. Subsequently at one level this appeared to be an individualistic type of approach in terms of cultural diversity whereas in the same organisation the cost estimator essentially required a holistic view, as a primary responsibility was to compile all cost-elements in order to create a bid. The practitioner explained the roles as:

*"My job's to go 'round and collect all the relevant data related to the product… and compile for review …bids… I effectively police the estimates submitted; …whereas cost engineers are a more technical role …highly focused on their specific area."*

[Senior Cost Estimator, Aerospace industry, 2001]

This contrasting perspective could be said to be communitarian [Trompenaars and Hamden-Turner, 1999] as it involved the requirement to liaise with all contributors towards the total cost. This particular amalgamation of working-cultures and interactions experienced challenges, partly due to the inattention given to the different types of cultures involved.

When discussed from this perspective the examination of cultural research appeared to become increasingly significant with regards to the understanding and resolution of challenges observed within the costing domain. The following section discusses some of the more established work within the area of culture, and goes on to relate the relevant findings to the main themes to emerge within product-costing, highlighting the affects culture can have on industrial costing practice.

## 5.3 Established Cultural Models

Trompenaars and Hamden-Turner [1999] developed dimensions of cultural diversity, see Table 5.1. Each dimension consists of two extreme states at either end of a spectrum. The disparity may be considered superficial when adopted for extremes within various cultures where they can be perceived as opposing each other. However they prove useful indicators when applied collectively, and in an integrated manner. Appendices 2a and 2b present a number of cultural models via illustrative descriptions, including those discussed within this chapter.

Hofstede [2008] developed five cultural dimensions which often parallels Trompenaars' work. However they also emphasize different aspects of culture, taking a different approach and highlighting many important considerations for industrial interaction, see Appendix 2a. These generic cultural headings were derived from research conducted on a global scale; and from within each dimension emerges a number of sub-dimensions, explaining how the overall area relates to different aspects of society and business, refer to Appendix 2.

Table 5.1 presents some of the more specific characteristics contained within the dimensions of cultural diversity. For instance within the dimension of Individualism / Communitarianism are a number of contrasting sub-themes such as competitiveness against cooperation, rivalry versus complimentary, and pioneer opposing catch-up. Such themes can be related to industry, and many to the costing domain. Only the areas within the cultural dimensions that are directly relevant within this research will be highlighted throughout the discussion.

### *5.3.1 Cultural Dimensions and Diversity*

Within Table 5.1, the first-listed continuum, of individualism and communitarianism focuses on the level of emphasis a society places on the collective or individual. Individualism, IDV, is where people place themselves inclusive of their immediate family and / or partner, at the forefront or as their primarily consideration; with other things such as the community regarded as secondary. Individual rights and recognition are focused upon and decisions can be made by one person. Alternately a low rating of individualism i.e. higher communitarianism gives prominence to society as a whole, demonstrating more of a collectivist nature. Extended families are reinforced and group decisions; with collective responsibility and recognition, important in a working environment are commonplace [Hofstede, 2008; Trompenaars and Hampden-Turner, 1999]. Refer to Appendix 2a and 2b for representation of a summary of cultural models.

Universalism tends to refer to rules; whilst Particularism, to relationships. The essence of the former is that whatever is successful in one situation, will successfully apply to all. Hence the fact that rules are derived, and generally expected to be adhered to universally. This is in contrast to the latter which adopts the view that the type of relationships involved, and the context in which the event occurs, naturally affect the particular course of action required. Universalism focuses on contracts which are readily produced, relied on, trusted and adhered to; with a single-view approach. Particularism focuses on relationships which evolve over time; therefore trust is based on such relationships, rather than on contracts which can be versatile to suit this multiple-perspective approach.

A way of describing the Specificity and Diffusion diversity is to think of it as comparable with the human brain: The left-side-influence includes control over the verbal, analytical, rational and assertive characteristics whilst the right is visual, intuitive, holistic, and tacit. Similarly specificity deals with facts and figures; it involves being purposeful and direct, clear, blunt and exact: Whilst diffusion is circuitous and indirect; tactful, evasive and ambiguous. Therefore it can also be envisaged as explicit knowledge: -specificity indicates records, instructions, accounts, etc against tacit knowledge, alluring to creativity, understanding between people, interactions and so forth. The working relationships people have developed and the ways in which they interact and relate to each other are differentiated in this dimension. For instance a position may be with consistent and independent of a relationship, or influenced by it. One of the main challenges encountered within the practical side of the research may be loosely viewed through this one extreme, the specific, being given disproportionate prominence over its complimentary side, diffusion. An example of how this cultural spectrum concept may be directly compared and considered against the research findings, is that its parallels with the analytical, objective aspects ranked more highly over relational and elaborative ones within the product-costing domain.

Table 5.1: Examples of the Sub-Categories within each Dimension of Cultural Diversity

| | |
|---|---|
| **INDIVIDUALISM**<br>*Personal Freedom, human rights* | **COMMUNITARIANISM**<br>*Social responsibility, Co-operation* |
| Profitability | Market share |
| Pioneer | Catch-up |
| Personal technology | Social technology |
| Competitiveness | Cooperation |
| Competition (narrows to the best of) | Complimentary (broader, wider things) |
| Voting | Consensus |
| Rivalry | Complimentary |
| Lone leaders | Escorted leaders |
| **UNIVERSALISM**<br>*Codes, Laws, Generalisations, etc*<br>*The whole* | **PARTICULARISM**<br>*Unique relationships, special circumstances, etc. Aspects of the whole* |
| Rules | Exceptions |
| Core competence | Getting close to customer |
| Low cost strategy | Premium strategy |
| Globalism | Multinationalism |
| **SPECIFIC**<br>*Facts, figures, quantitative* | **DIFFUSE**<br>*Abstract, wholeness, qualitative* |
| Report | Rapport |
| Agreed targets | Customer goodwill |
| Explicit knowledge | Tacit knowledge |
| **ASCRIBED**<br>*Status via contacts, family, etc* | **ACHIEVED**<br>*Status earned via ability, merit, etc* |
| Identification of 'potential' | Clear achievements |
| Nurture talent within organisation/ system | Take whoever appears most capable whether in-house or external. |
| Group dynamics<br>Recognises team contributions | Individual dynamic<br>-recognises individual contributions |
| **INNER DIRECTION**<br>*Principles, personal beliefs /convictions* | **OUTER DIRECTION**<br>*Influence of environment /relationships* |
| Inventors | Refiners |
| Questionnaires | Conversations |
| Idealism | Realism |
| Argumentative | Gaining Balance |
| Righteous /morale tendency | Can have gang mentality |
| Design strategy | Emergent strategy |
| **SEQUENTIAL time**<br>*Time follows a straight line; inflexible; adherence to time specifications* | **SYNCHRONOUS time**<br>*Time is cyclical; loose guidelines set flexibility taken for granted* |
| Speed | Timing |
| Short termism | Long termism |
| One at a time | Many things at once; multitasking |
| Cause | Effect |
| Push strategy | Pull strategy |
| **NEUTRAL**<br>*Reserved, seemingly distant in manner /nature* | **AFFECTIVE**<br>*Outgoing, seemingly open in character* |
| Detached, Objective | Expressive, Visible emotions |
| Low physical contact | Tactile |
| Dry humour | Unequivocal humour |
| Outwardly calm, relaxed appearance | Heated, animated expression |

Table 5.1. references: [Trompenaars and Hampden-Turner, 1999; Hofstede, 2008]

## *5.3.2 The Consequence of Gender Under-Representation*

The range of diversity within the dimension of Achievement and Ascription relates to whether people are judged upon their accomplishments, or they are ascribed their status based upon gender, class, age, education etc. The results from this work increasingly formulated from areas that can be categorised within elements of ascription. This is most apparent when examining gender representation of the practitioners within industrial product-costing. When looking at the collaborative stages of research i.e. the combined phases 1 and 2, there were 24 contributory organisations of which only three companies, one being within the U.S. had female employees working directly within costing. To give an idea of the scale of the numbers involved: The participants to the research totalled 102; of these approximately 70 were direct-costing practitioners, with the others contributing from perspectives of finance, engineering, software development, management and so forth. Of the 70, a total of 4 were female, two of whom were trainees. The majority of women encountered were from commercial / economic or computing backgrounds rather than engineering; consequently drawbacks to a degree were noted for their application into the technical domain, for instance via the necessity of having higher product learning-curves, etc. In turn, engineering / technical roles are not traditionally perceived as appropriate female pursuits [Simons, 2003]; a perception which the current state of costing seems to reinforce.

Given these figures, the absence of women working within this area was significant, particularly across UK industry. Therefore the masculinity rating (MAS) in UK and to a marginally lesser degree U.S. organisations was very high [Hofstede, 2008]. High MAS throughout the costing domain was deeply ingrained within the vast majority of organisations examined and may be linked to the identified challenges and where they initiated from; primarily in that the quality of communication and levels of integrated working practice were inadequate. Human interaction and communication are often perceived as feminine traits / strengths. Therefore the most logical deduction derived from an area which is effectively unrepresented in one gender, would be that the resulting qualities which that gender would disseminate within the environment would be also lacking. This appears to be the case in product-costing.

Simons discusses differences in communicative styles between the genders and the need for examination and learning opportunities in this area. The reference to gender differences via cultural barrier-research is further expanded through the way in which women may inherently be seen as unsuitable for certain technical roles [Simons, 1993].

To summarise this section, many of the challenges observed within industry are seemingly due to a lack of what are traditionally perceived as female qualities. For instance Phase 1 research exposed a clear lack of communication, plus general inadequate interaction between the related disciplines. Social integration is stereotypically seen a female trait; throughout the UK organisations examined at any of the stages of examination, AS-IS or in-depth, few female practitioners were encountered, specifically only 3. For the USA, 1 female trainee was interviewed, though a number of women were participants from within the USA software vendor / development organisation Price Systems in the in-depth / validation stages of research, though were not costing practitioners, but worked in related domains. A potential link can subsequently be forged between the lack of female practitioners within the costing process, and a substantial level of the overt insufficiencies regarding the challenges in the costing domain.

### 5.3.3 Integrated working concepts

The term 'wa' reoccurs throughout Trompenaars work, being highlighted as particularly relevant within communitarian cultures, refer to the table-headed continuum in Table 5.1. Wa is a south-east Asian term, which refers to the achievement of a state of harmony: This relates to business via the concept of several different aspects or expertise working together to create the type of excellence within a product which is unprecedented [Trompenaars and Hampden-Turner, 1999]. As the research was instigated due to the need to promote such integrated working practices within the observed subject-domain, it seems that the creation of such a state as described by wa, achieved within communitarianism business-working cultures, could be advantageous if similar conditions were strived for / implemented within the product-costing process.

A apparent link between the creation of organisational 'wa' would be to promote a systemic knowledge of the environment. This would in turn lead to an awareness of each contributor, and assist understanding of roles and the value of each departments input. Once this is established, integrated working and an adequate level of communication should systematically follow. Accomplishing such organisational states is discussed throughout the proceeding chapters.

### 5.3.4 Perception and Attitudes towards Time

The way in which time is perceived is discussed extensively within the cultural literature and Hofstede and Trompenaars are among those with hypotheses on this subject. Long-term orientation (LTO) either high or low, refers to whether a culture places importance on long-term adherence to traditional values. If the LTO is low, then changes may be allowed to occur more quickly, as the way in which things have traditionally been done will not hinder forward thinking ideas and progress made via innovation or modernisation. Alternatively cultures where LTO is high, improvements are worked towards in a thorough manner, over a comparatively lengthy period of time. Respect for tradition is the norm, and the concept of deferred gratification is in place within high LTO cultures. This means that the rewards for current work may be reaped in the future; so people feel they are working towards greater benefits and long-term commitments. In this type of environment new business may take longer to develop, but will be more stable once it has been; as opposed to the former mentioned, where novel ideas can be introduced more readily, outdating previously used ones rapidly, if deemed more suitable; see Appendices 2a and 2b.

The attitude of time being flexible and malleable to fit around tasks as required, synchronic orientation; or of it being fixed and acting as a firm parameter for when a task should be started and completed by, sequential orientation, is also applicable to different cultures. Clearly if cultures with different attitudes towards the use of their time attempt to work integratedly, then a knowledge of how time is perceived by each is essential. An obvious example would be Mediterranean countries having a relaxed cyclical approach to time, multitasking as appropriate and comfortably accepting approximations of schedules, absorbing modifications as they occur. Whilst countries such as the U.S. and Germany have the reputation of following the latter, maintaining a stricter attitude, where punctuality is important as are deadlines, and the predetermining of time scales which are closely adhered to. The primary country for this research (UK) tends towards sequential time keeping; therefore large inaccuracies in estimation of project delivery and timings can be negatively received. Products where state-of-the-art technology is required, and whose duration may be over decades, have been open to scrutiny when they overrun e.g. as prior observed within BAE Systems. Therefore a reassessment of the approach to time in conjunction with other improvements made towards estimation accuracy, discussed further in later chapters, may increase quality and project credibility.

### *5.3.5 Environmental Influences*

The way in which the environment is perceived by industry is changing. A lack of attention by manufacturing industries towards the hazardous and potentially damaging effects on a local and global scale receives increasing attention. This pressing need for companies to independently address such issues as a priority is not only to prevent severe economic implications for the organisations themselves, through the potentially impending imposition a growing number of proposed strict regulations and penalties. Additionally it is essentially to prevent the continuation of irreparable damage to the atmosphere / environment, through avoidable detrimental industrial practice.

With increasing evidence pressure from various sources is placed on industry to develop and adopt better, 'greener' practices [Wells, 2006]. For instance, the views towards nature may be that it should be managed, feared, controlled, imitated or ignored; such beliefs determine the approaches that will be taken within organisations to address environmental challenges encountered.

Due to the widespread attention provoked by the negative consequences of pollutants and other factors which have noticeably harmed the environment, regulations have already started to be introduced with the aim of controlling such affects. These affect many industries, including:

- Automotive; for instance with regards to product disposal, gas emission-control in cars, through manufacturing processes, and so forth;
- Aerospace; including suitable product-disposal;
- White goods; mainly issues as disposal of refrigerators, etc;
- And industrial waste in general.

In order to meet the legislative demands and avoid the costs involved in breaking them, redevelopment, or at least modification was necessary particularly with issues as airborne emissions from car engines and even a re-examination of the overall design for models identified as particularly hazardous, such as 4x4 vehicles or SUV / Off-road ones [Wells, 2006].

### *5.3.6 Risk and Uncertainty*

Different types of culture will display differential responses towards risk taking. This has been examined in terms of 'Uncertainty Avoidance' or risk aversion levels, see UAI [Uncertainty avoidance index, Hofstede, 2008]; which describes the degree to which a society supports ambiguity and uncertainty. If there is high UAI then the group has a low tolerance towards risk; this often reveals a high tendency to follow rules, regulations and places importance on career security. Alternatively low UAI depicts a high tolerance towards ambiguity; this exposes a culture in which there is a greater tendency to accept change, and take a higher number of greater risks.

This aspect of culture has reference to product-costing in specific and generalised ways. Industrial advancements can prove revolutionary when successful, but due to the scale of such projects, can be crippling economically if unsuccessful. If an organisation is willing to take risks in relatively new areas and finance the development of novel products, it can potentially be in a position where it has the capacity to lead the market in that area. Costing new products often creates results with relatively low levels of confidence, when compared against familiar, established products which have had varying degrees of historical data to work with, often in conjunction with previous product knowledge. Therefore if the estimated costs of development, production and even market response is too inaccurate, economic disaster can prevail; though as stated above, successful innovation can have outstanding benefits.

### *5.3.7. Establishing Cultural Contexts of Industrial Product-Costing*

Understanding the cultural norms in which the bulk of this research was conducted was key to establishing the environment within which costing could be improved. The majority of data utilised in this study were derived from within UK branches of international corporations. Therefore it was important to take into account that which is widely accepted as being cultural practice within the dominantly observed environment under investigation. This can help to explain some of the more common behaviours, and why they occur; along with identifying unexpected, less typical results / observations.

Having an awareness of cultural practices of different countries can arguably be used to predict the consistency of such behaviour across other branches of the same organisation, within other countries. For instance, will the processes implemented within Ford Motor Company, UK (Essex sites), differ to the same function within Ford, Germany, or even the U.S. branches? If having knowledge of cultural differences gives insight into the behaviour of practitioners, then it can presumably also assist in providing solutions to challenges within the costing domain. Refer to Appendix 3 for Hofstede's global cultural ranking of the U.K. and U.S.

### *5.3.8 Expanded Research:*

The themes which emerged from the exploratory phase of research, see Chapter 3, gave cause for examination of cultural constructs. The findings focused less on explicit technical challenges and more on personnel interactions along with issues surrounding communications and comprehension. The way in which people work with each other is indicative of the culture they are working within. As stated this applies not solely to international / global corporations but also occurs within organisations [Holden, 2002]; between contrasting but complimentary disciplines as purchase, engineers, costing and management.

However with regard to issues related to the culture of an organisation, it must be noted that other factors contribute to the difficulties encountered. Due to the intricacies within organisations, identification of the root of challenges is often less straightforward than pure cultural derivation; it is more complicated in its formulation: This must be identified and considered when assessing potential remedies.

Holden [2002] states that it is tempting to identify all challenges being culturally determined when organisational challenges can have other influences. In order to fully asses the causes of the cost-challenges experienced, the research was extended to examine other influential factors identified in the early part of the work, in particular knowledge management (KM) and organisational learning (OL).

## *5.4 Background and Overview of Knowledge Management and Organisational Learning*

Knowledge management (KM) focuses on the way in which organisations recognise, disseminate and utilise their internal competencies and in particular the knowledge and expertise of its individuals. KM ascertains where within the organisation knowledge is located; as well as identifying the knowledge-type, as either tacit or explicit. Thus KM basically facilitates the tracking and mapping of the knowledge held within the organisation, in conjunction with an awareness of cultural environment and attitudes towards the technology employed.

Polanyi believed that knowledge,
*"..or the process of knowing, is personal and related to the individual. It can be viewed as a type of "intellectual capital" that has the ability to change how individuals and organisations view and create the world around them"*

[Polanyi, 1998]

Unlike physical assets which are tangible, knowledge is often intangible and therefore difficult to formulate in an explicit, 'solid' manner. Knowledge is linked to data and information where data is represented in the form of unrelated facts described by Saint-Onge as arriving "in our lives and on our desks as dispersed elements" in finite volume and variety [Saint-Onge, 1996]. Information is the structuring of this raw data into something useable, and as knowledge is being able to utilise this information in order to make decisions it is essentially related to human action [Schoenhoff, 1993].

The areas of knowledge defined in the work of Collison and Parcell [2001] link closely to the knowledge briefly alluded to within Chapter 4, the 5W's and H. The former refers to know-how, know-why, know-what, know-who, know-when, know-where; each area depicts an aspect of knowledge, all of which directly relate to industrial product costing and will be used to guide the analysis of the next phase of work in Chapters 6 and 7.

### *5.4.1 Knowledge Types: Tacit and Explicit:*

Knowledge is often seen to be of two core types: Tacit and explicit. Understanding and recognising the difference between these two knowledge types and their essentially complimentary nature is key to this thesis. This is because the research focuses on the elicitation, identification, capture, and eventual reuse of costing-knowledge. Therefore recognition of tacit knowledge and the process of eliciting it and converting from tacit and intangible to explicit and reproducible is vital to the research contribution.

Explicit knowledge can be identified and shared with relative ease. It can be identified as within documentation, e.g. company reports; procedures, manuals, data, formulae and other tangible forms. It is relatively easy to articulate and may be expressed in formal and systemic language. Tacit knowledge, in contrast is embedded in individual experience and encompasses intangible aspects such as values, perspective and belief; it is also more challenging to express verbally. Tacit knowledge tends to be communicated through actions, such as the manner in which a practitioner will perform their work and interpret their environment; it is often unarticulated and comparatively evasive in relation to its elicitation, and storage.

#### 5.4.1.1 The Types of Knowledge Used within Product Costing

Although there are explicit knowledge such as guidelines and procedures evident within organisations, much of the knowledge used is tacit. This was derived through experience and working with experts particularly external practitioners and was often referred to as a 'black art' or 'black box' process.

Within supplier-quote analysis, over-estimates can be made regarding the project in labour hours, skill requisites, materials used, and so forth. In order to decipher the quotations, concise knowledge is required of manufacturing processes to enable accurate assessment of their practices. Suppliers may have manipulated these processes, using 'tricks' to justify their quotes when accounting for the costs. Therefore the costing-expertise gauging them needs to include an understanding of the intricacies of the processes to determine the validity of the quoted costs. For instance they need to be aware when equipment is performing to capacity, and when it is working slower than it could be when in actual production e.g. to know the difference between the optimum, and modified settings for the benefit of customer-cost assessments. Along these lines, the cost assessors should consider actions as checking supplier workshop on unexpected days / times, for instance not on the 1$^{st}$ and 2$^{nd}$ days of a visit as would be expected, so as to ensure they experience the actual practices conducted by the supplier, not staged ones. Such experience or knowledge adds to the effectiveness of their cost-performance. Supplier interactions, contribution, cost-assessment and knowledge are discussed at length throughout the following two Chapters, 6 and 7.

Knowledge about orders and batch sizes is also required, as larger orders comprised possibly of combined work from other organisations i.e. other customers of the supplier, will result in substantial price cuts. To elaborate, if large material orders are placed encompassing material required for orders other than the customer making the cost assessment, the supplier will incur lower costs than if the order was for one customers' material only. Such reductions will not tend to be passed on automatically, so the analysers and negotiators of quotes need to have the knowledge to query and debate such details. Refer to Chapters 6 and 7 for supplier 'tricks', including Section 7.2.3.3 and Figure 7.10. Therefore not only is explicit knowledge required e.g. how to read the supplier quote analysis forms, designers drawings, extract material composition and price information, assess budgets, forecasts and trends to see where costs need to be cut. Additionally aspects of the costing processes also rely on the possession of inherent, tacit knowledge of manufacturing processes, which then can be combined with economic knowledge to produce accurate costs, bid-compilation and analyse external costs, such as quotes. A prior, almost prognostic knowledge of what the approximate or ROM value (rough order of magnitude, or rule of thumb) of the figures should be is valuable, on receipt of the costs which require evaluation: This is discussed later in relation to training, formalised cost-models and the importance of retaining cost knowledge and expertise, see Chapter 8.

An important point to note is that these knowledge types are interlinked and complimentary; being generally reliant on each other and can be seen as cyclical. The movement between tacit and explicit knowledge is presented in the SECI model discussed in the following section; illustrated in Figure 5.2.

## 5.5 Knowledge Conversion / Creation; The SECI Model:

SECI represents Socialisation, Externalisation, Combination and Internalisation; this model concentrates on the states of tacit and explicit knowledge, and the conversion-stages between the two. As can be seen in Figure 5.2, there are four identifiable states of the interaction between these two types of knowledge. This section explains the SECI process and highlights the relevance to product-costing, [Nonaka and Teece, 2001; Nonaka and Takeuchi, 1995; Macdonald, 1999].

- Socialisation equals tacit → tacit knowledge conversion. The dominant aspect of this mode is social interaction, which not only allows the transferral of implicit knowledge, but also aids in converting new tacit knowledge, through shared experiences. The gaining and sharing of information and knowledge between roles / expertise is crucial within the costing environment. It is also focal for technical apprentices with knowledge acquired and passed on through interaction with peers and both internal and external experts [Nonaka and Teece, 2001].

    - Trust is created via this type of formal and particularly informal, daily social encounters. Issues surrounding degrees of trust arose throughout the industrial observations and were often manifest in the reluctance to share data; if data is not received by the costing practitioners, the process is hindered; this element of costing is expanded on in Section 5.8, see Table 5.5.

- Externalisation: Tacit → explicit knowledge conversion. The main idea behind this aspect of knowledge conversion is to extract and communicate tacit knowledge, which subsequently creates explicit knowledge that can be disseminated. An example of externalisation can be seen when improvements to manufacturing processes are enhanced through discussion with the practitioners who have gathered vast expertise / tacit knowledge about these processes over time. Tacit to explicit knowledge also occurs when anecdotes, metaphors and other implicit experiences are communicated, i.e. externalised [Morgan, 1997].

    - Product costing relies heavily on externalisation for training, which currently occurs primarily on-the-job. Current practitioners relay their expertise to the trainee via shadowing; as well as through placing their tacit knowledge into explicit forms. This can be undertaken through formalisation of procedures, systematic steps or documented guidelines; and computer based training tools (CBT's) which can in turn be internalised by a novice, as discussed further below; and in Chapter 8. However, the daily process of costing requires the practitioner to convert their tacit knowledge into developing the estimated costs with the use of the limited information available. This is especially true in the conceptual design phases that are required prior to there being any actual product-data to begin with and within stringent time schedules. Therefore this stage is evident in costing for both training requirements and daily working practices.

- Combination: Explicit → explicit. This conversion occurs when the use of knowledge which is already represented explicitly is harnessed and used to create new, updated and more intricate explicit knowledge. For instance, the juxtaposition of data and information gathered from different departments within an organisation can be used to create a performance-monitoring report, from which future expenditure can be predicted. Extensive data-bases and soft communicative networks can effectively facilitate Combination.

  - Within costing the development of a new product based on an older version or a model upgraded employs explicit knowledge which is converted to a more complex type. The most obvious manner in which combination occurs within costing is through the exchange of information both internally between the relevant department e.g. purchase, engineering, and externally (between supplier, OEM) to develop the cost; as well as from budgets and cost targets. Within training, explicit knowledge held throughout the organisation plus general, widely accepted practices can be amalgamated into training tools as CBT's plus increasingly comprehensive reports.

- Internalisation represents the explicit → tacit knowledge conversion which emerges when explicit knowledge, for instance in the form of documentation gets disseminated throughout an organisation, studied and subsequently converted into tacit knowledge.

  - In addition to externalisation this mode of conversion is particularly applicable to and regularly undergone within the costing domain. It is also important for training and development-of-learning for novices through 'learning by doing'. If a trainee can learn from practical, hands-on experience, the main benefit gained is when they can retain this knowledge tacitly and re-use it in a non-training environment, actually on the job; and when they can additionally implement it across a range of situations as required. Linked to this are other training concerns such as: When a person can pass a training module, but even though they may consciously 'know' the newly acquired information and knowledge, it is difficult to asses whether they have changed their old routines and habits of working when returned to their regular working environment. This is discussed further in relation to training within Chapter 8 where the tacit knowledge from an expert can be packaged into training tools such as CBT's.

- The tacit knowledge possessed by each person can then be converted, therefore returning to socialisation when it is conveyed to others; which continues this cycle of knowledge management and conversion. Tacit knowledge can also underpin bad practice.

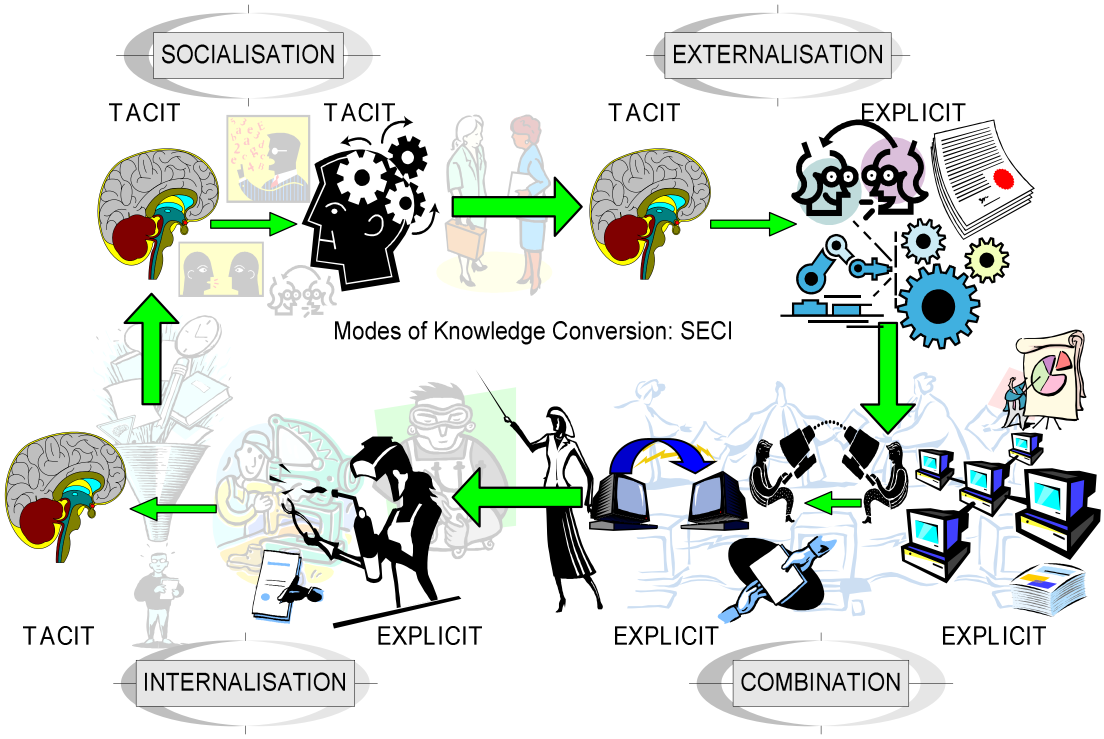



Figure 5.2: The SECI Knowledge conversion Model

[Nonaka and Takeuchi, 1995]

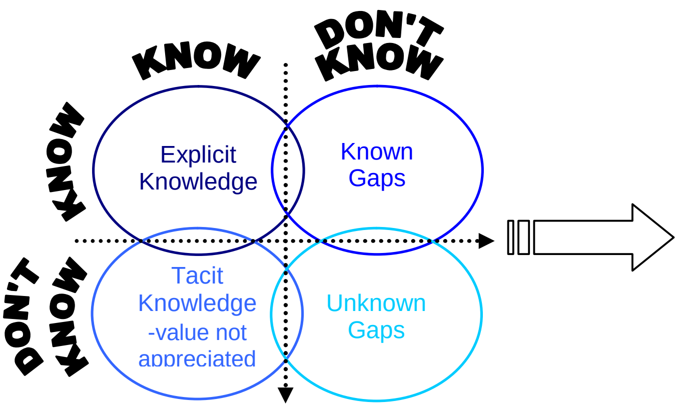
## *5.5.1. Model of Knowledge Gaps*

Another model of explicit / tacit knowledge which assists in the identification of knowledge gaps is illustrated in Figure 5.3. The axes represent the direction of that which is known and what is unknown. Where knowledge is labelled as being known and explicit in Figure 5.3 it depicts the knowledge that 'you know you have'. The knowledge that 'you know you do not have' is given in the known gaps area, and is subsequently along axes of both known and unknown. The knowledge that 'you do not know you have' is within the tacit knowledge sphere. This again spans the known and unknown, but along opposite axes to the known gaps; hence the knowledge is known implicitly, i.e. there is a lack of awareness regarding this knowledge on a conscious level. Therefore even though it may be essential, and utilised regularly in tasks which contribute to expertise particularly the exclusive elements of, for instance costing, it's value is not acknowledged: It may subsequently have difficulty in being shared explicitly, though could be absorbed tacitly, through socialisation, refer to SECI model. However of greatest interest for organisations within this model are the unknown gaps or the knowledge that 'you do not know is missing' is unknown on both tacit and explicit levels:

This knowledge model is related to the way in which an organisation can keep track of its knowledge, so is linked to knowledge management; with derivatives having been mentioned in the technical literature Chapter 3, see Know-how, who, why, where, when, what [Collison and Parcell, 2001] and is returned to in Chapters 6 and 7.

### 5.5.1.1 Industrial Costing Knowledge Gaps

Product-costing has frequently been referred to within industry as a black box activity, indicating that many of the practices fall into the tacit knowledge sphere; if this knowledge, which is necessary and utilised regularly, can be moved into the explicit domain, see Figure 5.3, improvements within costing will result and training requirements can be identified and implemented with greater ease. The known gaps of the cost-process appear to lie within the transfer of knowledge between the disciplines. As previously discussed, essential information is not regularly communicated to costing for an array of reasons, including fear culture i.e. a mistrust of why the information is required and what it will be used for. There are also issues such as inadequate process and tools to efficiently relay it; plus a lack of understanding as to why the information is required or even to the fact that it is actually needed. The knowledge and expertise -loss resulting from practitioners moving outside the company can be seen to fall both within the known gaps sphere and the tacit knowledge one. Whilst the 'unknown gaps' within this process seem to be in the unaddressed cost-challenges related to culture e.g. lack of communication and a high rating of MAS [Hosfede, 2008] which the industrial examinations revealed is not even perceived as an issue, let alone as requiring attention.




| | KNOW | DO NOT KNOW |
|---|---|---|
| KNOW | You know you have | You know you do not have |
| DO NOT KNOW | You do not know you have | You do not know is missing |

Figure 5.3: Illustrates a Model of Knowledge Gaps which Need to be Identified in Organisations

## *5.5.2 Identification of knowledge gaps:*

There are ways in which an organisation may explicitly identify any knowledge gaps within it, the main areas of focus are: People; The Environment; Structures and Systems. An initial focusing point is to examine desired outcomes, which are based on each organisations specific vision and goals. The knowledge required to ideally achieve the above mentioned outcome needs some consideration, and includes examination of the workforce capabilities, procedures, human and structural knowledge [Major and Cordey-Hayes, 2000].

In relation to the individual human contribution or role, demand and supply need to be identified. For instance the determination of what knowledge is currently held by individuals within the workforce which is required in order to achieve strategic results (demand), and who has this knowledge (supply); e.g. establish whether they are external or internal to the organisation, i.e. suppliers, or in-house experts? In order for the people-aspect of knowledge identification and subsequent transferral to occur there needs to be receptivity [Seaton and Jefferies, 2004] involving the: Perception; Willingness, and Ability to share knowledge by those who identify the gap and communicate the need to assimilate the knowledge known by another. However all of the three mentioned requirements may not be met e.g. there may be unwillingness to share knowledge if the perception of power loss is accepted. To elaborate, a person may feel that their worth is connected to the possession of this required knowledge, so communicating it to others could devalue their own role or value. A culture of fear may be behind the unwillingness to impart knowledge.

Table 5.2: Lists the Benefits of Knowledge Management:

| KNOWLEDGE MANAGEMENT: | |
|---|---|
| Improved product performance | Empowered workforce |
| Decrease in wasted effort / resource | Innovative breakthroughs |
| Quicker reaction to changing markets | Adaptation rather than control |
| Focus on Internal competencies | Multi-directional information transfer |

Additionally the tacit knowledge utilised on a regular basis is unknown, unidentified or what is referred to as 'second nature', which basically means it is implemented quite routinely without much conscious engagement to its application, see Figures 5.2 and 5.3. This implicit quality subsequently makes this type of tacit knowledge evasive and difficult to communicate.

From the industrial observations related to the costing process it seems that this gap in tacit knowledge is why the bulk of the cost-training is undertaken via on-the-job training / learning, see Chapter 8. As much of the process is routinely done, with tacit processes following one another, and there is little need to communicate explicitly the trail of thought undergone by the practitioner throughout the process. This is why the link between the original elements which comprise the cost, to the final result may seem obscure; hence the previously used term 'black box' activity discussed further in Chapter 6, because in most observed organisations there was little need for the practitioner to make their actions clear. Relaying of every-day practices to a novice can prove challenging for practitioners. Consequently the main solution is to integrate them into the environment to ensure that the knowledge will be imparted gradually and often tacitly over time through practice.

This point leads into the issues of knowledge-transfer and the time required for training which is currently felt to be too long. Two years is widely accepted as the length of time it takes to train a novice to an efficient standard and obtain enough knowledge about the cost-process to be able to work independently; before they are considered to be able to perform adequately and relatively independently. However if steps where taken in order to elicit the tacit knowledge within the process, this measure could assist in the reduction of this traditional two-year time frame; whilst helping to replace the depleting source of costing practitioners and expertise, at the necessary rate, refer to Chapter 8 for greater detail.

## *5.6 Knowledge Management*

Through the employment of knowledge management (KM), firms can increase their intellectual capital whilst gaining a competitive advantage. Taking measures to actively improve internal communication and understanding also results in a reduction in wasted effort and resource.

Table 5.2 lists the main benefits of utilising KM: They include an adequate dissemination of information throughout all levels of the organisational results from an empowered workforce. [Macdonald, 1999]. New, innovative responses to company needs can be supported via the combining of tacit and explicit knowledge; the capture and exploitation of which creates new knowledge as discussed previously, see Section 5.5. Another focus of KM is in how organisations identify, acquire, share and utilise their internal competencies, in particular the knowledge of individuals. KM is described as being:

> *"…about capturing, creating, distilling, sharing, and using know-how"*
>
> [Collison and Parcell, 2001 Learning to Fly, p8]

Knowledge Management can be implemented across cultural groups within organisations. As discussed in the prior cultural sections, there can be more than one cultural group within an organisation. This research highlights in particular the effects of the different cultures between engineering / technical, and economic / financial disciplines when required to work in an integrated manner. The cultural discrepancies, including lack of communication and comprehension of each others' role, can be eased when the fundamentals of KM are implemented within organisations, the benefits of which are listed in the following Table:

Brown and Duguid [2001] state that knowledge management can often encounter difficulties in implementation due to internal complexities within organisations. This supports the findings within the first phase of this research in which internal politics, fear culture and 'power struggles were commonly experienced alongside a lack of understanding of each others roles. Table 5.3 summarises the main ways in which KM can be promoted or stifled within industry.

Table 5.3: Disablers and Enablers of Knowledge Management

| ENABLERS of KM | DISABLERS of KM |
|---|---|
| Developing a culture with knowledge acquisition, assimilation and dissemination at its core | Overloading an organisation with too much information: Which it is unable to digest. |
| Using IT appropriately. | Believing KM to be a primarily IT issue: People are not computers and organisations are not machines. |
| Creating Trust and empowerment | Dismissing / not recognising and addressing tacit knowledge: Usually because it is more difficult to manage then explicit knowledge. |
| Adopting a systemic view of the organisation, addressing it as a whole, as opposed to dissimilar segments | Inability to perceive the organisation in systemic terms: Accepting inconsistency and uncertainty, rather then controlling it through rules, benchmarks, procedures, etc |
| Nurturing networks, both formal and informal | Not prioritising KM: instead expecting staff initiative to address it. |

## 5.7 Organisational Learning

Organisational learning, OL, is the ability of an organisation to increase its knowledge base; and subsequently improve its capacity for executing successful action [Kim, 1993]. Macdonald describes OL as the acquisition, creation and transfer of knowledge and the modification of behaviour to reflect new knowledge and insights [Macdonald, 1999]. This definition portrays OL as a broad phenomenon, encapsulating subjects that have been discussed earlier in the chapter such as knowledge creation, see Section 5.5 and Figure 5.2. MacDonald's description mentions the way in which behaviour is affected and how new knowledge is received, which is reflected in cultural examination when referring to attention, attitudes and readiness towards embracing change when encountering new knowledge, including technology and general innovation.

As culture influences the way in which knowledge is used and implemented, so organisational learning is naturally affected by the types of culture in place. Within costing this could be seen from not only the way processes are performed within similar industries but as the companies were significantly different cultural disparities in processes were observed. With this said interestingly one of the main contributors within this situation JLR, (Jaguar Land-Rover) were seen to have not fundamentally changed their approach to costing compared with when they were separate entities, i.e. Jaguar and Land Rover.

Within any organisation there will inevitably be a range of views and competencies, some of which will lead to conflict. The fact that increased complexity is due to such clashes does not mean that measures should be taken to control differing views. This could risk the stifling of innovation and even cause complacency. The difference between an alignment of thinking and actions or the learning of that which is diverse and creates innovation, between an expansion on what is known needs to be acknowledged and appreciated [Eden et al, 1993]. This is linked to the previous point regarding the inclusion of dissimilar views; likewise the incorporation of a variance in perspective and outlook needs to be facilitated, in conjunction with allowing the practice of open communication. Hence instead of there being reluctance to express differing opinions which is often the case, it should be to the contrary, where the community can learn from diverse opinions and viewpoints. If some of the more challenging contributors to the research adopted this attitude, for instance with reference to integrated working between costing and purchase departments, not only would the process of costing be improved, the company-performance on a systemic level would also benefit.

### *5.7.1 Systemic Thinking*

Complex situations which occur between people and things can more easily be resolved with the use of systemic thinking which involves examination of the 'whole', taking into account all the relationships and interconnections within an entire entity. This contrasts with isolating specific parts, which can lead to out-of-context assessment [Senge, 2001]. Systemic thinking is essential to the success of the costing-process; as opposed to 'over-the-wall' working practices, i.e. an informal industrial term for segregated working practices, where limited interaction with other disciplines is accepted as the norm.

Table 5.4 highlights the relevance of a systems thinking approach within and towards product costing, particularly at the conceptual design stages. It is at these early stages that the entire project needs to be evaluated in order to gather every relevant conceivable cost that comprises the whole cost, with as high a level of certainty as possible. However, many aspects can and will influence the overall cost as the project unfolds, therefore being able to view the project in totality at the conceptual stages, and being able to bestow a high level of confidence can be challenging. Uncertainty may be due to the fact that often parts may need modification, because requirements-change, for instance to suit specific customer requests for an upgraded / updated model. The change of one minor component e.g. within an engine, will have knock-on effects to the production system as a whole.

For instance the increase in size of one particular component deemed necessary to improve performance, may result in the use of a larger mould; alternately it may require the component to be produced with the use of two moulds. Hence this modification clearly has consequential effects, such as additional equipment and labour to facilitate the production and use of two, instead of one mould; as well as through the need for subsequent joining of the two. If so, consideration as to which joining method is feasible and most appropriate without resulting impairment, whilst remaining within budget. Accordingly it is clear that one relatively minor change can warrant knock-on effects which could plausibly ripple through many layers all of which will impact on the costs.

### *5.7.2 Fear Culture*

Within Systemic thinking is the recognition of the fact that there will be different perceptions, and viewpoints of interacting parties. These differences can affect the 'system of interest', as can be seen within industrial costing practices. An observation within this research has been that many organisations have a 'fear culture' primarily between areas of practitioners and management, but also between departments. An example of such tension or lack of co-operation and inadequate interfacing was seen between departments such as Purchase (also referred to as Buyers / Procurement), and Product-Costing. Chapter 4 has previously discussed examples in where Purchase had decided that they had made the best choice with regards to supplier selection, and were guarded in the information-exchange between the two companies; Product-Costing deduced that a more economical alternative may have been readily found, and inferred that the motivating reasons behind purchase-choice stemmed from fear culture, primarily in meeting annual decreased cost-targets. One organisation stipulated three-yearly reduction in expenditure; therefore in order to satisfy this demand Purchase may have negotiated a deal with the selected supplier, in which the costs were duly reduced at the annual required rate, see Chapter 4, Sections 4.8.3. and 4.8.4 for relevant supporting data, plus a cost-engineering manager added:

*"No over estimating could take place if costing stepped in, but purchasing would like to avoid this happening by us …it's total non-profitable, a false economy,…not in the interests of the company".*

[Cost Engineer Manager, Automotive Industry, 2001]

Although satisfying management guidelines, this meant the lowest cost was not agreed from year one, and it was also perceived that the cheapest option had not been selected, possibly in favour of the best supplier-buyer relationship; resulting in a reluctance to share information from the Buyers towards the costing department. This is just one example of the type of highly similar responses to fear culture that was observed within multiple of the companies researched.

When examining a situation or project from a holistic viewpoint, identification of where the challenges stem from can be pinpointed more vividly and immediately. For instance it may emerge that management are setting unrealistic targets, such as the above annual reduction example and creating a fear culture when difficulties are incurred in attempts to meet them. This highlights the benefits of applying systemic thinking in the identification of points and processes of intervention which can often emerge as being different to where they initially seemed to be. For instance leading on from the previous example it was the practitioners who were perceived to be overestimating, the points to address may superficially lie with them and measures taken to examine the codes of conduct within these departments. However wider, systemic thinking where the whole and relationships between aspects of the whole are examined reveals that the source of the difficulties initiates from management, and the fear instilled into the workforce via uninformed and thus unreasonable demands. This culture equates with one that has a particular perspective on the concept of trust.

Table 5.4: The Importance of Systemic Thinking in Relation to Product-Costing

| SYSTEMS THINKING | RELEVANCE TO PRODUCT COSTING |
|---|---|
| Accounting for the 'whole', not specific parts alone | In order to asses the cost of product fully, the entire project needs to be evaluated. |
| Identification of points and processes of intervention | Often if seen as a whole entity, challenges and risks can be assessed more accurately, and dealt with accordingly. E.g. the workforce may over-estimate due to a fear culture instilled by management. Therefore the point of intervention would initiate with management, prior to focusing on the workforce: - Although they are directly responsible for the overestimates, the catalyst for their actions is traced as being derived elsewhere i.e. from management and the fear culture they instil. |
| Recognises differences in perception which affect '*systems of interest'* | Focus and priority of Purchase, Engineers, Finance and Product-Costing, towards the same product my differ; it needs to be ensured that they do not conflict -at the expense of the project or organisation; primarily due to the production of over-estimates. |
| Encompasses soft systems:<br>Human behaviour,<br>and hard systems:<br>Man-made, relatively predicable with clear boundaries. | The need to asses the software and tools available to the practitioners and their attitude towards the use of them, including their ability to use these cost-aid; reliability, availability and relevance of products. This incorporates a number of soft systems within the issues of hard systems. E.g. human response to use of software; issues of data and information gathering from relevant departments, i.e. the interaction of personnel; even the perception of importance of the cost-function, in order to initially invest in and subsequently maintain such tools.<br>Hard systems are also seen in the manuals, corporate procedures, and documented processes / guidelines given, which often need interpretation / adaptation: Or can act as an overview, within which allows or requires practitioners to work, using their preferred (non-specified) approaches. |

## *5.8 Trust in Relation to Industrial Costing:*

Throughout this industrial research the initial observations regarding the subject of trust has been that it is considered in a secondary light to other priorities, namely the technical ones. This seems to be due to the fact that when approached in a superficial manner the high-level view of 'trust' is generally equated with intangible or 'soft' aspects, associated with interpersonal relationships and subsequently not perceived as applicable to industrial, professional dealings. This belief may have emerged, as the primary contributors to the results have been from a technical and / or engineering persuasion: Therefore when evaluating these findings within a stereotypical viewpoint, such disciplines do not traditionally equate soft issues as being legitimate factors within their working environment; also reference Chapters 4, 6 and 7. However despite this apparent dismissal, both within the same role and interlinked departments trust has emerged as a primary influence towards how the work is conducted [Pappas and Flaherty, 2008]. Consequently the degree of success of the activity or process in question, in this case costing, is directly related to interpersonal relationships and how the resultant reality of such interactions ultimately match the desired outcome [Rich, 1997].

The potential reasons why issues related to trust are not commonly recognised within the workplace may be associated to the fact that it is not one entity, but that there are components to this subject. Trust considerations are entwined within cultural ones; therefore the area for which they span and hold significance within is broad. Newell and Swan [2000] identify three broad types of trust: Companion, Competence, and Commitment trust, refer to Table 5.5. This type of differentiation helps identify situations in which challenges i.e. misunderstanding and potential clashes can be identified and addressed. The following sections discuss the different types of trust and expand on their relevance within product-costing.

## *5.8.1 .Companion Trust*

Companion trust is typically the type which is most commonly envisaged when addressing the general subject of 'trust': It occurs between individuals and is built up through the relationship they establish. From this, business partnerships and working confidences grow, having been nurtured over time [Morgan et al., 1994; Moorman et al., 1992]. Therefore due to the very nature of these relationships, if the trust is broken or damaged somehow, it is said to be virtually irretrievable; unable to rebuild having been developed in such a specialised and gradual manner.

Supplier selection can occasionally be seen to fall into this type of companion trust, as well as the other two categories; see relevant following sections. Industrial feedback has revealed that supplier choice is related to cost, but aspects of quality, reliability and stability need to also be strongly considered. Therefore when choices of supplier have been questioned by the costing practitioners, as the costs dictated may have been assessed as excessive in comparison to competitors, the purchase department responsible for making the decisions of supplier has been known to defend their choice by stating that the relationship built up over the years between the companies has developed and is mutually beneficial. This benefit is due to knowledge about what the customer wants, as well as the aspects of known quality and reliability from the supplier [Floyd and Wooldridge, 1992; Dutton et al., 2001].

Subsequently if there is a lack of companion trust for reasons as forced price cuts for instance imposed by powerful corporation on suppliers or internally between departments, this can result in a general mistrust in the relations. Suppliers will withhold detailed information as standard practice; they will escalate costs where it is possible, and thorough checks of quotes will be required. Purchasing / buyers will not provide the required information to costing; also they may not take their recommendations on board for cost cutting with regard to the use of different suppliers.

## *5.8.2 Competence Trust*

The previous industrial example is also relevant for competence trust which refers to a perceived level of expertise and ability. The level of competence trust placed in a particular supplier can decide whether or not they win repeated contracts over cheaper, competitive quotes [Floyd and Wooldridge, 1992; Dutton et al., 2001]. This is an example which extends across organisations; however competence trust has frequently been noted within organisations regarding product-costing; of the companies examined this included Nissan NTC, Ford Motor Company, BAE Systems, among others. It occurs when an associated department is unaware of the role of costing, or the benefits that can be gained through its utilisation.

Employment of costing processes can determine how a project should be conducted, through comparative cost analysis; and even whether a project should be embarked upon at all if costs are in danger of exceeding the realistic budgets and limitations of the organisation. The perception of product-costing being vague or a 'black–art'; or a general lack of knowledge about the benefits of the cost-process can be categorised within competence trust.

### 5.8.2.1 Perception

If the perception of costing is that it is not a worthwhile resource, then it will not be utilised. This is linked to the perception of competence in that resource. For instance if the view adopted is that technical specialities are trusted, but the associated social skills are incidental, then challenges created through lack of attention to the latter may result in excessive time and associated costs. This point leads onto the one frequently noted within organisations by costing practitioners, with regard to the perception of the costing process added-value. It was commonly stated that neither engineering nor purchase departments employed their services regularly enough and this resulted in superfluous costs being incurred.

Often product-costing, PC was needed along side engineering and / or purchase to assist in supplier negotiations, supplier assessments, and supplier selection. PC is also required for the assessment of project-costs in general, as well as for specific aspects and modifications e.g. derived from many sources including tear-down, an automotive-specific activity. However on all counts the need for costing assessment appeared to be underestimated. This stems directly from a lack of trust in the competence of the service provided, and in the added-value and aptitude for incurring and reducing unnecessary costs.

An unsurprising observation related to this type of trust was made within a number of larger manufacturing organisations, having been relayed via management. In an attempt to avoid the perception of incompetence of the workforce by management, the department in question would often resort to overestimates in many areas. This was done in order to avoid the over-run of budget, to meet cost-targets and to finish within the (over-)estimated time schedules; as discussed in previous sections. Therefore the perception of competence or incompetence, effectively created a fear culture within certain areas of organisations. It was the workforce's perceived lack of trust as to their competence levels [Singh, 2008] that would in fact drive them to act against the best interests of the company via overestimation, resulting in wasted or inefficient use of resource; and potential uncompetitive i.e. expensive bids and resultant products.

### *5.8.3 Commitment Trust*

Commitment trust relates to the commitments made and explicitly stated within a binding contract; for instance, when specified work has been completed, one would receive pre-agreed remuneration for it. Within the costing domain a clear example of this type of trust can be seen within contracts made by government bodies such as the MOD, and SPS and their suppliers and contractors. It is stated within such working relations that profit must be deemed 'fair and reasonable': This has been argued as too vague by some costing practitioners [Doney and Cannon, 1997], while others have noted that an inability to produce accurate, full audits can lead to individuals deemed responsible being held personally liable. Suppliers who prove to have made excessive profits, beyond the predetermined margins can be held accountable, and thus able to be pursued legally. In these type of situations relations are more or less contrary to those within companion trust, as those working within it are being held to contractual commitments and legal bindings, not bound by interpersonal relationships, and verbal agreements.

Table 5.5 : Types of Trust, related to the Process of Industrial Product-Costing

| TYPES OF TRUST | EXAMPLES WITHIN COSTING |
|---|---|
| COMPANION TRUST<br>Based on interpersonal bonds<br>Foundation is within principles / morals:<br>Gradual development;<br>Once compromised, is difficult to re-establish. | Can be seen between long standing supplier and customer.<br>Open to question by external party, particularly costing if not seen to be the most beneficial i.e. lowest, cost option. |
| COMPETENCE TRUST<br>Related to perception of expertise<br>Confidence of ability to perform task(s)<br>The perception of what skill /competence is considered important is key<br>May also refer to procedures and structures of an organisation | Observed, often detrimentally, between the costing process and interacting disciplines, namely:<br>Purchase for supplier choice and quote analysis / breakdown.<br>Engineers for project planning / cost engineering and estimation; plus regular updates ~as more actual data emerges and for modification /adaptation monitoring.<br>Surrounds the dominant issue of the costing process being involved automatically, not 'as and when required' which is currently commonplace.<br>Visible between management and workforce; can lead to over-estimation through fear culture if not addressed with diplomacy. |
| COMMITMENT TRUST<br>Relates to a contractual agreement of any description;<br>There is flexibility across both sides of the contract boundaries. | Between supplier and customer, particularly relevant to government bodies and the relevant contractors; whose prices and profits need to fulfil the 'fair and reasonable' criteria, e.g. BAE Systems. |

Reference for Table 5.5 [Newell and Swan, 2000]

## *5.9 Summary: Relating Cultural and Knowledge Models to the Industrial Cost Research*

The earlier chapters of this thesis have highlighted the process of costing as requiring a mix of engineering and economic competencies. This chapter has aligned the costing literature with practitioner interviews to reveal the need for a broader approach to the process. It has suggested that the way costing is undertaken, the way problems are solved and dilemmas reconciled

[Schein, 1985] are wider cultural issues than can be addressed by economic or engineering expertise on there own.

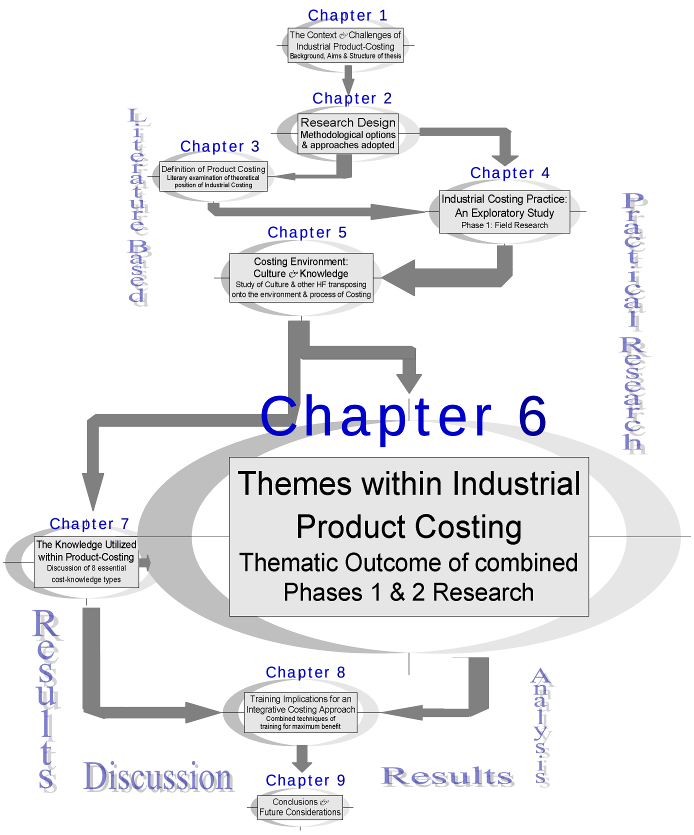
Literatures that are relevant to this broader interpretation, such as knowledge management and organisational learning, have been introduced and the resultant themes from the chapter are summarised in Table 5.6. These will form the basis for Phase 2 of the organisational-based research that is documented in the following chapter.

Table 5.6: Knowledge and Culture Literature themes, Relevant to Product-Costing

| **THEMES** | **SUB-THEMES** | **RESULTS** |
|---|---|---|
| Organisational Culture | Individualism / Communitarianism (IDV) | Promotes segregated working practices; may be difficult to nurture required level of interaction |
| | Particularism / Universalism | Specifically costing has been described as an individualistic process, full of expert judgment and tacit application of knowledge. |
| | Risk (UAI) | May have greater inaccuracies; and / or higher rate of successes through innovative means) |
| | Gender (MAS) | Natural inadequacies of essential working characteristics, due to contributors consisting overwhelmingly of only one gender. |
| | Specificity / Diffusion | Some aspects approach from 'the whole' and combined the elements of; whilst others focus on specific areas. I.e. Cost estimator and cost engineer in BAE Systems, respectively. |
| | PDI | Training implications |
| | | More open competitiveness. |
| | Communication | Inadequate data –flow<br>Lack of integrated practice |
| | | Not knowing who to contact, for what information |
| | | No means to contact; no processes in place |
| | Lack of Understanding | Fear Culture |
| | | Inadequate transfer of information |
| | | Misperceptions of roles; un-utilisation |
| | | Escalated / inaccurate costs / time, etc. |
| | Trust | Fear Culture |
| | | Lack of data-flow |
| | | Suspicion |
| | | Lack of integrated working practice |
| Knowledge Types: | Explicit / Tacit | Tacit challenges left unaddressed; perceived as 'soft' issues which are accepted as unimportant. |
| | | Tacit knowledge needs to be identified, captured and reused |
| | Knowledge creation | Gaps needs to be identified |
| | Knowledge conversion | SECI process needs promotion / implementation |
| Knowledge Management, KM | Trust and empowerment | Recognition of tacit knowledge |
| | Systemic Thinking | Looking at 'whole', not segments in isolation |
| | Adequate use of IT | Is limited to the users of it; & the facility provided |
| Organisational Learning, OL | Trust | Embracing multiple perspective |
| | | Experimentation / innovation |

# Chapter 6:

## Themes within Industrial Product-Costing




*"There's very much an 'us and them' culture present, for the employees and management respectively.*
*..In this respect*
*(through overestimations..)*
*..means that the workforce are acting directly against the best interests of the organisation*
*…this needs to be changed so everyone's working together -towards the same goal."*

[Cost Manager: Large Aerospace / Manufacturing Organisation, 2002]

*"We need to raise the profile of estimators..*
*…increase the understanding of what we do,*
*…in order to get more time and resources to produce results"*

[Cost Manager, Automotive Organisation, 2005]

This chapter will discuss the costing themes that emerged from Chapter 4, see Figure 6.1. The main issues and other challenges related to the cost-process which initially arose from the study, have been characterised thematically. The above quotes are typical of the type of responses encountered during the exploratory research, Phase 1 (P1); and are consequently examples of how the costing themes were deduced. A systemic examination of these themes allows the interrelationship between them to be highlighted, illustrated in Figures 6.3 and 6.4: They are subsequently linked to the Cost Knowledge Framework discussed within the following Chapter 7.

Within this chapter each theme and its costing relevance are discussed individually, with use of thematic tabulation to highlight the linkages between the essential cost-knowledge types. The latter end of the chapter briefly delineates the themes in relation to training implications, which is discussed in greater depth within Chapter 8.

## *6.1 Derivation of Phase Two*:

The first phase of research was exploratory and derived through a critique of the cost related literature, detailed in Chapter 3. This supported the examination of the industrial costing-process that was presented in Chapter 4, and prompted subsequent reference to a social perspective. The expanded research undertaken within Phase 2 (P2), could now be grounded within a milieu of human factors, and is depicted in Figure 6.1, a flow chart illustrating the relationship between the research activities.

### *6.1.1 Conceptual Framework*

The combination of the analysis of the documented material and industrial exploratory observations in Phase 1 identified a gap in the way in which product-costing was addressed. This oversight was in the form of a lack of recognition and attention towards the social and HF influences on costing. This created the need for a widening of the research focus, the theoretical aspects of which have been discussed within Chapter 5: This chapter elaborates on the need for this added research dimension.

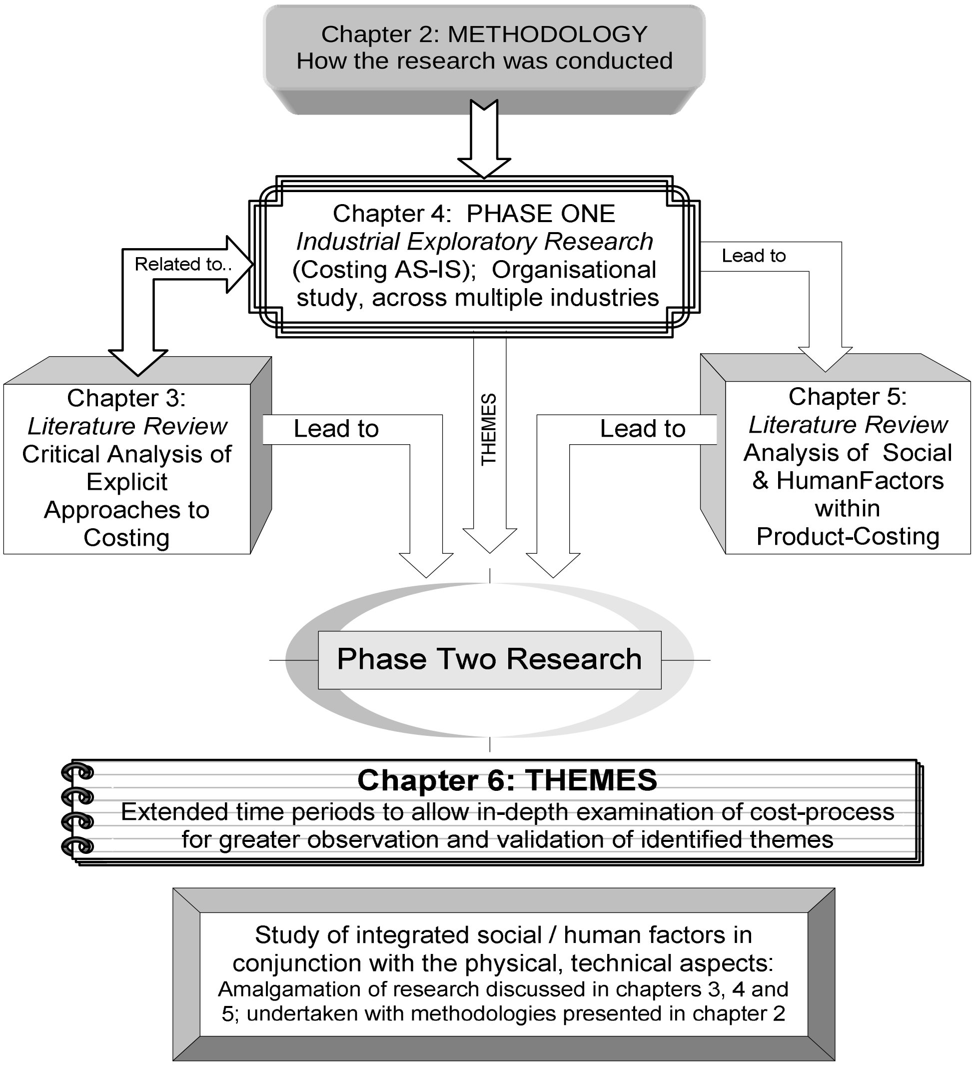



Figure 6.1: The Flow and Focus of Research, Leading to the Derivation of P2.

The outcome of the prior mentioned combined research, presented in Chapters 3, 4, and 5 created the conceptual framework, highlighted in Table 6.1. The table outlines the identified general characteristics and variables for product costing, subsequently giving cause for the extended social factors, alongside the technical more physical ones within the continued research of Phase 2.

Table 6.1: Conceptual Framework derived from Phase 1 research:

| **COSTING ATTRIBUTES:** | **SUB-ATTRIBUTES:** |
|---|---|
| *Explicit Technical* | *Engineering* |
| | *Economic* |
| Human Factors overlay | Culture |
| | Knowledge |
| *Integrative attributes (Holistic)* | *Communication* |
| | *Understanding* |

As can be seen from Figure 6.1 the integrated consideration of the previous documented and industrial research lead to the holistic characteristics of costing depicted in Table 6.1, from whose range and configuration of attributes, emerged the questions examined throughout Phase 2. The following are a selection of the questions posed to costing practitioners during each research phase:

Phase 1 Questions:

- How is the industrial costing-process performed?
- What are the perceived challenges encountered?
- What data and information are required to compile the costs?
- From where are they procured?
- Are they easy to obtain?

Phase 2 Questions:

- What Knowledge ~which types~ are involved in costing?
- Who needs this knowledge and costing information?
- Are those who need it able to gain access to it?
- Which knowledge–types are deemed essential?
- Why are these specific knowledge-types required?
- What training is required for product-costing?
- What training is currently available?
- What are the prerequisites for a costing practitioner e.g. knowledge and background?

Hence, it can be seen from the juxtaposition of the AS-IS phase and the technical and human factors literature, that a holistic conceptual framework for product-costing may be derived. This constitutes two main themes, Knowledge and Culture; and then subcategories, providing a set of research qualities and subsequent questions for P2. This emerged as it rapidly became evident that such crucial contributors could not be overlooked if the area under examination was to be addressed fully, see Figure 6.1. Phase 1 questions examine costing holistically, establishing the process and stages involved; whilst Phase 2 progresses to discuss the intricacies of product-costing, including establishing the main challenges experienced, and identifying the knowledge-types used.

### *6.1.2 Areas of Focus*

Phase 1 examined the way in which product-costing was performed from a comprehensive, universal position. This incorporated a study focusing around:

- What activities and / or functions are required to produce the end result;
- How these areas communicated and worked in an integrated manner;
- An assessment of commonly perceived challenges to the process;
    - What form they took
- Practitioner opinion as to how these difficulties might be effectively addressed.

The original structure of how the exploratory stage was conducted has already been relayed in Chapters 2 and 4. The former discusses methodology options; and the latter explains details of the techniques applied, including the questions asked, and why. Refer to previous sections for further examples of questions; and for full questionnaires see Appendices 1 and 4. Consequently the original focus of Phase 2 was to identify and examine the types of knowledge required to perform product-costing; to determine which domain was traditionally perceived as 'owning' these knowledge type, i.e. engineering or economic; and whether this matched the identified areas that required the knowledge.

Phase 2 scrutinised the major themes which emerged from the exploratory phase. P2 was specifically designed to have a greater period of time within each organisation, in order to study the issues in greater depth then P1 which was to establish the process, and basically gain familiarisation of the subject-domain. Therefore in P2 the themes can be explored within expanded contexts to check for rigour; whilst subsequently enquiring into related areas. The original findings, of the six main cost-themes are thus validated against the extend focus which was introduced in the previous chapter and elaborated on in this section of research. This is represented in the graphs 6.5 and 6.6 within the latter half of this chapter; also see Chapter 4.

### *6.1.3 Research Scope*

The previous research, as stated was conducted in preparation for this section of work which was designed to encompass greater depth and detail due to it being a more focused examination of the participating company processes, depicted in Figure 6.2. The previous range of observations in P1 were scoped, in order to allow a more in-depth and thorough level of examination in P2-A; and the numbers of companies examined were reduced to allow more time within each one; see Phases 1 and 2-A in Table 6.2. It would not have been feasible in this project to examine the same level of organisations as was looked at in P1, to the depth that was required for the first level of Phase 2, i.e. in P2-A, primarily due to time constraints. Therefore the twelve organisations included in P1 were reduced to six for P2-A of in-dept, scoped, focused, thematic examinations, see Figure 6.2 for illustrative guide of this aspect of research design. Three were looked at in Phase 2B; this section had the added dimension of capturing an additional geographic perspective within the U.S.; and three more were added to Phase 2C, whilst researching the cost-

knowledge framework implementation including training intervention and validations: A full list of industrial participants is presented in Table 6.2
Phase 1 was used as a basis for this chapters work, see Figure 6.2. In order to feasibly conduct a more detailed study, some scoping of the original sample was necessary. Although the depicted scoping of companies shown within Figure 6.2 had been planned from the outset of the research, the focus of this phase was modified in accordance with the primary findings of P1 (AS-IS results), as previously explained; see Chapter 5. To elaborate, a number of concerns expressed by the practitioners were ultimately linked to insufficient or ineffective communication. This manifested in anything from company software application, to actual practitioner skills with regard to personal interactions. In relation to this, communicational challenges were compounded by cultural misconceptions, or even founded by them. For instance a common observation was the fear of job-security, or lack of, which prevented the dissemination of knowledge. Suspicion lay in requests for information, when the potential contributor speculated about whether they were "..being checked-up on": And / or if the knowledge was imparted that perhaps their role and value would be undermined and even eventually unnecessary.

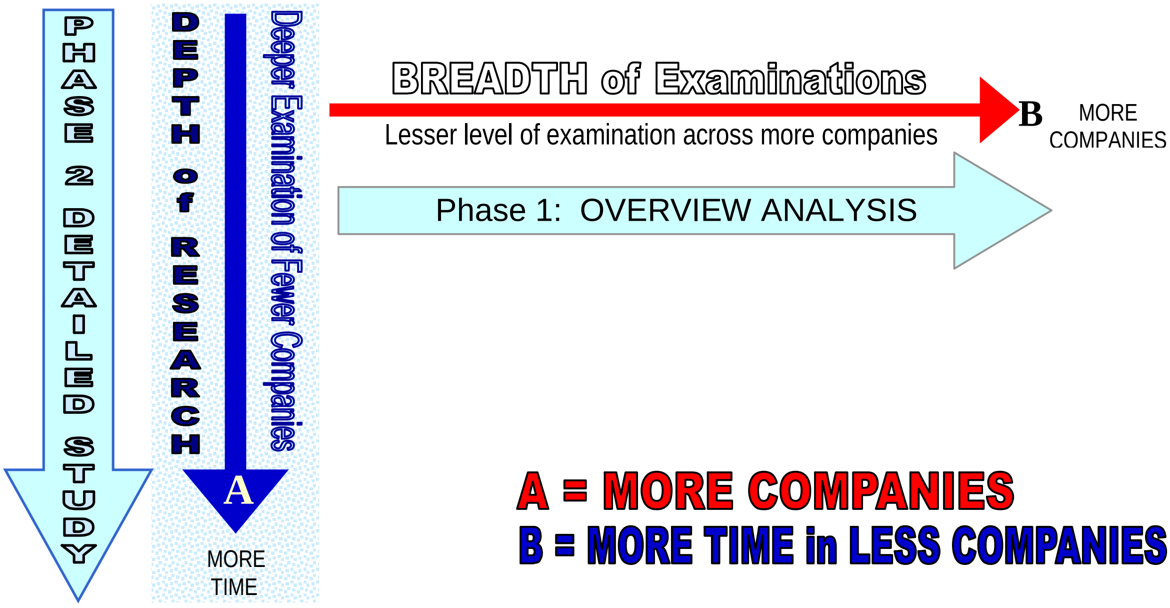



Figure 6.2: Intention Behind the Research Design:
P1 has Breath of Results whilst P2-A has Greater Depth.

Therefore, it was observed that anything from the particular interaction between the two parties, to the whole culture of the company was in need of some cultural-awareness insights. This was to establish exactly what detrimental issues were occurring per department / organisation due to cultural clashes, which impacted on comprehension and integrative working as discussed within Chapters 4 and 5. Therefore focusing attention on the culture of costing and its surrounding workplace or environment would potentially improve communication and understanding between the interacting bodies. Another issue which effected communication was that of time limitations: For example if an engineer was busy or perceived as overworked, the minimum amount of information would be forwarded to the cost-practitioners due to time constraint on the engineer. As comments received from varied cost-practitioners frequently expressed that the more information / data they received, the more accurate and rapidly produced the cost-result would be; the instance where a low level was obtained, resulted in the creation of challenges. It is in such an event where clearly communicational abilities are important in order to procure the maximum level of information. For instance, if only a final figure was given to the cost-practitioners, when ideally the detail of what this figure comprised of was needed to cross-check and validate the costs, it would benefit the cost-practitioner if they knew:

- Which specific engineering department provided the information;
- How to contact them, so more detail could be requested;
- Plus where they were located to assess potential for one-one interactions, or at least to get in contact quickly;
- If the specific engineers were known to the cost-practitioners, the request could be made personally, with direct contact with the contributor;
- This would save time relaying messages back and forth, via impersonal means e.g. emails, request forms, or even via third parties.

In addition to this the situation may not have arisen if the corresponding party i.e. engineer, had a greater awareness or appreciation of what was involved in the costing role: If they had known they may have provided an adequate level of information to begin with. Such instances show unequivocally that the softer factors, including communication, culture (fear culture), and understanding have influence on the process, so must be considered concurrently when examining product-costing. Incidentally, all of the aforementioned have been identified as primary Cost –Themes: All six of the Themes are interlinked with each other, as graphically described in Figure 6.5.

This chapter examines industrial product-costing in greater depth than previously, spending more time within the organisations in order to build on those initial findings of the exploratory study, consolidated in the Themes, see Chapter 4 and later sections of this chapter. The challenges derived from Phase 1, inclusive of the more intangible areas of costing are subsequently examined in greater detail.

### *6.1.4 General Industrial Participants*

A systemic assessment of the field-research, considering the combined phases of all interactions, revealed that the costing-practitioners involved throughout the data collection were generally from a technical background: With the majority, approximately 85% having been trained via the practical route of technical apprenticeships. Almost 50% also had academic degrees in a related subject, or were currently undergoing degrees sponsored by their company within their industrial disciplinary domain.

#### 6.1.4.1 Knowledge Elicitation:

The number of organisations that contributed to the overall research totalled twenty-four; from which the individual participants numbered one hundred and two: This complete list of contributors for all phases of research is recorded in Table 6.2. As explained in Chapters 2 and 4, personal and group interviews were conducted: These were semi-structured and often guided by a pre-designed questionnaire per section of research. For instance the exploratory phase had a specific questionnaire for the research focus at that stage, given in Appendix 1; along with sections of P2 including a training-issues survey; see Appendix 4. A small minority of the knowledge elicitation was conducted via telephone interviews, and workshops; a larger minority included group interactions: Though the majority when examining the phases jointly were individual interviews.

Table 6.2: List of Industrial Contributors within Research Phases 1 and 2

| RESEARCH PHASE: | *ORGANISATION:* | *INDUSTRY:* |
|---|---|---|
| **2000-2001** PHASE ONE **AS-IS, Exploratory Study** | Ford Motor Company | Automotive |
| | Ford Finance | Automotive |
| | Nissan, NTC | Automotive |
| | Lotus | Automotive |
| | BAE Systems | Aerospace / Defence |
| | Airbus | Aerospace |
| | T5 (Terminal 5) BAA | Aerospace commercial, Service sector |
| | GKN Westland Helicopters | Aerospace / Manufacturing |
| | M.O.D. | Defence (Government) |
| | Cognition | Software |
| | TTW | Software |
| | Alstec | Manufacturing |
| | Rolls Royce | Aerospace / Manufacturing |
| **2002-2006*** PHASE TWO A **In-depth Observations** | Ford Motor Company | Automotive |
| | Jaguar | Automotive |
| | Land Rover | Automotive |
| | BAE Systems | Aerospace / Defence |
| | Airbus | Aerospace |
| | S.P.S. | Defence (Government) |
| | M.O.D. | Defence (Government) |
| PHASE TWO* B **USA Input** | Price Systems | Software |
| | Lockheed Martin | Manufacturing (Aerospace / Defence) |
| | U.S. Navy | Defence / Military (Government) |
| PHASE TWO* C **Training & Updates / Validation (2005)** | WFEL | Manufacturing / Military |
| | Nampak Plastics Europe Ltd | Manufacturing (Supplier) |
| | Rolls Royce | Aerospace / Manufacturing |
| | JLR | Automotive |
| | Nestle | Food |
| | SPS Technologies | Manufacturing |
| | Ford Motor Company | Automotive |
| | BAE Systems | Aerospace / Defence |
| | Price Systems | Software |
| | The Aerospace Corporation | Aerospace / Space Technology |

Please note: The industrial classification in Table 6.2 was established by practitioner in-put as well as via the companies official websites.

The total number of interviews conducted was one hundred and eighteen, as some practitioners contributed more than once relating to the various areas of interest, but no more then three times. For instance there were two visits to the U.S., over two years: During the second visit, approximately 50% of those interviewed had participated during the first visit, but towards a different area of focus. For example, the first visit focused on the specifics of the process itself and challenges; the second on the identified knowledge types and proposed training interventions. Workshops were also conducted which aided in the knowledge identification, discussion on how to disseminate such findings, which included development of training content;

detailed further in Chapters 7 and 8. The total research was conducted across the industries as classified within Table 6.2. For practicality of analysis and to aid comprehension of the results, the industrial differentiation drawn within this work has been scoped to focus on three areas:

- Aerospace,
- Automotive,
- Manufacturing or *'Other'*.

As can be deduced from Table 6.2 the classification of manufacturing / 'other' therefore encompasses a range of contributors; from SPS, (Special Procurement Services) to Nestle, the manufacture of food products and beverages [United Nations Statistic Division, 2008]. A number of the 'other' industries were based around manufacture of some type, e.g. WFEL specialise in military bridge-building; Alstec operates across five market sectors including airports, defence, nuclear and thermal power, and caters for specialist material logistical needs [The Engineer online, 2008; Thomson Financial Venture Economics, 2008]. Lockheed Martins domain includes defence contractor, aerospace manufacturer and advanced technology development [http://www.lockheedmartin.com, 2008]; SPS are the principle procurement service for MOD; whilst Cognition and Price Systems provide cost software tools for a range of industries particularly those manufacturing-based, along with the relevant support required for the users.However it was impractical to attempt to assess all relevant industries included within this study separately. Therefore although the costing practices within each organisation have all been fully analysed and hence equally contributed to the research findings and cost-knowledge framework, industrial differentials have been drawn for the three as listed above. See Figure 6.7 and Table 6.11 which present results for the industrial classification of Aerospace, Automotive and 'Other' for all organisations within Table 6.2. Plus refer to Table 4.2 in Chapter 4 for the specifics of P1 industrial contributors.

*DATA-COLLECTION STATISTICS:*

- *Number of Industrial Participants:* *102*
- *Number of Interviews:* *118*
- *Number of Organisations:* *25*
- *Number of Industries:* *6*
- *Range of levels of Experience:* *From 2 months To 34 years*
- *Range of Roles:* *From Junior / Trainee*<br>*To Senior Management / MD position*

The primary location for the knowledge elicitation was from within the UK, where the majority of interviews were conducted on-site within the environment of the participating practitioner: However a significant minority were carried out within U.S. In order to establish a rounded view of the cost-process and the development of competence / expertise within this area, a range of experience levels were deliberately targeted for examinations instead of aiming observations towards the most experienced members of the community. As the industrial implementation of the results were a focus of investigation, which in turn incorporated training implications, the challenges that materialised from all levels were of interest, particularly that of the cost –novices. Insights were also sought comparatively between the levels. In other words, from expert to novice with the difference between them being formulated into training, were possible.

The fundamental function of product-costing, PC was to assess the cost of product. Whether at conceptual design phases, at the bidding stage, for upgrade or refresher model, or whether validating supplier quote / costs. In order to do this a certain level of interaction with the functions that contributed to the cost, was necessary. This systemic view of costing involved gaining an understanding of the roles of interaction. An appreciation of what these contributing functions comprise of, and how they interact and overlap with PC gave more holistic insights into the process and how integration could be improved. Consequently the disciplines which most frequently interacted with PC were established and examined within the research whenever the opportunity arose within the organisation listed in Table 6.2, as listed below. However the main focus of the research remained within the costing departments themselves.

#### 6.1.4.2. Range of Disciplinary Domains Examined:

- ✓ Product-Costing role *
    - Cost Estimating / Cost Engineering
    - See Table 4.2 in Chapter 4 for range of inclusive Job–titles, (terminology)
- ✓ Purchase; also referred to as 'Buyers' / 'Procurement' *
- ✓ Engineering (manufacturing) *
    - Various engineering / production disciplines
- ✓ Product Developers / Vendors (software) *
- ✓ Finance, including Accounting
- ✓ Marketing
- ✓ Sales
- ✓ Supplier (Contractor / OEM)
- ✓ Management Functions

The above lists the areas of expertise that contributed to the findings, along with PC. Each discipline listed has significant interactions with PC and therefore needed to be considered in the research, with the first three * being key.

- The role of Purchase is discussed at length throughout the thesis: To summarise this tends to be the department which selected the supplier company; the supplier would often interact with the user-organisation throughout project lifecycles: So a cost-effective choice was important. Purchase also tended to control the degree of involvement which PC had in this selection process; from inclusion in the bid assessment submitted from potential suppliers including determining the degrees of information relayed to costing; to negotiation interactions with them.
- Engineering departments e.g. Design, R&D, Production / development, Manufacturing, all significantly interacted with costing for an array of reasons. These included conceptual estimates to budget setting, risk analysis, change management, and / or even to determine whether the company could afford for projects to commence at all.
- R&D contributed towards bids, i.e. provided the number of prototypes that expected to be used, time scales and so forth.
- Manufacture would need to input predicted costs with regards to labour hours, specialist costs, timings, among other considerations.
- The product-developers in software organisations held a similar role to the prior mentioned, in providing lines of codes used, time-scales for developments i.e. in labour hours, and other such information.

- Finance often set targets and needed to interact with product-costing through projects from a budgetary stance.
- Marketing inputted towards product-costing regarding market trends e.g. predicted consumer demands.
- Sales, for upgrades and future product-estimates.
- The supplier, OEM, and contractor required assessment by PC, so there was often interaction prior to selection and usually regular transactions between them particularly in the large organisations, once the project was in progress. Cost breakdowns and quotations needed to be analysed and approved by costing; as well as supplier techniques / manufacturing sites needing direct evaluation whenever possible.

On analysis of the data, see Table 6.3, a number of themes emerged from P1, which were then validated and further examined within P2: They consist of the main issues that arose around the area of PC, see Figures 6.4. and 6.5.

## 6.2 Thematic Analysis:

There are six themes within which are a number of sub-themes which are all generally interlinked to each other, illustrated basically in Figure 6.4 and in more detail within Figure 6.5. The themes are discussed throughout the remainder of the chapter, see Sections 6.2.1 - 6.2.6 with their relation to the essential cost knowledge-types being presented within Tables 6.4 - 6.9. Additionally each knowledge type is discussed in greater depth in the proceeding Chapter 7.

Table 6.3: An example of the Coding and Classification Technique of detailed Data-Analysis

| STATEMENT No. | THEME | KNOWLEDGE TYPE | KNOWLEDGE CATEGORY |
|---|---|---|---|
| | T1 | KT7 | KC1 |
| S1: Personal communication has been lost! People need to talk to each other more, in order to avoid misunderstandings which waste time! | T3 | KT8 | KC2 |
| | T4 | | KC3 |
| | T5 | | KC4 |
| | | | KC5 |
| S2: | " | " | " |
| | " | " | " |

Figure 6.3 illustrates the technique used to identify and link aspects of each theme, with initial colour-coded, wall-chart style schemes. The themes were initially identified via this type of coding and clustering system; part of the actual analysis undertaken for this research is pictured in Figure 6.3, as discussed in Section 2.5 of the methodology Chapter 2.

The intensive coding and classifying system used to derive the themes (and knowledge types) were done via a structured data-analysis method, discussed in Chapters 2 and 4. Basically each theme was labelled, T1-T6; as were the knowledge types, KT1 - KT8; and knowledge categories, KC1 - KC8, see following Chapter 7 for greater discussion. Then each statement given by the interviewee was classified against the above criteria, undertaken as shown in Table 6.3 which gives an example of the coded analysis.

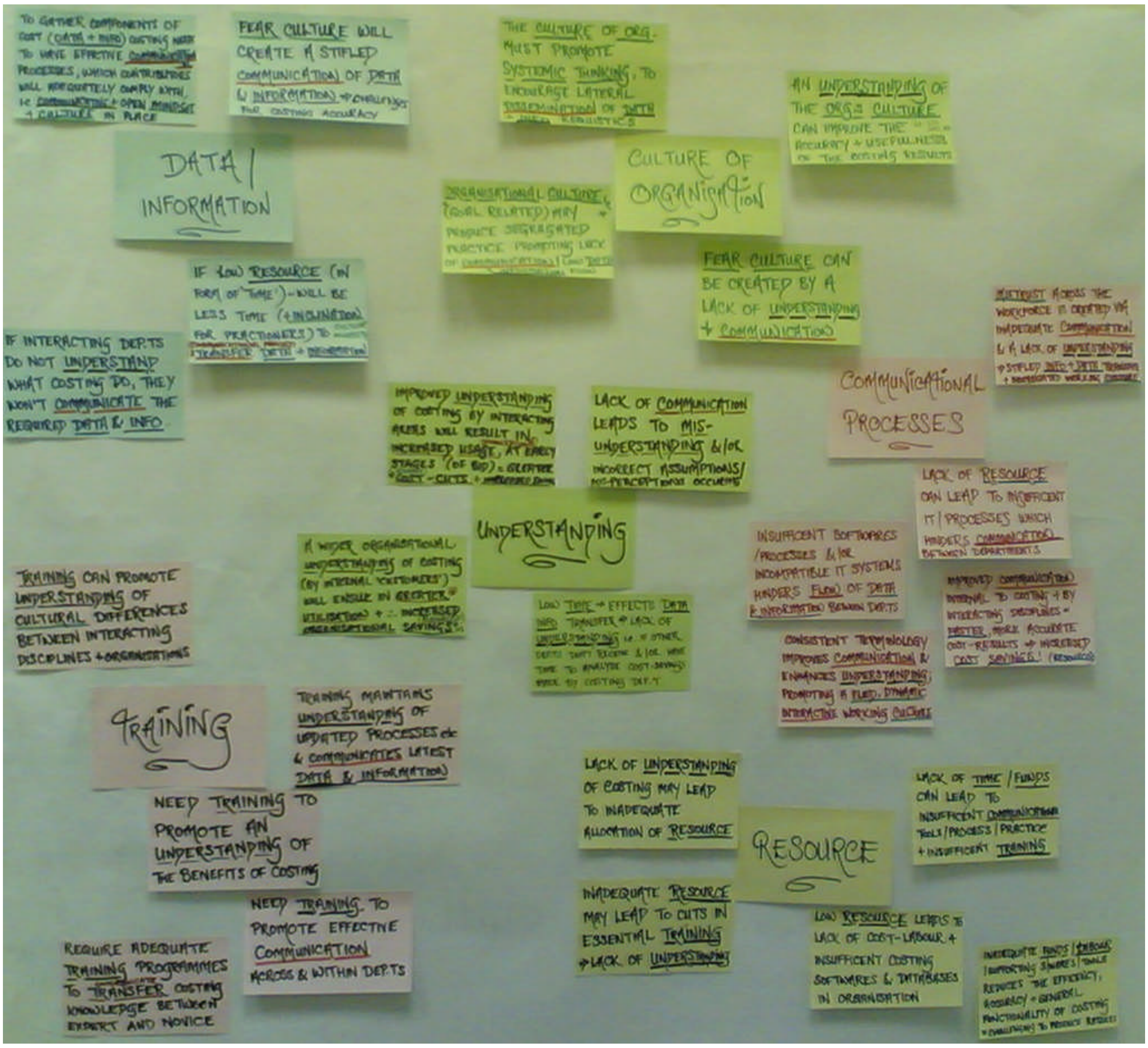



Figure 6.3: Depiction of the Technique which Derived the Thematic Grouping and Linkages of the Raw Data.

Once the interviews had been analysed, the results were placed within SPSS, a statistical analysis software package. SPSS produced the graphs / tables which gave the frequencies and cross-tabulations of the results against each other; showing the prominence of each, and immediately illustrating any points of interest, or relevant issues.

This pragmatic, hands-on system was employed in order to identify vivid visualisation of the reoccurring issues, i.e. essentially the Themes and subsequent links between them. It aided in the recognition of the prominent issues emerging; reinforcing data familiarity and analysis. The statistical analysis reinforced the physical colour-coded breakdowns as illustrated in both Figures 6.3 and 6.5, whilst converting the results into numerical values, providing data in a format which could be assessed comparatively; and which highlighted detail. The identified six themes are discussed in the following sections, and illustrated in Figure 6.4.

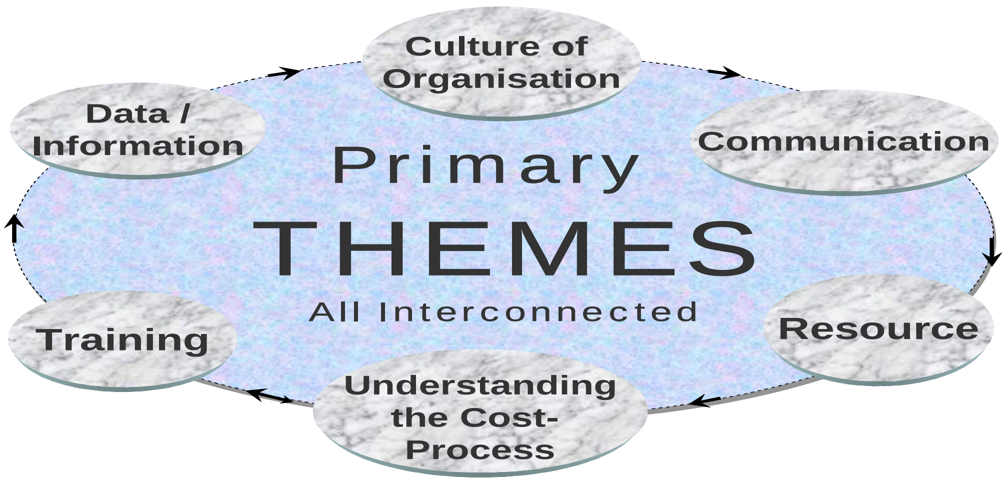



Figure 6.4: The Six Interlinked Cost-Themes

## *6.2.1. Resource:*

The issue of resource was a recurring theme, throughout the organisations examined. Resource deficiencies affect costing in both explicit and implicit ways, as will be explained. Though to summarise, the explicit manifestations of decreased resource often ultimately lead to implicit results: For instance issues as having a lack of time will impact on communication levels; and subsequently how interacting departments appreciate costing needs. Without adequate communication, misunderstandings will occur, creating a lack of trust and general inflexible working practices; the main manifestation of which is through a reluctance to impart requested information. Overall cuts to the workforce often result in demoralization of the remainder of employees, which has been shown to detrimentally affect working attitude and application; as well as the levels of trust towards management and the overall organisation.

### 6.2.1.1. Typical Effects:

The level of resource available impacts across every area of a project, including that of product-costing; therefore there was a generic element to this theme that could be detected, in the sense that a number of pragmatic issues which affect costing will also affect other departments in a similar manner.  With this said there are also idiosyncratic aspects to the way resource handling affected the costing departments examined.

The general impact includes the observation that when budgets are reduced, it tends to effect projects across the board, as opposed to applying to only one or other area. With regards to costing, the consequence of general cuts tended to result in an increased workload, within ever-reducing timeframes; all expected from the same amount of labour. With this said it is not unheard of for specific departments to be targeted, though there will often be a reason for this, such as their costs tending to fall markedly above the other costs, or consistent overshooting of budget allocation. This may be observed from any component / engine part failing to DTC (Design-to-Cost) which may result in a VEVA meeting: Where expertise is gathered to collectively brainstorm and then formulate in detail potential reductions.

When a budget decrease is imposed an explicit result may be the loss of a percentage of labour. This may be accounted for in labour hours; the more expensive levels of expertise e.g. consultant time; head counts may be reduced, resulting in perhaps two people absorbing what was previously three jobs, and so forth. Each scenario will affect the workforce attitude and morale, and / or product out-put, not just due to tacit elements as low morale; but sometimes as a direct consequence of lost skills. Such cuts could ultimately be counterproductive explicitly at times as explained within a large automotive organisation: When budget-cuts lead to losses in the immediate workforce, the expertise which had been released was still required. So it was felt ironic that the same practitioners were hired back in consultant-capacity to provide the specialist knowledge they held. Additionally it was noted that the fees charged by these employees were subsequently significantly larger then the practitioners would have commanded when they were employees of the firm, as one cost-practitioner stated:

*"..laid off.. got rid of the expertise.. ..ironically they're back again ..as consultants.. ..next week doing the same job for triple the pay!"*

[Cost Estimator, Automotive industry, 2002]

In this instance the short-term budgets-cuts lead to long term additional costs, plus a potentially unstable knowledge-base as the expertise in the form of external consultants, now independent of the company; so possibly not always available when required. Additionally they may not be in the position where they were willing or readily able to transfer their knowledge; potentially resulting in the company being unable to retain and reuse it.

Insufficient resource may lead to the cancellation of whole projects, potentially undermining the stability of the company long-term, when new investments / products are not developed, produced and marketed. It may also lead to changes such as outsourcing against in-house capabilities. Cost comparison exercises will need to be undergone with the results affecting the status quo in the organisation, whichever way the decisions are made. For example, it may be decided that it is more cost-effective for a number of components to be outsourced. This may be deduced after consideration of capital and running costs, when examining in-house capabilities. Outsourcing may lead to the necessary loss of in-house labour of whom usually perform such activities / functions, as firstly the labour may not be required any longer. Secondly, savings will need to be made in order to pay for the now outsourced goods. These are the immediate effects: Long-term, the in-house expertise may be lost to supplier companies, similarly as with the consultant situation of ex-employees, who in turn will then be in a position of strength, e.g. can dictate prices charged and so forth. Bosch was given as an example of a powerful supplier organisation, with this described type of influence over its customers.

### 6.2.1.2. Specific Outcomes:

Throughout the various options and outcome of the generalised effects related to resource, e.g. budget-cuts, allocation, the product-costing function are often required to analyze and compare the various cost options. Therefore they will indirectly have work-related activities linked to resource considerations, from this stance. More specific effects can be viewed with regards to time shortages within costing, which often impact the levels of communication. A major concern was in the fact that vital interpersonal interactions were subsequently reduced or not routinely possible. Lack of this type of communication leads to misunderstanding and misinterpretation which ultimately hinders the flow of costing transactions between the required areas. For instance, if there is less time to explain what is being done, the correct level of information may not be relayed. An example of this is when a costing practitioner verbally communicates regularly with the design-engineer for the component that they are collaboratively working on. The result is often that an adequate amount of information will be freely obtainable between them; and if the conversations take place at conceptual design stage, the part may be developed with costing input, avoiding escalated, unnecessary costs. However with the reduced time and / or labour hours, both parties may be working to the point where only a minimal interaction is possible. The costing practitioner may be responsible for a number of components, and it was not uncommon for them to have additional responsibilities to product-costing. For example, in one large automotive organisation they were each responsible for different parts of the vehicle. This included engine types / each component, where all aspects of that area, its development, its redesign and so forth, would involve the particular cost-practitioner who was allocated to it. Therefore when time was stretched, limited interactions took place resulting in a hindered flow of essential information and knowledge. If the lack of resource results in the practitioner being given a basic drawing to produce a cost from, the result will not be as detailed or have as high confidence levels as if they had had more input and interaction with the contributor of the information.

Another serious consequence of a lack of communication and understanding potentially stemming from resource deficiencies as well as other factors, had been observed when the other areas of the organisation do not understand the value and contribution of costing, including management / financial sectors. This has resulted in reduced funding for the department, who have been perceived as not adding value. Within one particular international automotive organisation, this action created a self-fulfilling reaction in the sense that insufficient labour and time to produce costs, resulted in low output from that department. As management had not understood the value of costing, this misunderstanding was relayed through the allocation of resources, or lack of them, which simply reinforced the misconceptions held, as the below quote alludes to, and which is expanded on in the following sections:

*"Cost estimating has a problem because it has a low profile. …But management's a key problem; they don't understand were the cost estimators role is in the company and the value we add."*

[Product-Cost Manager, Automotive Industry, 2001]

The level of resource will affect the depth / quality of the costing outcome, mainly through dictating the number of hours allowed to work on it, which may be reduced. Therefore less detail will be able to be incorporated, and a ROM (or Rule of Thumb) estimate may be the only option in the time provided, with the resources available; see Chapter 3 for costing techniques. This was the case within an automotive cost-department, who stated that they had undergone cut-backs over the years, and as a result were currently unable to perform detailed costing techniques due to simple lack of time / personnel; they were too low on labour to compile the information required and spend time producing the costs: They also had little time for supplier-site visits, which was stated as beneficial when negotiating the reduction of the supplier costs, as explained by the following two cost practitioners:

*"…previously, we could do detailed estimates each time …spend time building up the costs ..adequately assessing them; …our results had high-level confidences…*
*Now it's just not possible ..to that degree of detail …too much time which we just don't have these days. …Detailed estimates are just not expected …it's all ROM"*

[Senior Cost Estimator, Automotive Industry, 2005]

*"I would like to visit suppliers each time …not possible ..no time, ..just not enough resource available for that. …puts us in vulnerable position when it comes to negotiations …haven't seen their processes, …so ultimately the supplier knows we can't comment or contradict their costs with any certainty.."*

[Cost Estimator, Automotive industry, 2005]

This time pressure also largely contributed to a lack of trained practitioners as well as reduction in time to produce the cost, hence necessity for ROM more often then detailed estimating, see Chapter 3 for costing techniques. It also impacted on the depth in which costing was performed, e.g. not enough time or budget allocation for supplier visits; so was generally perceived as negatively impacting on the costing-results / quality to which they were able to perform the process.

#### 6.2.1.3 Links Between Resource and Cost-Knowledge Types:

In addition to the identification of the main challenges which have been analysed thematically, the knowledge used to produce a cost has been established specifically, and is discussed in the following chapter. The relationship between these process challenges and the process knowledge types have been tabulated and are presented within each theme-section.

Table 6.4: Relation of Resource to the Knowledge Framework

| **KNOWLEDGE TYPE** | **THEME: *RESOURCE*** |
|---|---|
| Costing Process Knowledge | Affects type of costing technique that can be used e.g. ROM (parametric) or detailed |
| | Time pressures: Result in lower accuracy if less time to gather information and compile costs. |
| Manufacturing Process Knowledge | Insufficient time to determine innovative processes. |
| | More outdated equipment / machinery may be employed, creating greater costs then if purchase updated / better quality products. |
| Knowledge of Design | Insufficient time to determine, and hence implement most advantageous design options |
| Knowledge of Materials | Decreases time to trial (test) better, cheaper new materials; so cannot be used. |
| | To suggest appropriate alternatives, if cost-saving options involve material changes. |
| Knowledge of Product | Can affect time to predict future performance via studying product.<br>If less time can miss cost-opportunities; if funds are excessively diminished can compromise product maximisation. |
| Knowledge of Risk | Low time / finance affect supplier visits |
| | Increase risks if labour and / or time is reduced, as will not be predicted properly / too little time to assess thoroughly. |
| Communicative Knowledge | If low resource, can result in insufficient time to communicate personally and via processes; |
| | Plus lack of adequate IT to transfer information will hinder transfer |
| Cultural Knowledge | Different areas will be affected in different ways by resource cuts; time-pressures and budget cuts will affect working environments, possibly creating fear culture / heightened competition e.g. between departments & / or individual practitioners, for fear of job losses. |

Table 6.4 highlights the direct relationship between the cost-theme of resource against all of the other eight essential cost-knowledge types, which arose from the accumulative results of both research phases. The Table shows how the knowledge and themes are interlinked, and

therefore influence each other. It reinforces the situation where a systemic view of costing and its environment must be adopted as any occurrence does not happen in isolation, but instead impacts on the whole system it is within; as is shown by the knowledge-types all being influenced by issues of resource.

### 6.2.1.4. Supplier Assessment:

Another main concern of the costing community was supplier analysis. An experienced practitioner within a large automotive organisation explained how on-site supplier visits are preferable to a purely paper analysis of their costs; see previous practitioner quote. When on-site, there is the opportunity to assess the manufacturing techniques implemented, gather realistic ideas about the labour levels required and employed, material batch-sizes, and so forth. Each of these aspects and more are included in the quotations, and need to be negotiated. If the user-company has not been able to examine the suppliers' premises first hand, the practitioner explained that it can then be difficult to argue the case for cost reductions. It was stated in this organisation that a lack of time, resulting in high workloads, were the main reasons for lower frequency of supplier visitation than was necessary. However, other organisations did state that insufficient funds also contributed to their diminishing on-site visits, particularly when it came to assessment of every overseas supplier.

### 6.2.1.5. Training:

One of the first areas to be cut-back on when budget decreases are imposed was said to be training. This affects the costing community in a detrimental way, across the board, from novice to the more experienced cost-practitioners. With the latter, difficulties occur because courses which may update, refresh or expand upon their current knowledge will be axed, tending to be viewed as 'an extra' or unnecessary cost. Even if this is not the case and the option of training is still there, when faced with a high workload, for instance time shortages due to lower labour, the practitioner may see training attendance as a secondary concern when compared against the daily pressures of their (mounting) workload. This type of increased expectation from the workforce can often be seen when companies have merged, been taken over or are generally expanding. This is the case as, for instance, an account was given in reference to a recent company merger: It was perceived by the cost-practitioners themselves, that there was now double the workload. Although the departments from both companies had merged into one, the practitioner–level did not feel doubled, so did not match the work requirements; mainly due to the fact that through the company changes some practitioners had left, and had not been replaced. There was also the inevitable period of adjustment, which included a certain degree of confusion, in which the same output was still expected. Due to the changed environment, seemingly increased workload, and general alterations of procedure to contend with and become accustomed to, more than one practitioner admitted that there did not seem to be time to fit in training. In general if the practitioner's knowledge does not continue to expand throughout their costing career, there is a risk that this will impact negatively on the results they produce. This may be due occurrences as not being updated or trained on the new, most advantageous technological advancements: There are continuous changes in technology i.e. IT and manufacturing equipment / machinery, which the industrial experts should have knowledge of; as well as ensuring an awareness of new materials; and the latest, most efficient manufacturing processes. Such are areas where state of the art practice is important to achieve in order to maintain high standards of costing, as the updated knowledge can be incorporated into the costs.

In addition to the practical product implications i.e. the explicit, are considerations as personal development. If practitioners do not feel that their jobs have value, worth and credibility, they will not stay within PC. This was raised as a concern by managers within automotive organisations and aerospace, among others. As costing requires a relatively diverse set of skills and knowledge, a difficulty in practitioners leaving the costing community within only a few years, is that there will not be enough mature costing practitioners with sufficient experience and knowledge to perform the function required, inclusive of on-the-job training, and other knowledge-transfer activities.

Related to this is the general issue of mentoring: When resource i.e. time and funds are low, direct training, and related areas, such as mentorship will suffer. A clear observation was made with regards to on–the-job training, in that it was widely accepted as an effective technique of training, and hence relied on across the board of current costing. Nonetheless both trainees and practitioners have stated that during times of high demand, e.g. leading to launch date (automotive) or bid compilation (aerospace), that the training is placed on hold because the practitioners are required to focus solely on the pressing job at hand. This delay seemed to be commonly perceived as unavoidable, or inevitable in industry: Plus where resource is generally low, this type of postponement may be frequent. Therefore in the long-run this will overtly impede a novice's training and progress excessively, resulting in a shortage of skilled practitioners when required. Clearly a more reliable and consistent training method needs to be available, including the tacit issue as perception towards its prioritisation: Training is discussed further in Section 6.2.6 and Chapter 8.

### *6.2.2. Data / Information:*

The location, request, receipt and subsequent analysis of product-data and information is at the core of the industrial costing-process. This is due to the nature of costing which is fundamentally to compile all individual costs related to the area under question. These are subsequently used to produce a cost of item and /or project with as high a level of confidence as possible, given all the information and data available. For instance within a large aerospace organisation the chief cost estimator stated that prior to placing a bid, his job was to obtain the costs from each section of the project and subsequently derive the figure which would ultimately be used to win the business, see quote in Chapter 5, Section 5.2.1. This naturally involved a high level of communication between the corresponding areas; and a high volume of data and information would be exchanged, particularly on such projects as the large aerospace ones.

It my be worth noting here that the product data provided can be minimalistic, and has often been criticised when obtained as being too basic to provide real insight for the practitioners to make informed cost-decisions based on it. For instance the suppliers which organisations regularly interact with have been quoted as frequently conveying as minimal information as possible, and even at times submitting only a single figure including everything within their final cost. The practitioners within a large automotive firm explained that they regularly needed to pursue these figures further, to get as detailed a breakdown as possible, regarding how the figure(s) were compiled. The particulars sought, even aspects as procuring what manufacturing processes and systems were used provide the actual information behind the bare data, which assists in assessing the costs, and establishing whether they are reasonable or escalated. For such cases the role clearly involved an element of 'chasing-up' of information and the need to have sufficient knowledge of the product, and the various components involved in order to ensure all costs were included in the final bid; to recognise the accuracy or otherwise of supplier costs. A certain amount of diligence was also required when ensuring that any updates or general modifications were relayed, as this may affect the costs. Therefore information and data transfer in these, as in all other organisations examined, was crucial with regards to the costing-process. Table 6.5 highlights the relationship between each essential cost knowledge-type, and issues of knowledge and information.

Table 6.5: Relation of Data / Information to the Knowledge Framework

| **KNOWLEDGE TYPE** | **THEME: *DATA / INFORMATION*** |
|---|---|
| Costing Process Knowledge | Imperative to know what data / information compiles the cost, where to find it, how to collate it, when it will be required |
| | As much actual product data / information as possible is desirable to cost a product |
| Manufacturing Process Knowledge | Need to have information about the type of equipment an organisation holds; for instance in order to assess in-house capabilities, against outsourcing options |
| | Suggest lower-cost alternatives |
| | To enable an accurate time assessment for work |
| Knowledge of Design | Need to attain as much information as possible about the component in question from design engineers, in order to assess the costs |
| | To know what modifications will affect the cost, what will not, and how great the effects will be, i.e. large or negligible |
| Knowledge of Materials | To be able to accurately cost the materials used, including the affects of batch size and delivery requirements, e.g. machined or basic shape |
| | To enable propositions of suitable lower cost options |
| Knowledge of Product | To be able to incorporate all aspects of the product, when compiling the costs / derive accurate bid for proposition |
| | To cost updated models –based on current product knowledge / past projects (historical data) |
| Knowledge of Risk | Need the maximum level of available information / product data, to help assess risk –regarding all areas directly related and indirectly linked, when product may be affected. |
| Communicative Knowledge | In order to effectively transfer data / information, adequate communicational knowledge and skills are often necessary, for personal delivery |
| | Information about who needs and hold various product data is necessary. |
| Cultural Knowledge | Cultural misalignments and misunderstandings can create barriers in the dissemination of required data and information. |

### 6.2.2.1. How Data and Information are Transferred:

Throughout the organisations, a spectrum of techniques to transfer information was observed. There were no noticeable standardised processes, though in general IT / software systems tended to be in place to store, update, and transfer data and information. With this said, these systems were often not wholly successful, as they did not tend to make it as readily accessible as the practitioners from different but interacting departments needed it to be. One practitioner of a medium sized automotive company stated that difficulties lay in attempting to transfer required information across incompatible systems, to different departments within the same company. Occasionally the systems differed as widely as attempting to transfer between computerised-softwares and paper-based structures, which as expected, proved problematic; see practitioner quote in Chapter 4 Section 4.8.2.1.

A main grievance concerning information and data exchange was with regard to the maintenance of regular updates. When changes were made which would affect the costs, often there was not (effective) procedures in place to automatically update the relevant department. A lack of current status of product e.g. changes made / updates, any setbacks / overruns of schedule, and so forth would clearly impact the accuracy of the cost produced.  Not only were difficulties experienced regarding the dissemination of internal practice, e.g. modifications within other departments, which would affect the cost; but also with regards to the tools used. Costing departments often employed software tools in order to aid the estimator [C.Rush, 2002]. A couple of large automotive organisations noted that the main database for running their primary formalised tool held information that was often out of date, not just with regards to the regularly shifting costs for aspects as materials, labour-rates, contributors to overhead derivation, etc. but also in respect to items subject to continuous innovation, such as material-composites. It was commented that there were so many variant materials in use or new additions, that information related to them was commonly not found in the cost model provided. This created difficulties on a number of levels, but can be summarised for now as ultimately an excessive use of time: A notable grievance within these particular automotive companies was linked to a lack of maintenance towards the contributing software databases.

#### 6.2.2.2. What Hinders Integrative Working?

When product modifications were made, as mentioned in the previous section, the information did not seem to be routinely filtered through to the required parties. A number of reasons were identified as the cause of this; however a repeated one was stated as lack of time. When the cost-estimator of a large aerospace organisation queried why an R&D engineering department had not relayed relevant cost-related information, the response seemed to consist of a mixture of: *"..no time; ..no process to automatically convey the changes to those outside the department ..didn't think to tell anyone else..."*.

[Cost Estimator, Aerospace Industry, 2005].

As there was not formalised process in place that would automatically inform the cost-practitioner, it seemed that the communication of such relevant information was reliant on individuals within the corresponding department: In this case it seems that it simply had not occurred to them to forward the details. Clearly the cost implications were not apparent within the interacting discipline, so the need to communicate the information regarding development activities including modification was not perceived as relevant not within the other departments 'role'. Therefore when the submitted estimated cost by this R&D department turned out to be less then originally stated, the grievance conveyed by the cost estimator was that the decrease had not been communicated due to the combined prior-stated rationale. To reiterate: There were no official explicit processes in place; no implicit fundamental understanding that the information was required and how important it was to report activities that affect the costs, to the costing department. Reasoning behind why data and information is often not exchanged appropriately is discussed further in the Communicational Process, and Culture of Organisation Sections, 6.2.4., and 6.2.5.

### *6.2.3 Understanding of the Cost-Process:*

An interesting finding of the research was the almost universal claim that there was a lack of understanding, to various degrees, about all aspects of product-costing. The inadequate comprehension ranged from superficial ignorance, to a fundamental lack of awareness concerning the costing function. Everything, from:

- The general role / function of the costing practitioner
- How the costs are derived;
- What information, data and knowledge are required to compile them,
    - And should therefore be communicated;
- What is produced,
    - I.e. the cost-results: Quotation analysis / bid compilation, etc;
- The benefits of undertaking cost assessments
    - E.g. potential savings made;
- Realistic timescales involved to produce the costs;

These were all among the substantial grievances experienced by PC, which detrimentally impacted on the process and results, and required attention.

#### 6.2.3.1. Implications of a Lack of Understanding:

If those around costing do not have an understanding and appreciation of the process and its results, a number of observable difficulties arose. For instance, the areas that should be transferring information / data to costing may not do so. They will not know why they should be relaying it; this unawareness results in anything from accidental non-communication from the contributors including purchase and engineering i.e. basic absentmindedness since it is not accepted as a priority. Alternately it could be withheld willfully due to a fear of why it is being requested, see fear culture Section 6.2.5.2. This is detrimental to the process as if there is information, of which only a restricted amount is made available to costing, the practitioner will incur challenges when attempting to produce the highest levels of confidence in their results: Results which have necessarily been based on incomplete product-information / data. Therefore if corresponding departments as those prior-mentioned do not understand the costing function, they have been seen to invariably stifle the flow of information, though with varying motives. For instance it has been noted that the supplier tends to impart only the most basic data to the user company. However it is not in their interests to divulge all details, as part of the product-costing function is to figure out ways to cut the supplier costs (company-dependant); or to meticulously assess them, to ensure every possible cost-reduction has been given. Hence the more evasive the supplier can be with what their cost is compiled from, the more likely any escalations on their part will be overlooked and accepted as a legitimate cost, see Chapter 7, Figure 7.10 and Section 7.2.3.3. for supplier 'tricks and trust' issues.

Alternately modifications may be made to the design of product, or an aspect of the manufacturing-process, which the particular engineering discipline involved may not be aware that such changes need to be relayed to costing. Although this causes difficulties for the costing practitioners, it will not directly impede them, as ultimately they will derive the cost-assessments required with use of whatever information they do have. Though indirectly, will affect them in both a long and short term manner: Short-term, because the costs will be based on unnecessarily sketchy evaluations; so may not be as accurate as they could be if they had been accessed all the available information provided for the cost compilation. Long term as consistently inaccurate costing-appraisals can result in large company losses.

If poor results by costing are produced due to low information and data availability because of a lack of understanding of the costing needs and / or inadequate communication, the cost-function may subsequently be perceived as not adding value to the projects in general; hence the role could be in danger of diminishing. In other words, if management does not have an appreciation of costing, their budgets will be reduced, making the process even more challenging to perform effectively, which in turn will result in low quality outputs, which will reinforce the negative perception of the costing function, and so forth. Therefore if product-costing is not receiving the information required to produce costs with high enough levels of confidence, the detrimental cycle which includes managerial negative perception can set in. Instead of management improving the culture and communication between the departments, and allowing PC to function as it should, they may not understand that this is what is required. A cost manager in an automotive organisation explained:

*"Management's a key problem, where they do not understand were the cost est's role is in the company and our values; ….Historically ..purchase have a high turnover in staff; their ethos …basically keep data and not share it; so when new people come into company , transfer this practice to them, to not share data, …so it snow balls, ..becomes more and more of a problem.*

*There was relationships with some of the older personnel, …as were all previously located in Sunderland, ..but not now; ….and people have moved on that have formed relations with.*

*So cost estimators can't do their job if they don't have the data. …if they can't do their job as estimators due to lack of data, ..the cost est's - are of no use to them!*
*…They cannot see any use from the cost .estimating …so are thinking 'why are we here?'!"*

[Cost Estimating Manager, Automotive industry, 2002]

Subsequently such a trial of events of internal company misconceptions leading to fear culture and / or a basic decreased significance of the function has been described as jeopardising the whole costing department in a significant minority of observed organisations.

#### 6.2.3.2 Internal Considerations of Raising the Profile and Understanding of Costing

Within the realm of issues resulting from a lack of understanding from within managerial levels, a practitioner from a large automotive organisation stated that product-costing have been perceived as "..a luxury overhead". This was due to the fact that they worked across a number of product lines. Therefore when each product was being accounted for, the area of costing fell into the overhead section within each of them, as opposed to being allocated a secure position within one or other project. A lack of understanding of the costing contribution and the value it added towards each product line and acknowledgement of the cost–savings made, had created the impression that they were basically an 'extra', so were in danger of being cut when budget reductions were stipulated. In relation to this point, and raising the perceived value of costing, a manger within a company producing software cost-models raised the issue that cost savings made should be identified explicitly in order to present a tangible value of PC, stating:

*"..want to know the results… …the actual savings, figures should be reduced to basic 'hard cash terms"'.*

[Managing Director, Cost Software, 2002]

This currently was not being considered within the examined companies, as would certainly be challenging for some elements of the function such as the conceptual-design phase cost assessments. However for aspects as reduced supplier costs, VFM (value for money) checks, the costing contribution towards DTC or the collaboration towards redesigns of components / products, CCRT (commodity cost reduction team) to lower costs; for these issues a figure could potentially be derived. If such cost-savings were established and forecast internally throughout the organisation a number of the difficulties encountered with regards to lack of understanding would be overcome. This would be due to both the profile of costing being raised by such dissemination of savings; and as the value of the role would most lightly attract internal customers to them. It would create the situation where they were curious to find out about, if they did not know about it; and utilise as well as be associated with such a revenue-generating function.

Additionally a practitioner from within another large automotive organisation explained that the issues of raising awareness towards what costing entails, needed to be addressed with regards to their internal customers. The reason given was that, as the users of costing did not seem to understand the depth of the process, and what was involved in their request for cost, they often would not allow adequate time for the cost-practitioners to produce the required results, stating:

*"…they need an awareness of what we do …what exactly's involved ..so can give us enough time, instead of saying ..costs for …or checking through …need this by tomorrow"*

[Cost Estimator, Automotive Industry, 2005]

If understanding of how the process is performed was improved, the hope was that they would be given sufficient time as the users of PC would allow enough, due to an understanding of how long it practically takes. This is as opposed to the unrealistic demands / deadlines which was said to be requested of the costing practitioners.

This situation was exaggerated within the large automotive organisations at the time when most work was required, from all areas, and the most 'chaotic' environment was evoked, which was prior to product-launch date. In such situations, all regular procedure tended to be necessarily bypassed in order to meet this deadline, which could not be moved. The whole project had (generally) lead up to this date, and external factors would be in place i.e. publicity related to launch date, prior preparations from retailers, show-rooms, and so forth. During this time, a research observation was clear: If more understanding of what conceptual involvement of costing would result in, as well as if there was prevalent trust in the figures produced, then many escalated costs could be avoided, earlier. This was because, it was explained by an automotive cost-practitioner that by launch stage, even if lower cost options for the product are suggested, it is at this stage that priorities are switched and time-savings overcome those of cost–reductions. Therefore even if costing produce a valid suggestion which would reduce costs, no changes will be made that may jeopardise the launch-date. Ultimately further down the line of development, i.e. with 'refreshed' models and updates, the changes can be incorporated, though avoidable losses to revenue will have occurred by that stage. Therefore earlier realisation by inter-dependent, internal cost-customers would improve profit margins.

Table 6.6: The Relation of 'Understanding' within the Knowledge Framework

| KNOWLEDGE TYPE | THEME: *UNDERSTANDING* |
|---|---|
| Costing Process Knowledge | How the cost is broken down, specific to company, what to include, etc |
| | Overhead, annual cost breakdowns, and other often organisational -specific |
| Manufacturing Process Knowledge | Need an awareness of the most efficient methods for production, in order to assess supplier costs;<br>Will assist in identifying supplier add-ons and other 'tricks' |
| Knowledge of Design | Having enough design knowledge to enable the reading or understanding of designer-drawings of parts to be costed. |
| | Suggest design alternatives, i.e. lower-cost options. |
| Knowledge of Materials | Knowledge of basic properties, to know suitability of different materials for different application |
| Knowledge of Product | Need to know All contributors to overall product, so can compile costs, inclusively |
| | To cost a product when little actual data is available |
| | Understand the nature of the product, necessary when assisting in making suitable modifications i.e. design alternatives/ refreshed models |
| Knowledge of Risk | Market: –how it could change; who it is aimed at; competitors,<br>Understanding cost implications of overruns, etc |
| | Recognition of problematic areas from Loss Leaders |
| Communicative Knowledge | To interact with all parties involved, in order to gain relevant information |
| Cultural Knowledge | Other contributors towards the cost may have different focus and why, internal and external to company; Knowledge of which will assist in an integrated working environment, where information may be exchanged freely, without fear, etc. |

Table 6.6 lists how a basic understanding of all knowledge types is required, in relation to product-costing, whether directly or indirectly affecting the process. The knowledge-types are discussed further in the following chapter.

To Summarise, issues around the understanding of product-costing include:

- ✓ A lack of required data / information exchange;
- ✓ The relevant departments will either assume that they do not need to communicate it;
- ✓ Will not prioritise its dissemination, as will not realise it is a requisite;
- ✓ May invoke 'fear-culture' issues, as will not understand why the request for information has been placed;
- ✓ So may therefore withhold most or all requirements;
- ✓ More time may be allowed to produce the cost requested, if the process / work involved to create the costs is understood;
- ✓ Cost request made earlier, potentially allow subsequent modifications, if presented in the flexible (conceptual) stages;
    - o I.e. when still in developmental stage, and therefore is still time to incorporate the cost-cutting changes;
- ✓ Financial backing / resources may be reduced if there is not an appreciation of the cost benefits added by the function;

- ✓ A danger of misconception where costing may be seen as a 'luxury overhead' or unessential if the value added by the costing evaluations are not known or understood.

Clearly the departments which interact internally with costing primarily engineering purchase, and management functions are in need of clarification of the role, to varying degrees as explained by a number of the industrial contributors. This would improve the overall process greatly. Chapter 8 deals with ways in which understanding of the process can be approached, when discussing training implications within the costing domain.

### *6.2.4. Communicational Processes:*

Differences were evident to the way in which products were costed across industries, fundamentally due to the diversity of product. There were even notable distinctions to the way in which various organisations would approach costing. However, a common theme which reoccurred across all the studied participants of medium and large organisations, was that of communicational processes. This was due to the core element of what is involved in costing. As cost compilation tends to be undergone by a separate, dedicated department, all information which feeds into it requires accumulation from sources external to costing. Therefore the communicative processes in place i.e. the ways in which the information is gathered from the contributors, are imperative.

Within this theme there are explicit and implicit aspects, both of which are interlinked. The more explicit areas raised were related to IT / software, and the requirements for adequate systems to be implemented. This would invariably improve the levels of internal and external organisational communications. However the implicit concerns, which were more universally voiced, were primarily with regards to interpersonal interactions.

#### 6.2.4.1. Interpersonal Communications:

Costing involves a large number of regular communications, including interactions between product-costing and:

- Design engineers, at the conceptual stages
  - In order for the cost-practitioner to maximise the data about the item being assessed,
- Purchase, regarding information about the supplier selections
  - And relaying the inputted bids, for costing to analyse,
- The supplier, to assess their costs,
  - And obtain as much information about how their costs were compiled as possible.

A main concern observed within organisations was with regards to the lack of personal exchanges between corresponding parties. It was felt that misconceptions would occur as industries steadily moved towards a more technological approach to such interactions. With extensive availability, use, and therefore reliance on technology, human interactions were seen as increasingly less important; resultantly provisions were not in place to promote them. Such events are detrimental to the costing process, and the overall integrative working practices within any organisation. What was described as the overuse of IT / systems was liable to create increasing miscommunications, which lead to misunderstandings. For instance, one senior automotive cost-practitioner explained that people were emailing each other, from across the same floor, let alone the same building. It was felt that emails are open to interpretation and often are not as fully comprehensive as a brief conversation would be. Therefore it was stated that when overused, misinterpretations are often the outcome which ultimately lead to mistakes. Such errors could manifest in wasted time if the information needed to be relayed several more times before the misunderstanding was identified. Alternately it could result in excess costs, which could have been avoided if there had been direct, clear communication throughout the process.

### 6.2.4.2 Formal and Informal Personal Interactions:

A number of the more experienced practitioners i.e. with twenty or more years within industry, perceived that the more practitioners personally interacted with each other, the more effective their interactions would become with ever-increasing familiarity and understanding between them. This was thought to lead to improved trust and a better, more harmonious working relationship; which would promote effective integrated working and LCC (Life Cycle Costing). For example, a common complaint from cost practitioners was related to not receiving enough detailed information from the design engineers: An experienced automotive practitioner observed that if more effort and time was made to speak with the designers, an increase in the amount of information relayed could be achieved. This would be due to a couple of reasons; firstly on a pragmatic level PC could directly explain what data is required for the most favorable conditions to produce the highest confidence cost. Additionally, if the practitioners and their roles are known and understood by each other due to regular interactions, they are more likely to take steps to provide prototypes, as well as drawings i.e. more and higher quality of information. This will be because on a personal level a positive working relationship will have been developed via interactions.

The enhancement of practitioner relations may seem like common sense; in other words, it is advisable to be on good terms with those who one relies on information for. However, within a daily routine that does not automatically allow time for personal meetings even casual conversations to exchange information; when working schedules tend to be full, it can be difficult to make efforts to communicate personally. Instead busy practitioners may end up relying on procedures as WBS (work breakdown structure), BoM, (Bill of Materials), RFI (Request for Information) QAF's (quotation analysis) QMF's (query management) forms. In such cases, the contributor may not even be known to the recipient, let alone be able to evoke more then minimalistic levels of product-data / information. The general perception observed across organisations, particularly large ones, was that a lack of personal communication was resulting in detrimental working relations, and creating problematic (impersonal) environments.

### 6.2.4.3. Hard Systems:

Although significant numbers of the more experienced practitioners in particular had voiced concerns towards diminishing personal communications, it was also acknowledged that such interactions were often necessarily limited or simply not feasible as frequently as was desired, from a practical viewpoint. This would apply for instance when large distances were involved, and weekly or even monthly meetings between the sites may therefore be perceived as too time-consuming, see following section. Alternatively, as previously mentioned schedules may simply not permit regular personal meetings, particularly when approaching launch dates; or during the later stages of bid compilation. During such times all project teams would be pressed for time, and collectively rushing to meet the deadlines. Such situations were commonly described, as a reality of industrial endeavours. Therefore with the absence of personal liaisons, a frequent suggestion was to improve communicational processes currently operating within the company, with regards to IT systems. If these technical enhancements were considered in juxtaposition with the intangible aspects of communication such as video linkage to promote personal interactions, their implementation would be more effective.

### 6.2.4.4 Personal Practitioner Directories:

In order to save time and reduce the effort involved to communicate, practitioner-directories of varying detail were suggested. One example of this was within a large aerospace / manufacturing organisation: As projects were lengthy i.e. spanning many years, the intention was to help keep track of practitioners who would move to work on different projects; this was a common occurrence. Once they had changed, it was more efficient to locate and establish from them personally the manner in which they had implemented their area of the project. The cost manager explained:

*"…Practitioners regularly move on ..or across to other projects ..before they've* (the projects) *finished; …the way they've implemented things is often tricky to follow for the person taking over.. ..it's a large organisation.. ..Save a lot of time and effort if could keep track of where they are… ..like a personnel directory, of who's worked on what project, on what dates, and where they're located now.. …kept automatically updated.."*

[Cost Manager, Aerospace Industry, 2002]

This would be more successful for the person taking over, then simply following the paperwork attached to the task; or if they had to resort to re-setting things in a way which the replacement practitioner themselves could then follow.

Similarly a personal practitioner-directory was suggested as being in need within a large automotive organisation as a way to fundamentally promote personal working networks. Basically, if the role of practitioner, expertise or area they managed and contact details were readily available, they could be directly located and contacted as and when required for information. Currently within this organisation, a weak version of such a directory did theoretically exist. However the main grievance relayed with relation to it was that it was not updated, to the point where it was of little–no use, so the employees were unable to gain benefit from it; and did not refer to it, though did acknowledge the value of a regularly maintained one [Collison, 2008].

### 6.2.4.5 Innovative / Efficient IT Systems:

The type of IT system which was described as being ideal by over half of the companies examined was one which could be automatically updated and hence convey any changes accurately. A cost engineering manager from within an automotive organisation explained that a compatible linking system was required in order to disseminate changes as they occurred, to the relevant areas. For instance if the information could be typed into a programme, which would be available across departments for those who required it, a lot of wasted time and excess costs could be avoided. Within this particular organisation however the departmental systems were incompatible, as there was not systematically adopted software at organisational level. Instead the most appropriate system per department could be selected, depending on each ones preference and / or needs: This limited communications between them. A common system, or at least one which was compatible with the different ones in use and could relay instant updates, encompassing any modification, was a specified ideal for communications and data / information transfer.

Video calls and conferencing are a solution when physical meetings are impractical, e.g. relied on within a number of international organisations. They are also another example of 'hard', IT systems allowing interpersonal, (face-face) communications. Although 'softer' elements are rarely given prominence within manufacturing / engineering environments, interestingly 'hard' major technological advancements have been developed in order to facilitate them. This possibly suggests that though intangible elements within, say communicational issues, are not openly focused upon there is implicit acknowledgment towards their importance, which leads to them being addressed. However if they were acknowledged more explicitly, the opportunity may arise to tackle them more fully, quickly and effectively.

#### 6.2.4.6. Geographical Considerations.

A practical barrier which hindered interpersonal communication was often linked to the geographical scattering of work sites. One automotive practitioner stated that when departments or teams needed to get together to discuss areas of the product, it tended to be difficult i.e. time consuming to arrange. This applied to managerial meetings where getting the required people together physically to agree on tactics and so forth was often problematic. Due to the distances between them, this meant it took longer than was felt necessary to make decisions; which in turn slowed down response time and therefore the results.

However, with large companies it tended to be a necessity to split sites not just across one country but often globally, e.g. as Ford Motor Company with sites in the UK; plus other locations including Germany and America. As potential issues with regards to distances between sites was recognised, the way in which difficulties were minimised was not only via improved technological systems, highlighted in prior section; but also through considered structuring such as co-located IPTs. One cost-manager stated that though sites had been re-arranged through the merger of companies, restructuring of work-bases were planned. The intention was to locate on a project – based level, rather than having functions or disciplines work together. This would mean that costing practitioners were physically closer to the teams they were working with, the relevant engineers and so forth, which subsequently meant that personal talks and discussions with them, whether formal or casual conversations, were made more accessible.

Table 6.6. summarises how communicational aspects impact industrial-costing and specifically highlights the relation of the communicational issues, against the knowledge-types discussed in the following Chapter 7.

### *6.2.5. Organisational Culture:*

A primary reason for the commencement of this research was to examine the factors behind why the economic and engineering disciplines within costing were not interacting as freely as they should. As the examination continued these types of stifled relations were paralleled in other areas, across industries. The cause of the ineffective communications between the cost-related areas is in part due to cultural diversity. The two disciplines are rooted in different areas of product focus, so have a number of contrasting working practices. Such differences are necessary, as economic functions deal predominantly with monetary issues associated with the product. Whereas engineering areas are concerned with performance, and aspects directly related to product development and functionality. As these roles are so dissimilar they are bound to experience diversity in attitude, perception and focus; not to mention the clear requirements for a different set of knowledge types necessary to perform the respective activities required

Unaddressed cultural differences between disciplines create a lack of integrated working practice, which ultimately affects the outcome. For instance as explained within the communicational processes section, product-costing relies heavily on adequate interaction between the contributors towards the cost; if this is not achieved the results tend to be less accurate. Reasons why a lack of integrated working occurs is due to cultural clashes or misunderstandings related to:

- Terminology: A lack of common, hence widely understood terminology;
- Perception: Misconceptions about motives for actions e.g. RFI forms, request for Information;
- Issues of Trust: Linked to misperception and generally not understanding and subsequently appreciating others roles', which extends to supplier relations;
- Priorities: Which can be mismatched e.g. economic working towards financial competitive advantage; engineering focus on product functionality.

The issues surrounding uncommon terminology have been discussed throughout the thesis; see Chapters 1, 3, and 4. The confusion occurs because it has been noted that terms used or words, descriptive as well as nouns my have different meanings attached to them. Whilst conversely, reference may be made to the same point or situation with use of a variety of words, all of which may not be understood or perceived as being the same thing. So even though interacting parties may be discussing one issue, they may not realise this, or may waste time figuring it out due to inconsistent terminology.

Within an aerospace organisation, a cost manager noted that across different phases of a project, the same words will have different connotations depending at what stage they are used; and who i.e. which discipline / company is using them. Separate, but interacting departments will hold more prominent levels of responsibility for each stage. Therefore when they have cause to interact, errors can be made because they can at times be communicating with each other quite literally with use of different language, if the meaning of the words used is not understood as the same thing. Refer to Figure 4.2, Chapter 4 for title inconsistency, which created challenges even in the identification of who should participate in this research. For example the emphasis on "risk" changes throughout the project life-cycle. At the conceptual stages two main aspects can be noted:

- There is little-no data available to base the costs on, so more assumptions / expert-judgments need to be made; therefore confidence levels are lower then when there is more actual data to incorporate.
- Many budgets and cost-targets are based on these early costs, so inaccuracies can result in high revenue losses.

At the conceptual design phases, risk is higher then later in the project when more actual product-information is available. Therefore different implications are linked to 'high risk' decisions, depending on which stage of the product life cycle they are derived from.

An industry-wide consensus of standardisation needs to be established not solely for prominent list of terms used, but also for the descriptive roles of the cost-practitioners. This may help to enforce their role and disseminate the importance of integrated working; see fear culture Section 6.2.5.2. An alignment of the common language used will create not only greater credibility for the cost-process, (or profession); but also assist in the alliance of internal cultural clashes experienced and towards the cross-industrial cultural barriers observed.

Table 6.7: Relation of the Communicational Processes towards the Knowledge Framework

| KNOWLEDGE TYPE | THEME: *COMMUNICATIONAL PROCESSES* |
|---|---|
| Costing Process Knowledge | Interaction is required with many departments in order to compile costs; particularly for bid-tender. |
| | Areas internal and external to organisation are often involved on large manufacturing projects i.e. automotive and aerospace products. |
| Manufacturing Process Knowledge | Gathering information such as cycle-times, labour-hours, etc |
| | Supplier quotation breakdowns assessments |
| Knowledge of Design | Communications between design-engineers and PC can assist in lowering costs when working together. |
| Knowledge of Materials | Often with external bodies e.g. suppliers, PC are required to gauge potential costs |
| | Knowledge may need to be passed between disciplines / practitioners. |
| Knowledge of Product | All information about the product needs to be communicated to the costing department when costs are to be compiled. In large aerospace, automotive and other manufacturing organisations this can involve extensive communications between parties. |
| Knowledge of Risk | Risk from all areas of product needs to be communicated, assessed and incorporated into the estimated cost: From predicted technological breakthroughs and the impact; to potential unreliable / unstable supplier; to previous-project risk / challenges, which should be taken into account. |
| Communicative Knowledge | Companies need suitable modes of communication: Organisational communicational-processes can be misleading, if they are inadequate. A common example is over-usage of email, when a personal interaction could avoid misunderstanding. Companies, particularly larger ones often do not have suitable procedure in place for personal exchanges: And / or it may not be practical, i.e. due to geographical limitations. |
| | How companies capture internal communicational challenges and needs: Feedback back into company via for example shop-floor suggestion boxes, to identify the need for: -Networks; improved IT processes; skills of communication, including interpersonal skills and so forth. |
| Cultural Knowledge | Communication between disciplines e.g. financial, and engineering. Between hierarchy e.g. management and workforce; with avoidance of issues as fear culture. Between interacting organisations –with different aims, focus, priorities, (whilst embarking on successful working relations between them); and an awareness of global differences. |

### 6.2.5.1. Cultural Indexes

The cultural indexes discussed within Chapter 5 were apparent within the costing sphere. These spectrums examined the issues behind cultural difference, providing explanations for certain behaviours and attitudes. The cases observed within costing could often be related within these areas, and could help to explicate the challenges experienced. For instance ‘universalism’ was often evident in the cost-process in the sense that codes, rules and generalisations could be applied, such as with ROM costing. Companies often quoted percentage-figures which would represent a considered approximation of an aspect involved in the cost compilation, e.g. 5% scrap; or 30% overheads, depending on the industry and area. However, due to the nature of costing, and its' unpredictable elements, the other end of the cultural-spectrum, 'particularism' [Trompenaars and Hampden-Turner, 1999] also applied, which meant that exceptions and special circumstances needed to be catered for within the process. This manifested not only within deliberations of risk, but in the more predictable exceptions such as material envelope, overruns to the project; or escalated costs to counter impending delays i.e. spending more to make sure a deadline is met. Another interesting contrast was seen in 'individualism' [Hofstede 2008], where on one hand costing practitioners derived the costs alone, and were repeatedly quoted as stating that each practitioner would complete the process in a very individualistic manner using techniques or combinations of such, special to their preferred style. This is not in contrast to the requisite for standardisation within costing, as the need for common terminology for terms regularly used, techniques employed and processes undertaken still needed alignment, where relevant. The personalised choices or application of such process and techniques per situation is what is being referred to here: Practitioners will apply individual judgment to items requiring cost-assessment. For instance one practitioner may decide to use a formalised cost model to deduce the costs, whilst another may perform a detailed estimate without reference to a cost model. It was stated that though different techniques may be used, depending on what each practitioners' preference is, a similar figure should be deduced even if the same item was costed by separate practitioners, all using different techniques.

Conversely, the process of costing additionally involved a high level of 'communitarism', [Hampden-Turner, 1999] not only in a direct way, where all areas of project needed to relay information centrally to costing. This meant that costing would need to have a systemic knowledge of the process, and to an extent relied on integrated, communitarian working between the contributing elements. In a more indirect way the interacting departments would also ideally need a systemic view of the process in order to appreciate the value of costing and see the importance of the contributions to them. This type of holistic understanding of where PC fit into the process assists in the avoidance of fear culture and misunderstanding about the requests for information. Hence it facilitates the open, regular cross-communication of the required level of information as opposed to stifled, limited levels. Knowledge of LTO (Long Term Orientation) is necessary within organisations, in relation to loss leaders and cost attitudes which are appropriate per project. If working relationships are required between countries and even organisations, as is often the case when using suppliers, and even on projects as Eurofighter, where BAE Systems collaborated with four other nations. Here at least a basic knowledge of the other contributors cultural attitudes with regards to aspects as LTO is import. Similarly, UAI (Uncertainty Avoidance Index) ratings are important, as if innovation is expected in a first tier supplier, a company with a low tolerance due to it's economic stability or geographic location would make an unsuitable partner. The interaction between organisations and particularly between countries, requires a knowledge of the PDI (Power Distance Index) levels within the new alliance; and to an extent an awareness of the MAS rating (Masculinity) is advantageous too, see Chapter 5, for further discussion [Hofstede, 2008].

#### 6.2.5.2. Fear Culture

Much of the previous cultural spectrum application can be related to when part or all of the organisations workforce experience the detrimental state, which has been referred to as 'fear culture', see Chapter 5. This is exactly as stated, when individuals or collectives feel they have cause for concern to various degrees due to some organisational environmental element(s), or in other words, the culture.

#### 6.2.5.3 Perception / Priority Diversity:

Examples of what is plainly some form of a fear culture have been provided throughout the industries examined. A cost estimator within large automotive organisation explained why the costing department was currently very weak,

*"..having been slashed to almost one tenth of its size ..over five years".*

[Cost Manager, Automotive industry, 2005]

The reason given was that the purchase functions who were a key information source were reluctant to work collaboratively, or co-operate with PC at all. This was due to fear of scrutiny towards their practices which may have been questionable, ultimately due to excessive pressure for cost-reductions from management. The lack of interaction had lowered the credibility of costing in this instance, as PC was basically severely limited in their role via this refusal to divulge information from a department which was a main contributor towards the costs. This lack of results, coupled with a general 'feeling' or discernment of the importance of costing function had aided in its cutbacks. The reason expressed for the lack of integrated working was explained as being basically due to fear and ignorance about the driving force behind costing. The manger of the depleted costing department stated:

*"..The main problem is culture; purchasing see themselves as a separate entity, and are protecting themselves not just from the cost estimators, but also from design..*
*..they're reluctant to break down info. to design too; …*
*..they feel they're the only ones who have the ability to deal with the commercial aspects.*
*Another element is fear culture. ..*
*…Project management ..they report to; The fear is a personal fear, if anyone encroaches into your area, and tells you you're not doing your job, then you'd feel threatened, and stop liaising with, ..put up defences."*

[Cost Manager, Automotive industry, 2005]

For example, the cost-practitioners would suggest low cost alternatives for the current suppliers used. As supplier-selection were Purchase-decisions, it was felt that purchase were defensive about being assessed by costing. Subsequently they would defend their choice, by arguing that there were other considerations for supplier choice, along with the cost e.g. good relations, reliability, quality etc. Resultantly shielding their activities from the costing department for fear of correction or even exposure of substandard performance. Although the costing practitioners in this case did acknowledge that cost alone was not the only factor in supplier selection, they did note that their perception was that Purchase were settling on certain suppliers due to other issues, related to fear. For instance an assumption was made that Purchase may make unofficial agreements with the chosen supplier, in order to meet annual targets; thus giving the work to the ones with whom they had the best relations with as opposed to focusing on cost-savings. For this case the mindsets of these two areas can be seen as culturally different, in a number of ways: PC were focused on getting the best VFM supplier; whilst Purchase centered on keeping their contributions as being seen as valuable. Fear culture, due to some type of exposure from costing (to management), could subsequently lead to their choices as being questionable: So showed a fear of both PC, tracing any discrepancies in their activities; and management viewing them in an unfavourable light, e.g. if targets are missed. However, it must be noted that the Purchase team were not interviewed within this automotive organisation, so the previous case study may be viewed to simply reveal the differential attitudes, with regards to perceived importance of good relations, over basic cost-savings. Costing may criticise Purchase for choosing suppliers with whom they *"..play golf with"* or attain other perks. Whereas Purchase may view this as good relations, where the supplier will be more lightly to behave in agreement with them and work more harmoniously with the user organisation e.g. provide better quality service, on time; strive to meet special specification, due to these good working relations. This types of cultural diversity was discussed in Chapter 5, potentially falling within the Specificity–diffusion cultural spectrum, [Trompenaars and Hampden-Turner, 1999], in reference to objectivity against relational developments, discussed in the previous section.

Another noteworthy point of this automotive case. It may have been said that Purchase were potentially at fault for placing their reputation above the pursuit of genuine cost-savings; whilst Costing focused on decreasing costs. However within this particular organisation the result was that the purchase department was strong, being influential enough to curb costing involvement with seemingly little interference from the external working environment, i.e. outside these two functions: Whereas costing was weakened to the extreme of being effectively unable to perform their role. An observation here, is that although the cost-practitioners were said to have been originally enticed from another company which had been merged with this one, where the cost-department had been substantial, the practitioners should possibly have paid more attention to the culture in which they were being drafted into. They should have been mindful of things as the PDI rating, considering the original company was UK founded, and taken over by organisation established not just non-UK but outside Europe, and with a markedly different culture. Other examples were given where product costing was not included early enough if at all, in supplier selection; as stated, a process usually lead by Purchase. The reasoning behind this was due to either, as stated fear culture; or to ignorance of the benefits of utilisation of the costing process i.e. a lack of understanding about the cost-focus.

Within a large aerospace organisation the cost estimator described the function of costing to be akin to "..policing the overall processes …activities". This statement was made in the course of the presupposition made by the practitioner that departments would routinely overestimate the resources required to ensure that they would have more, rather then less to work with. Again these overestimates were seen as being due to protecting their perception by management, and ultimately not wanting to appear incompetent or be perceived negatively if deadlines are missed and / or targets overshoot. The general attitude displayed by the cost-estimator here was that if resource was provided it could always be utilised, regardless of need. Therefore the approached adopted was to routinely reduce the requests, to the point where this particular individual was quoted as saying that

*"..the estimates submitted by the engineering departments should be instantly halved!".*
[Senior Cost Estimator, Aerospace industry, 2002]

Not unexpectedly, this attitude often resulted in conflict between these working parties. The tension can be summarised as being due to the cost estimator perhaps not fully appreciating the overall need for the level of resources specified. Alternately, by the contributing departments, generally engineering not working towards the lowest common denominator with regards to the requested costs. The culture depicted not only described fear-culture evoked within the engineering functions due to the regard towards management perception, but also via the cost estimators' instant reductions of their assessments.

The main areas for mistrust and culture-clashes lay between Product-Costing and Purchase, Engineers, and the Suppliers; as well as management and occasionally the financial functions. Often the very nature of these different roles, or in the case of the suppliers, different organisations, meant that some degree of knowledge of their role, priorities and working-practice was required. Between such areas with different focus and priorities, detrimental culture-clashes would often be inevitable if the diversity between them was not addressed. This can clearly be seen in the previous example where the cost-estimator includes a high level of monetary considerations, and therefore is focused on cutting costs. The interaction is with the respective cost-engineers, whose role is dominated by direct product and engineering focus. The maximised costs are towards endeavouring product-excellence and competitiveness of performance, over product economic competitiveness, as with the cost-estimator.

Table 6.8: Relation of Organisational Culture and the Knowledge Framework

| KNOWLEDGE TYPE | THEME: *CULTURE of ORGANISATION* |
|---|---|
| Costing Process Knowledge | Knowing the importance or emphasis that may be placed on aspects. E.g. loss-leaders, to break into a new market / country. |
| Manufacturing Process Knowledge | Can affect the manner in which manufacturing processes are performed. E.g. competitive, driven environment, demanding fast results; or relaxed but with perhaps more attention to detail. |
| Knowledge of Design | An understanding of the culture of designers helps cost-practitioners interact with them: Cost-cutting suggestions will be adopted; and more information will be imparted, if there are good working relations between disciplines. |
| Knowledge of Materials | Are innovative materials adopted, or are they considered as risks: Are only tried and tested materials utilised, due to the known properties. E.g. Do new materials get consideration, or not get approval regardless of the claims and even the evidence of enhanced performance. |
| Knowledge of Product | How all aspects of the product are handled; e.g. will knowledge & information flow between departments, or be subject to procedure / potential obstructive 'red tape'. Total product-knowledge and information can be difficult to collate, if there is reluctance to fully impart it, e.g. due to lack of understanding as to why it is needed / culture clashes, particularly within large organisations. |
| Knowledge of Risk | Are the organisations 'risk takers' e.g. within a large multinational corporation, a calculated risk may be an absorbable cost, perceived as learning experience: In contrast, other organisations may see such a risk as a damaging threat to their revenue and potentially, their future; and go to great lengths to avoid it. |
| | A knowledge of culture when assessing risk, for instance in a potential partner (or supplier) is crucial, to establish suitability. |
| Communicative Knowledge | The culture of an organisation strongly dictates the modes of communication, and levels of such, e.g. whether integrated working, or segregated. |
| | Does the organisation have data bases and is IT based, or is it 'hands on' per practitioner. E.g. do individuals need the skills to find and contact the suppliers, or will costs be updated & available via in-house system. |
| Cultural Knowledge | The extent to which internal (disciplinary) and external cultures (other organisations / the differences in how other countries operate) are understood, is greatly depend on the organisations own culture, manner of implementing procedure, and so forth. |
| | Whether business is lost or won can hinge on an awareness of culture between interacting parties; on whether it is known / understood, or not. |

#### 6.2.4.5 Budget Stipulation

Research that focused on the judgment of industrial designers found that when people who set the goals are dominant within the functions that are adhering to them, the difference between the estimate and the actual outcome tends to be similar; with the designers keeping the reality close to their estimate on an almost subconscious level [Busby and Payne, 1998]. This was not found to be the case in this study: Often goals were missed, and the concern around working towards them could be identified as being at the root of fear culture, lack of communication, and other detrimental practices. This was partly due to the fact that the assessments and resultant targets did not tend to be set by the recipients of the set criteria, particularly within the large and medium sized organisations. Although the estimates by each department were considered within the target formations the actual budgets set tended to be established at senior management levels. As discussed previously (see Chapter 3), the profits were often initially established, with the remainder of the budget being available for the product including development and production. As these figures were set at senior organisational levels it was deemed important to meet these costs, and not seen to exceed them; see cultural definition and implications of PDI, power-distance index, Chapter 5,

#### 6.2.5.5 Communicational Constraints:

The research highlighted that there was apprehension to varying degrees, with regards to the communication of data and information; which was partly due to fears about job security. A common misconception was that if what was requested was transferred fully, then the need for the role which had imparted the data / information may be redundant. The reality of the situation was that this tended not to be the case and the request was in fact required to support another area. For example financial and engineering input would be used in the derivation of costs; therefore the contributions were valid and not replaceable by the users of the received data. A systemic view of the process i.e. encompassing all inputs and outputs with an awareness of how things fitted into the organisation, was required in order to eliminate such unfounded fears which ultimately served to hinder progress on projects, give misleading results and / or generally create challenges within the working environments. This can be addressed by training, to give comprehension of the costing role, so the way in which costs are derived is understood i.e. what information is required so the interaction of all relevant areas will be highlighted, along with why their contribution is needed: As well as reinforcing the benefits of PC. Training in what information is required by whom and from where, would promote understanding and therefore help diminish fear culture. The final cost theme which is that of training issues is discussed in the following section.

Table 6.8 summarises cultural issues within PC, highlighting these points in relation to the cost-knowledge types. Attitudes towards the adaptation of new materials often emerged, and were particularly elaborated on within both a large aerospace organisation and a military-focused manufacturing company. The former mentioned that due to the strict guidelines, it was very difficult to introduce innovative materials onto aircraft, despite their suitability, e.g. lightweight, high strength and heat resistance carbon fibre substitutes over metals. This was due to a culture which conformed to rigid rules and regulations, founded within national security issues. The latter spoke of levels of confidence with regards to experimental periods. Their products may have been successfully in use for thirty years or more, so it was stated that as impressive as such new materials may appear they did not tend to have this type of credibility and consistency associated to them, due to the very fact that they were new. As a result they were still considered as test materials; so the company was reluctant to modify the materials they were using due to their past records of reliability, over lesser known ones.

### *6.2.6. Training:*

The general industrial perception in relation to the other themes was that most of the issues which arose could be addressed via the appropriate training. This was particularly expressed in reference to the issues around understanding of the costing process, communication, and organisational culture; and was also conveyed to an extent towards the flow of Data and Information, and Resource concerns. However, with regards to this theme there seemed to be a degree of contradiction, as although training was widely acknowledge as a necessity, the realistic commitment to it was often not equal to the theoretical intentions.* The attitude observed can be summarised by this quote:

*".. training is important, but the day-day activities often need to take precedence"*
[Cost practitioner, Manufacturing organisation, 2005]

Therefore it can be observed that it was seen to be more important to get the work at hand done, than to attend training; which was occasionally even seen as an inconvenience. Subsequently when there are time pressures in the organisation e.g. close to launch date, or bid submission, training tends to become a secondary consideration, according to a number of practitioners. When a training course of a week or even a couple of days away from the office is contemplated against tackling a high workload, often the training is bypassed in favour of addressing the more direct needs of the job.

Already faced with this negative attitude, as training appears to be perceived as less important and not interlinked with the job activities, but almost seen as superfluous; in the course of budget cuts, it was often stated that training is an area which is considered as more of an 'extra'. This is in comparison to any of the other direct product-related activities or functions. The position of training, in light of financial and time pressures and continual reductions can be indicated by this statement, from a CEO who stated that he:

*"..shouldn't have to train people to do the jobs that they've been hired to do: …I employed them, with an understanding that they can already perform the roles they've been hired for."*
[President, international medium-sized software company, 2002].

Table 6.9 highlights the way in which training is important for every element of product-costing; and how targeted training is necessary in order to adequately cover each area. The training suggestions which result from the combination of cost-themes and essential knowledge types are discussed further in Chapter 8, where all the tabulated training points are covered.

Table 6.9: Relation of Training towards the Knowledge Framework

| KNOWLEDGE TYPE | THEME: *TRAINING* |
|---|---|
| Costing Process Knowledge | Adequate training is imperative, as this type of knowledge was not perceived as being commonly acquired during general working life. E.g. as an engineer. |
| | Company-specific training is often required for cost-compilation. |
| Manufacturing Process Knowledge | Keeping this practical knowledge-type updated with the latest technologies available in manufacturing is important to accurately predict costs. E.g. cater for cost of updated machinery, & / or techniques. |
| | Knowledge needs to be kept current in order to assess the efficiency of suppliers; and to have an awareness of their potential 'tricks' in quotations / cost breakdowns. |
| Knowledge of Design | In order to work effectively with design engineers, which was regularly referenced throughout the industrial observations, PC requires a comprehensive, minimum basic knowledge of elements of design e.g. from reading a designers drawing, to alternative re-design for lower cost options. |
| Knowledge of Materials | As material costs comprise a large portion of the overall costs, training in this area needs regular attention, e.g. to know which materials are suitable for different applications; to keep update on novel material performance. |
| Knowledge of Product | To assess basic costs throughout project life cycle including assessment of upgraded models, a full knowledge of product is essential. |
| | This applies to both products where little historical data will be obtainable i.e. new product or 'one-off's'; as well as for when previous product-data is available: Training for familiarity in the products (re-use of captured information / knowledge), is essential. |
| Knowledge of Risk | Though unable to fully cater for unpredicted occurrences training in all areas of known, potential product risk can ensure that the identified ones are not overlooked. This can often help recognise further, unforeseen risks. Therefore it is essential not to rely on the assumption of word of mouth / historical knowledge; but to conduct such training, if minimisation of risk is to be achieved. |
| | It is a risk in itself to bypass training, and hope that less structured approaches alone will provide enough consistency to produce skilled practitioners. |
| Communicative Knowledge | The costing process involves extensive interactions within and across departments and organisations: Training in acquiring such communicative knowledge and skills would assist in the efficiency in which this is done. |
| Cultural Knowledge | A knowledge of the main areas in which costing interacts with is essential; issues as understanding their roles, systemic understanding i.e. where it fits into the process holistically; and having an appreciation of each others priorities helps in creating a productive working atmosphere where each area will co-operate systematically and generally more integratedly. |

### 6.2.6.1. Training Challenges:

One reason why training emerged as a theme in itself was related to the concerns about a perceived shortage of skilled cost-practitioners across industries. The research found that the primary source of cost-practitioners was derived from technical apprentices. This was because costing (within the UK) seems to be founded in practical engineering know-how, and a genuine understanding of technical processes. The economic, commercial knowledge was deemed to be acquirable on top of this fundamental work-shop experience. However, the source from which cost-practitioners were traditionally derived was perceived to be depleting, as industrial apprenticeships become less common; with the potential (theoretical) replacement being the technical graduate. The latter mentioned would basically differ from the former, in that they would possess more theoretical and academic knowledge, and less practical engineering experience. With the fundamental source of novices being modified, the type of training that was implemented required reassessment, accordingly. The research found that industry was slow to adopt and cater for these changes with regards to the training prerequisites; with the result manifesting in the fact that there seemed to be a shortage of potential practitioners with the required skills for product costing. The current training embarked on was not being modified to suit the subsequent metamorphisized novice who was now utilising it.

### 6.2.6.2. Current Industrial Training:

The type of training undergone within the studied industries is discussed in Chapter 8; though generally it was accepted as taking two years for a novice to become an independent cost-practitioner. Although this time scale was widely accepted across the industrial areas of observation, it was deemed too long to replace the natural depletion of expertise from the domain. This issue has added complexities, as the cultural framework or internal systems of the organisations in question needed to be accounted for when considering these points.

As stated, the accepted time frame for a novice to be trained within was approximately two years to reach a basic standard of costing. To progress in the field, experience was required generally prior to this training period of which typically took two years, just to gain entrance-level knowledge to the costing process; whether through apprenticeships or organisational graduate-training schemes. In light of the fact that many of the highly experienced experts had been within the domain in excess of twenty years and hence encompassed an impressive knowledge span, it can be deduced that with the current training methods coupled with the intricate nature of costing, a number of years within the field are required to attain genuine levels of confidence. Given this, a conflicting aspect within organisations was the fact that relocation between departments was commonplace and achievable seemingly with ease: This extended to job changes within and between organisations; even industrial moves were not unusual. A large automotive company actually encouraged practitioners to move internally, as part of a personal development programme. The idea was to move on, once obtaining two full years experience within an area; then gain the same depth of experience within another domain, and so forth. The company endorsed this with the feeling that it promoted rounded expertise and comprehensive product knowledge; as well as more fulfilment / job satisfaction on a personal level. Such broad experience would ultimately (in theory) enhance overall personal plus organisational performance. However, this culture of constant change was felt to be a hindrance within product-costing. A cost-manager within a manufacturing / procurement organisation perceived that in order to gain real insight to the process, the practitioners needed to be established in the field for a number of years. The organisational culture promoted therefore, was highly detrimental to the area of PC in this respect, even though it was instigated internally.

This further highlights the need for interacting departments to gain an understanding of costing, having both an awareness of the process, and the deeper intricacies involved in the production and assessment of the results; see Section 6.2.3 which discusses the theme of understanding. The value of PC contributions need to be appreciated in order to accept and subsequently support the level of expertise required, and the realistic time frame currently needed to reach the required standards. Training across departments inclusive of managerial levels, will help promote the culture of stability within product-costing, so by the time the novice is competent, they are not intending to move into another area of expertise.

In relation to the training time-frame, a majority of training was imparted via the on-the-job technique, as opposed to being structured and targeted. If a greater level of fixed training was implemented it could cater specifically for the needs of the different types of novice, e.g. the graduate-trainee, as well as industrially pre-trained novice. A more tailored and intense amount of structured training could target areas of need, followed by employment of learnt scenarios within the workplace; such a programme could assist in reducing the training period. In others words, more structured training in conjunction with the on-the-job (SWN) type could be used to develop the trainee at a faster rate; as opposed to SWN being the primary technique. Chapter 8 discusses training in detail, including TNA and courseware proposals.

#### 6.2.6.3. Knowledge Capture Issues:

The issue of knowledge capture within costing has previously noted that there is a lack of recognition towards the tacit knowledge implemented. The work of Busby and Payne [1999] noted that the technical expertise was considered as the whole knowledge required, without recognition to the surrounding elements involved in estimating the unpredictable aspects of task. This meant that it was questionable whether a novice could learn from more expert practitioners, if there was not acknowledgment of the complete skills involved, e.g. in addition to the explicit elements [Busby and Payne, 1999].

Although an overall finding of this research was that softer issues are not adequately understood and therefore not valued commonly across industrial-costing; it could be observed that actual practitioners who were experienced were nonetheless still valued for their knowledge by their colleagues. This was particularly noticeable in larger organisations, where the more experienced personnel were recognised by each other and consulted routinely when making decisions, particularly by the less experienced, relative novices in the department. However, the lack of recognition tended to formulate through departmental and organisational levels, via a lack of concern towards capturing the knowledge of these experienced individuals. As many of them had worked in the company for twenty or more years and not uncommonly having spent the majority of their time within PC, it meant that rich source of knowledge which was contained implicitly, would cease as and when the individual practitioners left. Their departure was imminent through the natural depletion of expertise e.g. change of department or even organisation; or more likely in most of the cases in question, retirement: Therefore a total removal of the knowledge from the industrial domain, if their knowledge or expertise fails to be captured before they leave.

The issues of capturing the knowledge of these practitioners needs to be taken more seriously by the organisations they reside within. Their knowledge, of which was observed as highly contributory both directly through good practise and high quality results; and indirectly through advisory means. If withdrawn, this will be noticeably detrimental to the quality of results. Subsequently such knowledge-losses will be a true failing if allowed to gradually diminish without structured capture.

## *6.2.7. Inter-Related Themes:*

Clearly, issues involved with the theme of data and information incorporate the consequences of when the required inputs were not obtained, including reasoning behind why this might be. This has been mentioned throughout the themes, involving reasons stemming from areas as the organisational culture, e.g. fear culture; the understanding of costing, and basically all other identified themes. These linkages extend to how the data and information was accessed, including procedures, IT systems, meetings, reports, general communicational processes related to accessibility. As the themes are explained individually, the overlap between them becomes apparent. Figure 6.5 illustrates this mesh of integrative relations: The figure was developed systemically, refer to Figure 6.3 as all six themes are inter-related with the linkages displayed. Figure 6.3 shows how the themes and subthemes were physically displayed, colour-coded and linked to each other. Figure 6.4 simplistically illustrates the main themes; depicting them in a circular manner as to highlight the continuous connection and impacts between them. Figure 6.5 is a more concise, clear and detailed illustration of the photographic image depicted within Figure 6.3; which ultimately presents what has been explained within Sections 6.2.1.-6.2.6 where each cost-theme has been individually discussed. The factors that directly influence each of the six themes have been highlighted along with how they link and / or impact upon each other. The explanations in the previous sections incorporate how many issues which arose have equal prominence within a number of the themes; others are related less directly.

The illustration in Figure 6.5, (derived from the analysis shown in Figure 6.3) shows the directly related areas by grouping them around the focal theme; then links them with the others which have relevance. As the themes related to each other, the associates have been noted within each particular theme-section. However Figure 6.5 shows the direct and clear linkages, making it easier for the observer to see the relations. An issue which was prominent throughout the themes was that of IT and formalised costing tools, the use of which was becoming ever more prominent throughout industrial costing. The following section highlights some of the points made in relation to these softwares.

### 6.2.7.1. IT and Software:

As there are potentially so many parameters towards the costing of a product or component, a number of computer-based tools and software have been developed to assist with the process, calculations, and other requisites such as material costs, overhead-estimation and so forth. The type of software developed tend to comprise of the requirement to in-put a number of essential parameters such as start and end-dates, labour hours, etc; along with non-mandatory ones, which help with accuracy if known [Rush, 2002]. When this information is provided, equations within the software calculate the results, and produce an estimated cost. This is a basic and generalised description of the type of assistance a computer-based tool will provide, but summarises the type of system that is employed. Many issues surround this area:

- A significant number of practitioners felt that even after considerable investment, the tools were inadequate, and manual results produced higher confidence levels. This was primarily due to constant changes in the environment that were not updated regularly enough within the supporting software databases. This did not just apply to price-changes of material, labour, etc but also of the ability to incorporate every type of material composition available, which was numerous, at the desired rate required.

- The decision of whether to buy from one of the vendors, and if so which one; or whether to develop in-house tools. Although there are a number of commercial products from companies such as Price Systems, Galoreth, Cognition [Rush, 2002] see Table 3.8, Chapter 3, many organisations found that none of these products satisfied their needs completely. This was in part due to the lack of information regarding the equations used. However, it would not be commercially viable for the software developers to release detailed information with regard to this, primarily because a number of organisations developed their own in-house tools. As each tool, either in-house or commercially-sold are developed from scratch, they will all differ to varying degrees; but this will result in differences, minor or otherwise, in their resultant out-put.
- Such inconsistencies do not help in the endeavours towards any kind of standardisation within the costing process.
- Due to the nature of the tools i.e. in-putting project figures, outputting an estimation, it has aided in the perception of PC being a ‘black art’ or ‘black box’ activity. This in turn leads to lack of confidence in the results, as it cannot always clearly be seen or explained how they have been derived, so assumptions are made that it may not be accurate.
- Lack of technological consistency: Within medium / large organisations in particular there can be different IT systems in place, which are not compatible with each other. The diversity can range from sophisticated, state of the-art software, to paper-based systems: This consequently stifles information-flow.
- Other organisations may have had such technology available to them via management changes or corporate take-overs; therefore there was the distinct impression of imposition of such tools, which the practitioners neither wanted nor felt confident using. Hence little confidence was placed in the tools, despite their high cost of development, and perceived state-of-the-art technology being presented to them.
- In contrast to the previous point, there were a small number of organisations with a complete lack of such software. This was when the organisation has not invested in the products, leaving the practitioners to work as efficiently as they can without them. The reason for this lack of investment can be down to management unawareness of the need for them; lack of funds; the perception that they will not add value, or more commonly that it is not worth investing in the costing department.

## 6.3 Knowledge and Themes

The knowledge required in order to cost a product has been identified and falls into eight main knowledge types, these are summarised within the previous Tables 6.4 - 6.9 and represent all aspects of costing, from the physical, explicit to the implicit, soft areas. The major themes which emerged are related to each knowledge type, and are represented in the relevant tables within the individual sections discussing the themes. The knowledge types are examined in detail in the following Chapter 7.

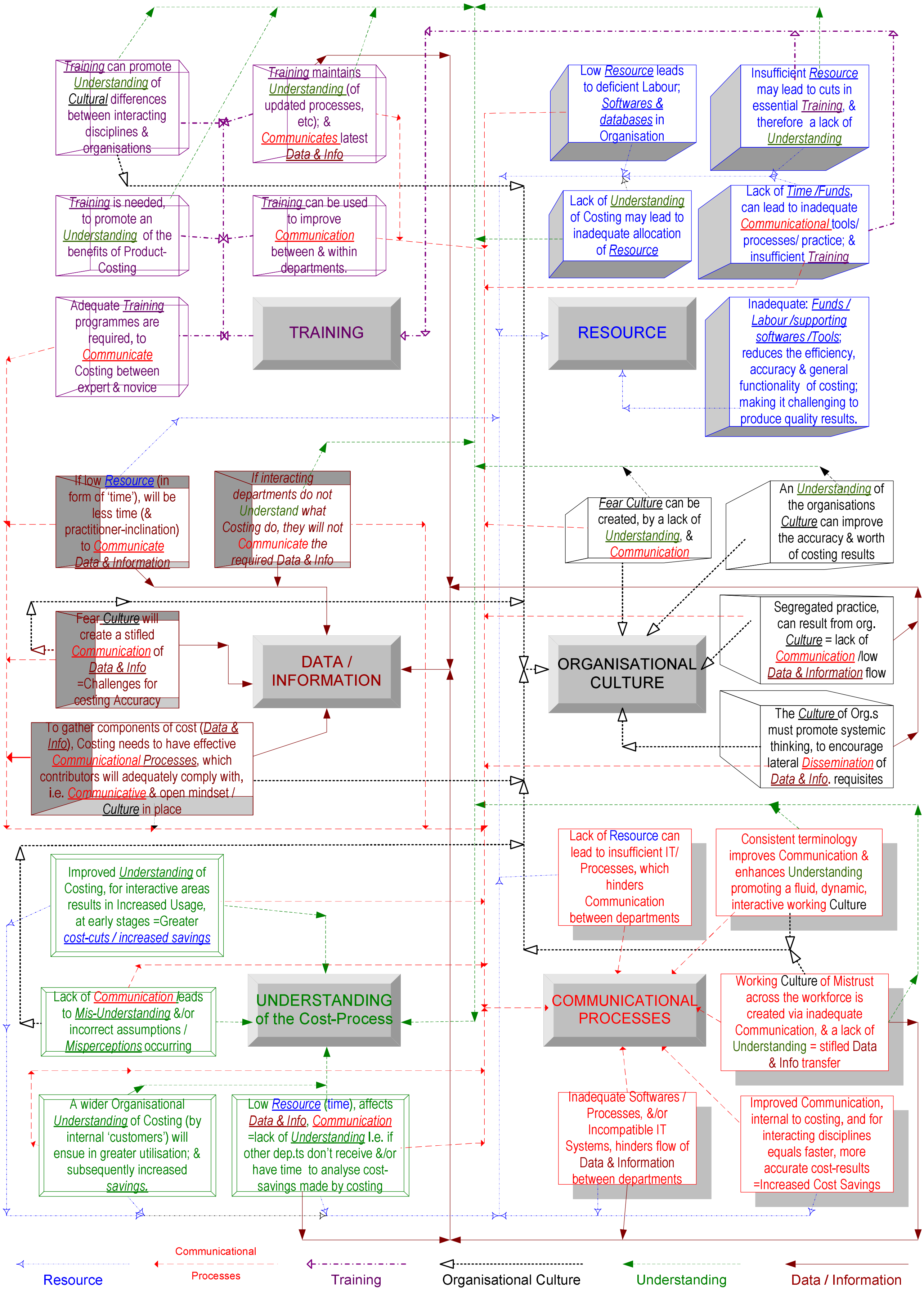



Figure 6.5: The Cost Themes and the Relationships Between Them

### *6.3.1. Knowledge Categories:*

The thematic classification and essential knowledge types were identified as a direct result of the industrial findings. As well as analysing these aspects individually and against each other, they were also considered in terms of knowledge categories, listed in the text box below, and discussed in the following sections. The reason for this further dimension was to help decipher cost-results, and assist in the training requirements through the company responses to the knowledge framework. These categories can be generically described as:

***KNOWLEDGE CATEGORIES:***

*Know –**How*** *Know –**Why*** *Know-**What***
*Know –**Who*** *Know-**When*** *Know-**Where***

#### 6.3..1.1. Know-How:

Know-How: Involves having the knowledge of procedures, techniques, tools, and processes required to undergo and complete tasks: Basically knowing how to do something. Within PC knowing how to breakdown and assess the cost at hand is key. It is linked to know-why, see following section, plus to knowing-what to do. Additionally it interacts with knowing-who; because if knowing 'how' to carry out the function is not known, often other knowledge practitioners are available in order to help determine how. This was commonly seen within organisations where the costing department was larger e.g. 8 or more practitioners, who were co-located. Having knowledge of the different techniques which could be used to cost a product is fundamental costing-knowledge. Chapter 3 has discussed the primary techniques, and listed the focus of each one, e.g. ABC bases the cost on an assessment of the activities required. Whereas FBC relates cost to the features of the product; though the results may have low confidence, they may be performed at the conceptual stages. Detailed estimates are undergone when more data is available to base them on e.g. at later project phases; but it was observed as being more specifically related to the amount of time the practitioners were given to produce the costs. This can be linked back to the culture of the organisation, and whether costing is a valued function or whether the lack of resource indicates that it is not. Included in the definition of know-how are the tools used. There are a number of costing aids in the various forms of software tools, and as mentioned in the previous IT and software section, are a few major commercial competitors in this domain. However it was not uncommon for organisations to develop such tools in-house to suit their own specific requirements. Either way the practitioners must know how to use the tools in order to gain benefit from them: Practitioner ability of use, trust in the tools and willingness to use them has been discussed in the previous two chapters, particularly in relation to the culture of product-costing, and the environment in which it is performed within.

#### 6.3.1.2. Know-Why:

Know Why: Denotes a real understanding of the fundamentals behind what is being done and why things are undertaken in the ways that they are; knowing where and how specific sections of work fits into the overall process. This level of understanding tends to encourage commitment and a sense of responsibility. This description of knowing 'why', can be assimilated with holding a systemic viewpoint; therefore within costing it was considered as highly advantageous. One industrial example of when a more in-depth stance was preferable was presented by an experienced practitioner from within a large automotive organisation. The comment was concerned with purpose-built software, developed in-house; it was a sophisticated programme, which ultimately fundamentally allowed novices and non-specialists to perform estimates on a range of product areas: This of course presented many benefits. However one of the negative points which was raised, was in relation to the potential lack of process-knowledge of the users, particularly the less experienced ones. If the tool was used almost 'blindly' i.e. parameters were specified, without a prior sense of what the outcome should be, then mistakes could be made, but go unnoticed. A senior cost practitioner expressed views that:

*"…they need to have a rough idea of what the outcome's going to be …'cos the output could be way-off …need to know when it's not right.. …and be able to check it"*

[Senior Cost Estimator, Automotive Industry, 2002]

Such events could be problematic for the organisation, through lost revenue e.g. if escalated costs submitted from supplier went unnoticed and therefore unchallenged; creating unrealistic budget / time guidelines. In other words, if the user of the costing-tool does not already have an approximate idea of what the cost should be, then any errors-inputted either human error, or actual inaccurate data collected, would subsequently result in those mistakes being out-putted, filtering into the final result. If the software is used with confidence, but with a lack of the systemic knowledge required to judge the validity of the output, then the results will be accepted without question, and placed into the cost system. One off's may be straight forward to identify and rectify; however if miscalculations are absorbed regularly, especially across large projects, the resulting cost will be inaccurate beyond acceptable margins of error. The unreliable results will have been created from potentially avoidable blunders. Therefore it was conveyed that although the tool could be an effective aid for the practitioners, if used with a lack of knowledge to validate the output, could be detrimental.

To summarise: Knowing why a cost was being undertaken, having an understanding of the contributing elements and an awareness of where the outcome fits into the overall process will give a sense of what the result should be. The ability to recognise whether the output of a programme as well as the contributing parameters are within the expected range, are essential if inaccuracies are not to be overlooked. Throughout the industrial observations, it could be noted that knowing 'why', in accordance with the previous description when costing, was advantageous, as it outlines the possession and implementation of a systemic view.

#### 6.3.1.3. Know –What:

Know–What Focuses on knowing what to do; what activities are needed to accomplish a task; the information required to make a decision: Knowing the collection of components which need to be gathered to produce something. This definition refers to knowing what to do in order to make decisions; it is understandably dominant within the costing results. Within the general frequencies shown in graph-form within Figure 6.6, know-what has emerged as the highest frequency factor involved, though percentage-wise there is not large differences between the knowledge categories; see the detail listed in Table 6.10. With this said know-what is notably dominant, not unexpectedly as the need to make judgments from the information at hand is imperative to the costing process. The very nature of PC dictates that even with a large amount of reliable data and information available, the product-cost cannot be definitive. Although it is not expected to be, significant budgetary decisions tend to be based on the costing-outcomes, so the ability to make credible decisions and high confidence assessments are central to the process. As can be seen within the industrial breakdown, refer to Table 6.10, know-what emerged as a notably dominant frequency within both aerospace and particularly automotive. This shows that the estimating decisions are strong within these environments, with possibly a more integrated responsibility of these decisions placed within the 'other' organisations, represented in graph-form in Figure 6.7. For example when PC are sent a prototype component, the practitioner needs to understand what is involved in its' development and production to know what comprises the costs. This includes knowing what ensures it is accurately assessed, and that none of the areas which will contribute to its cost will be overlooked. When a supplier submits costs to the company, product-costing need to know what is being costed and have an awareness of the details of the item in question, in order to establish whether the supplier costs are reasonable. See section 7.2.3.3 and Table 7.2 in the following Chapter, 7, for further discussion on supplier interactions.

#### 6.1.3.4. Know-Who:

Know-Who encompasses the knowledge about networks, relationships, and contacts; it's related to developing a system, often tacitly, about the people who can provide assistance in different areas. Communicational issues across the costing process have emerged as a key aspect within this research, with both the themes and the knowledge types identifying specific communicative aspects. The Know-who category highlights more interpersonal forms of communication which have been identified as needing development if the process is to thrive: Development of working relationships and networks assist in the identification and flow of data and information. It also promotes integrative working and subsequently a greater understanding of the different, but interacting disciplines or cultures involved in producing a cost for product. Internal and cross-disciplinary relationships as well as those between organisations have been discussed throughout the thesis, including Chapters 3 and 4 when examining the cost-process theoretically and in practice. The importance of the development of interpersonal relationships, in order to gain knowledge and locate data / information is an important finding of this research. The fact that it has not been the most highly referenced throughout the analysed interviews as illustrated in Figure 6.6, further reinforces the notion that although it is crucial to the process, it can often consciously be neglected or considered as less important than some of the more technical, physical knowledge aspects required. The reason why is linked to a lack of appreciation towards integrated working which knowing who, the use of networks etc., is associated with.

#### 6.1.3.5. Know-When:

Know-When is linked to understanding the timings involved: When something is needed by; when it needs to be started and / or stopped; an awareness of the times involved to complete activities. With regards to the Know-when category, although it was referenced notably less frequently then the other five categories, was still referenced; see Figure 6.6, Table 6.10. Time frames are assessed within costing: Durations of projects; and when the costs need to be compiled by: However the primary concerns have fallen within the other categories even though it is evident that knowing-when does factor towards product-costing. This may be due to the fact that the real concern is related to when a cost is required by: This will influence the type of technique used to perform the cost e.g. whether enough time / information available for detailed costing; or whether parametric, or ROM will suffice. However other then this, knowing what is being costed, why it is required, and how to do it; along with who has the contributory data and where this can be found are clearly more pressing factors within the process. The aspects of when costs need to be compiled is often pre-specified on request; and the durations of project running-times can be derived via compilations from various contributing departments. From this perspective, the other ‘knowing’ aspects do require more direct input from the practitioner themselves, as opposed to consideration of the time assessments or constraints of those inputting to the cost.

Figure 6.6 presents a histogram of the frequencies of the cost knowledge categories. This essentially highlights how often each of the six categories was referenced within the data; knowing what to do has marginally emerged as the most prominent; whilst know–when was clearly the least pressing concern of the research contributors.

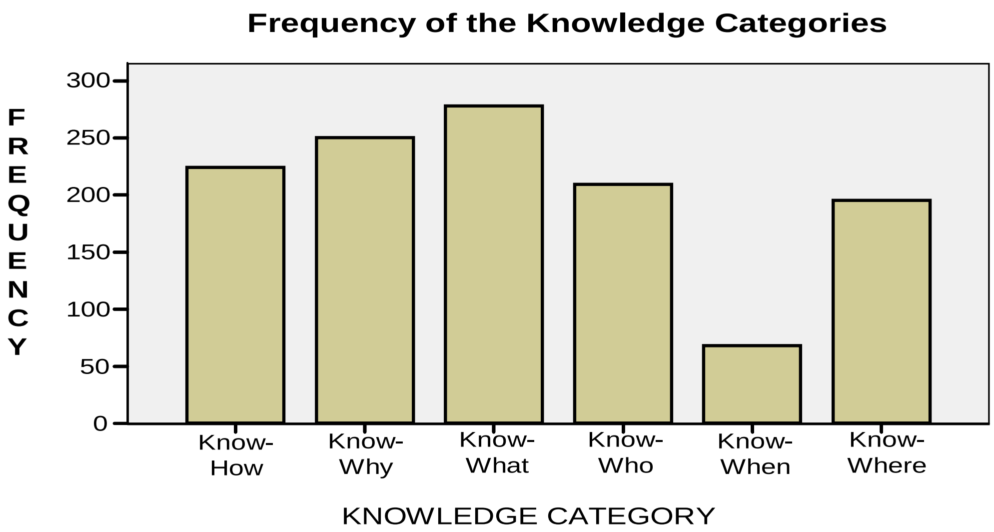



Figure 6.6: The Frequency of Each Knowledge Category

### 6.1.3.6. Know-Where:

*“Knowledge is of two kinds, we know a subject ourselves, or we know where we can find information upon it .”*

[Samuel. Johnson, cited in Fanning, 1993, p8]

Know-Where related to having the ability to locate things and information; knowing where things that are required can be found, the ability to navigate through to find what is needed [Collison and Parcell, 2001]. With this description in mind, knowing where information / data could be found was a fundamental aspect of costing, particularly where databases were either not kept, or not updated regularly; and aspects as material costs and labour rates were continually required. Know-where emerged more strongly then knowing ‘who’ within aerospace and automotive industries, as shown in the graph within Figure 6.7: In these cases the tendency of emphasis can be seen to be placed more on the physicality of data and information itself, rather than the people who may posses and convey it. This is not untypical of the general findings of results e.g. practitioners mentioned physical directories of functions and / or personnel; or perceived that an increase of more sophisticated, compatible systems was the way to improve the process. Hence validating the need to reinforce the importance of personal communications i.e. the development of human networks, with regards to the location and delivery of the required cost-data and information. With this said, the variation between them, on the industrially cross-tabulated graph of Figure 6.7, is marginal. Therefore the process of communication, whether interpersonal or otherwise, is inextricably associated with locational issues of data and information, as this knowledge category represents.

Section 6.1.3.5 discussed that Knowing-when appeared less frequently then the other 5 categories, which was again as expected since the primary sense of timing required was often linked to project durations, and cycle-times within manufacturing processes. These elements were encompassed within other aspects, so did not independently manifest. Knowing -what, -how, -why, -who and -where are key within the fundamentals of costing. Knowing what needs to be done is a core element in costing; coupled with how to do it: As with a number of functions, the combined knowledge of 'what' and 'how' is essential to undertake the process. However, an understanding of why is additionally an essential within costing. The ability to predict costs requires a fundamental knowledge of the elements which lie behind the hows' and whats', in order to predict uncertainty and risk. The knowing of who and where information is, is related to the important issues of communication and culture; which both relay the requirements and allow them to be communicated, respectively. Given this overview, it was clear that the costing-research would be assessed within these categorical forms of knowledge reference; classification against each one can broaden the perspective in which the domain results are perceived and evaluated.

## *6.4. Statistical Analysis:*

Clear links can be made between the cost themes, cost knowledge-types, KT and the previous descriptions of all the generic knowledge categories, KC see Section 6.3, Table 6.6. Therefore analysis within them gave further validation to the importance and application of the results found. The statistical analysis which was conducted for the exploratory phase of research incorporates these knowledge categories, illustrated in the graphs within Figures 6.6 and 6.7. An initial point is to note that these categories were present within the analysis: The final and first four were highly frequent, which is as expected, see Table 6.10.

Table 6.10 Detail of the Knowledge Category, (KC) Frequencies.

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Know-How | 224 | 14.3 | 18.3 | 18.3 |
| | Know-Why | 250 | 15.9 | 20.4 | 38.7 |
| | Know-What | 278 | 17.7 | 22.7 | 61.4 |
| | Know-Who | 209 | 13.3 | 17.1 | 78.5 |
| | Know-When | 68 | 4.3 | 5.6 | 84.1 |
| | Know-Where | 195 | 12.4 | 15.9 | 100.0 |
| | Total | 1224 | 77.9 | 100.0 | |
| Missing | System | 347 | 22.1 | | |
| Total | | 1571 | 100.0 | | |

Table 6.10 was generated by SPSS, a statistical analysis programme. It gives the frequencies of the knowledge categories i.e. how often each one was mentioned within the results. It also presents each KC in percentage form; hence not only highlighting how often each one specifically

occurred but also converting this figure to a percentage to represent it as a proportion of the overall results. The missing parameter signifies how often a KC was not mentioned: See Table 6.3 which gives an example of how the results were formulated. The figures against each practitioner statement were then fed into SPSS to produce a basic statistical perspective of the analysis, principally in the frequency of KC and KT as overall results, and then classified within their respective industries.

Figure 6.6 shows how often each KC occurred, whilst Figure 6.7 gives further insight into the spread of results, presenting how the KC emphasis occurred per industrial classification. Section 6.1.3.5 discussed that Knowing-when appeared less frequently then the other 5 categories, which was again as expected since the primary sense of timing required was often linked to project durations, and cycle-times within manufacturing processes. These elements were encompassed within other aspects, so did not independently manifest. Knowing -what, -how, -why, -who and -where are key within the fundamentals of costing. Knowing what needs to be done is a core element in costing; coupled with how to do it: As with a number of functions, the combined knowledge of 'what' and 'how' is essential to undertake the process.

However, an understanding of why is additionally an essential within costing. The ability to predict costs requires a fundamental knowledge of the elements which lie behind the how's and what's, in order to predict uncertainty and risk. The knowing of who and where information is, is related to the important issues of communication and culture; which both relay the requirements and allow them to be communicated, respectively. Given this overview, it was clear that the costing-research would be assessed within these categorical forms of knowledge reference; classification against each one can broaden the perspective in which the domain results are perceived and evaluated.

The themes have been analysed quantitatively, in Chapter 4: Whilst the frequency table revealed the strong presence of all themes throughout the analysed interviews within the exploratory section, see Table 4.6. This reinforced the qualitative findings, where all themes were identified; even though at the early research stages training was not a focus, it is still present if slightly less frequent then the other themes, see Figure 4.3, Chapter 4. Observations in occurrences between the industrial spread was also presented and the statistical differences were assessed and discussed, see Figures 4.3 and 6.7; plus Table 4.6, Chapter 4.

The main findings as discussed in Chapter 4 include a notable high result for Organisational Cultural issues within the automotive industry; relating this finding with Figure 6.7 shows that knowing 'what' is dominant within automotive. This can be caused by a number of cultural angles within these organisations: An obvious one being the fact that often the contributors were international organisations. This meant that understanding was required for many of the cultural barriers between the internal, but global branches. Accompanying this is the fact that the theme of Understanding of the cost-process is also prominent within this industrial grouping. In addition a number of the companies examined had experienced merges with other organisations, thus creating potential confusion of the organisational culture(s). The below graph illustrates the levels of prominence placed on the knowledge categories within the industries examined.

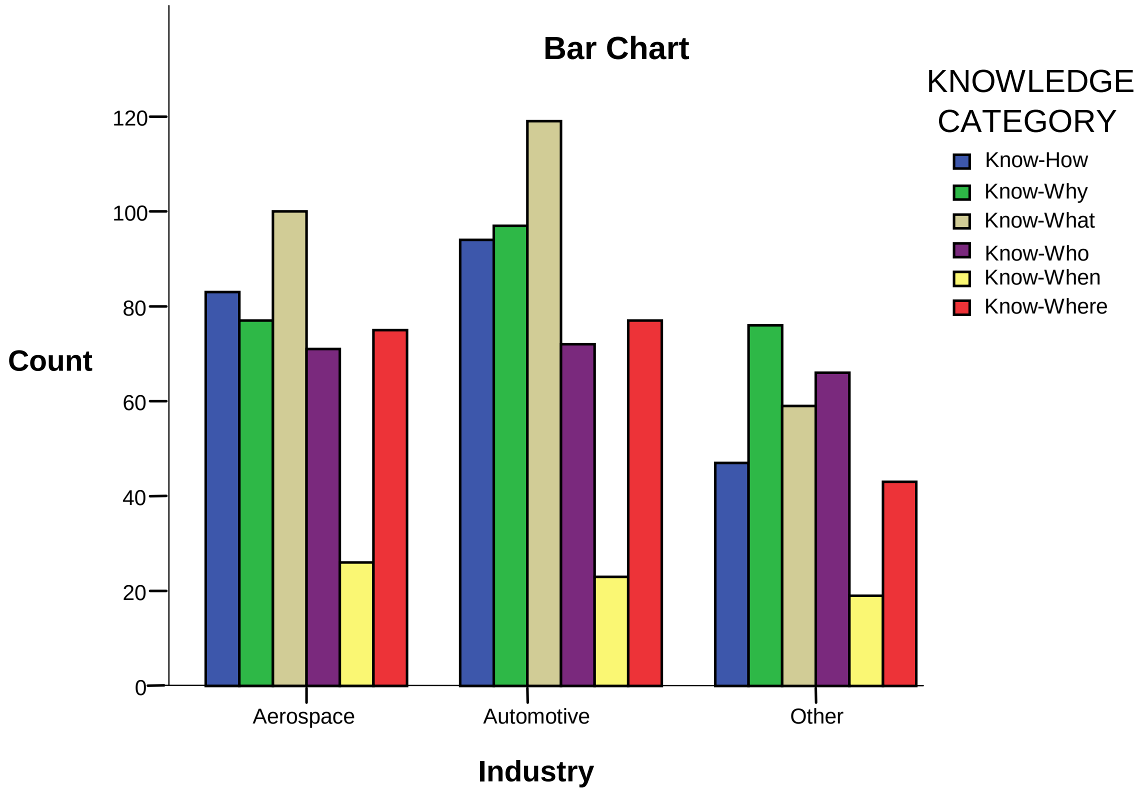



Figure 6.7: Graph to Represent the Industrial distribution of the Knowledge Categories

### *6.4.1. Industrial Influence on the Knowledge Categories:*

Know-why category was high in all industries i.e. it was within the top three KC, but noticeably lower in aerospace organisations. This was due to the fact 'over-the-wall'-type working practice was more apparent within this domain, more so then in the private companies, who tended to adopt innovation more readily. Such working practices were catching up with the more established, largely publicly-funded bodies; but due to the regulatory culture, not as rapidly as was perhaps preferable.

Again knowing what was clearly key in automotive organisations and aerospace. No matter how systemically the workforce should be working in theory; they tended to keep to their specific roles, with the idea of systemic working needing constant validation. The general feeling was to complete ones own tasks as priority; as unless the organisation actively promoted integrative working, the fear of failing within your own role was always dominant, and would thus govern attitudes. This is revealed in the know-what frequency of statements that emerged within the high pressure and competitive automotive culture; as well as in the segregated, long standing practices of the aerospace community.

Within a couple of the 'other' organisations general good practice with regards to communications and overall integrative working could be noted. This was partially apparent within the SME which did not naturally suffer from the challenges which were inherent within the larger organisations i.e. communicational difficulties / cultural barriers between large bodies of diverse disciplines. This was evidently due to the fact that the number of employees was smaller, so it was easier to communicate between the departments and for all the employees to gain a systemic understanding of both the intricacies and overall aims of the company.

One large manufacturing organisation was notable, due to their overall best practice of general working processes, adopted across the board. This was by far the most advanced organisation in this respect, with the others interestingly displaying the predicted challenges, if at various levels. However this efficiently-working organisation had high quality practices not simply recognised at the managerial levels, but also actively implemented throughout the organisation. This was due to a low point in their overall success a few years prior, which forced them to re-evaluate their procedures, and general culture. Outside bodies (consultants) were employed to assist in the turnaround; the solutions from which were seemingly trusted and subsequently relied upon owing to its being recognised as a last resort. The manager explained:

*"…We were on the point of collapse ..called in outside help to turn things around ..implemented integrated working ..all levels of staff were involved ..better communications …things totally picked up from there."*

[Proposals Manager, Manufacturing company, 2001]

This is interesting in itself: The issue that bodies do not re-evaluate themselves voluntarily, as long as there are other options. Providing there still appear to be safeguards e.g. perhaps as with government funded organisations, then it can be challenging to implement fundamental changes to working environments, possibly because the need is not there. Therefore accepted practice, detrimental or otherwise, will prevail, due to a perceived lack of need to implement change.

Within the 'other' organisations category, know-why was dominant within the results, often because best practice techniques were employed and adhered to across the organisation; with roots as mentioned above, stemming from potential collapse and failure. The know-how category was stronger in the other two industrial domains; denoting strength in communicational aspects, which is a driving factor within the success of product-costing: Though it must be noted that within the aerospace and automotive industries the frequently-cited categories were observed via interview analysis, as being referenced in order to highlight the weaknesses experienced, and not the current-practice strengths.

The percentage ratings of knowing-who and -where were lower in the aerospace and automotive industries then in the 'other' listings. This enforces the view that not only do the medium sized and smaller organisations have fewer challengers with regards to communication and locational issues: It also shows that commercially driven products need to work more integratedly. This can reveal fundamental differences regarding the priorities of the companies, and in what is used as motivation. Namely, the overall profits may be accepted as key at all levels, rather then specific departmental working practices in the private companies, in comparison to the public ones with the large automotive organisations displaying similar characteristics in this respect to the latter mentioned i.e. the government funded establishments. In other words, privately funded companies had no safeguard with regards to revenue loss; therefore if working practice was not effective, new approaches were seemingly adopted more readily then within government bodies where the perception was that there was more of a safeguard regarding financial loss. The latter situation was also evident within the larger, more established automotive organisations. As discussed previously, knowing-when is notably low within all industries. This reveals aspects of the nature of costing namely that though issues of timings are accounted for, it is not the most important element of the process; with knowing what, why, where and how to conduct the process, prevailing.

Many concerns in respect to individual company-culture needed to be tackled at local, as well as systemic, organisational levels; whether within the same country, or across the international branches of the amalgamated companies, which were now acting as one. This can also explain why the theme of communication was also prominent within the automotive industry, as this area was dominant for merges within the industries examined; refer to the graph in Figure 6.7, and the following Table 6.11.

Table 6.11: Industry * KNOWLEDGE CATEGORY Cross tabulation Count

| | | KNOWLEDGE CATEGORY | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Know-How | Know-Why | Know-What | Know-Who | Know-When | Know-Where | |
| Industry | Aerospace | 83 | 77 | 100 | 71 | 26 | 75 | 432 |
| | Automotive | 94 | 97 | 119 | 72 | 23 | 77 | 482 |
| | Other | 47 | 76 | 59 | 66 | 19 | 43 | 310 |
| Total | | 224 | 250 | 278 | 209 | 68 | 195 | 1224 |

Aerospace had the highest level of occurrences from the theme of data / information flow, which was seconded by culture, refer to Chapter 4, Figure 4.3. Here, the participants examined were often large, established organisations, who had experienced a number of cultural changes, though were noted for their routine techniques, which were ingrained within the working culture. The perception of such organisations was that they were not quick to adopt fundamental modifications, tending to embrace the established systems. Subsequently communication and understanding were frequently occurring themes within this industry, due to the described lack of information and data which was experienced, often as a result of fundamental cultural misalignments between the internal interacting disciplines; see Figure 4.3 and Table 4.6.

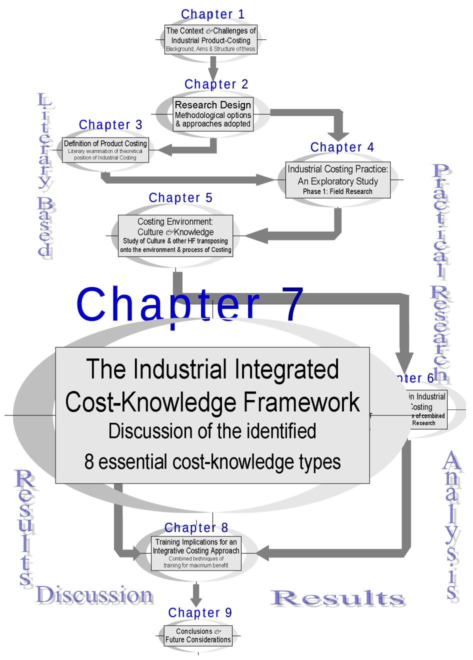
## *6.5 Summary:*

This chapter has presented the background derivation of Phase 2, linking literature directly related to costing in Chapter 3, with the first phase research, P1 presented in Chapter 4. This highlighted the need for an expansion of the targeted examinations, in order to incorporate the context in which the costing process was performed within. These environmental issues were studied from a literary perspective within Chapter 5 highlighting aspects which require awareness, due to the fact that they have influence over the process: Namely organisational culture and communicational issues which affect the understanding in and of PC. These three aspects affect the level of integrated working both within the cost-discipline as well as impacting the external contributors; therefore are among the 6 main costing themes which resulted from P1 research; being validated and reinforced within P2. Table 6.2 lists the total contributors towards all research phases, showing the diversity of perceptions incorporated within the results: 24 organisations from within 6 industrial domains. The cost-themes derived from the industrial feedback have been outlined, individually: Figures 6.4 highlights the headings, whilst 6.5 illustrates the themes and sub-themes, indicating the linkages between them. The relevance of each theme has been discussed individually and tabulated against the essential knowledge types within costing.

Whilst the themes tend to indicate the major challenges experienced within costing, including the ones associated with the contexts that costing is grounded within; the knowledge types are what is needed to conduct the process, particularly within the challenging environments observed. The following chapter presents the way in which these knowledges' were identified, along with specific discussion on each of the 8 types; including their importance, relation to each other, and industrial differentials. Chapter 7 discusses in-depth, the specific essential knowledge-types required to cost a product, relating them to the industrial cost-themes.

# Chapter 7:

# The Industrial Integrated Cost-Knowledge Framework




Product Costing is:
*"…is a 'black art' ..and highly individualistic"*

*"No two practitioners will produce the same results, via the same route for any given estimate; though it will lie within the same ball-park figure."*

*"Knowledge is when you are able to do something, via a number of routes; and are not limited to one or two ways: So are capable of producing results, even in difficult or limited circumstances…"*

[Industrial Cost-Practitioners]

This chapter highlights the knowledge that is required within the costing domain, as determined by direct input from the contributing industrial practitioners, combined with the literature on this subject.

The process involved in producing costs for a product has been perceived as a 'black-art', with the relevant tools implemented to assist this process being known as 'black-box' exercises. This implies that what is involved within the process of product-costing, PC is not known or unclear, which can naturally result in skepticism towards the results and the validity of the overall process. The image of the costing process, and levels of confidence held by other departments towards this activity have been discussed in the previous chapter. The general feeling was that it was not understood and as a possible consequence of this, was undervalued and under-utilised.

The vagueness emerging from attempts to pinpoint a standardised, regular process for costing is almost certainly due to its very nature -which involves soft and hard aspects equally in order to produce the results. The explicit elements employed are able to be relayed in a direct manner. However it is the implicit aspects which although are intrinsic to the process, are more challenging to include within it in an unequivocal, comprehensible form due to their being simply 'understood', therefore incorporated in an automatic-type manner, as opposed to deliberately or on a conscious level. The combination of the tacit and explicit which comprises PC, is why it is perceived as being ambiguous, particularly from a viewpoint external to the costing.

The above industrial quotes highlight the widely adopted industrial perception that the costing process is inconsistent, idiosyncratic and subsequently difficult to define. The general industrial belief seemed to be that there is *"…no substitute for experience"* [industrial cost-practitioner], and only the basic fundamentals of product-costing can be taught. This chapter discusses the results of a thorough dissection of the costing process, and breaks down the elements involved in determining the costs of product, defining how the process is conducted, in a direct, coherent and comprehensible manner. The result of such definition and clarity leads onto how the process can be conveyed, implemented industrially in an effective, practical way via training among other means, all documented in the subsequent chapter. Tacit knowledge is perceived by technical domains particularly those external to costing, as capricious in its identification, let alone its assessment and measurement of use in activities and processes. However, within this chapter the knowledge required to perform the costing-process has been established and is detailed.

Although initial perceptions of knowledge can often be that it is implicit, the interesting observation made within product-costing is that areas of knowledge are quite tangible, being recognisable requirements within organisations. The use of specific knowledge becomes obvious due to their regular use and reference by the practitioners. Within the product-costing domain, across the organisations and industries examined, see Table 6.2 in the previous chapter for details, eight distinct knowledge-types (KT) have been determined, all of which are interlinked when conducting a cost-assessment. Throughout this chapter the necessity for each one will be supported with the use of industrial anecdotes and case-studies. Examples of how they, the KT are each utilised, in a variety of actual situations suggests how they can potentially be adapted and re-used for future requisites. The meticulous and measured dissection is hoped to dispel the 'black art' image of the costing process, perceived by interacting disciplines. This is in conjunction with redefining the practitioners own admissions, that it is a highly inconsistent process which can be derived in a variety of ways. The research results instead endeavors to reinforce the confidence that industrial product-costing is a consistent, logical process; which can be performed via a finite variant of established techniques. Such codes of practices can be implemented in a professional manner which, though will necessarily vary in accordance to conditions, will produce credible, consistent results internally, which can be validated and trusted by the external customers of PC.

As only the most essential knowledge types were incorporated within the final cost-knowledge presented, on review amendments were been made to the original selection reducing it from ten to eight, see Appendix 9, Table A9.1. Section 7.2.3 addresses each knowledge-type discussing why it either stayed within the requisite classification, or whether it would be represented within the other areas sufficiently enough to allow this amalgamation to address the omitted knowledge-type adequately. I.e. the minority of those identified within the initial phase of research were not kept within the final knowledge compilation. Although they are still utilised within the process, it was determined that they did not need to be listed as independent knowledge-types, as were sufficiently represented within the other knowledge-areas, therefore unnecessary to list them independently as well.

This chapter initiates by discussing consistencies in terms utilised throughout the research, ensuring the contributors were aligned in their thinking towards the concepts used, e.g. for knowledge. It redefines the preliminary draft of knowledge-types considered, scoping them to ascertain total relevance and their direct influence and prominence on the process. The knowledge types are then discussed within Sections 7.3.1. -7.4.2, detailing their application within PC and relation to each other. Despite the fact that all the mentioned knowledge types are linked heavily with each other only the dominant ones, within the overall environment incorporating both the explicit and tacit-knowledge issues, were included within the final list of essential knowledge-types for costing practitioners, reference Appendix 9, Table A9.1. This is because the knowledge used in costing is directly linked to TNA and other training issues, discussed in the following chapter. The review of the cost-knowledge was necessary, as the knowledge framework on which the training assessments were based, needed to be both accurate and concise with regards to consideration of the core elements of the cost-training programmes.

## *7.1 Deducing the Knowledge-Types*

A total of 25 organisations have participated in this research, allowing their costing processes, activities and interactions to be examined; see Table 6.2 for a full list of contributors. Analysis of this data resulted in the identification of a number of issues from which similarities were detected and classifications were able to be made. Subsequently they were structured into themes which have been discussed in the previous chapter. These themes were recognisable due to the reoccurrence of elements or points raised across the subject domain. Analysis of the data resulted in such exposures becoming evident i.e. when contributors from various organisations noticeably made reference to similar or related issues; and familiarisation with the data subsequently enabled recognition of emergent themes. As the research unfolded it appeared that these aspects were not always linked to technical, explicit sources. This is as might have been assumed when referring to this area, prior to accessing the revelations derived from this research; highlighted fully in Chapter 6. The results can be seen to show the contrary, that not only were the main issues and ensuing challenges not predominantly technical, but were more often linked to communicational issues, organisational culture and social aspects / general human factors: The importance of which can often be overlooked in an engineering, manufacturing-type environment.

Knowledge issues are ubiquitous to the themes classified in the previous chapter. The research has identified the main knowledge types utilised within product-costing. They have been listed within Chapter 6 against the costing themes, see Tables 6.4-6.9; and can be seen in Appendix 9 in Table A9.1, and Figure 7.7. Of the eight main knowledge types which are employed throughout industrial PC each have a number of subheadings which are all generally interlinked with each other; see Table 7.3. Details of the KTs including their identification, application and relation to each other within the performance of product-costing are discussed throughout this chapter.

### *7.1.1 Generic Understanding of 'Knowledge':*

The knowledge types deemed essential towards costing a product were identified via a process of analysis, namely over familiarisation of data and breakdown of the interviews, as discussed in earlier chapters; and from direct questioning of the practitioners. This meant that subtle, indirect and direct probes were used to address this issue; see Chapter 2 for the detailed methodology applied to the study, and Chapters 4 and 6 for specific research-technique throughout P1 and P2. The interview-analysis has been described in the former chapter, and the main issues arising from the studies became clear with such detailed quantitative and qualitative analysis. This also made the knowledge that is required recognisable, as certain issues were constantly reoccurring from the process; which made both the presence of the knowledge–types and their importance rapidly apparent, being explicitly identifiable.

With regards to direct queries on the subject, questions asking the recipients to convey which knowledge-types are needed by the cost-practitioners to complete the process, was an important part of the knowledge-identification. Within the workshops, this section of knowledge elicitation would start with a session in which the meaning of knowledge itself was discussed, along with information, data, plus skills and competencies; all of which was examined and established for use within this research. The reason that the generic issue of knowledge was addressed was because it was deemed necessary to explain any concept referred to inclusive of participant interactive-discussion, in order to guarantee that the contributors were familiar with them; and ensure that they understood specifically what was being asked. In other words to endeavour to create one, collective understanding of the word 'knowledge', which all participants had a uniform understanding and awareness of: Explanations and discussions towards the word were included in the steps taken to determine a consistent meaning; so that the responses given were all in reference to the same thing. The alignment of the perception of knowledge, along with all other concepts employed across the research, are depicted in Figure 7.1. This measure was taken because knowledge, as mentioned earlier can be perceived as an intangible, implicit issue: Individuals may not have ever had the need to have thought about what knowledge is, but instead always assumed or adopted an implied understanding of it, which naturally will be individualistic, and therefore unclear in its alignment as to what others perception are.

The concepts examined within Chapter 5 which examined fundamental literature related to human factors, supported the bulk of the field-research, subsequently detailed in Chapter 6, by enabling the research to recognise variant ideologies, mindsets and approaches. Broadly speaking there are differences either in ways individuals articulate their opinions and observations; dissimilarities in their view of the world, and subsequent understanding, responses, behaviours and so forth [Trompenaars and Hampden-Turner, 1999; Hofstede, 2008]. Development of the knowledge framework needed to account for these differences in the analysis of data, as well as through striving towards clarity and standardisation towards participants understanding and thinking. Incidentally the knowledge and training workshops proved to be an ideal forum for such group discussion, clarification and alignment of thought, see Figure 7.1.

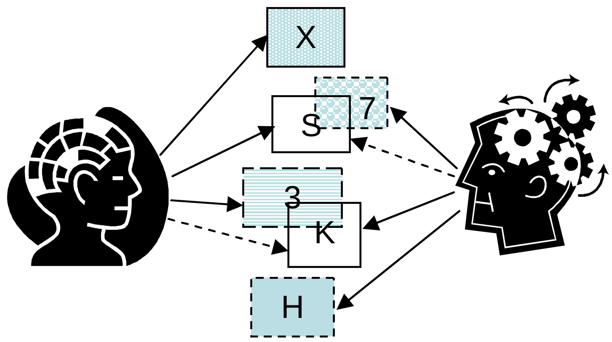
The issue of knowledge and related areas, such as knowledge management and knowledge conversion as relevant to PC were discussed from a documented perspective, detailed in Chapter 5. This laid the foundations for discussion of the more domain-relevant knowledge areas, such as product-costing knowledge, from a practitioner viewpoint within the specific industries examined within this research, see Table 6.2, in the previous chapter.

### *7.1.2 Diagramming Techniques: Representing the Knowledge*

The knowledge types utilised within product-costing had not been formerly identified prior to this research, so it follows that there had not been the need for them to be explicitly communicated. In order to disseminate them into the relevant areas once they were established, the most effective methods of relaying the findings required consideration. The research documents the evolution of the knowledge types describing how they were derived, their implementation and general importance within the costing process.

A number of diagramming types have been developed in order to represent information graphically. A concise collection is presented by Craig, where each diagramming technique is given highlighting its most suitable application. These diagramming types include Force Field Diagrams, Control Diagrams, System Maps, Input-Output, and Tree Diagrams [Craig, 2002]. The specific type selected for use is determined by the properties which are being emphasised, as each one is designed to accentuate different aspects of the information. For example, if an issue which had two generally opposing points of view debated about it, needed to be depicted; for instance a 'for and against' topic, then each point could be conveyed via a force-field diagram. The pros and cons could be graphically communicated, and even the weight or consequence of each factor may be illustrated on the schema. An example of a force field diagram is given in Figure 7.12, when discussing the benefits and drawbacks of IPTs. However, a number of the diagramming techniques by Craig are implemented throughout this thesis, and particularly this chapter as a way of illustrating aspects of the research, with the intention of supporting the descriptive text and enhancing communication of the concepts relaying the findings effectively and as comprehensively as possible.

**A.**




A. shows a natural inconsistency between individuals' ideas: B. illustrates the alignment of understanding more closely, and shared schools-of-thought regarding research subject-domain

**B.**

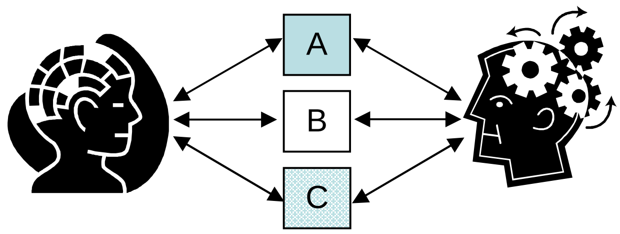



Figure 7.1: Highlights the Necessity of Ensuring an Alignment of the Level of Understanding Between Research Participants, of the Major Areas in Question.

### 7.1.2.1 The Need for Descriptive Illustrative Techniques

Throughout this thesis these diagramming techniques have been utilised in order to depict the knowledge identified, and to present the results in a format additional to the textual descriptions. In addition to this practical usage, the conclusions drawn from the research include the need for the employment of adequate diagramming techniques in order to relay the findings in a universally comprehensible manner, within and across industries. The prerequisite to utilising an adequate range of means for the dissemination of new research findings within these areas, hold more prominence then is initially perceived. This is due to the fact that a number of different areas concurrently interact with product-costing e.g. design and other engineering functions along with purchase, finance; these disciplines can have quite different cultures, which are brought together for the purpose of creating the cost. For instance they may use different languages e.g. product-specific or generalistic; technical against financial; regular, verbal interactions against IT communications; international differences or more local, cross-functional ones. The manner of description should be adequate and broad enough to cater for the level of diversity involved. Verbal descriptions, i.e. lecture / tutored material, documentation and illustrative methods utilised in an integrated way are the most comprehensive approach to communicate the findings fully. Chapter 8 discusses further the different stimuli which people respond to when examining industrial dissemination of concepts including training development within product-costing. It would be useful for the costing domain, not only to utilise diagramming techniques in training but to actually train the practitioners in them, in order to provide another dimension within the communicational process used. See the following Chapter 8 for discussion about the way in which people learn, assimilate knowledge and information.

### 7.1.2.2 Research–Utilised Diagramming Types

As mentioned above there are a number of publications in which a wide range of diagramming techniques are described, whilst discussing their benefits and application [Young, 2003; Craig 2002]. Although not all of the diagramming techniques listed have been employed within this thesis, they have contributed to the understanding of the ways in which knowledge may be represented, and why it is necessary to do so in different formats.

Systems Maps which have been utilised extensively in this chapter, refer to Figures 7.2, 7.5, 7.7, 7.10, highlight the boundaries of any specified focus and not only depict the primary area in question but includes the environment and influential factors it is undergone within. This subsequently draws attention to the importance of having an awareness of the milieu in which the focal domain is situated within, as it tends to impact on the area of focus to varying degrees. For example within a specific industry, a change in components of environment can have significant consequence within the domain under scrutiny. As seen within this research, boundaries can be physical, conceptual, and also perception-dependant. They could comprise of organisation structural issues; or the effective and ineffective elements towards costing. In this research, the boundaries can be seen as the way in which focal areas are identified against their influencing surroundings. System maps can highlight what the central issues are, whilst showing what lies outside the main focus of the inner system, affecting and influencing the core; the environment can be described as the area in which the subject of interest is undertaken within. There can be many levels at which the boundary is placed, e.g. over the entire costing process, with the affecting influencing factors external to the primary contributors. Alternatively the boundary can be broadened to the organisation, with the environment being the more holistic factors which affect it e.g. market trends, world events, and recessions.

The area which binds the focal point is more concentrated in Figure 7.5, which focuses on the engineering elements of product-costing and places the other aspects in the surrounding, but influential environment: Whilst Figure 7.2 depicts a generalised view of the main components of PC as it is performed within an organisational context. The immediate influences on the process are highlighted, namely engineering (technical) and commercial (economic), with the major consideration being towards the levels of communication between these two main contributing disciplines. The interaction between these different specialties namely technical and ecomomic, is affected to varying degrees by their fundamental cultural differences which have been discussed in former chapters as being mainly due to differences in the focus of role; including their perceptions, different priorities i.e. product-performance against product-cost. Both these explicit and implicit main contributors towards costing are at the focal point, as placed within Figure 7.2; whilst the areas which influence but are external to the central boundary are shown to lie outside the core, though influencing or feeding into it, e.g. purchase, engineering-information. Figure 7.7. examines the cost-process in a different and more detailed perspective, by highlighting the main cost knowledge-types identified. These are placed on the central level; with the knowledge that still impacts on the process but which is secondary to the eight which are deemed essential being placed within the costing environment. This technique of depiction can comprehensively illustrate what elements are involved, both primarily in relation to the secondary influential factors surrounding and impacting upon the main area; and highlight how the domain in question is largely influenced by its environment.

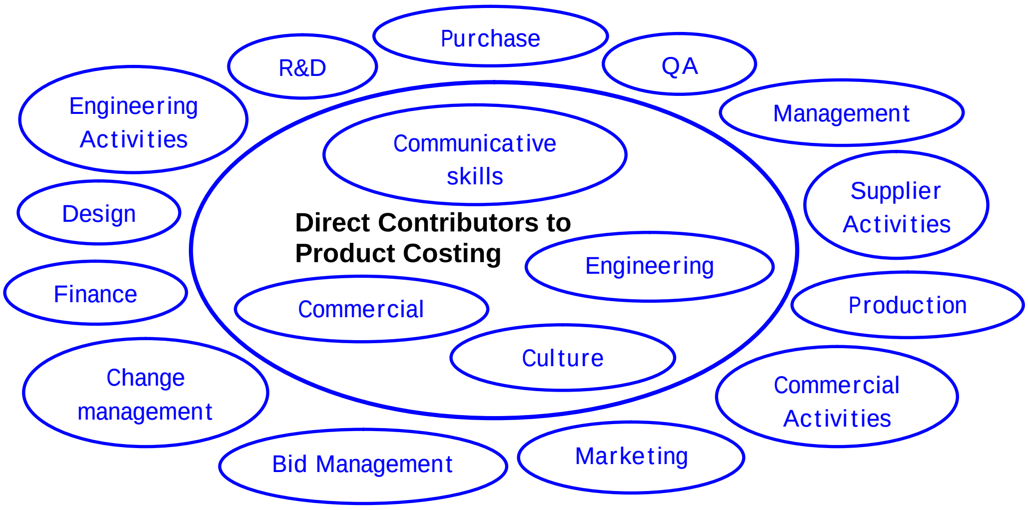



Figure 7.2: Systems Map of the Organisational Costing Process, showing the Environmental Influences on the Core Activities.

Rich Pictures are where an idea or explanation can be communicated by simple, direct images. An example of which can be found in Figure 7.8 which illustrates the basic interaction between the explicit cost-disciplines, within the implicit influences on their interactions.

Tree diagrams are a familiar technique for representation of information and knowledge, see Figure 7.9 which shows the layers within negotiations. They take a number of forms, which differ according to purpose. For instance ‘Family trees’ are a format which are commonly implemented and understood, and can be employed using the same theory within organisations e.g. using structured, echeloned relationships and highlighting the links between each layer. The ‘Categories tree’ is when two major categories head the diagram, and further expand, illustrating the layers and relationships between them in a hierarchical manner, when breaking down each of the header-classifications. They are commonly seen within organisations. ‘Organisational trees’ present a hierarchical structure of the organisation, and have been witnessed within this research to depict the complex structure in corporations. Larger companies use this technique to logically structure departments, showing contributors within various areas, under the specific management. Logic trees are used in domains such as physics. They work on the principle of 'AND' & 'OR', but could also be applied to specifics of costing, when breaking down the components and determining different outcomes, dependent on the caliber of the inputted elements For example if an overseas supplier was used the cost would be 'x'; but if a home local supplier was used the cost would be 'y', primarily dependent on basic costs, plus logistics. The Objective tree clearly states objectives at the top, then the branches lead to sub-objectives that need to be achieved in order to reach a key objective. A derivation of the latter mentioned can be the most comparable form of tree diagram which is implemented within this research; Figure 7.9 used to illustrate negotiations within costing.

The author will utilise the diagramming techniques discussed within this chapter if and when necessary. I.e. if the need to show the relationship and effect that a wider scope of a certain domain has on the area, for instance how the overall company affects an individual department, then a representation will be made with use of System maps.

Alternatively, if the positive and negative points of an occurrence require evaluation, then a Force Field diagram will be used, illustrated in Figure 7.12. There are many other diagramming techniques which can successfully be used within the domain of product-costing in order to illustrate the concepts and ideologies behind the practices in order to help disseminate them and promote their understanding. These include Input - Output diagrams which comprises Figure 7.3; Control Diagrams, and even Wire diagrams. An example of the latter is the London underground map, accurately portraying a simplistic flat structure of the complex relations and interlinks between the tube lines; Figure 7.6 has similarities with this technique.

The concept of Input–Output diagrams have been compared to some of the perceptions regarding PC, as the black-box metaphor has often been applied to it, see Figure 7.3. In reality, it was implied as a criticism of costing, with the underlying inference when referring to the process of costing as a 'black art' or 'black–box' activity is that it is unclear as to how the costs are deduced. This criticism was made by practitioners external to costing such as purchase, or by the costing practitioners themselves, when explaining challenges related to trust and the image or perception of what the process entails, and how it is received and valued by external functions. However the software tools marketed at the costing process have tended to be described in a similar vein, by potential users of it. The tools fundamentally work through the user inputting values into generally pre-specified parameters, and the software calculates the resultant cost. Skepticism within this area appears to have risen, with the main concerns being related to the equations within the software tools that are applied to the in-putted data; and how the figures are manipulated to derive the outcome, illustrated in Figure 7.3. Therefore the black-box analogue is apt in this context. Software tools within product-costing have been discussed in Chapters 3, 4 and 6. Whether they are treated with caution and cynicism or esteemed with their use valued, the fact that the presence of formalised cost-models across the costing sphere is becoming ever prominent cannot be denied; whether in-house models or commercially purchased ones. Figure 7.3 shows the system of information and knowledge inputted into a cost and the formulated output; along with the fundamental nature of the computerised cost-models.

The former mentioned perception of costing being a 'black-art', in other words of deriving costs via unclear methods, has been defended repeatedly by the practitioners. They have explained that costs are calculated via the combined use of their experience and knowledge, fused with more tangible information including historical data, previous projects, BoM (Bill of Materials), FIR*, supplier costs, along with a multitude of other aspects which produce the costs. *FIR denotes finance information request, documentation which incorporates the people involved, time scales, contact list, cost investment, volume, glossary of terms, procurement assumption, launch size, exchange rates, body styles / options, e.g. alloy wheel or steel for product specification; therefore when completed can be a comprehensive source of data / information.

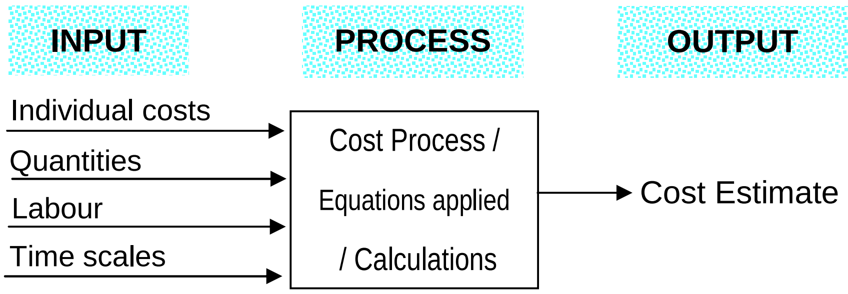



Figure 7.3: The perceived Black-box process of PC using formalised cost-models

Partly in order to dispel perceptions of it being an inconsistent, 'black-art' activity, the need to represent the data and knowledge within product-costing in an accurate, concise and transparent manner has emerged as being an important consideration for the costing domain. Many of the functions, systems, and relations involved in the process are extensive and complicated, so accurate representation in a coherent form is imperative when communicating ideas and best practice techniques. The ideas relayed in this and the following chapter highlights the manner in which the diagramming techniques employed are a useful means to convey the process of costing: Including effective communication of the challenges, interactions and remedies proposed.

## 7.2 Costing Knowledge

Knowledge has been defined within Chapter 5 [Polanyi, 1998]. This definition can be related to costing when comparing the individualistic nature of the process, and examining how the judgments and thought affect the actions and impact on the final cost in various ways. The individualistic aspect is important to consider, as in general an experienced practitioner will create the cost via a different route to a relative novice. For this research the data, information and knowledge model has been adopted as:

- Data being raw, random elements within a context;
- Information is ordering / structuring these elements into something useful;
- Knowledge is being able to make decisions based on this information; see weather-trend example in Appendix 8.

Therefore, as knowledge itself has been described, the issue of what PC knowledge is comprised of can subsequently be addressed; in the way that knowledge enables decisions to be based on cost-data and information. The quotes heading the chapter are taken directly from industrial practitioners. The first two relate to the perceived uncertainty involved in the process as previously discussed, in relation to the ambiguity related to it. This perception of uncertainty is particularly true for those external to the process and do not comprehend how it is conducted. The final quote relays the high level of diversity involved in costing, and how the practitioners need to hold a large repertoire of knowledge and information, and be able to apply it to a range of situations. It refers to the fact that results may be required with use of low actual data and information levels. Therefore the possession of knowledge such as past-project awareness, engineering and particular component knowledge, depending on the item being costed, will assist in the derivation of costs in the absence of adequate levels of information.

### *7.2.1. Literature Definition of the Process of Costing*

Product costing involves an array of activities around those two key words: 'product', which involves much engineering / technical knowledge; and the 'cost' which encompasses a number of monetary, financial and economic knowledge in which to derive it [Mishra et al, 2002a]. These product and cost domains are comprised of a number of fundamental elements and it is the identification and subsequent analysis of these areas that formulate costing expertise, allowing the challenges to be recognised, not just superficially but from the root causes. Addressing the core of these difficulties from which they stem is the only way to ensure they are managed effectively, where the changes can impact upon the outcome in a positive, productive manner.

Before breaking down the process and examining it in elements, a broader more holistic look at the currently held perceptions of costing, its results and the processes, facilitate the formation of the overall function. This gives more of a top-down understanding, with an appreciation of the whole, from which could lead to the parts its constituted of, which work concurrently to produce the wider costing process. Hence a literary reference to cost estimating is that it is:

*"The art of approximating the probable Cost or value of something, based on information available at the time"*

[SCEA online, April 2009]

The same internationally recognised reference defines a 'cost estimate' as:

*1) A judgment or opinion regarding the Cost of an object, Commodity, or service. 2) The product of a Cost Estimating procedure, which specifies the expected dollar cost required to perform a stipulated task, or to acquire a specific item. … 3) A calculation of the total resources (labor hours, material costs), travel, Computer costs and other costs, including appropriate rates and Factors, which are required to accomplish a Contract, task, or work item.*

[SCEA online, April 2009]

The Society for Cost Estimating and Analysis, SCEA, goes on to discuss a number of activities within the Cost Estimating Process itself. These include the determination of the types, quantities and costs of materials; parts, and manufacturing processes involved including labour hours. Variables i.e. the risks and 'add-ons' need to be known and accounted for; as well as stating that the establishment of teams is required, involving much interaction, communication and knowing who posses what knowledge and information. Profit and other cost factors are required for the overall costing-process. These are a selection of issues involved within costing as documented primarily by the industrial institute, SCEA.

Having determined a literary definition of a cost estimate and the process of costing, see Chapter 3, the next step was to derive the knowledge involved in order to be able to undergo this process. The research found that these small number definitions of an estimate, or the process of product-costing do exist including the ones prior stated, there was no reference or breakdown, outside this research, as to the knowledge that is required within the costing process and how it is applied.

**The specific knowledge required to cost a product has not previously been identified within the documented literature**

Therefore the knowledge types highlighted within this section have been deduced with combined reference to the direct interactive 'action' research; coupled with derivations from the literature, such as Cost Estimating Process definitions, SCEA; and other major publications within the area. The former mentioned a number of activities and requirements for product-costing, which were also reiterated within the industrial observations as being necessary requirements. The final eight cost-knowledges' identified were redefined throughout the research which initially identified ten types [Mishra, et al, 2002a, b]. The scoping process is discussed in Appendix 9 proceeding sections, with the initial selection being highlighted; and the finalised list being justified.

### *7.2.2. Industrial Definition of Product-Costing*

Earlier chapters have stated what product-costing is comprised of, both from a documented and a practitioner view, which was deduced by regular practitioner reference to them. To expand on what the process involves, the knowledge deemed necessary by the practitioners themselves, was subsequently addressed. Cost Estimating Knowledge was defined by software experts within an interactive workshop as:

*"Cost Estimators posses a comprehensive overview of the business, and through a wide background of experience (including engineering, design and economic), understand the processes that drive cost"*

[Workshop derived definition: Collective practitioner source, Price Systems Software industry, 2002]

This definition was derived during a specifically designed knowledge workshop conducted within the US, undertaken with a selection of practitioners from a company which developed formalised (software) tools for the costing profession. An interactive workshop gave opportunity for multiple viewpoints about knowledge requirements within the area of software development for the costing process. Six leading practitioners participated from within this company, including the Chief

Scientist, Senior Software Engineer, Accounts Manager; Director of Marketing and the President of the company, who also has extensive experience in product-costing. This angle of observation external to actual product-costing, though directly involved via the support and assistance towards those who conduct the cost-process, was deliberately selected for use, being of particular interest. As the majority of contributors not only had direct experience within costing but were also in a position to have seen the process across a number of organisations and industries. This is due to the fact that they were producing software tools to aid the cost-practitioner with the derivation of costs; so therefore needed to have a thorough understanding of how this process is conducted. Hence they possessed an awareness of the requirements and limitations of the costing process, as well as appreciating general market trends, so they can pre-empt ways in which businesses are likely to be turning and be ready to cater for them when required. The customer, for which they are providing service, requires the software-organisation to be knowledgeable in a wide scope of products, across industries, so can accommodate customer specific wants and needs. In parallel, there needs to be an appreciation for cultural differences by this particular research contributor-company, in order to anticipate difficulties which may be encountered by the product, as are selling to a global market. Subsequently those participants within the workshop who were not directly experienced within costing if the role was in marketing for instance, had a different view of the process, due to the nature of the business they were in. I.e. a product directly catering for costing practitioner needs, across companies and encompassing differing methods, even the marketing director would need to know about product-costing and challenges encountered from a marketing viewpoint; therefore could contribute to the findings from this relatively unique perspective. The view was relative, when compared against other research contributor–organisations.

The prior relayed industrial quote, stating the industrial contributors' definition of what they jointly perceived cost-knowledge to be, was selected as an example due to the fact that a number of practitioners composed this statement, collectively. It was also an interesting view, as was taken from such a diverse slice of contributors towards and within the costing community. What the definition states is that the knowledge required to perform the costing-process is broad, encompassing many aspects directly and indirectly linked to the product in order to understand how costs are deduced.

Throughout the series of interviews also conducted within the described company, individual interviews with the practitioners accompanied the integrative workshop. Additionally, there were the other contributors; see Table 6.2, Chapter 6, listing the phases in which organisations contributed: Therefore such statements as above were broken down into more specific knowledge types. This was done through the prior mentioned analysis, including over-familiarisation i.e. reading and rereading the interviews to strip them down to the essential contributions made. Refer to Chapter 2 for more detail regarding the research methodology and analysis techniques used. A general, as well as specific awareness towards the central, key aspects of the process was gained, and could thus be analysed in more quantitative breakdowns and comparisons. Reference Table 6.3 in the previous chapter for an example of how statements were classified within the knowledge types, KT, categories, KC, and against the six cost-themes.

### *7.2.3 Redefinition of the Essential Knowledge Types*

Throughout this research, there have been continuous iterations of the data collections and methodology applied towards the expanding subject-area; and subsequent revisions of the conclusions drawn, as dictated by the data received. An initial derivation of knowledge types which are essential for the product-costing, is listed within Appendix 9, Table A9.1 [discussed in Mishra, 2002b]. As more data was collected, and the areas which were seen to have an effect on product-costing widened primarily to focus on the important affects which culture and communication had on the cost-process, the original ten knowledge types initially identified within the more limited scope, were adapted accordingly to suit the broadened environment in which the central areas were now being examined within.

#### 7.2.3.1 Human Factors and Cultural Influences

Within Phase 1, P1, of research there was a distinct recommendation which was continuous in its reference and subsequently could not be overlooked, regardless of the limitations of the initial research perspective. This reference was in relation to the need for what was originally referred to as contact-knowledge. This knowledge correlated with knowing who to contact, for what information; how to contact them, e.g. personally or whether technical means were sufficient. It also had links to IT and the requirement for adequate databases. However although this knowledge type made some limited degree of technical, explicit connections, the large majority of it was linked to more social issues and human factors. Therefore when the research expanded, so did this knowledge-type accordingly; being re-classified as communicational knowledge, and recognised firmly as one of the essential knowledge-types that the product-costing process could not be wholly performed without.

A significant benefit of incorporating social and human factors into the research was in the recognition of the ubiquitous impact which organisational culture has on the costing process, see previous section and Chapters 4 and 6. On review of the primary works within this area, it became evident that the issues within product-costing could not be discussed fully, without reference to the processes' environmental-factors, which are encapsulated within its culture, discussed in Chapters 4, 5 and 6. When discussing culture within the industrial examinations, a common perception was that it was solely related to creed, races, and had its main affect between vast geographic distances. On the contrary, it can also be related to the differences observed between different industries; across diverse organisations within the same industry; between different branches of one organisation both internationally or nationally. It can often be observed amid dissimilar disciplines, within the same organisation; and even within the same department, between different practitioners, dependent on their experience, age, gender, and so forth. Culture includes attitudes, beliefs and subsequent codes of practice within domains [Lemon, 2008], which ultimately affect results as well as the way practitioners interact, process information, and their working conduct in general. As PC has been seen to experience challenges due to the level of diversity within the process and required expertise necessity to produce results, the knowledge of culture has been deemed crucial for implementation of the costing process.

Appendix 9 contains details which address the derivation then subsequent updating of the essential knowledge-types. The following sections focus on the final list established of the eight essential cost-knowledge types.

### *7.2.4 Expansion of the Original Technically-Focused Research to Incorporate Social and Human Factors*

Within Phase 1, P1 it became evident that a sole scientific approach to costing was inadequate; as it needed to be examined in the context in which it was conducted i.e. taking into account ubiquitous influences as culture, communication and other social and human factors (HF). P1 research was grounded in a technical perspective, i.e. a model based around engineering and economic and commercial issues. From this phase a number of themes which were HF related prevailed, requiring more exploration. This was conducted within P2, where a number of issues emerged which were evidently influential towards the costing process; these included trust, communication, knowledge and culture; see Figure 7.4. These were examined independently of the original model; as well as within it, i.e. went back to the engineering and commercial themes, and re-examined them through the lens of human factors and social issues. Even without any additional core elements, the initial context could be re-evaluated through this widened perspective, with the result of procuring valid points. For instance issues around how the use of product-costing varied between organisations and why, could be examined. The original stance focused on direct, straightforward differences in practice and posed potential questions about the distinctions due to product-type, across different industries, e.g. aerospace and automotive. When re-examining the level at which PC was utilised for example, a number of points surfaced. For instance usage is often resource-dependent: The level of resource allowed for costing will depend on a number of aspects with more explicit reasoning being due to market trends, state of the economy, and therefore economic pressure on the organisation and resultant cuts, which could be across the board and thus affecting costing. The direction the organisation adopts may involve the need of increased profits therefore cuts in budget, thus deductions in availability of resource for product-cost: Competition and technology are among the factors that could also impact on resource level.

These are very explicit reasons; on a more implicit level however, lack of resource was seen to be caused by a fundamental lack of understanding of the function of costing. For instance, if other departments, i.e. the internal customers of the process, do not fully understand its function, and/or not trust in the outcome, they would not request its use; examples of which are in the previous Chapter 6, throughout Section 6.2.1. Partly due to this circumnavigation of utilisation, management would not allocate valuable funding towards it, due to a perceived lack of value towards costing: This is one level. Further exploration would look into potential causes of the lack of understanding, which arises through issues as use of dissimilar language, manifesting in inconsistent terminology, and subsequent miscommunications. Even further or ‘deeper’ investigation reveal a lack of common culture, creating a mismatch of priorities and focus; different meanings attached to the same terms; and different mindsets; in accordance with the nature of the work. For instance, Finance focus on monetary issues, economics and budgets; Engineering focus includes technical detail, design of product, performance and functionality. Everything from the physical environments these practitioners routinely work within, to their required non-physical mindsets differ greatly; and contribute to how they will behave, process information and perceive the importance and value of other specialisations.

Thus the employment of product-costing, PC, is subject to whatever the levels of awareness are held about the costing function, e.g. whether it is highly valued and utilised or overlooked and not used. Further focus has been placed on why it may be unused which as prior-stated, has been seen to be on occasion due to a lack of understanding: This would bypass its use. Alternately the cause may be due to reasons as fear culture, for fear of exposure of target-meeting practice, as opposed to cost-cutting; which again exposes another layer behind the actions taken. The fundamental reasoning behind a degree of exposed behavior which could verge on malpractice, would not lie solely with the direct instigators, but indirectly can be traced as the fault of management. For instance if unrealistic impositions are in place, the workforce may overestimate to ensure they meet them: Thus highlighting an inadequate understanding of process by management who having subsequently imposed unrealistic expectations on the workforce, insight a reaction from them, which can ultimately be detrimental to the organisation; examples discussed in detail within Chapters 4 and 6.

Further still, how did the issue of cost-process execution vary between industries: In this instance there are many different elements, such as whether they were privately owned or government run, and if limitations of confidentiality were imposed or not. For instance with the former-mentioned, an observation was that within a minority of private companies costing was performed with more support then with the public-funded establishments, possibly as costs were more strictly or meticulously monitored within the private, profit-making firms. For the latter-mentioned regarding issues of confidentiality, an overt difference noted was that if costs were derived within environments where it was routinely accepted that issues of national security were potentially at sake, the process would be conducted with more accountability. I.e. there was greater transparency then there tended to be within the private organisations, and practitioners were inclined to log their actions and reasons for them, as part of practice. Such records and hence transparency of process proved to have multiple benefits; see the following chapter which discusses training material. On a related note, the difference in risk would be from loosing competitive advantage if exposure occurred, to potential prosecution if state security was involved -perceived as compromised. Other immediate differences were observed between countries, primarily American and UK in the practice and perception of costing; a major difference being in the background from which cost-practitioners tended to be procured from. Within the UK it was almost solely from technical / engineering experience; whilst the US notably procured personnel from both economic / financial and technical backgrounds. Refer to Chapters 3 and 4 which discuss the prerequisites for costing; and Chapter 6 which notes subsequent differences in knowledge requirements for non-technical backgrounds whilst within costing.

However as discussed within this section, costing may be examined in limited terms of purely economics or engineering, and from this tangible context it will still be established that there are HF and social issues which arise. The costing process may also be observed when broadly looking at culture and all related aspects involved in the costing environment, directly and in its surroundings. This will include the explicit elements of engineering, and economics, as well as all the other implicit and explicit contributory areas, discussed throughout the thesis.

When examining costing from a purely technical, ‘hard’ perspective as with the initial research scope, even then it can be more accurately addressed when examined in the broader view. For instance communication-networks are needed both within departments, between them, and across interacting companies: Through knowledge and data-exchange, technical factors, are improved when thought of with communicational-networks i.e. a ‘soft’ area. Technical networks can be derived to assist communicational ones e.g. hard processes promoting soft, encouraging systemic perception and working: As improving technical approaches can enhance the overall cost-process.

### 7.2.4.1 Research Evolution:

Figure 7.4 maps out the evolution and development of the research, stating the initial perspective, within Phase 1, P1; to the final approach adopted towards the research. P1 research perspective was grounded in technical, 'hard', explicit issues. The results from P1 lead directly into human factors, 'soft', implicit areas, which subsequently dictated the expanded angle of Phase 2, P2. The amalgamation of both these perspectives, of both hard and soft issues resulted in an improved overall result for PC. This was because it was inadequate to examine the process of costing in isolation; the context in which it was undertaken needed to be incorporated into the considerations, and these environmental aspects tended to hinge on human factors; elaborated on within Chapters 4, 5 and 6.

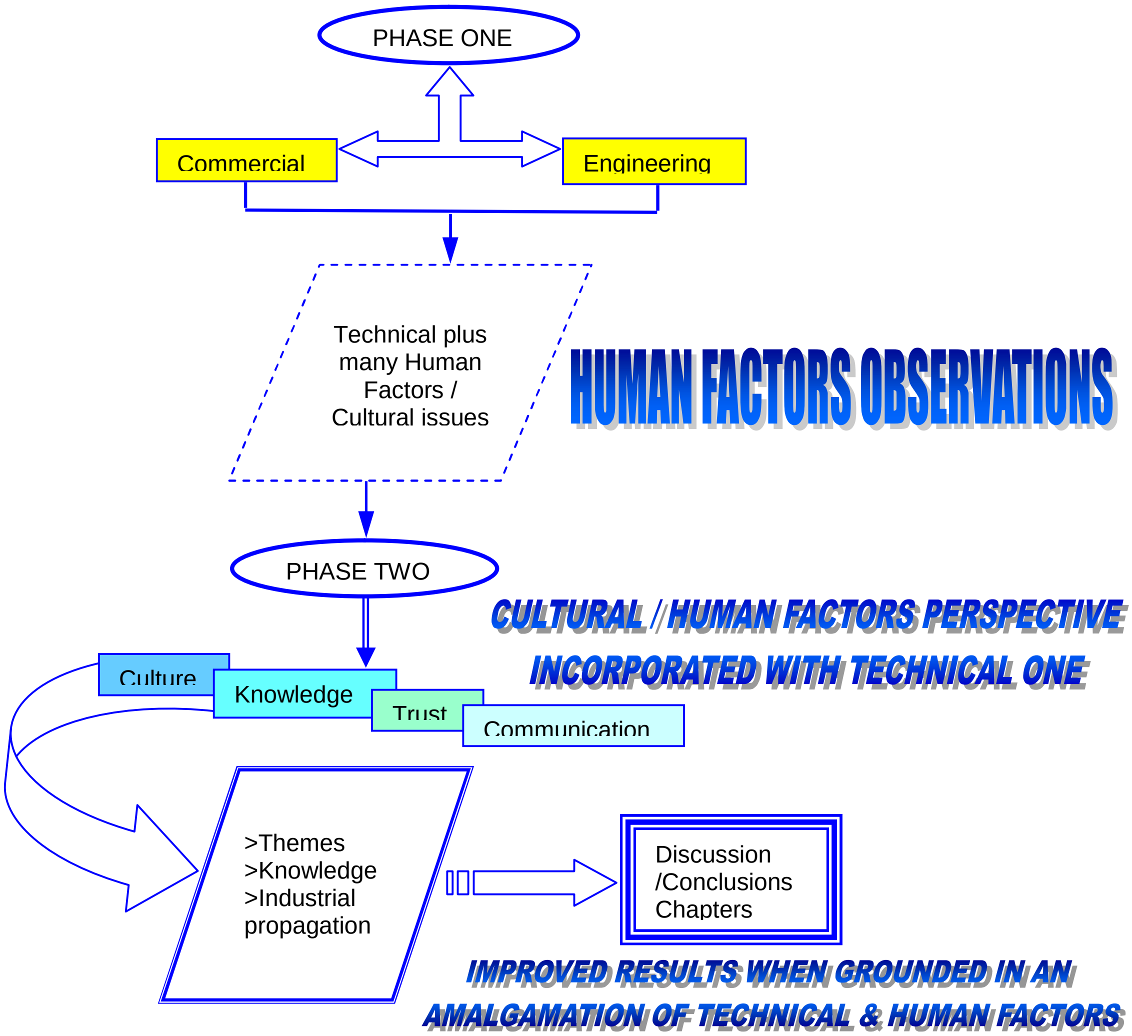



Figure 7.4: The Steps Leading to the Active Juxtaposition of HF and Cultural Aspects into the Originally Technical-Bias Research.

Therefore when examining the technical, explicit issues from an implicit viewpoint and with the application of soft issues, the outcome is seen to be more effective and successful then when examining those areas from a solely hard, explicit perspective, as discussed above. Thus even a restricted view can be understood more fully if approached with reference to issues such as cultural interaction. For instance, adequate communication makes the costing process more effective, technically; this can be seen when applying aspects of communication-networks to an IT system. In others words, within the technical issues there are specific cultural insights, a sympathy towards which will be beneficial. Therefore even when the scope is confined to technical deliberations alone, improvements can be made more effectively when approached with human factors and social applications.

The most overt example of how social skills improves the cost-process is in the way in which cost-information is procured. A commonly relayed point with regards to this came when discussing the costing of an item at the conceptual design stages. A number of cost-practitioners explained that they regularly did not receive sufficient information immediately, often needing to make further request for information (RFIs) from the engineering disciplines. It seemed that quite often a telephone conversation with the relevant practitioner would result in their, PC, being forwarded a prototype if available; or generally more information to add to perhaps a designers drawing alone, or any other type of rushed cost-request. The telephone-call was said to be in preference to submission of RFI form or other less personalised mode of interaction; even more preferable was to *"..just get down there and talk to them, personally!"*, as one senior cost-practitioner stated would give greater benefits then any other system. This highlights the need for knowledge of communication, personal interactions and social skills; which will ultimately aid in bridging cultural gaps; plus will improve understanding about cost-process and its requirements, from for instance the engineering specialists that contribute information towards the cost.

Subsequently, it could be observed in Phase 1 which initially was derived from a dominantly technical perspective, that reference to communicational issues would still improve the technical specifications. This particular technical perspective, namely engineering and economic / commercial, could been seen as being able to enhance the process by improving the more tangible i.e. engineering / monetary aspects of it, even when interpretation of knowledge, communication and culture is limited by application to a technical perspective alone, as Figure 7.5 highlights. Technical areas can be improved for instance by the development of networks: How effectively this is done also affect the process, for example:

- Can contacts be made?
- Then subsequently be kept?
- Can more be done to broaden the number of people available in the network, so more and better contacts are at hand to maintain and keep updated / improve the engineering, tangible side of PC?
- Is the range of contacts available for use only the most obvious ones, i.e. suppliers, experienced practitioners?
- Or are there other contacts outside the immediate, such as marketing, purchase, finance, product-developers, etc, who can give a broader input and a wider view of how to cost the product?

P1 overtly highlighted that the approach to making improvements within product-costing, PC should not be restricted to the technical environment of researching solely the economic / engineering features. This perspective must be added to and incorporate a wider, expanded, enhanced approach to the overall domain of PC to include social, human factors and organisational culture: This would benefit the costing process in general, more then when utilising only explicit, hard techniques; as the knowledge involved proved to incorporate both types i.e. tangible and intangible knowledge. Figure 7.7 presents the main knowledge directly involved in PC whilst illustrating the external contributors and / or influences on the process. The presence of hard knowledge types, KT, show the need to communicate and for cultural awareness, as it is rare to find expertise of all these areas within one practitioner; which often means they will need to liaise with others and thus at times with different mindsets / cultures, to obtain it. The interactions go beyond the boundary of the essential KT towards the secondary contributors towards the costs; again drawing on more intangible KT.

The technical perspective is important and does contribute, but it needs the combination of technical and human factors working together as they are inextricably linked: As both the main cost-themes show in Chapter 6; and are highlighted by the list of KT. The costing process clearly suffers if they are separated and / or if the more implicit elements are overlooked.

#### 7.2.4.1 Initial Categorisation and Scope of Research:

As explained within the earlier chapters, the initial assumptions made when encapsulating the subject-area was expanded upon as directly dictated by the outcome from the Phase 1 research itself. P1 was an exploratory study, which validated engineering and economic (commercial) disciplines as the prime contributors towards PC. The knowledge types identified within the early phases were resultantly categorised into either one or both of these areas. A representative selection of the classifications are listed in Table 7.1: This lists the commonly perceived disciplines in which costing or cost-related activities typically feel into.

Table 7.1: Industrially perceived 'engineering' and 'economic' classifications of cost-related issues and activities [adapted from Mishra et al, 2002].

| ***Economic*** | ***Economic AND Engineering*** | | ***Engineering*** |
|---|---|---|---|
| **Indirect Labour** | **Supplier Selection** | **Direct Labour** | **Skill level** |
| **Overheads** | **Training** | **Recruitment** | **Labour hours** |
| **Audits** | **Risk** | **Tear down** | **R&D / QA** |
| **Organisational Cost Breakdowns** | **External Negotiations** | **Internal Product Negotiation** | **Tooling / Machinery** |
| **Cost Forecasting** | **Government Legislation** | **Database Development** | **Product Performance / Functionality** |
| **SG&A (Sales, General & Administration)** | **Material choice / delivery (envelope) / logistics** | **Competitive Awareness (performance / financial)** | **Manufacturing Process** |
| **Exchange rates** | **Budgets /cost targets** | **Supplier interaction** | **Design** |
| **Marketing** | **Bid Compilation /Assessment** | **Cost-Reduction Alternatives** | **Product Development** |

Engineering and economic / commercial activities themselves were loosely classified, in that they were determined generally through a sense of traditional perceptions. This meant that the elements identified throughout the research were categorised as specified by the contributors, whose opinion was formed via their experience and the way in which activities had traditionally been classified industrially; coupled with organisational practice. For instance, machining, manufacturing technology and labour associated skills were traditionally speaking, seen as engineering concerns. Whilst marketing, overheads and organisational annual-cost-breakdowns were generally considered economic pursuits. Table 7.1 lists activities and tasks undergone directly and indirectly in relation to product-costing within various industries, and categorises them into 'traditionally' perceived disciplines.

Thus, the engineering category incorporated aspects that required an understanding of the product at a technical level. This included manufacturing process–knowledge, including labour and R&D / QA activities related to the product development. Alternately, the economic / commercial classifications required an awareness of the fiscal functions and associated methodology, with any monetary aspects or influences on the product being included either by the environment, e.g. market trends and other indirect costs associated. The more commercial, economic function was described by one practitioner within aerospace, namely an industrial commercial-cost estimator as being *"..the commercial conscience of the company"* [Aerospace cost estimator], ensuring that other functions embark on activities with a full understanding of what they are doing, how, and why they are doing it.

Many aspects of costing however fell into both classifications, being prioritised by both disciplines. These include issues surrounding material selection, the form in which it is delivered or the 'envelope', e.g. the cost implications of having it cut to size or delivered in a basic, standard shape; the batch-size, see material knowledge Section 7.3.4. Competitive awareness needs to be recognised at both economic and engineering angles, so considering the price and the performance and functionality of the product in relation to competitor models, was recognised as important across the disciplines. Negotiations had also been identified at this stage as an integrated activity, requiring economic and engineering expertise to assess costs and negotiate appropriate reductions.

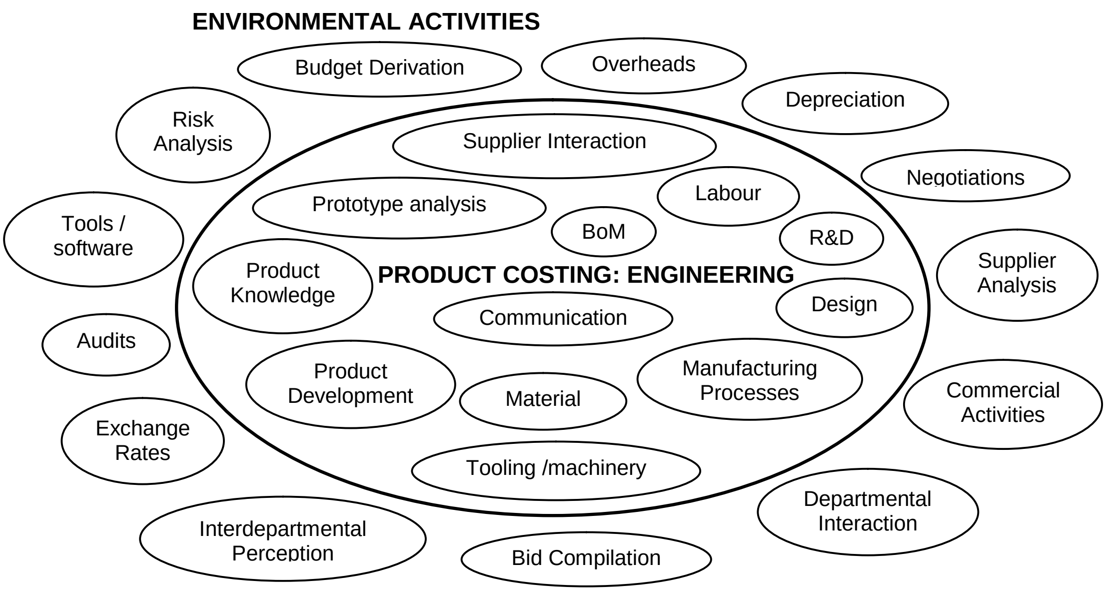



Figure 7.5: Knowledge and Engineering Activities within the Cost-Process, which Automatically Incorporates P2 Social and HF Aspects

Within the classifications were a few interesting, slightly ambiguous headings; the most relevant one within this research was risk. Risk in the traditional sense is seen to be an economic function. However, it has also been described as an engineering activity, when for instance engineers need to assess the risk attached to a new manufacturing process and equipment. Often the cost of purchasing new machinery is high, so needs informed consideration prior to purchase. On-top of its cost price, a limited or unreliable piece of purchased equipment could waste a lot of time and / or materials, incurring a lot of surplus expense. Therefore their recommendations are subsequently passed onto the economic domain who act on the advice of the engineers. For reasons as this one, risk in this research was placed under both headings, see Table 7.1.

Table 7.1 lists a selection of how these activities were categorised. Therefore when domain-specific cost-practitioner knowledge is mentioned, it is with reference to these categorisations. Many of the activities examined were relevant to both commercial and engineering aspects of cost estimating. This is in compliance with the companies examined, primarily automotive, aerospace and related organisations; see Table 6.2. for industrial participants.
Figure 7.6 highlights economic and engineering activities within product-costing. Typical issues / questions regularly addressed showing the overlap and links across the knowledge types, and stressing the need for communication and understanding. The points signify a slice of the emergent results from the P1 research, and illustrate the links between the issues and interacting aspects of product-costing. This figure is just a small sample of the actual activities and questions which need to be addressed on a regular basis, in order to give an idea of the complexities of the relationships between the disciplines. The concurrently performed diverse level of activities, even in this limited, early-work figure (see Chapter 4, AS-IS study) expose the need for the expansion of the research perspective in order to stretch the view of engineering / technical, and economic / commercial to incorporate social and human factors. This was subsequently addressed, see Chapters 5 and 6; the outcome of which is discussed throughout the remaining chapters.

The essential knowledge–types were finalised following exhaustive data collection and analysis within the wider environment in which the costing process ought to be considered within. This expanded focus involves what the technical, financial and other explicit domains are grounded within, which are basically the human factors and other implicit aspects related to the culture and communication within and between all interacting parties. For example disciplines which contributed actively towards the cost process were incorporated into the research, including financial practitioners, engineering and even purchase: With evaluations of how communication occurs, what the challenges were from the external perspective and assessment of the primary cultural characteristics involved. The inclusion of all these contributory factors shaped the final results, in the form of eight knowledge-types, being identified as essential within the process of costing.

## *7.3 The Knowledge Types*

There were a number of factors which were identified as being important within the costing process: The costing practitioners through interviews, observations and other KE, knowledge elicitation techniques, see Chapter 2, highlighted many areas which are integral to their role. However, though there are numerous essential considerations within product-costing, the knowledge types (KT) which are essential to conduct the process were identified. This was through the reoccurrence of certain main points which were omnipresent so rapidly became clear throughout the process and deduced the KT, see Figure 7.7.

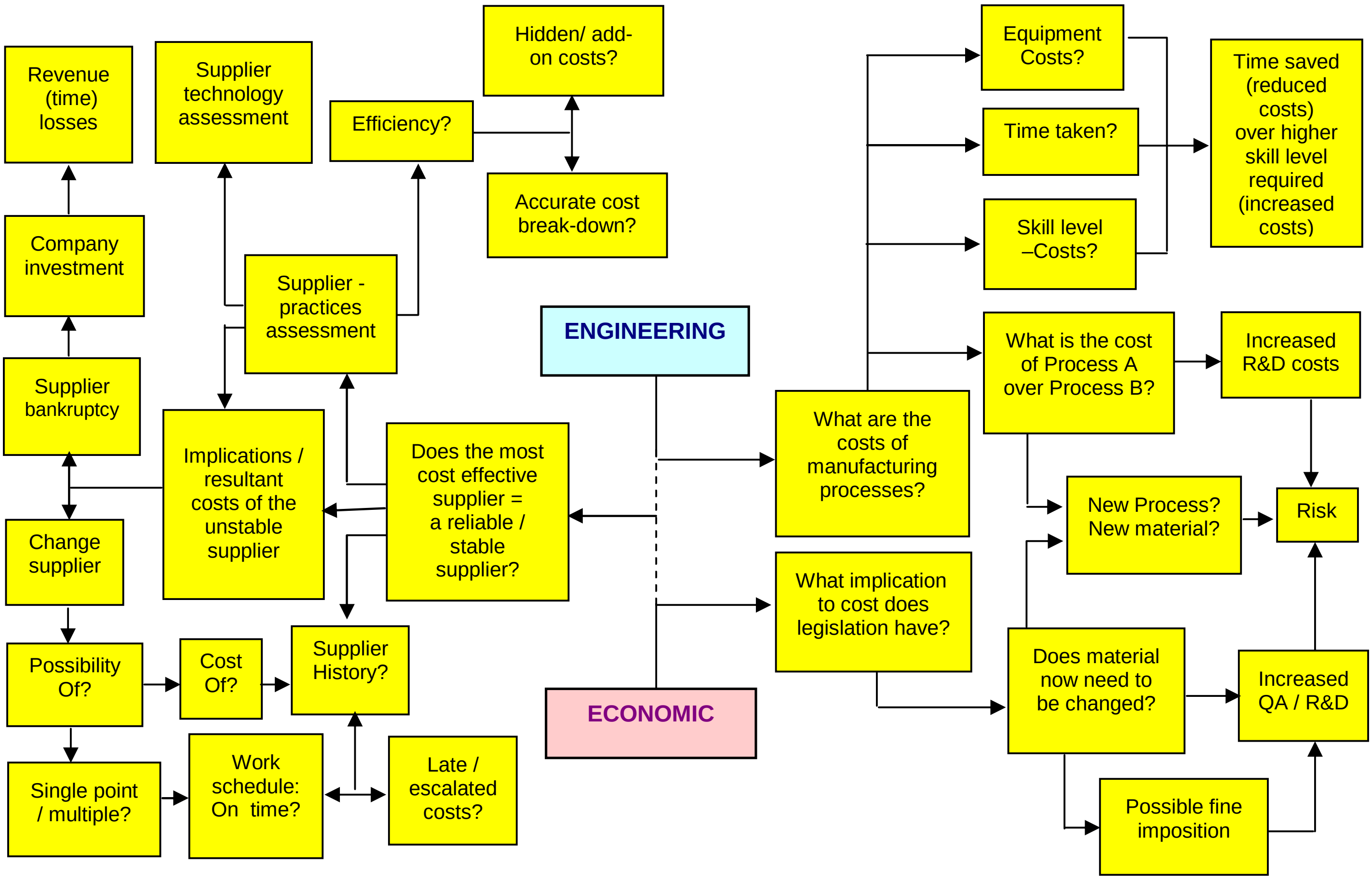



Figure 7.6: Issues and Questions Regularly Addressed, which Highlight the Overlap and Links Across the Knowledge-Types, Essentially Utilised across PC [Mishra et al, 2002a].

Although all the defined knowledge-types identified are interlinked with each other, eight types of knowledge emerged as being essential to the process of product-costing. These are illustrated within Figure 7.7, being displayed as the core KT within an array of other associated KT that contribute to the environment in which costing is performed. The outer core of KT are indirectly related to PC, so depicted as outside the central area which hosts the main eight KT. Also reference Appendix 9, Table A9.1 for the original and refined research KT listing. Within the principal types are many other factors as mentioned, but the reason why every important activity was not classified as an essential knowledge type was due to the fact that they were either compilations of a number of the KT as with negotiation skills. The importance of negotiation abilities was constantly referred to; however this skill is comprised of a knowledge of the product and components involved as that creates an awareness of what is central to the negotiations. Additionally knowledge of manufacturing processes are required within negotiations in order to compare and check costs, discussed in greater detail in Section 7.3.2; as is knowledge of the materials used. Knowledge of Design is needed, along with both manufacturing-process and material knowledge for suggestion of suitable lower cost alternatives, if required. To enable a decrease to the stated costs of the supplier, the cost-practitioner needs to have an overall knowledge of the costing process. A thorough knowledge of communication, interpersonal skills is clearly needed; and knowing the cultural norms involved also helps the process of negotiations. Such combinations of knowledge are required; whether for different departments to reduce costs [finance] or increase budgets; or whether dealing with external organisations such as supplier or customer, it all helps the success of the negotiation-process, see Figure 7.9.

Figure 7.7 illustrates via systems mapping the primary, most essential knowledge involved in PC, along with the 'environmental' knowledge required, i.e. the knowledge used to assist the process. Though the knowledge external to the inner boundary is secondary, it is still important for practitioners to be familiar with this associated knowledge. When differentiating between 'direct' and 'environmental' perceptions a way of clarifying the term is to understand that the environment is relevant, has an impact on the direct aspect to varying degrees; but is not really able to be controlled. I.e. the culture of organisation or environment the PC is performed within effects it, for instance if it was within a culture of segregated working, then interactions with other departments and the procurement of information would be more challenging. More so then if the environment in which PC was performed within was open, where communications were fluid and integrated working was the norm. As stated PC cannot control this level of its working environment; but it is important to recognise and react to it, as it does affect the whole process to varying degrees.

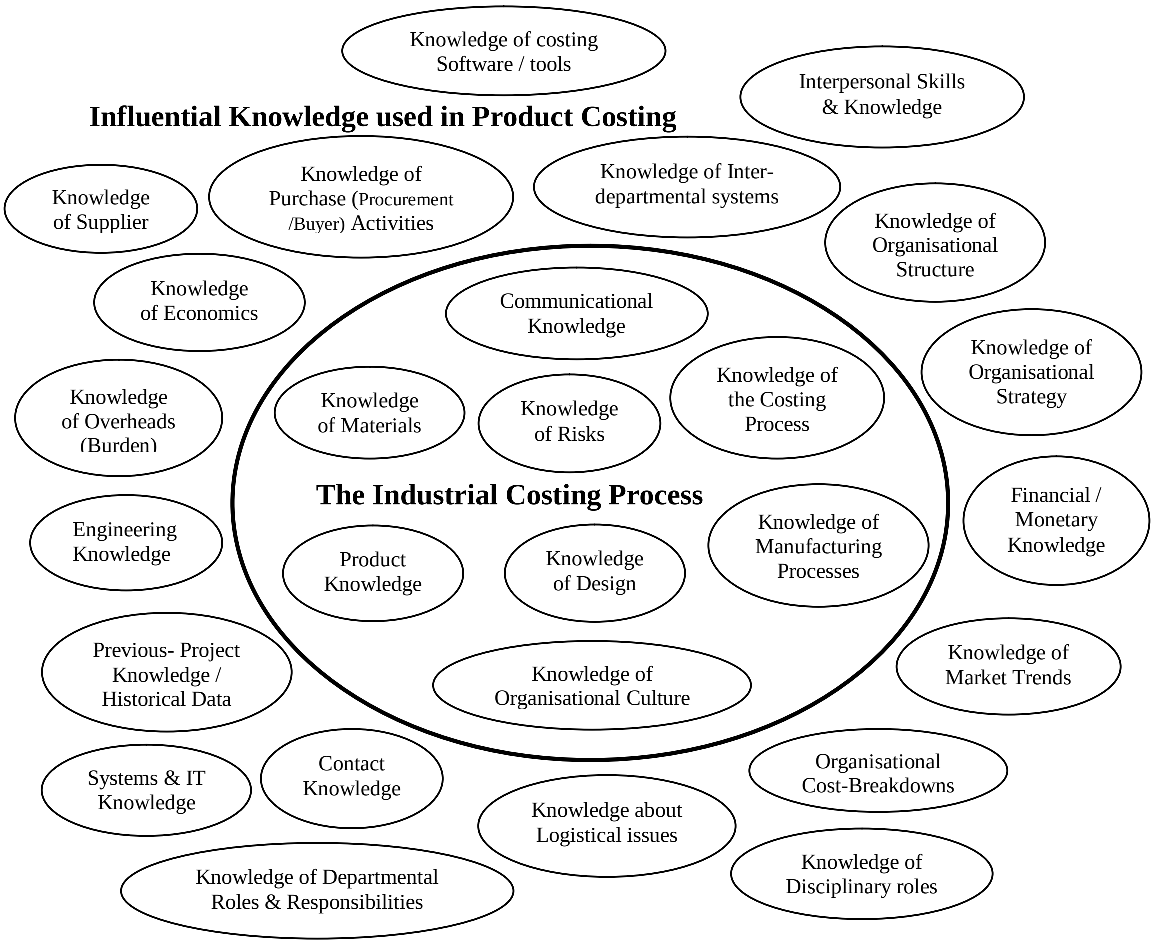



Figure 7.7: Systems Map of Knowledge used Both Directly and Indirectly within the Industrial Product-Costing Process

In addition PC was incorporated under either the engineering functions or financial, organisation-dependent; hence its classification would impact on the process. The functions that worked along side PC, events associated with or as a direct result of these other disciplines would impact PC e.g. if product-development overran and was therefore pressured for time, it was likely that costing would get minimal interactions / contributions, due to these time constraints. Therefore although these departments, principally engineering and financial based, were within the cost-environment or only its' outer boundaries, they still influenced the process in a number of ways, see Figure 7.2.

However the principal elements within the process of industrial product-costing have been identified within this research, and fall within eight primary knowledge types, KT. The following sections discuss each KT including the explicit and intangible aspects, and the contributing areas that are relevant to the KT and hence the overall costing process.

### *7.3.1 Knowledge of the Costing-Process*

A thorough understanding of the overall process of costing was confirmed as being an essential knowledge requirement by all practitioners in every participating organisation. This knowledge type may initially appear to be an apparent requisite, i.e. any practitioner attempting to asses the cost of a product would require knowledge about how to perform this process, and need to understand how a cost is broken down and what it comprises of. However the elements which contribute towards the compilation of PC are derived from a diverse spectrum of disciplines. The cost constitutes a number of variables, inclusive of every aspect of the product which affects the cost and are often variables, especially in the early stages; all of which need to be solidified to a degree of accuracy, the level of which (accuracy) also needs to be approximated.

Figure 7.7 highlights the main disciplines involved in costing from a generalised perspective. It illustrates the engineering / technical and commercial (economic / financial) aspects which are brought together in the costing process. These elements are combined through the use of communication, and only effectively integrated when an understanding of the social and environmental issues which can affect the outcome are understood and catered for. For supporting data and analysis see Section 7.4 later in the chapter which examines culture and communication. Subsequently, as all factors need to be incorporated and accounted for to a specified measure of confidence, the intricacies involved in this process are not necessarily straightforward. Therefore the multiplicity of this KT, the costing-process knowledge, is not unequivocally known widely primarily due to its nature of requiring a degree of understanding from incongruent disciplines, and being able to bring these elements together effectively.

As the disciplines from which the types of knowledge required for costing is traditionally not mixed, e.g. training programmes tend to focus on either various aspects of engineering, or on the financial functions when training a new recruit.  Therefore a novice to the profession, whether an inexperienced novice i.e. young graduate or apprentice, or if an expert from another industrial domain; if new to PC the likelihood is that they will not already have the appropriate mix of required skills necessary to produce an cost.  Subsequently having a thorough knowledge and understanding of how costs are compiled, what is included in them, and how to obtain and bring these elements together in order to create the overall cost needed, was identified as being the primary knowledge requisite.

#### 7.3.1.1. A Collaboration of 'Hard and Soft' Contributors

The process of costing has been broken down [Stewart et al, 1995], see Chapter 3. It can be seen that the contributory activities are fundamentally from a number of areas, some of which are readily identifiable, others are less tangible in their origins and even in their importance. Often there is a combination of the two, explicit and implicit knowledge-types which makes up the activity; an example of which is seen in negotiation interactions. Here, a degree of product, component, and manufacturing-process knowledge is required ('hard' issues), as well as communicational knowledge, and an awareness of the cultural factors which may affect the outcome, often perceived as 'soft' issues. It was even quoted within a large, multinational automotive company that success in negotiations may be down to "..muscle" in the communications. This may potentially have referred to the adoption of an aggressive approach, so that the opposing, interacting party effectively "backs-down". It was also stated that having more then one person present in the negotiations was also a help, again in the perception of 'forcefulness' or strength of opinion. This is partly why product-costing preferred to be involved at the supplier-selection and negotiation of costs stages. A combination of all these knowledge types including the soft and hard aspects are among those required in order to negotiate effectively and are discussed in more detail later in this section, see 7.2.3.3.

#### 7.3.1.2 Explicit Areas Constituting the Knowledge of the Costing Process: Engineering and Economic

The main explicit areas which require comprehension are, in broad terms engineering / technical, combined with economic and general financial functions: They are tangible aspects as are perceived as being measurable, repeatable and therefore reliable, see Chapter 2. Traditionally speaking these two areas are not typically incorporated within an individual practitioner. As discussed in the previous and proceeding Chapters 4, 5, 6 and 8, and also within the cultural-knowledge Section 7.4, these disciplines are often very specialised, and therefore tended to focus on one area within the overall discipline, which in itself for one specialisation involves extensive knowledge. For instance, there is vast array of technical aspects involved in the engineering of an aerospace product, or an automotive vehicle. Often the primary contributors will be highly specialised within their relevant, contributing engineering domains. The reality is generally that the engineering practitioner will tend to be experienced and focused within one area of engineering e.g. avionics / electronics / hydraulics, materials (with even further specialisations including polymers, metal, glass-fibre), design or more specifically, interior / exterior trim, body in white, engine and chassis, stealth, emissions, thrust, etc. They will therefore not be skilled and knowledgeable to the same degree in the other engineering areas, let alone another domain entirely, such as the economic, financial aspects associated with the same product.

However when breaking down the cost elements, compiling a bid and generally deriving costs the knowledge involved includes both monetary issues which are fundamental to the process, coupled with technical breakdowns and knowledge of the focal item. These areas, of technical and economic elements of the product / project are tangible; being readily identifiable within the process. There are more subtle, intangible components of costing, which lie in the social and human issues, for instance the cultural and communicational knowledge utilised, which are integral to the process, see Figure 7.8.

#### 7.3.1.3 Tacit Elements within Costing-Process Knowledge: Communication and Culture

A significant majority of practitioners interviewed claimed that the manner in which they costed a product was unique to them. The general feeling was that an estimate could be produced via many routes, dependant on a number of variables such as:

- The experience of practitioner;
- Information / data available;
- Tools / software utilised;
- The use or purpose of the estimate,
    - E.g. to set a budget, for bid proposal, for supplier negotiations, etc.

Refer to Chapter 3 for an explicit, literary breakdown of the costing process. This perception of variants meant that a combination of the explicit and implicit was used in a permutation of ways. For instance, a practitioner who was knowledgeable in the type of material being assessed may feel confident enough to make an adequate estimate about the cost–information required via a mental calculation, incorporating previous knowledge about the material and allowing for environmental changes / add-ons i.e. inflation, currency. Alternately a practitioner without such an in-depth level of knowledge about the material may consult price publications, use software tools, or even contact the material suppliers / producers directly to access the required information. Either way, a cost will be reached even with use of different information-sources whether they are tacit or explicit; and compiled in the manner deemed most appropriate by each practitioner. Decisions will be made relevant to their background, experience, level of information to hand, knowledge of contacts and interpersonal skills. A mixture of tacit and explicit knowledge will be applied in deriving the results.

A link between the two most explicit, easily identifiable domains within costing namely economic and engineering, is communicational knowledge; see Figure 7.8. This is like a bond or implicit glue used to hold all the areas involved in the costing-process knowledge together. In other words, the components (information) towards the process may be available, but the way in which they are communicated makes a huge difference to the quality of cost-results. For example is there fluid, interactive transactions so the means to obtain comprehensive, accurate data; or minimalistic formalised exchanges such as QAFs, BoM, FIRs. Communicational issues i.e. an array of challenges, occur in different guises throughout the costing process; hence knowledge and skill in this area is thus essential. For instance the variant aspects which contribute to the process need to be obtained with use of contact knowledge and skills; knowing who to contact, for what information; knowing how to reach them, where they are, and when to contact them, are all elements of communication, see Section 6.3.1 in the previous chapter for KC in product-costing. This is also discussed further in the impending Section 7.4.1, which focuses on knowledge of communication.

Although certain communicational areas involved in PC are subtle so less overtly detectable, others in contrast are very evident. For instance, the need to be able to negotiate skillfully, an aspect of costing which is prominent, requires a great degree of cultural awareness of the interacting parties: Coupled with a proficiency in interpersonal skills; firstly to be utilised in the negotiations themselves. Additionally to gain the relevant information needed initially, in order to interact with the negotiating party. An almost inherent appreciation of the organisational culture is required to enable relevant communication with all contributing parties. This spans from the multitude of technical areas working on the product in-house, to the suppliers, customers, internal management, finance, purchasing, among other. If such knowledge is not known and utilised throughout the compilation of the costs, the impact of such will reflect in the quality of the results. Adequate interactions are even more crucial within larger organisations, where an ineffective system of conveying information across to the relevant domains will ensue in wasted time via attempts to obtain such information, and errors if not received; all ultimately resulting in revenue losses.

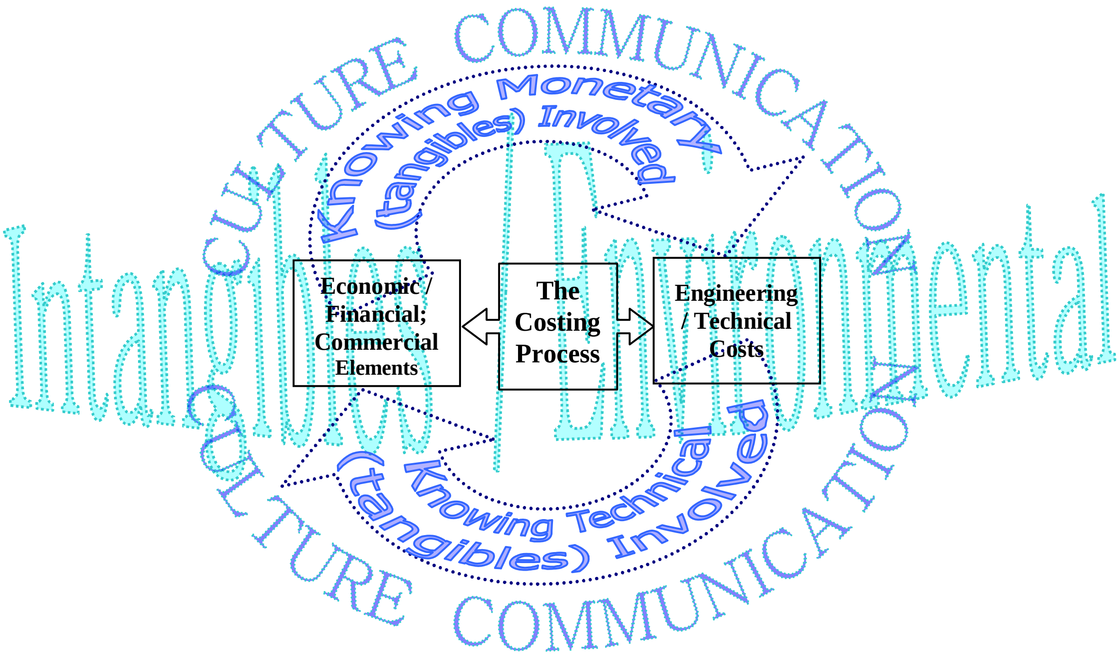



Figure 7.8: The Tangible Components of PC within the Intangible Environment of the Process.

### 7.3.1.4 Amalgamated Economic and Engineering Knowledge

In order to perform product-costing, PC a practitioner needs have an awareness of a number of economic issues, though not necessarily be an expert in these areas. It is sufficient for such expertise to be contained within the relevant disciplines and departments, and consulted if the need arises. For PC the type of monetary areas that should be known are things as budgets, exchange rates, logistics, labour rates both national and international. Knowledge of how a company will breakdown the overheads is needed including indirect labour, overtime, being aware of company policies regarding external expertise such as consultants; and knowing how much overhead is placed into each project. PC also needs to know about annual cost breakdowns i.e. how the organisation classifies and sections its costs. Aspects of audits; the financial implications of depreciation and batch sizes need to be addressed, along with tooling against capital costs, financial considerations of legislation. Such considerations are imperative within the costing process and seem to emerge via an amalgamation of engineering experience and economic know-how; how such knowledge is utilised is highlighted in Figure 7.6. For instance, an engineer will know what tooling is attached to the main machinery and understand approximate wear e.g. times and levels. This knowledge will tacitly and explicitly be gained from experience within an engineering environment. However, the actual monetary-figures of different types of tooling as with that of depreciation-effects will need to be formulated to more specific levels, as such information will be available when researched. They can thus be used within the final compilation of costs, basically ensuring costs may be attached to the appropriate manufacturing processes / specifics of tolling and so forth. To elaborate though such knowledge is tacitly and explicitly acquired during engineering experiences which will often be approximate and not specific enough to be used in a cost assessment. This is because the engineer has different priorities to the costing practitioner and that of the economic domain. Therefore the former will not need to know specific costs of say tooling and depreciation; but will use the information for instance to asses how long production can continue before tooling requires replacement, and to ensure working ‘add-on’s’ for the machinery will be available when required. Similarly, when accessing project-production the depreciation of equipment needs to be accounted for in forecasting production rates, and included in the budget for replacements if necessary, for long-term programmes. This differs from the economic assessments of the same considerations; clearly more definite figures are needed for tooling and depreciation. For example costs need to be attached to the predicted use and life-span determined in units of time –which is sufficient for engineering needs- to compile the overall bid, or project-budget for the cost-practitioner. Subsequently the engineering knowledge about such issues are used in conjunction with economic information and knowledge. The fundamentals involved in PC have been classified within a large international automotive organisation as: “labour, material and overhead, or “burden” , a US term. This is essentially what is required in order to cost a product, and needs to be compiled by the practitioner.

Therefore the way in which the costing-process knowledge was derived was via the collaborative assessment of the practitioners' perception of what is required at the compilation stages. Subsequently, given the in-put of the other seven knowledge-types, what else is required to compile the cost once these contributing elements have been obtained. A fundamental requisite is the economic / financial knowledge, often company-specific with regards to cost breakdowns. This may be made available from the relevant departments, and knowledge of which may also be learned by the practitioners as their experience increases. These costs are assessed in relation with the other generally engineering-based costs: Historical data is applied in the absence of actual product-information, ultimately producing the costs with use of whatever information is accessible, formalised cost-tools and previous-product analysis, economic trends, among other elements; all assessed using expert-judgment.

#### 7.3.1.5 Knowledge of Organisational Strategy:

The cost-practitioner needs to be aware of the strategy of which the company is adopting, in order to make the most appropriate cost decisions to coincide with this long-term or immediate focus or organisational aim. For instance, the company may intend to expand the area in which it trades within, e.g. plan to source the product or range of products within a new area in other words to break into new industrial sector, or country. This capturing of the new area of market may consequently need to be a long-term goal. For example there are already similar products being sold within this country, which the consumer is familiar with and trusts, e.g. a similar automotive model. Therefore the strategy deemed most successful by the organisation may be to sell lower-range products, low specification and / or lower cost models of cars at a loss, in order to initiate sales , and become a name / brand which the consumer knows and is comfortable with. The thinking behind this strategy is to subsequently introduce higher grade and cost vehicles, which by then will be competitive within that market. Therefore, the company may necessarily make an initial loss on the cheaper products within this area in order to get their product into the market before being able to introduce the higher cost models and accordingly make profits, which are stable and large enough to reap back the initial losses, i.e. loss-leaders. Hence this relatively short-term negative revenue will ultimately lead to an increased, stable market-share for the products and / or organisation.

This type of strategy needs to be taken into account by the costing-practitioner in order to know when budget-cuts are essential and when they are not; and when short-term losses equal entry into a new market so can be viewed as an investment; and when they need to be addressed. The costing practitioner is involved in reducing costs on product, so needs an overall awareness of the direction of the business as well as the general trends within the market, to know where costs should be inputted in addition to knowing when they must be reduced. A comprehensive knowledge of the overall costing process, which includes technical and economic areas related to the product / item being cost is essential, so the practitioner knows where costs can be cut, spread and expanded upon.

#### 7.3.1.6 Market Trend Knowledge

Coupled with the need to be aware of the direction and intentions of the organisation, is the necessity to have an awareness of general and relative market trends. For example the general trends may include recessions, therefore less revenue may be expected to be expended on luxury items as a whole: More particularly to be aware of market trends towards the specific product in general, across all competitors and to note any impending disturbances. E.g. bad-press towards a dangerous product / model such as in automotive, the design of air-bags proving fatal to lower then average height users; or foreseeable world events effecting the demand of military vehicles. Plus a tailored regard towards the actual product and its placement within the market. Potential decrease in sales pending design changes, i.e. in the automotive air-bag example; or the impending commencement of a war: Such events will effect costs via production, design and units sold. An obvious example of why this prevalent market-knowledge is needed is for negotiations with supplier; see proceeding two sections. If the market appears to be growing, heading in a direction of strength the reduction in prices of certain commodities may be arranged. In other words this awareness can be used as leverage within negotiations, in order to decrease the price of corresponding outsourced items e.g. procured from suppliers: Thus assisting in cost-cutting exercises, and cost predictions.

Market trend knowledge and information can assist in predicting future technology, which can aid in projections for project technology. This is especially relevant for organisations whose projects are long term, i.e. 10+ years; new advancements in technology are rapid and not always straight forward to predict 10-15 years and more in advance. The cost practitioners need to follow guidelines as to such developments derived from historical data; for example, how quickly technological advancements in the areas in question have been made to date, and what impact it has made on the product, and consequently the cost. In addition, market trends can reveal which areas are dominant and of general interest; and therefore are more likely to be focused on and as a result advance quickly. Given these trends, potential future profits may be predicted, with reference to market trend knowledge and information, e.g. sudden popularity or ‘explosions’ in certain domains e.g. computer games / low pollutant emission automotive vehicles, which will have knock-on affects on the product. Plus the direction of the product value, i.e. whether it will increase or decrease over time, can be estimated with the aid of following trends within the market. Hence having an awareness of such is useful, providing the information employed e.g. historical trends, are effective guides: Consideration of whether it is or not needs to be applied.

### 7.3.1.7 Supplier

Knowledge of the supplier is important and a theme relevant throughout product-costing, see Table 7.2 for guidelines as to how this aspect occurs within each type of knowledge identified as being essential to the cost-process, included within the eight KT. Given this, knowledge of all inclusive aspects of the costing-process is necessary when dealing with contractors, particularly when assessing supplier-quotations and invoices. This is because when / if the supplier provides a detailed breakdown of their costs, as is usual to request from them, (though not always given), analysis of such a breakdown can often reveal a number of areas from which costs may be decreased or removed. These reductions can be made via both legitimate and purposely derived escalations. For instance, the former could be due to old machinery or outdated processes being employed, which ultimately make production slower or requires more labour costs, and so forth; see knowledge of manufacturing-process Section 7.3.2. The latter can be due to when for example, the use of consultants being accounted for in more then one area, e.g. within the labour costs, as well as included as an overhead, and even within the subcontractor costs. Subsequently when breakdowns of the costs are examined for validity, any such overestimations or duplicates can be identified and removed.

When selecting suppliers, quotations often from a number of bidders need to be assessed. An appraisal of the received quotes will require knowledge of the costing process utilised, including how overheads have been derived and whether profits are fair and adequate, as they can be too low in order to secure the contract, as well as too high, see Risks Sections 7.3.1.9 and 7.3.6. By comparison of the bids, an economic judgment can be made as to the most suitable supplier to use via comparison of costs and making decisions based on costing process knowledge about the validity and reasonableness of the contenders' bids, see Table 7.2. The supplier will often need to be prepared to be flexible and accommodate the changing needs of the customer; being prepared and able to work closely with them particularly on long-terms projects where upgrades or some other form of product-modification may be required for future models / product launches; see communication and cultural sections. All such activities will usually need to be specified in the original contract between the supplier; and accounted for in the costs and suitability from supplier-assessment stages and onwards, also refer to Section 7.2.3.1. for contractual / payment impacts on contractors, and resultant priorities and pressures.

### 7.3.1.8. Knowledge of Negotiations

Negotiational interactions and subsequently the relevant skills required to perform this activity has emerged as an important activity within the process of costing a product, and it appears to take place on a number of levels. They can be conducted in both a structured, direct, manner; or in an indirect, more subtle way, shown in Figure 7.9. The primary negotiation function is in the explicit form undertaken as part of PC in relation to the supplier-costs.

#### *7.3.1.8.a) Primary Negotiations with Supplier:*

When a supplier submits a breakdown of costs, ideally a cost-practitioner will validate these costs either by performing their own independent cost-estimate, detailed or otherwise and then comparing it against the submitted supplier costs; which can be time / resource dependent. Alternatively, by simply scrutinising the suppliers submitted figures, and detecting areas which may not be accurate, where costs could / have been escalated: This is as opposed to having created their own cost-analysis independently, then comparing it to the suppliers figures and highlighting any increases in the supplier submission, or investigating excessively low quotes. Negotiations with the supplier will commonly proceed these costs-assessments, as it was frequently stated by the cost-practitioners that a costing practitioner will rarely totally accept all elements of the supplier costs when given the opportunity to assess it, as described.

Thus the general process leading to negotiations is that the supplier will submit one set of costs for any given aspect of the contracted work and the user-organisation will tend to want to agree to a different (lower) set of costs. As a result, the two companies will embark on negotiations to establish the amount paid for the service or product provided. The negotiations themselves can vary in conduct, but will almost always be lead by the Purchase department, also known as Procurement or Buyers. The majority of companies would engage PC at this stage, to provide technical knowledge about the product and processes under negotiation. They assist the purchase representative and are ideally physically present in the meetings in order to counteract any over-estimated, repeated and generally inaccurate costs proposed by the supplier. A more subtle aspect of the presence of united disciplines actually physically present at the supplier negotiations is to bestow support, confidence and what has been termed as *"mental muscle"* ; see Section 7.3.1.1, discussing the implicit and explicit factors related to negotiations. This is necessary, as it is in the suppliers interests to keep their cost-assessments as high as possible; therefore it can take more then just lowered figures as derived by the user-company, per element of the supplier-quote / invoice to persuade the supplier to accept decreased costs from their customer. A level of assertion and confidence / experience conveyed from either-end of the negotiating arena will gain advantage in the process; which will be particularly evident in cultures displaying high MAS levels [Hofstede, 2008], see sections on culture and communication. The explicit need for the presence of PC is to provide the product and technical expertise required, in order to gain credibility for the terms and costs proposed.

#### *7.3.1.8.b) Industrial Differential Practice in Negotiations:*

This description of the negotiation process is generalised and is highly dependent on the circumstances. For instance, within government–related interactions, (UK), the profit allowable for any outsourced work with any supplier by must be deemed *"fair and reasonable"* as stated by a number of practitioners within this sector. The reaction to this rule within the stated environment was mixed; a number of practitioners felt it was too vague a guideline to adhere to, whilst others stated that it was suitable and generally abided by. The latter point is due to the fact that it is in the interest of all interacting parties to keep a preferred supplier in business; therefore a suitable level of profit for them from any contract, must be allowed.

An element to this area of industry which was not applicable to others, was in the fact that if it could be proved that excessive revenue i.e. above what was deemed 'fair and reasonable' was made by the supplier they could incur legal repercussions; and face consequences in other words penalties against them plus not be given further business. It was for this added dimension of accountability, which seemed to have lead to the practice of the practitioners in these organisations to provide adequate information about their work, to cater for audit trails. I.e. they were noticeably far superior then other industries in not only recording the costs meticulously, but also in detailing the reasons behind their choices regarding costs. This was because if audited and questioned for any given element of the cost-breakdown, they would need to provide adequate reasons for why certain expenditure was included, and could be personally liable if mistakes were made which lead to excessive figures. This attitude of detailing costs and choices behind them is relevant to the result in relation to training e.g. having a comprehensive historical data-base would assist in novice knowledge-transfer; see Chapter 8. In other industries such as automotive, practitioners often claimed to be too busy to document their jobs. Although a library of accurate, historical project-data would be of great benefit to any trainee and could even assist a trained practitioner in day-to-day activities, it was often perceived as something excessive and unnecessary which would only add to their workload. This is discussed further in the following Chapter, 8 when examining training options.

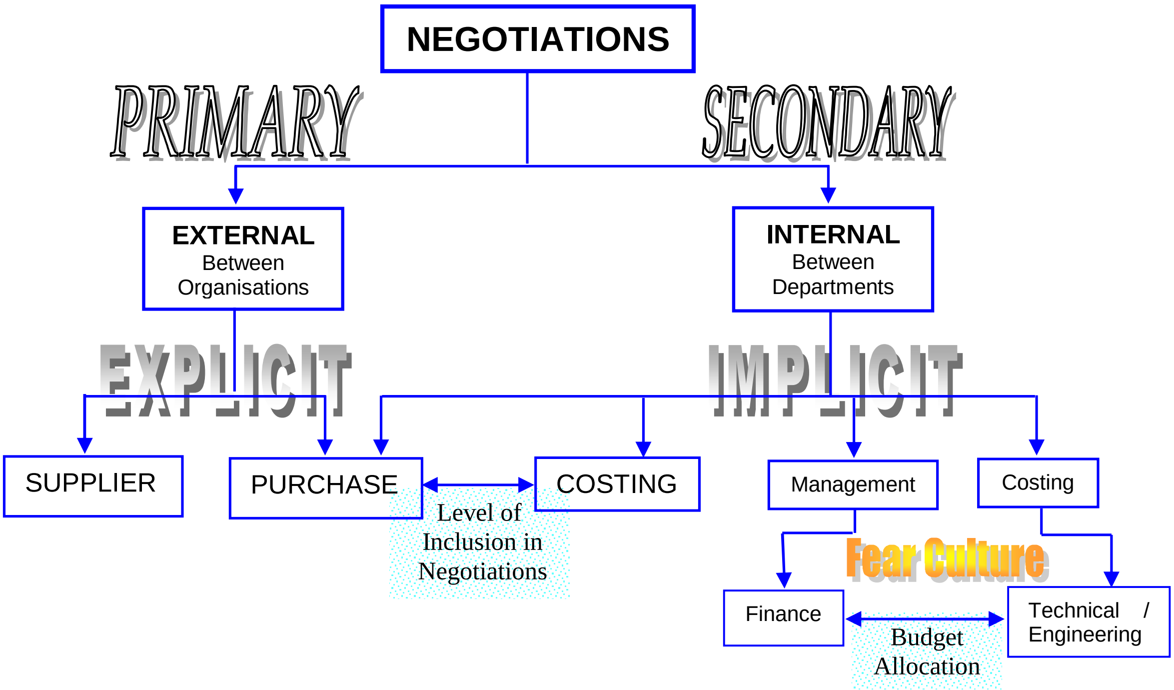



Figure 7.9: Levels and Interactions Involved in Cost-Negotiations Within and Between Organisations.

However, with regards to audits the results of such stipulation i.e. profits and costs needing to be fair and reasonable, was consequently seen in the type of attitude present in the negotiations of costs between the relevant organisations. The general feel of negotiation which was seen within the industries which do not have such consequences, e.g. between private organisations, will be quite different. As expected, these negotiations were relayed as being more 'cut-throat' with each side of the negotiation aiming to procure the maximum results; the supplier to keep their prices as high as possible, and the customer to decrease them as much as possible. A purchase manger within a large automotive organisation stated that percentage-cost cuts could be demanded of the suppliers by the customers who were essentially powerful enough to bankrupt the supplier if they moved business elsewhere, for instance if the stipulated cuts were not complied with. Here it was stated that if budget reductions were required within the large customer-company a knock-on effect of this would be passed onto the supplier who would be expected to absorb such percentage decreases as well, even if this meant the cost-cutting affected their profits. In this instance the powerful automotive company could end up bankrupting the supplier, with little room for negotiations depending on a number of factors, including market trend and company strategy; but in general terms may be dictated by the more powerful entities. With this said there are various consequences to such unyielding practice: The obdurate powerful customer will gain a reputation within their field for such harsh working conditions and suppliers will consequently avoid partnerships with them where possible, tending to work with companies who are known for their productive, successful supplier collaborations. Plus it is not necessarily in the customers interests to assist or even be the cause of the supplier companys' collapse, as their collaboration is required.

Though, where the negotiation process is conducted on a more even keel the element of 'mental-muscle' plays an important role. This means gaining a stronger negotiational position via either better cost analysis, and thorough assessments of the cost-breakdown; which means for the customer, the fact that a full cost-breakdown was able to be procured from the supplier to begin with, which is not generally forthcoming. It more typically involves the forcefulness in which the negotiations are conducted between the interacting parties, which may be affected by issues such as how many are present to represent each side. Whomever is in the most persuasive position, both factually with facts and figures; and via perception e.g. from perhaps having force from numbers, greater persistence, even giving the perception of more experience and / or knowledge, will lead the negotiations.

*7.3.1.8.c) Time Constraints:*

The type of negotiations described in the previous section may involve detailed cost-assessment of the supplier costs, so often depends on the availability of the costing practitioner who will have needed time to prepare for the interactions, been provided with the relevant information among other considerations. Within a minority of organisations examined, the practice of strategic-level negotiations often occurs especially when there have been large cuts stipulated on an organisational level and cost-reductions need to be found. Product-costing may also be too pressed for time / low on resources, in order to conduct such detailed negotiations in every instance, if under-resourced or during busy phases. Therefore strategic-level negotiations take place where purchase conduct them with the supplier, independently of PC, as loosely described in the previous section. These were referred to industrially as Strategic negotiations, which were described by a purchase manager within an international automotive corporation as usually involving the supplier as being obliged to reduce their costs by a specified percentage, regardless of their current practice. For example, even if their costs are already as low as possible and their practices efficient; purchase will dictate the reduction required, and the negotiations will commence from there. For instance if purchase receive the cost from the supplier and without consideration of the cost breakdown insist on, for instance a 40% cost-reduction. The results can range from a degree of leeway allowed, to threatening to re-source. Actual re-sourcing, to another supplier is only done as a last resort, but can be imposed. This may occur if deemed necessary, especially when the customer is a large and powerful organisation. They can threaten re-sourcing and moving all work to another company if their cost reductions are not met: This type of action often takes place when there is a low level of interaction; the supplier refuses to or is unable to comply with the cost-reduction demands; or any other reason which would result in the failure of negotiations.

The supplier could potentially find it challenging to meet these (seemingly) undiscriminating cuts in costs, across the board. However, it was stated by an automotive purchase manager that they may feel that the costs are excessive in general, so therefore could feasibly be cut. Though it was explained that what is more likely is that there have been budget reductions, and costs need to be reduced. The supplier may face huge losses, if the large company does re-source the work, as in the case of this large automotive organisation examined who have a number of other holding-organisations / sister-companies, all of which could change suppliers accordingly, and consequently remove the current one from all of their books immediately, as well as ruling them out of future contracts. Subsequently although this may at times seem demanding and harsh on the supplier, strategic-level negotiations are often conducted. When they are it may be of longer term benefit for the supplier to meet the percentage cost deductions specified by purchase, rather then lose long term business prospects with the customer.

Therefore in times of recession and 'credit crunches', although cuts may essentially need to be made across the board for the user-organisation, the resultant demands have been known to be very detrimental for the supplier. The latter may consequently prefer to associate with organisations which are known for being more ethical, yielding and interactive with the contractors. This is because if profits are too low it could drive the contractor out of business; unlike the larger customers who will be more financially stable, being supported by elements as holding companies.
With this said, there of course needs to be another supplier capable of providing the required service, e.g. a strict imposition of strategic negotiating cannot be done if interactions are with a single-source supplier. In which case the unfair advantage can transfer to the supplier who if essential and the only source, will hold the position of power particularly in negotiations and regarding the overall service they will provide.

This is all in contrast to the other end of the spectrum, with regard to negotiations, wherein the customer including the product-costing function, will scrutinise the suppliers costs, and negotiations will be based on the outcome. Best case scenario is that they agree that no more cuts can be made; however if there has been time by the cost practitioner and adequate cost–breakdowns provided by the supplier, it was stated by more then one practitioner that it is rare that supplier costs cannot be cut by the user company. On this subject a supplier representative actually stated that they will escalate costs wherever they can, and this aspect of practice is known, he indicated it is almost accepted by the customer company. With this 'understanding' in mind, it seems that scrutiny of supplier quoted costs by the customer product-costing function, with the aim of detecting where the unnecessary increases have been included, is commonplace; see Section 7.2.3.3.

Alternately a senior cost-practitioner conveyed that PC may agree that the costs are low usually with known, frequently-used suppliers, but still state that cuts need to be made if they are to stay within the cost-target. When such cases have occurred both organisations will work together to reduce the costs, occasionally by even redesigning the part so it can meet the budget, which is termed as Design to Cost (DTC). This is less usual then the most common occurrence which is as prior stated, the costing-practitioner finds areas of potential cost reduction from within the submitted supplier quotes / invoices and raises these points in personal-negotiation sessions with the suppliers.

It was observed that negotiations can range from a high level of flexibility, adaptability and integrated work, to inflexible, blanketed percentage-level reductions imposed by the buyer to the supplier. Thus it can be strategic, i.e. percentage-cuts, to detailed where they, the customer and suppler work together to bring down costs. The cost practitioners can also assist Purchase in the negotiations in a more subtle way, namely by providing information required by them. Again this is time–dependent for all parties involved, as it was noted that costing tended to be overstretched, so under-resourced in a number of organisations examined.

#### *7.3.1.8. d) Secondary Negotiations: Internal*

The explicit negotiations which have been discussed tend to take place between organisations and so are external to the company itself. The more subtle, implicit ones tend to occur within organisations, between departments, disciplines and hierarchical levels. They can involve product-costing, different branches of engineering, the financial, commercial branches and management, and are discussed further in Sections 7.4.1, communication and 7.4.2, culture. Often these informal negotiations can be centered around budgetary concerns. For instance in one organisation where there were commercial cost estimators assessing the financial side, and technical cost engineers focused on the engineering and performance issues, there were often subtle negotiations regarding the level of finance allowed. Though unofficially, these interactions were said to consist of occurrences such as the cost engineers from the aerospace industry in this instance, who would be placing costs which were quoted as being instantly halved by the cost estimators, who would assume overestimations had automatically been submitted. These subtleties would go back and forth, with the technical side constantly trying to justify their costs, and the commercial side trying to find reasons to cut the costs, keeping them as low as possible. This type of alleged overestimation became apparent within other large manufacturing organisations, between management and specific departments. It often transpired due to a culture of fear, where the workforce did not want to be perceived negatively by management, and such a perception was envisaged if targets were missed, either time or cost-wise. Therefore the various branches of management were vigilant in their attempts to recognise overestimations when costs were being submitted for budget-derivation, and they were making attempts to again implicitly persuade cost-reductions to realistic levels. This workforce attitude was beginning to be addressed via assurances that job-security did not depend on hitting targets, but rather by not escalating costs; leading them to adopt a more systemic view, that would enable them to understand the genuinely detrimental consequences of company over-spending. This subject has wider implications and is looked at in more depth in the proceeding culture and communication sections.

Another area in which negotiation was subtly performed is in the level of inclusion that product-costing were allowed in certain stages of the process. A common complaint from the participating practitioners was that they were not included as a standard part of the process, therefore were utilised on an "*as and when required*" basis, at the discretion of other disciplines. A form of tacit negotiation would thus occur between PC, and often purchase for supplier selection; and occasionally engineering too, to increase the usage of PC at certain stages such as conceptual design and during refresher model derivation. This was undertaken by the internal contacts made and relations developed between them: If confidences grew, trust was established and competence determined, the costing-practitioner was far more lightly to be consulted then if such endeavors where not embarked upon. Refer to Figure 7.9, which illustrates via a tree diagram the chief negotiations within the cost-process, which include explicit often external interactions, in addition to the related implicit elements involved more indirectly. Hence the level of use by costings internal customers is important, and can be increased by these subtle interactions. See Chapter 3 Section 3.2.7 for literature relates to supplier interactions.

#### 7.3.1.9 Associated Knowledge of Risks

The knowledge to estimate as many as possible of the unforeseen escalated costs which may feasibly occur throughout project duration is important, as it affects the overall estimated cost. The risks may be in the form of accounting for technical occurrences e.g. breakdown of machinery, logistical risks including late delivery of goods, or for pre-empting for such events as change of weather relevant for outdoor construction projects. Risk knowledge is in the recognition of the need for the validation of supplier reliability. For example, if an unknown supplier has placed a competitively low bid accepting this bid on its merits alone would be a risk. Research would be required into background, financial status and general ability to deliver a quality product within project schedules. It is preferable to acquire information on supplier past performance prior to contract; see Section 7.3.6 on risks, for more detail.

The perception of risk can apply to having an awareness of consumer perception, e.g. viewed as reliable or unstable products. For instance, an automotive practitioner explained how the long-term sustainability of the company often depends on short-term losses; see previous section which examined market trends and discussed loss-leaders. These losses do not indicate crisis, but instead are necessary to create familiarity, trust and confidence among potential customers. Therefore the knowledge is in recognising the need for such a situation to not be perceived as a risk, and act accordingly; discussed in Section 7.3.1.5, organisational strategy. For example, the company will sell a certain style of product at a very low price within targeted countries; and aimed at specific but wide markets, in order to still be in that market in 10 years, referred to as loss leaders. However, in this time the company may have gone from being unknown 'risks' to the consumer, to an established, reliable, good value household name. This has created the position of being able to increase the price of the same products currently being sold cheaply, as well as allowing the introduction of higher value models. In this example the knowledge of risk comes from an externally viewed angle, i.e. how the organisation is seen by the users / market, and estimating the pro's and cons of creating a change in perception.

A specific example of a loss-leader was given by an automotive company regarding their successful method of introducing their cars to an overseas market which already had a number of its own known brands of automotive. The loss-leader was the small model of car, followed by larger, luxury models introduced over the years. This type of practice has also been noted as being used by suppliers though, in their endeavours to secure bids. A defence practitioner described how in such cases, collaborative working on a major project with an overseas supplier who was quoting substantially lower costs then the competitors was considered a risk, as the practitioner assessed the supplier and discovered that they were unstable. Interactive working with a financially volatile supplier was risky, as the customer would incur (potentially) huge financial losses if the supplier went out of business; and time would be wasted forging a new code of working-practice with another supplier.

### *7.3.2. Manufacturing Process Knowledge*

A thorough knowledge of manufacturing processes was identified as essential for the costing practitioner, CP, by 95% of all industrial contributors. This knowledge type is required as so many costs are associated with the manufacturing processes; which evolve and are subject to change on a fairly regular basis. Keeping abreast of manufacturing process, MP, innovation is essential as such advancements impact on the cost. However, prior to any new technology assessment the cost of the initially utilised MP itself has to be determined for a component. This includes the machinery running costs which encompasses cycle times and associated labour. For instance, determining how many individuals will it take to run the machine; assessment of whether it is a complex process, e.g. will it need to be monitored, attended to in any way throughout its cycle, making it time and labour–consuming. Alternately is it a simple process once it has been loaded, i.e. fully automated, therefore can be left to run itself with minimal attention required. How much of the process can be automated was included in the questions posed regarding the loading and running in total or whether parts need to be handled manually throughout. Whether the labourer(s) running the equipment and supervising the machinery need to be highly skilled or basic, needs to be accounted for, as this all affects the costs associated with the machine. Aspects such as size, therefore floor space used as well as power, i.e. electricity and other running costs are included within the overhead breakdown.

A CP needs to be knowledgeable in all these areas, i.e. MPs, their implementation and labour requisites. A comprehensive knowledge of what each process entails; the associated machinery involved, and time and labour related to it including numbers of engineers needed to run it; skill-levels; cycle times for each process is required. If the CP is not knowledgeable in every type of machine piece of equipment used for each component of the product, they need to know where they can procure the required information from. For instance, they may be experienced in welding processes, but have less knowledge about moulding. As long as they are able to access the knowledge required usually from another practitioner, they will be able to include those aspects of the cost within the final cost assessment. An automotive cost-practitioner explained that regarding tooling, machinery, and part knowledge; the CP must be aware that the investment of the company will be sectioned, explaining:

*"..Piece cost is separate to tooling, which is separate to capital equipment costs, and machinery ..often not paid for by the company, as it's an asset, but it will be covered under depreciation"*

[Cost Estimator, Automotive industry, 2002]

Knowledge about how depreciation is calculated is necessary to avoid multiple charges for it; see previous section. In such cases it is clear how the knowledge of economic breakdowns and MPs, machinery usage and wear is utilised in an integrated way.

#### 7.3.2.1 Change Management: Alternatives

If the design of the part or product is modified, as can often happen within a project, see design knowledge Section 7.3.3, this may have a knock-on effect on the manufacturing process. For example if the product is enlarged even slightly it can effect whether it will fit into, for instance one mould or whether two may consequently be required. This will subsequently call for a joining process of the most appropriate type for part, material and cost-effectiveness. Two moulds and a joining process may not have been necessary, prior to the changes made; and will evidently have substantial effects on the resulting cost at least for that particular component. Therefore the issue needs to be addressed as to whether the current method used is suitable or able to cater for the modifications, e.g. if it was manufactured in-house, is the equipment, machinery and / or capabilities available to accommodate upgrades and other changes; will new equipment be needed; or perhaps outsourcing could now be the most appropriate option. The limitations of the process, as-is needs to be known in order to for assessment. Such modification can therefore have a large affect on the cost, which must be considered when these decisions are made.

When a product is updated or refreshed as often happens in the automotive industry among others, many relatively minor modifications are made. Each one will potential have major manufacturing-process implications as mentioned above, which must be accounted for in the costs, prior to finalisation of the changes. Change management is therefore key to embarking on product modification and updates. The cost-practitioner needs to have enough knowledge of processes to suggest suitable, realistic alternatives when required for both modifications, which are made by customer or via upgrades, when it is necessary to reduce costs to stay within the budget: In this instance a low cost MP alternative has to be practical. The CP needs to have the knowledge to suggest a feasible alternative, not just one that would lower costs, but end up not being suitable for gain physical and practical awareness in order to for instance, relate to the product purpose. As manufacturing-processes are so important, this would explain why an overwhelming majority of experts encountered within the UK had an engineering background, often having been trained as a technical apprentice typically lasting two years, which gives a thorough knowledge of MP. In contrast, the commercial and economic aspects were said to have been subsequently learnt, being wholly more prominent in the U.S. observations, reference Chapter 6. A practitioner from a large U.S. manufacturing organisation commented that the contributing novice who was from a more financial background would largely benefit from accessing the marine product they were currently working on, in order to gain physical and practical awareness or *" ..an idea of the product"* being costed.

#### 7.3.2.2 Continual Updated Awareness: New Processes and Technology

Manufacturing-process knowledge has notably been contradictorily stated by various practitioners as being both challenging to gain comprehensively; and straightforward. The former was stated due to the fact that there are numerous methods of manufacturing and associated processes, of which are periodically updated: New processes / machinery / equipment / technology are regularly developed which enhance the fundamental process. Therefore it is said to be a time-consuming task to become adept in the workings of them all, and challenging to keep up with the new developments sufficiently.

Alternatively, views were also expressed by experienced practitioners which stated that many of the processes are finite in the manner in which they can be performed. Hence once these are understood, the updates and new methods are simply variants on these basic principles of how to perform these tasks. For example, there are a number of ways in which items may be fastened; which include welding / soldering and bolting. When these processes are updated they are based upon known, reliable fundamental principles of joining of which there are only a certain number. However, regardless of specific opinions about the level of difficultly in gaining and maintaining this knowledge type, the fact is that all costs associated with each utilised manufacturing process needs to be incorporated into the cost-breakdown. Therefore they require recognition, to be understood to a degree, and accounted for in totality. This includes skill-levels, time-taken (cycle-times), associated overheads, maintenance, tooling (add-ons) and labour rates. In conjunction to knowing the basic costs of the directly utilised processes, and the potential cost implications due to any modification; the CP also needs to be aware of the workings of the manufacturing processes, MP, in question in order to assess supplier quotes and their related justifications. This is discussed in the previous section and expanded on in the proceeding ones.

#### 7.3.2.3 Knowledge of Supplier-Processes: 'Tricks' and Trust Issues

This aspect of costing, understanding supplier quotations, cost breakdowns and practices focuses on trust-issues between the interacting organizations. It has been frequently referenced in relation quotation-analysis from the quotes provided by supplier, validation of supplier invoice, and negotiations with contractors, see Table 1. When a component, product or any type of service is outsourced, initially an ITT (invitation to tender) is disseminated throughout the relevant communities instigated by Purchase department, within the relevant industrial communities. This often generates a number of quotations from potential suppliers. The research shows that the services of PC does not tend to automatically be utilised at this phase; their inclusion here depends on factors including their relationship with purchase; PC prominence within the organisation, and whether the nature of their role is known and understood. Practitioners from across industries were repeatedly quoted as saying that the function was employed on an 'as and when required' basis. This attitude has been widely seen to be a source of much concern to PC as has been prior discussed, but basically PC relayed that they should be included systematically within the process. This includes incorporation at supplier selection through to analysis of their costs from conceptual design stages in order to assess every bid and determine the best cost-option. However, it must be noted that although not routinely consulted, they often are involved; in which case the quotes will be assessed at the bidding stage.

There is often already a relationship established between a supplier company and customer, in which case they may procure repeat business. The trust between the departments in these cases has been known to be an issue; in relation to judgments made by Procurement regarding supplier selection, see the cultural Section 7.4.2 and Chapters 4, 5, and 6. Whether costing are involved at this stage or not, a supplier will be contracted for the work. Once this occurs, a certain level of interaction between the organisations will be required in order to establish the details of the job, see communication Section 7.4.1. The supplier will subsequently produce an invoice for the work, which will need validation; it is at this point that the costing department will more commonly be involved.

The costing processes employed by the supplier will need to be assessed; the degrees of thoroughness can vary according to aspects as time and resource, discussed in detail in Chapter 6 within the cost themes.  Ideally the supplier will be visited by PC allowing observation and general scrutiny of practices. Workshops will be examined; the type of area PC will be assessing is efficiency. If the supplier has outdated machinery and inefficient MPs, this will be addressed by the user-organisation; as practitioners stated that they will not expect to pay for 'bad-practice' in the supplier cost breakdowns.

Another key element to visitations is regarding potential escalated costs via 'tricks' the supplier may bill the customer for. There seem to be numerous ways in which costs for various MP can be stretched or somehow exaggerated on invoices, resulting in fundamental overcharging, illustrated in Figure 7.10. Product-costing needs to be vigilant with regards to such conduct, which can often be very subtle in the running of processes as well as in the cost breakdowns, e.g. double costing for practitioners, see costing-process knowledge, Section 7.3.1. Such covert escalations can easily go undetected, if observed by an unknowledgeable costing-practitioner in MP. For example, the aperture in a pressing machine can be set at a greater distance than is strictly necessary. The material being machined may fit into a much smaller space, and thus be machined in a greatly decreased time frame. However, this increase in distance will create an increase in the cycle time; which would create an increase in the costs. A cost-practitioner would need to be knowledgeable in both the overall costing process in order to note the stated figures, see previous section. As well as knowing about the MP itself to know how it should run, what aperture–distance is adequate, have an idea of what the correct timings should be, as opposed to accepting supplier figures; and subsequently the CP should possess an understanding of how all aspects affect the costs, see Table 7.2. The machinery, running costs and required labour-levels are among the items which need to be known to ensure that any duplication of labour costs or overstating of these costs can be detected e.g. costs for three highly skilled employees is included, when two basic-skilled are adequate. If detail of the performance of such machinery is not known, such escalation of costs will be overlooked, and not removed from the invoice, see Figure 7.10.


Figure 7.10: Supplier Negotiations

The history of the supplier is a useful guide to their expected performance. For instance several practitioners within automotive and manufacturing domains stated that its important to try to ascertain whether the supplier is reliable, timely and provide quality goods / service; or are they prone to tricks, such as quoting low costs to win the bid, then escalating costs during the course of production. Evidently this does happen; it was said that at times it seemed that the increases were unavoidable, and had genuinely been unforeseeable. At other times though, the cost-practitioners were well aware that the escalated costs, also referred to as 'top-loading' occurred due to the suppliers quoting low to get the contract, which once secured meant they simply raised the costs with use of one guise or other; the way seemed to be gradually, or minor additions but over many areas. For example:

*"..if you want the material or component to be delivered to that spec. it will cost you more ..somewhere in the region of xx; the quote we gave you was for basic delivery…"* .

[Cost Practitioner, Automotive industry, 2005].

With this said it was often not worth re-sourcing at this stage due to factors as: The production / interactions and the supplier product was already being utilised, or well on the way to be. Therefore by the time another supplier had been sourced, perhaps even needing to put out another ITT, it would not be cost-effective to go through the process of re-selection. As often, for the investment already made coupled with the cost to resource, it would be worth staying with the initial supplier and just paying the escalated costs, for the cases where the customer i.e. product-costing / purchase, could not negotiate them down.

Table 7.2: Lists Supplier Relevance against the Essential Cost Knowledge–Types

| KNOWLEDGE TYPES | KNOWLEDGE of SUPPLIER (Contractor) | | |
|---|---|---|---|
| **Knowledge of the COSTING PROCESS** | Cost breakdown assessment (how accurate is it?) | Who is most competitive, economically (including logistics, etc.) | Flexibility; integrated working in order to meet needs |
| **Knowledge of MANUFACTURING PROCESSES** | Who can provide the service; who has the knowledge, expertise and capabilities? | Supplier Technology: Efficient and updated? (*Tooling, machinery & part knowledge) | *Tricks –recognition of actual against stated working practices |
| **Knowledge of DESIGN** | Adequate design and R&D facilities –need for | Integrated working towards design modification for lower cost | Integrated work towards updates / new models |
| **MATERIAL Knowledge** | Who can supply the material? | Material batch sizes –has cost implications | Standard or special form -delivery requirements |
| **PRODUCT Knowledge** | Integrated working – supplier experts based on-sight for fixed time periods | Adaptation /change management –requires product understanding | Improves timing; allows pre-empting of requirements /delivery, etc |
| **Knowledge of RISK** | Supplier stability | Supplier reliability | Supplier working practices ('add-on's'; escalated costs, etc) |
| **Knowledge of COMMUNICATION** | Negotiations (cost breakdowns) | Obtaining information (invoice analysis etc) | Integrated working – promote communication |
| **Knowledge of ORGANISATIONAL CULTURE** | Language and terminology (especially for overseas contractors) | Working practices – Awareness of differences /Norms | Integrated working practices –IPTs to promote understanding |

It must be noted that advantageous behaviour towards procuring idealised costs is performed by both supplier bodies and the customer. Section 7.3.1.8. discusses how powerful and arguably unrestrained user organisations can potentially push suppliers into bankruptcy with their percentage cost-reduction demands, and threats or actual moves to other contractors. Both sides will take measures to secure the best deal possible for their company: This all seems to be part of the acknowledged trading conditions; hence the need for skills which specifically address these issues at both ends of the negotiations i.e. for supplier and the customer.

#### *7.2.3.3 a) Accessibility*

In order to access the practices of the supplier companies, the CP needed to view the actual day-to-day running of the MP, as opposed to potentially 'staged' operations. For instance it has been prior mentioned how a CP within a large manufacturing environment of which increasingly tended to outsource components, suggested that a tour of the workshop should be undergone on the second day instead of first which is often as expected, when visiting the supplier sites. If the visit from the customer is expected, then it was stated that costing-practitioners will view unrealistic and possibly unsuitable / uneconomic processes being performed, and could therefore accept them as part of the price. However, the idea is to encounter realistic working processes, to determine where costs can be cut legitimately, as well as when such 'trick's as prior-mentioned have been employed in order to procurer higher margins of profit for the supplier. Amounts of material used is included in such cost escalations, e.g. if the supplier orders in bulk to cater for a number of customers, their costs will be lower. If bulk orders of material are noticed, such savings can be negotiated and passed onto to the customer.

This said, there are times when cost-practitioners will be too busy to visit the supplier or may even be denied access if the supplier organisation feels confidentiality issues are at stake, and / or competitive advantage. A practitioner from a large automotive organisation explained that in such cases, when negotiations of cost between supplier and user organisation are embarked on, the position of the customer i.e. users of the supplier company will be weakened, due to the fact they have not had the opportunity to examine the supplier premises.

As observation of supplier manufacturing-processes and general approach to working have not been personally assessed, it is subsequently difficult to challenge the supplier on their quoted costs: Often the supplier can use this lack of knowledge about them as leverage giving strength to any bargaining. It was stated that a distinct lack of credibility will be linked to the cost-reduction 'claims' of the customer, CP and Purchase, because supplier will know that they cannot validate proposals of how the suppliers working procedures costs may be cut:

*". …puts us in vulnerable position when it comes to negotiations …haven't seen their processes, …so ultimately they know we can't comment or contradict their costs with any certainty.."*

[Cost estimator, Automotive industry, 2005]

Instead they will know that the negotiations are based on assumptions, which the supplier can simply deny and not accept, thus justify and maintain their cost-breakdowns. The CP relaying this example felt that due to lack of resource, mainly not sufficient time to visit supplier premises, their role in the negotiation sense was being seriously compromised. When the supplier is based overseas a limiting factor towards the visitations in addition to time constraints can often be resource, principally a lack of funding, as well as time. Such criteria need to be considered in supplier-appointment within suitability determination.

Within the area of accessibility is both physical access, as mentioned above; and access to information. In order to take costs out of a supplier quote a cost break-down is requested. Chapter 3, Figure 3.2 details the activities within PC, with components towards the costs being highlighted throughout that chapter. Throughout this research the cost practitioners mentioned that the supplier will frequently not provide this type of detailed structuring as to how they have arrived at the quoted figure for work. So approximately 50% of the time, the PC function will be working with a basic breakdown, or even one final summarised figure. In this case the PC if able, will perform as cost assessment independently to the supplier figures, and by means of comparison between their cost-outcome and the suppliers proposed figures towards the same process, will use this within negotiations for reductions. However, even with their own detailed and realistic breakdown, they may not necessarily be in a strong position to negotiate, in such situations. The reasons why the supplier may not provide full itemisation of their costs, other then when linked to competitive advantage, will almost always be when they are in a stronger position then the user organisation. For instance, they may be a single-source supplier, i.e. when they are the only producers of the service or product in question. This may be for very specialised items; or when an conglomerate is large and powerful, larger then the users, and can even get a monopoly on their area of the market. Alternatively, if they do not have such total domination, their advantage may be that they are generally more economic, or produce a superior service, with state of the art technology to support all activities. This could result in smaller companies finding it difficult to compete with them for final product, even if cost-dissections are more readily procured from the smaller suppliers; e.g. as with Bosch, the powerful supplier to Ford Motor Company. Negotiation with large and powerful organisations are difficult; it is more common that they can dictate the price, which will be uncontested, as discussed in the previous sections, and the following cultural ones.

### *7.3.3. Design Knowledge*

A cost-practitioner is required to have knowledge about design for a number of criteria, namely in relation to the extensive aspects related to change-management. In addition to a more elementary use of such knowledge, e.g. it was frequently pointed out by practitioners that often a designers drawing was all that was sent for evaluation. Therefore during the conceptual design stages of product when the earliest cost-estimates are requested, if the fundamentals of design are not known the costing practitioner, CP will find it challenging and time–consuming to produce even a basic estimate, although a prototype of the component has often been stated as preferable, particularly by the more experienced practitioners, who explained that it gave them *"…more of a feel for the part"*, enabling a quicker, more accurate costing process to be performed. However prototypes are frequently unavailable at such early stages; in which case, the ability to read the designers' drawing is essential. Therefore the practitioners need to have a fundamental understanding of the technical drawings used, and basically be able to work from them in order to derive cost assessments: Hence this level of design knowledge is a requisite [Mishra et al, 2002b].

For the occasions when a physical part or prototype is accessible the CP will need to understand the design in order to assess the associated costs. This is imperative if there is little other accompanying information. As the CP has to then evaluate the component through their knowledge of design, the related manufacturing processes and judgments about the material via a visual assessment and any other information that can be obtained. Refer to Chapter 6 Section 6.3.1 on KCs and 5WH.

It has been stated that designers and cost-practitioners need to communicate, as costing does not account for design [Coley, et al, 2007]. This has not been observed during this research; in fact costing practitioners were often seen to be allocated a number of other product-related duties, in addition to costing. These responsibilities were inter-related with their core cost-activities which included working directly with design teams, for example VEVA, focus on DTC (Design-to-cost), refresher models; and generally redesigning to suit budgets and reduce costs where applicable. Though evidently CP design knowledge was not required to be at the same depth as the actual designers, an array of cost practitioners observed within this research have been deemed to possess various degrees of design knowledge and awareness, which they implement as an integral part of their cost-activities.

#### 7.3.3.1 Change-Management:

Managing the various aspects of change is a primary concern within industrial manufacturing environments, in which the need for design–knowledge is vital. There are a number of causes which lead essentially towards a change, modification or variant on an original product design, as the customer may decide to change the specification after the project has begun. This could be due to a number of reasons, e.g. if working within aerospace / defence, then a military threat may be perceived which previously was not there when the original specification was derived. For within the automotive domain, a recession or some other external forces on the global or national markets may affect the consumer behavior; related to markets trends and organisational strategy, discussed in Sections 7.3.1.5 and 7.3.1.6. Alternatively the changes may be due to budget cuts, therefore it will be necessarily to re-evaluate the product in order to find the cost-reductions, which will often include at least the consideration of redesign of component(s). For instance, an automotive vehicle may be redesigned or updated to lower costs, or to simply refresh an older-style model in order to re-launch it into the market. Either way, design changes, if only slight, will be needed. The CP needs to have comprehensive design knowledge in order to be aware of what potential changes can be made in order to reduce costs. They need to have been able to assess how these changes will affect costs, in order to make reliable changes. For instance there are times when a large change may save ‘pence’ i.e. small units of cost. If these minor savings are made on lower use items, the change may not be cost effective overall; implementation of such changes result in only marginal savings, in comparison to the amount of work created in carrying out the aforementioned modifications. In contrast changes made, whether if decreasing the amount of components / materials used, to using a cheaper material alternative, to using higher technological equipment / machinery, may save greater units of costs. For instance a significant percentage of the initial cost e.g. $3 saved from an item which initially cost $10: If this was the saving for a high production item, it would be highly cost-effective to implement such change. Such cost analysis exercises need to be conducted on a regular basis, making the CPs’ knowledge of design an essential aspect in relation to how well they can perform such tasks. In addition to the actual practical knowledge of design, the practitioners need to have the ability to engage with the designers as well. This type of communicational knowledge is discussed later in the chapter, see Section 7.4.2; and knowledge of their priorities and mindsets is highlighted in the cultural-knowledge section.

Design and safety requirements are continually evaluated within major corporations, e.g. at the research and development stage, R&D, prototype analysis, and quality assurance, QA stages. For instance within an aerospace designed product, challenges may require evaluation of stress through rib panel, sprue, skin, etc. This may all need to be checked in order to assess where difficulties may lie, creating flaws which if present would ultimately lead to high costs. PC often assists in the re-design and appraisal of product, ensuring the costs are kept focal among the other design concerns, such as functionality, enhanced performance and safety.

On a more basic level a CP needs to be able to input feasible design alternatives, as opposed to suggesting lower-cost but unrealistic modifications. For instance any substitute material needs to be suitable for purpose, so a softer more malleable or degradable choice, which happens to be cheaper, may be totally unsuitable for the function. The CP needs to be aware when looking at the area of either the actual product or the design, of what it is and what it does. An industrial cross-section of practitioners have expressed that a knowledge of the product / component design, and an understanding of why each area is designed as it is, is necessary. They particularly elaborated on issues such as change-management where low-cost alternative suggestions are required which are still realistic. Otherwise a lighter, cheaper material may be suggested for a denser requirement; plus springs and barings may be reduced, when it could make the whole structure unstable and / or decrease performance. On the other hand such items could be surplus, and omission of the odd spring and / or bolt could serve to save costs without adversely affecting the product at all. Knowledge of design plays a huge part in such types of cost cutting exercises, and change management.

A point regarding market-trends and design can be linked to environmental issues: This was commented on within the aerospace domain in relation to product-disposal; the manufacturers were increasingly taking responsibly for this stage to the point where it was routinely incorporated with their LCC (life-cycle-costs). However this does not only affect aerospace vehicles, as white goods e.g. disposal of refrigerators, and the automotive domain are increasingly coming under scrutiny towards their practices across the board. An evident concern for automotive is linked to carbon emissions. However the ways in which products are produced, the materials used and the reliability e.g. the throw-away culture are on course to heavily impact costs and the redesign of current products [Wells et al, 2005]. With this said, the observations within the examined industries exposed a general trend of unawareness. This seemed to be primarily due to a lack of systemic thinking, e.g. practitioners interviewed stated that they were not responsible for such impending considerations, with more emphasis on the systems at hand.

To summarise, design knowledge is crucial, as it is utilised to provide cost effective alternative designs for designer and engineer, incorporating material knowledge and manufacturing-process knowledge. This is an important aspect within aerospace, as design reviews are conducted throughout the duration of the project, at each phase by IPTs which include Production, Design, and PC. This knowledge-type is essential in automotive areas too, order to be able to estimate the piece-cost solely from a designer's drawing when necessary; and to enable work with a designer providing input to design-to-cost projects. The cost-practitioner needs to have detailed knowledge of the product as discussed, see Section 7.3.5 for among other needs, trade-off studies.

## *7.3.4 Knowledge of Materials*

Knowledge of the material commonly used on projects is required, primarily to assess costs when compiling bids, along with setting cost targets and budgets for projects. A comprehensive knowledge about the types of materials frequently used on the product, properties of these materials, and their approximate costs and volumes required is essential in the assessment of potential, overall costs of any given product.

### 7.3.4.1. Cost-Reduction Alternatives

Cost-reduction exercises for product modification are undertaken at every level, particularly to appraise material-costs; as on occasion there may be the requirement for lower cost alternatives. When this occurs a comprehensive knowledge of materials is necessary in order to evaluate potential substitutes. Material selection needs consideration, and therefore knowledge of its properties and purpose e.g. strengths, corrosion, heat resistance, density, ductility, absorption, impact-resistance. The costing practitioner needs to ensure any alternatives are suitable for purpose as opposed to being low cost but inadequate for both use and the MP associated to the part. Therefore all the mentioned properties are included in what the CP needs to consider, when evaluating a potential substitute for a component. For instance, a lower cost alternative which is also lower strength may be impractical if the part calls for a high strength, tough material. An awareness of the specific properties of each material is required, as not only will it clearly impact on the usage it is applied to; but it will need to be suitable for the MP involved with the part.

Each component needs to be known see product knowledge section, so a suitable replacement can be made, if there is a lower-cost alternative, within required specification. However, it has been stated that the introduction of new materials whether lower cost or even enhanced performance, can be a difficult and lengthy process. This is because the original materials used have often been tried and tested through actual usage for decades: It is extremely difficult to produce the same type of validation for a relatively novel composition, as for a carbon fibre blend, for instance. This is especially true for aerospace / military products where even if the material is seen to be the result of advancements in the field, it is not a straight forward process introducing it onto products. This is due to issues of confidentiality, security, validity and performance which usually all create challenges for such new introductions. This has been said to be a source of conflict for PC who feel there would be benefits to introducing lower cost, performance-enhancing materials into project such as the carbon-fibres, piezoelectric materials; but who recognise such advancements are subject to excessive standards, testing, clearances and general scrutiny. See the organisational culture Section 7.4.2, and Chapter 5 in reference to UAI index. However the counter-arguments in this area are steadfast, generally focusing around the level of time-against-results equation. To expand on this, an expert from an organisation which had been building bridges for 30 years with the use of a small number of tried and tested specified materials and compositions, noted that it was difficult to valid a new materials' performance to such certainty, stating:

*"..materials used are known ..performance is reliable ...in the absence of a thirty-year research period, how can the results of new compositions compare ..and convince the producers to make a substitute?"*

[Cost Manager, Manufacturing / Military, 2003]

One experienced practitioner explained that in such circumstances, the use of a new or even comparatively new material would be perceived as too great a risk by those who had a stake in the products performance, including management and potentially the customers. This was regardless of the identified benefits and technological breakthroughs associated to it. Issues of safety, reputation and investments would all contribute towards the onus being placed with the use of what is known with the greatest level of certainty.

Consideration of lower cost alternatives either to innovate ones product or too lower the cost for budget reasons, lead to the necessity of an integrated knowledge of manufacturing-processes and material, in order to know which processes are suitable for which materials. Performance and predictability of such also play an important part in material selection.

### 7.3.4.2 General Material Costs

In addition to a materials' properties and performance a CP needs to establish its current cost. Updated costs can be procured via a number of methods; these include material and industrial publications, information from supplier, or direct from the material manufacturer. However the price paid for any given material will tend to be subject to the batch size of order; this is a major consideration when procuring materials. Therefore when contacting these organisations e.g. material producers / suppliers, it may be challenging to obtain an actual price of the materials from them, as there will be a number of considerations which will affect the prices, primarily the amount of material ordered i.e. its batch size. Along with the specifics in which the material is specified by the customer for it to be delivered in, e.g. the shape or material 'envelope'.

Other than this inflation, exchange rates and logistics particularly if overseas supplier, are among the factors which affect the costs of material. The price is more straightforward to estimate if the material in question is commonly used; this is because there will be much previous data about it, so such additions as inflation, fret costs and any market-trend factors which may affect the price will be easier to assess. However if the material is a new or unusual composition, this can be more challenging to assess. Although such materials as the aforementioned are less commonly used in government projects, private companies, i.e. automotive tend to encounter them, and therefore regularly experience more challenges in establishing these prices. This relates to the computerise softwares' which organisations implement as costing-aids, and the described issues surrounding the maintenance of the databases which run these systems.

Expert-systems are utilised within a number of the organisations observed. These were either purchased from external developers and vendors, or developed and built in-house by the practitioners or users knowledge in the relevant domains. Within a number of the companies, noticeably within the automotive sector, it seemed that these softwares did not always contain every type of material that was required. This was said to be due to the database having not been updated with the information for various reasons, primarily as there were too many combinations of material to input, and maintain. In such situations as the practitioner being unable to establish the cost via the expert system, publications were often utilised to determine the prices, for instance Metal Powder, Metal Bulletin for steels; or reports from specific companies, e.g. Corrus, with direct company interaction if necessary. This method is efficient, but time consuming; results are derived more rapidly when there is adequate information available within a system, which is kept current.

Given the above there is potential for the novices to lack the knowledge required to procure such necessary material information, outside the use of a developed database. For example when determining the cost of a physical part by analysis of an actual prototype, there may be deliberation over which publications contain the relevant information. When such publications have been determined, it may be challenging to asses which of them are the most reliable e.g. if there are many, which each provide differing material information. To gain the required insight, a novice may find it problematic to establish 'who' is the most suitable to contact within the company, and external to it, across the industry. The knowledge of who knows is separate to the knowledge of the 'what' e.g. journal. The former may however be necessary to ascertain the latter. The need to locate this information, independently of software systems, highlights a need for material knowledge, which is linked to communicational aspects and knowledge exchange.

A fundamental way in which material costs are procured is via making an initial assessment of the basic costs; then adding the relevant influencing factors, including inflation, logistics, any required milling, formation, special delivery. The reason that a knowledge-exchange is required between the appropriate expertise is in order to obtain the level of material knowledge that is necessary in respect to properties, usage, etc. about each area that needs to be costed, particularly when more then a ROM cost is required. Different components on a product will often use the relevant range of (different) materials, possessing properties specific for each one and having various manufacturing-processes associated with them. If a CP is required to assess a variety of these components, techniques of ascertaining the required degree of material information about each one needs to be determined by them. For instance a practitioner may have suitable knowledge about polymers in order to produce an estimate with use of their experience and prior knowledge about this material. However possessing a comprehensive knowledge about one material does not equate to having a similar level, about another, e.g. the same practitioner may not have the same degree of knowledge about austenitic stainless steels, alloys or carbon compounds. Therefore in order to produce a cost, they would need to consult a practitioner who did, or who could direct them towards obtaining the information sought. This involves knowing who this individual is, how to contact them, where they are located, when to contact them; what information is needed, both general properties or more specific, and why it is needed so can check suitability i.e. heat resistance required, tough or malleable requisites, and so forth. See both the communication section, within 7.4; and refer to the previous Chapter 6, Section 6.3 for explicit discussion of the 5W's and H, and more specifically how they are related to costing.

#### 7.3.4.3. Batch Size and Material 'Envelope'

As mentioned earlier, the amount of material purchased will greatly affect the cost, in that relatively small quantities will be more expensive then larger orders; this fairly overt point was frequently referenced by various industrial practitioners. It is a fundamental principle applied to the consumer market in general, so can be seen as common sense. However, what can also affect costs are these potential 'tricks' that appear to be commonly known as being employed, such as the prior mentioned irregularities with the MPs; see Section 7.2.3.3. The primary aspect that affects material cost is when a supplier is ordering the same material and for more then one customer. The cost can be greatly reduced for them if this is the case; although they may not necessarily pass these savings onto their user-organisations. One of the main ways in which multiple clients can be detected will be via supplier visitations, enabling observations of their company practice coupled with examination of relevant documentation e.g. the books / financial records including material orders. However, an experienced practitioner from a large automotive organisation explained that a significant component in carrying out negotiations is in knowing what questions to ask. If the negotiator does not ask the supplier whether or not they are the sole customer for any one specific material order, then the supplier will not volunteer the information. Along this idea of specific questioning, if the supplier is asked about other customers it was said that they tend to convey the information, at least in part.

"…if you don't ask the right questions, they [the supplier] won't volunteer the information!"

[Cost supervisor, Automotive industry, 2003]

The reason that this is an important point, is as prior-mentioned, was that it was stressed by a number of diverse industrial contributors that batch size has a large impact on the range of costs that can be associated to any given material.

Additionally, when ordering a material, the form in which it is required to be delivered in affects cost. For instance it could be received in a standard shape and size. The organisation may then have the means to machine it to the required dimensions. This will reduce the costs for that material initially, as the specialised work can be performed in-house, so generally will cost the company less than if charged for the work by an external entity whether vendor, supplier, original source producer. However, the user-company may not have the equipment, expertise or even the time to do this, and may request that the material be delivered to a specific size. Additionally a certain shape may be necessary, ready to fit a part, component or machine. The costs may then escalate, especially if the ordered form is complicated; the supplier can add on many additional costs including that of machinery use, expertise, labour hours, as well as the more standard aspects such as packaging, storage, delivery.

However it may still be more cost-effective for the material to be delivered to the required dimensions than for it to be machined in-house. Assessments with regards to in-house manufacturing capability; and subsequently as to whether it is beneficial to invest in new machinery if required accounting for costs of obtaining and maintaining of the necessary equipment and parts / tooling which may be required for this, coupled with whether there is the required internal expertise. If non-standard shapes and sizes are deemed necessary, these are among the considerations which need to be accounted for in material orders, when assessing overall costs and budgets.  As well as manufacturing process issues, there are further practical evaluations, such as storage space for material to be brought in bulk, machined to size and used when needed; or whether is it more cost-effective for supplier to deliver the goods as required. However if storage is an issue within organisations, it will also be for supplier companies, who will pass these costs onto their customer. These considerations will have an impact on the cost and need to be known before they can be assessed, in order make the most cost-effective decisions via cost analysis exercises: Accounting for all aspects involved, including issues as material-type, envelope, batch size, storage and general transportation requisites and distances i.e. for international deliveries.

### *7.3.5 Product Knowledge*

Knowledge of the product being costed was identified as essential by 95% of all participants. This is another KT which may seem like common sense, as in order to cost a product the CP will clearly require knowledge of the product itself. However, this is not always a straight forward matter, especially with regards to project which run over many years and deal with high cost, such as within the aerospace industry. In these cases a comprehensive overview of the product is complicated, as there are so many facets involved. It is important to have an understanding of all variants, contributory disciplines and other aspects as they will need to be accounted for in the cost-breakdown. All influencing factors must be included otherwise the results will not be accurate if an item is omitted.

Product knowledge is specific to the industry; and to a degree to the organisation, in the sense that each organisation will have practices and procedures specific to it. In this sense, this is not a generic knowledge, as could be argued with the other KT, particularly the more tangible, product-related ones such as material, design, and manufacturing knowledge types. However, from a very superficial, simplified level the components can be seen as transferable across industries. For instance, “labour, material and overhead” is how a large automotive organisation described their fundamental approach towards PC within that company. This could potentially apply to an aerospace product; though would be less transferable towards the software industry unless ‘material’ was replaced with code or ‘lines’ per programme. Thus it can be seen that general cross-industrial principles are not sufficient for this KT, other than from a view which would prove too general to be usable for a detailed product cost. Therefore knowledge of the product needs to be gained specifically. This was said to be obtained via experience within the industry, interaction with other knowledgeable practitioners, and access to associated information including previous projects and other historical data.

#### 7.3.5.1 Historical Data

During the conceptual design phases of projects very little actual data is known regarding the product. However, to refer to the 80 / 20 rule, a widely quoted percentage estimation is that 80% of costs are committed within the early stages of the project; 80% of costs within the first 20% of the time. With a number of practitioners claiming the bulk of costs are committed within the first 10% of the project duration. Given this, it is the nature of PC which dictates that much will be based on these early predictions such as overall budgets, time frames, specific budget allocation. Thus, the paradox of costing is that many important costs are derived when the least amount of information and data is known. This is due to the necessity to set budgets, procure contractors and establish other elements of the project; even determine whether the organisation can afford to embark on the project to begin with. Therefore a high level of product-knowledge is required in order to produce as accurate a cost as possible: Historical data will detail aspects of prior projects, providing all information which was used on past products. This is particularly useful when the previous project was an old version of the impeding project, as it will mean all cost-elements are laid out, with the final results available for comparison. This assists with potential risks, e.g. risks which were not expected and accounted for in the early phases of the previous project, which are subsequently known so can be anticipated. A reasonable approach to product-costing when using historical data is to develop on aspects of the past projects; thus, start with it as a fundamental template for the new project to be built upon. A basic version would be to simply update each area, to account for inflation, and any other influencing factor of cost, including predicted technological advances, and any affecting global, social or economic activities e.g. events such as 9/11, a terrorist attack that affected international finances; and general recessions. Examples of vehicles based on an existing model are vast; for instance within aerospace in relation to previous projects being updated e.g. the aerospace vehicle could have either one or two pilots flying it. However the new requisite was for it to not have any pilots actually on board. Therefore the design had to incorporate avionics and equipment that would control the flight path remotely. Only a degree of previous-product data could be incorporated, as such a large level of modifications were involved in this change of specification, the materials used, design: Interior, electronics, etc. Therefore the historical data can act as a guideline for the new project with updates, and risks added in accordingly; see the following Section 7.3.6 on risk. Conversely for substantially novel models, cost analysis on the particular product needs to be undertaken, as established data may be redundant.

A major cost consideration, which historical data and information may not be able to provide stable guidelines towards, is with regards to new technology. It is clearly challenging to predict the cost-impacts of future technology, sometimes 15 or more years in advance; and to assess how innovation will influence resulting costs. However, this can at least in part be catered for within the risk analysis, see proceeding section.

Historical data can give an idea of time frames. These are essential in the longer running projects; but also impact on projects of shorter time-scales. The industries which make comparatively high levels of a few product-lines e.g. automotive, which are updated and refreshed, base the new models on the older ones; so are much more able to learn from previous projects. Organisations that produce comparatively low numbers of a greater level of product-lines e.g. aerospace, or even one-off's in some manufacturing organisations, are more lightly to get less of an indication or guideline from historical information. Either way as full a knowledge as possible of the aspects of what the impending product will be, coupled with what it has been historically, help towards gaining a comprehensive knowledge of the product: Hence this KT is an essential component towards cost derivation.

#### 7.3.5.2 Continuous Product Costing

Costs are needed throughout the project; including during change management, modifications, updates, unexpected cost escalations, subsequent VEVA, see Figure 1.1 in Chapter 1. As the project matures, more actual information becomes available. Ideally this information should be both documented, and fed back to PC from the relevant areas, like engineering functions and R&D. This feedback between the initial cost-assessments and the actual product-data, can allow comparative analysis and assess where the estimated costs may have been inaccurate; leading to why, and how to avoid future erroneousness. The accurate costs should also be noted for best practice tips.

Knowledge of each process within the product and discipline responsible per area is required, as they all need to be incorporated within the final cost. The practitioner may be skilled in one specialty e.g. avionics / electronics, but not in other still relevant, but just as specific domains, such as the material used for the outer skins / body-in-white. However, they still need to have an overall awareness of the product, knowing all the aspects involved in the programme in order to ensure they produce a full and comprehensive cost of the product. This is particularly important for situations such as bid compilation. It was stated by an aerospace practitioner that when deriving bids all contributing aspects of the costs have to be covered, or the overall bid will not be accurate: Aerospace projects tend to be major undertakings, therefore it is challenging have detailed knowledge about all aspects of the product. As this is often not the case, the information has to be collated per area: meaning that each area must be known, in order to ensure the respective associated costs are included. The practitioner explained that if any costs are unintentionally omitted from the final costs, the subsequent bid will be inaccurate; and if the area was a significant one, the result may actually be unrealistic. In order to ensure this does not occur, knowledge of the product being costed is required, to produce all-inclusive, representative costs.

The knowledge integration applies to MP (manufacturing processes) and material knowledge. I.e. the costing-practitioner, CP needs to know which processes are suitable for which materials; along with component knowledge, how they are made, and with use of which potential selection of materials. In addition if the material is replaced, determination as to whether this effects MP; and if the component is modified, how will it affect the cost of material i.e. will more or less be needed; a different shape be required among the considerations.

For an upgraded model, consideration needs to be given to the fact that it may now need a material with different properties; for example with more heat resistance, or a higher-strength material if making more durable, or equipping to endure different, harsher conditions. For example, a different polymer blend may be required if car tyres are to be made safer when traveling in a model which is sold as being able to go faster, in hazardous, i.e. rain / storm weather conditions: Not only would such an upgrade affect the tyres, but the brake-system as well. The costs of the latest model would need to be assessed to include all aspects of the intended upgraded product, and establish the difference, which would need to be costed; and the similarities which can then be assessed with use of historical data.

### *7.3.6 Knowledge of Risk*

Within the traditional classifications of the knowledge types within costing, Risk can be perceived as a predominant consideration of the process, incorporating both economically grounded factors such as exchange rates and recessions: In conjunction with engineering and other tangibles, including supplier collapse. Hence, knowledge of risk within the process of product-costing covers a wide spectrum of areas within which a reasonable assessment needs to be made of the potential events that might occur throughout the duration of the project, and / or changes towards the item being costed, in order to incorporate them into the costs. In order words, the perception relayed by the practitioners tended to be that risk assessment involves the ability to access the unexpected; the likelihood of the fore mentioned happening, e.g. is it 10% or 80% probable; the knock-on effects and associated costs linked to the occurrence of such events. This perception has been supported throughout the case-studies which are presented across the thesis, including the detection of supplier-stability, particularly overseas. At a fundamental level even the issue of possessing an awareness to understand from the onset that substantially lower quotes, in response to ITT may indicate uncertainty towards the submitter; as opposed to relief at potentially finding a low-cost option supplier. Having initially identified this anomaly and recognised the risks, knowledge of how to investigate the supplier bidding for contract is then needed. In this example given from an experienced defence cost-manager, (see following section) he was aware that cross-continent enquires would be unreliable / incomplete at best; futile or even misleading at worst. Therefore he traveled to the country to assess the supplier, first hand, this way not only could he directly evaluate the company e.g. their premises, MPs, labour-force; but also made indirect enquires with regards to the stability of the company as a long-term investment, as far as collaboration with the user-company went. Supplier stability is important generally, though in particular when long-standing programmes are being undertaken like with the defence industry for items such as military vehicles. The practitioner basically established criteria along the lines of the labour-rate in comparison to inflation and general standards of living; the pay was excessively low in this company. This, plus similar information lead him to believe that this supplier company were a risk, as may  not stay in business for the duration of the project, let alone future ones. The knowledge involved in risk therefore, in this instance included:

- Initial questioning of the quotes, and so the suppliers validity and feasibly, as opposed to taking them at face value;
- Thorough investigation of potential good business investments, because if it was a legitimate bid from a stable source, the supplier would definitely have been a beneficial selection, due to their low bid;
- The assessment included direct contact, even though overseas;

- Understanding the type of information required to make a comprehensive decision as to their stability as a supplier which extended beyond company visits, but involved placing their standing within the wider environment in which they performed the costs;
- Evaluation of the process within a wider, contextual perspective; having a cultural awareness is discussed later in the chapter; and was highlighted as a consideration within Hofstedes' cultural dimensions (UAI) in relation to risk-taking tendencies in Chapter 5, [Hofstede, 2006].

Assessment of the practitioners perception about risk lead to it being described as:
"..when the maximum possible costs that are and that may be involved in the overall project, including all aspects of production, manufacture, supplier, procurement issues and so forth are ascertained, as far as it is possible to do this.. ..and when worse case scenarios are foreseen and accounted for…"

[Senior Cost Estimator, Defence industry, 2005]

It was also added that the uncertainty's which occur on projects are by definition difficult to predict, un-measurable and intangible, until they actually manifest. Coupled with this cost-practitioners have reinforced the fact that costs are by nature approximations, therefore will rarely be 100% accurate, if ever. However in order to ensure that every possible predicament that could be accounted for is in fact recognised and addressed is within the power of the cost-assessor. This is to ensure that if a 'worst case scenario' occurred, it would not result in devastating consequences for the project or company; because having been foreseen costs would have been pre-allocated for just such events as these risks becoming realities. Risk can also dictate whether certain alliances should be entered into i.e. with supplier, as described previously; or even whether or not the project should be embarked on at all. For example if the worse-case predicament happened to occur, consideration needs to be turned to whether the company could carry this risk. If not the project may be bypassed: Alternatively they may be willing to proceed, if the likelihood of the worst extreme events affecting them was low. Risk assessment, merged with overall costs against company financial positions can indicate such measures.

### 7.3.6.1 Supplier Research

An example of risk-assessment is expanded here through the potential choice of supplier. An aerospace / defence procurement company observed, described an incident having globally circulated a proposal for work (ITT). A competitive bid was received by the company, from a supplier located overseas, outside Europe; and with whom the initiator-company had not previously dealt with. Before accepting the bid, research was necessary by the costing practitioner in order to establish the validity of this submission. This in itself is a point of knowledge, exercised by the expert: As mentioned even the recognition of the need for substantial validation when dealing with an unknown company, and not accepting the bid at face-value e.g. on its initially perceived merits, alone is part of the knowledge of risk.

In order to assess the company the CP identified the point that the most valid and reliable information would tend to be collected from within the country from which the supplier was based, as opposed to attempting remote enquiries. On having decided to investigate the validity of the bid from a personal visit, access to many aspects of supplier and the environment in which this company operated became apparent, referred to in the previous section. This point again demonstrates a level of knowledge: The CP understood the need for a high degree of reliability from the information being considered; and recognised the fact that much access to high quality company-information would only be gained by attending the location itself. Conversely, there was a high probability of obtaining inaccurate information via distant interactions / searches, which would be limited in comparison to personal physical contact, and may act only to support the initial bid, which would therefore make it a futile cost-exercise; this is linked to the knowledge of communication, Section 7.4.1.. These decisions and arrangements needed to be made rapidly, therefore the practitioner was required to act hastily. Knowledge regarding feasibility of bid, and unknown elements of supplier were utilised with conclusions drawn which indicated a potential risk and a need for a more in-depth analysis of bid. Fortunately resource was available, both time and funds for the international company-visitation, so travel abroad for these in-depth supplier investigations was possible. It has been explained within Chapter 6, within the theme of Resource, Section 6.2.1 that this was not always the case. The research conducted by the CP once within the supplier culture of the potential supplier company, involved social and economic elements. This included examination of employee wage, p.a. as prior noted, was very low even by that country's standards and the company profit-trend, which was negative. The research by the practitioner also uncovered the fact that this company had defaulted on their tax payment, and were also quoting too low a profit margin, in relation to the country's inflation. The combination of this information exposed the company as being unstable; making them a risk, for the three-year project proposal in question. The primary concern, as a combined result of the findings, was that they may not be able to stay in business for three years, even though their bid was very low and non-profit making, presumably to secure the business in the first place. This deduction was based upon the investigative findings, which revealed that they needed to secure contracts. Suppliers are known to place this type of bid with low–nil revenue in order to secure a large project with the aim of it getting them gradually back into a profit-making position. Another example of loss-leaders, discussed throughout Section 7.3.1 is via observation of organisational strategy. However, if their figures are simply too low or unrealistic it will make them unstable, and therefore a risk for such customers to work with and invest costs into. As unless they are large powerful entity, any unforeseen challenge or even changes in their environments, such as a recession may push them out of business. It can be noted that the previous example of loss-leaders was conveyed from within a large, thriving western-based automotive organisation, whose organisational strategy and market-trend assessments ensured that they were able to shoulder the losses: This is in contrast to a struggling supplier working within an unstable economic environment. The knowledge of the CP was apparent in the initial understanding of what information was relevant; in accurate assessment of the reliable information; and thus basing decisions on it; that lead to a potential cost-saving, low risk alternative for the company. The CP needs to possess knowledge of the supplier on all levels; including their past performance, e.g. reliability / quality, as well as their current and future stability.

There are situations where it may not be possible to travel abroad to make an assessment of a potential supplier. This is commonly due to time / budget limitations, as previously discussed; because every supplier who places a credible bid will generally not undergo such scrutiny. Such a level of research at the bidding stage is infrequent, only tending to be done in special circumstances as opposed to being standard procedure. Due to lack of funds, and more commonly lack of time, suppliers are usually accessed closely after selection when quotations and invoices have been received. Alternatively such investigations may be limited due to lack of accessibility. Where the cultures, rules and regulations are substantially different, the user company may have great difficulties in gaining permission to access the relevant information. In either case i.e. resource or accessibility limitations, other methods will need to be derived in order to assess risk of the supplier. Interpersonal communication and 'contacts' are essential in attempts to find information about external organisations, whether to act as gateways or to provide historical data / other documentation when access is not possible. The systems map in Figure 7.11 presents the primary and environmental influences of risk. The need to research the areas thoroughly, and knowing where to find the information required, who holds such information, how it is obtainable, why it is even initially required and for when it is needed, are discussed further in communicational and cultural sections. Plus refer to the previous chapter, within Section 6.3.

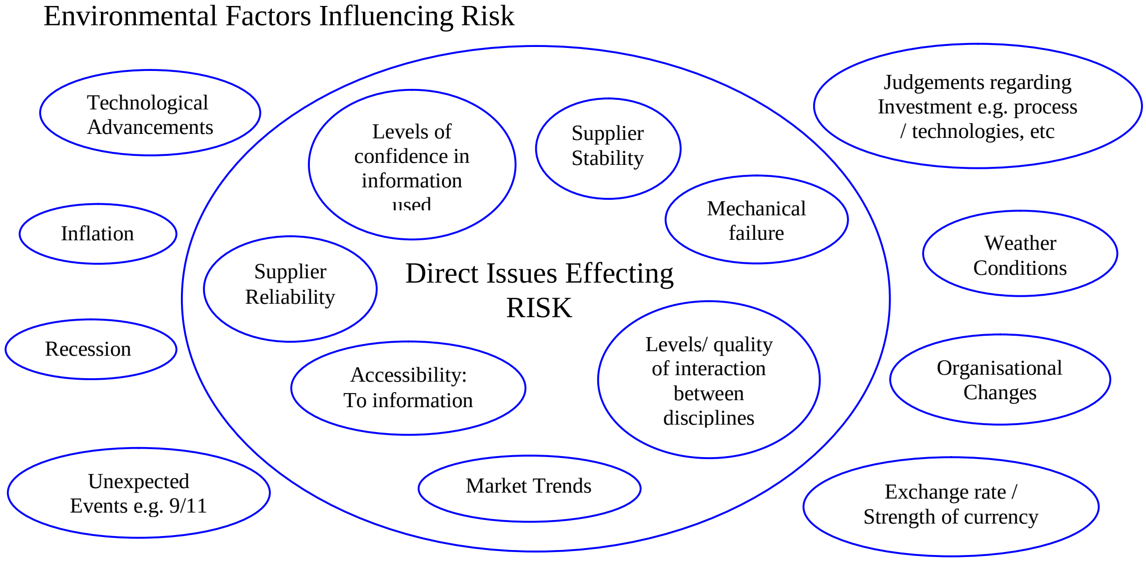



Figure 7.11: The Direct and Environmental influences over Risk Analysis

Risk can be classified within economic, engineering, communicational and cultural criteria. A combination of these elements has been encompassed within the above explanations and case studies, including the economic elements. Engineering issues are linked directly and indirectly with risk, with occurrences such as mechanical malfunction, direct effects; and aspects such as delivery. E.g. failure to receive parts will affect the products' progress; indirect technical risks: relating back to the need to address reliability of suppliers. However factors such as weather conditions if project involves working outdoors, is a consequence of neither engineering or economic influences, though affects both. This particular example given by a practitioner from within a manufacturing company has an impact on the level and rate of production, which in turn has financial considerations. Therefore must be taken into account through the risk assessments, e.g. bad weather conditions on outdoor projects could be the cause of long spells of non-productivity. Part of the locational evaluations when undergoing such projects must include such issues e.g. it would be beneficial to gather weather-trend information. The practitioner that highlighted this environmental affect worked within product-costing, though had extensive experience of manufacturing and civil engineering projects, including project-management. In such instances location-selection becomes a major factor in reducing risks from weather trends. To summarise, influences on risk include:

- Supplier reliability. Exploration into the quality of the work, timeliness and even whether the initially quoted costs are subsequently escalated over the project duration; these are among the considerations of supplier selection;

- Supplier stability is also an important factor, as it is in all parties' interest for the supplier to remain functional for the duration of the contract;
- Market trends can contribute to unpredictable changes which affect cost, as well as unforeseen events which affect social and global status quo; such as terrorism, the outbreak of wars and recessions;
- Technological innovations are a major challenge in risk assessment;
- As are miscellaneous entities and occurrences, including weather trends / unpredictable acts of nature.

Industrial risks can take many guises and evolve from any number of areas. An inaccurate assessment of risk can at worst be the cause of collapse of an entire project. Therefore it is essential that as many as possible of the potential risks are identified and accounted for. As PC can often be a link between the commercial, economic factors and the technical ones, it is important that costing-practitioners are knowledgeable in these areas, in order to provide adequate guidance and to transfer concerns across the disciplines. A primary means of assessing risk is to obtain previous-project data, which is accurate and complete. Subsequently the initial costs can be considered against the finalised ones, where analysis of the actual data can highlight the way in which the estimated costs were inaccurate, i.e. reveal what was added / omitted which was not required or foreseen. This type of lessons-learnt exercises can assist in the prediction of a number of the future impending risks; though of course not all. In addition to the insights bestowed from historical data, is the need to obtain as much current product-data as possible, as discussed in the cost-knowledge section, and previous chapters: As it is a fundamental point of costing. The more input from the collaborating parties working on the product who contribute towards the costs, the greater the level of confidence in the final cost-results will be. Updated, comprehensive past-project information coupled with contributing disciplinary-inputs, in juxtaposition with relevant expert-opinion will all create adequate risk assessment.

## 7.4 Social Criteria and Human Factors

Chapter 5 discussed basic human factors (HF) literature relating it to industrial product-costing. This section conveys the social issues and their effects within the companies observed in relation to the eight essential knowledge types (KT) identified within PC. The knowledge types that emerged from this domain were occasionally more subtly present, or initially appeared intangible due to their implicitness, which is in contrast to a number of the other more explicit knowledge-types described within the previous Section 7.3. The most perceptible knowledges' to be identified is that of organisational culture and communication.

Though the aforementioned KTs may initially appear indistinct, once identified it seems that their presence is highly significant due to their ubiquitous nature. It is this very aspect, of the type of universal applicability of these knowledge-types which ironically seems to make them be perceived by the industrial practitioners as intangible and therefore unreliable. The ironic element is due to the fact that they are so heavily present within the more tangible, explicit entities, that it is easy to overlook their importance, almost taking them for granted and leaving their influence as inherent. For example, an experienced automotive cost-supervisor frequently stated that there needed to be more personal interactions between the cost-practitioners and contributing personnel. He stated that "..just going down and having 'a chat'.. would clear up any problems..."; also stating that the overuse of technological communicative techniques created more challenges then it solved, e.g. excessive use of email, used in place of basic personal communication with those of close physical proximity. This point was fair enough and the research showed was a valid one: However although he relayed this point with certainty, this practitioner did not elaborate any further on the means by which the interactions should occur, other then saying they should make efforts to walk to the domain of the recipient and converse with them. This further exposed that issues involved with communication, both what hinders and promotes it, did not appear to be addressed even by an experienced practitioner who seemingly understood the importance of clear channels of communication. The intricacies involved through the evolution and maintenance of networks to propagate and reinforce working interactions was not approached in an informed manner. The perception as to why seems to stem from a lack of recognition of the importance to formally, tangibly address a component towards costing, which appears intangible to the general body of practitioners; discussed in the following section.

As this research needed to dissect the elements which composed product-costing, it was essential to conceptualise these influential factors which had so frequently been perceived as intangible and nebulous. This included personal communications and the issues surrounding why this is insufficient within the costing process; which the research showed as largely lying within culturally grounded factors, see Section 7.4.2. Although many elements within these areas have been perceived as implicit, there are examples of when these knowledge-types are highly visible and explicit, particularly that of communicational knowledge, examples of which have been highlighted throughout this chapter. In relation to the previously mentioned lack of personal communications, an evident and explicit cause of such difficulties lay in the practical consideration of geographical distances. When an automotive cost-practitioner required interaction with an engineer, it was noted that the main site was in one organisation approximately a 25 minutes commute; whilst in another closer to an hour. The issues of formalised meeting therefore occasionally seemed inconvenient, let alone regular, less formalised transactions. It may be noted that these distances were relatively comfortable in comparison to organisations spread over wider distances; plus there were overseas considerations. Either way, whether explicit communicative challenges or implicit, knowledge of communication was a fundamental core within product-costing, as the following section discusses.

### *7.4.1 Knowledge of Communication*

Within the eight identified KTs essential for PC, the majority are what can be described as technical. This is as would be expected, given the type of industries, organisations, and resultant product-range that was the focus of this research. Subsequently, as a consequence of so many technical and engineering knowledge types being necessary to cost this range of products, an essential aspect of costing is therefore in having the knowledge of communication to draw al the relevant explicit areas together, as eluded to in the previous section: This is true for a number of reasons.

Purchase, engineering and product-costing often need to work together, particularly within the automotive and aerospace industries. As these departments have specific roles, they are often separate and very busy; involved within their specialist areas. Therefore the practitioners tended to agree that the level of integrative working which is required needs to be an accessible, straightforward knowledge and information exchange, readily available and to hand, as required. This was suggested as being either via compatible databases, or the availability of Information Request Forms, IRFs: Various types per organisation had been developed, e.g. QMFs, Query Management Form; FIR equals Finance Information Request; BoM denotes Bill of Materials, WBS is Work Breakdown Structure.

An adequate communicative atmosphere between the main contributing disciplines is imperative, in order to exchange required information. Hence the promotion of integrative working needs to be recognised as an essential element of PC within industries and developed accordingly; also see the following culture section. In this respect, a contradiction within the industrial perceptions can be clearly observed, once examination commences: This is in the form that is has been observed that technical functions still place a low importance on HF related challenges and general soft issues, which are seen as intangible and structure-less and therefore unreliable and unusable. Conversely over 90% of companies observed made specific reference to communicational issues, and attached high importance to it when asked to identify challenges to the process. This was noticeable despite the commonly perceived notion that communicational knowledge has often been classified as a ‘soft’ area. This again highlights the ever-present integration between the social and technical spectrum of organisational working. For the frequency with which it is mentioned refer to Table 4.6 and Figure 4.3 in Chapter 4, reveals the need for training in this area as well as the other more technical ones; discussed in the proceeding Chapter 8, which proposes methods of implementation of the research cost-knowledge framework. Within the knowledge of communication includes having the social skills to interact with the relevant parties; networking approaches may be addressed in the training interventions, Chapter 8: Plus ways in which the interactions can reach maximum benefit by having an awareness of the background and current activities involved in the function of the disciplines being associated with. This will allow informed communications, so time will not be wasted by making superfluous enquires which may also serve to alienate the contributor, if they perceive that the communications are not valid or that they do not have the right information desired by the enquirer.

Chapter 6 which examined the thematic analysis discussed the knowledge categories 5WH i.e. know-how, -why, -what, -when, -where; having knowledge about communication is linked to all these categories, either explicitly or indirectly, see Table 6.9, Chapter 6. The knowledge categories proved to be an effective template to measure the other issues involved, which reoccurred throughout the data-analysis. The primary way in which this knowledge type is linked is through the need to communicate with others. For instance, in knowing how and what to do to complete any given task, a novice will at some point receive training. This training can be in many forms, see Chapter 8, but will contain material which has either been conveyed or produced by another person or other mode of delivery including IT e.g. CBT’s, which will communicate the knowledge to the apprentice. The knowledge of why things occur or why tasks are undergone; in addition to information about when things are required, and where to find them will also be communicated to the user in this way; training, from whichever mode it is received, has initially been designed by another expert within the field. Knowing who to contact for information so who is involved in the work often relates to direct interpersonal channels. In summary, knowledge of who to communicate with, why they are being contacted, where to find them, how they can help, e.g. the benefits of contacting them, understanding what they will bestow, and being aware of when is the most suitable timings for communication are all essential within product costing.

Due to this necessity for contacts, communicational knowledge was initially described as contact knowledge, though has been developed by the expansion of contact knowledge, see above costing-knowledge section and Appendix 9. The need to increase this knowledge type was due to the high level of integrated working practice necessary within product costing, and often between departments. Fundamentally, the transfer of all relevant information related to the cost is required to be made towards PC; including financial aspects as overheads plus engineering information and knowledge. Therefore creating and sustaining networks with professional contacts, both within the costing domain and more widely throughout industry is valuable knowledge for PC in order to open channels of communication. This applies both internally towards the practitioners own organisation; and externally with interacting companies such as suppliers, vendors, consultants.  The ability to make and keep contacts, and communicative knowledge related to utilising them to capacity, is essential within the costing domain. Co-location and Pits assist in the regular interaction between co-workers, (see Figure 7.12); as do organisational networks, which may provide information about the whereabouts of knowledge, and reduce time in establishing who and where the required personnel are.

#### 7.4.1.1 Knowledgeable in Interpersonal Communications

In respect to interpersonal communication, knowledge-transferal from expert to expert across adjoining fields involves some mode of communication; which additionally, provides the costing practitioner information about supplier, pricing and further product information. I.e. an estimate of a physical component or part is preferable to a drawing. Though if only a drawing is available, the expert needs to obtain as much information linked to the drawing as possible; therefore the knowledge, in this instance is in knowing ‘who’ to contact for ‘what’ information.

The gap within the fluid and updated communication of expertise per specialisation causes a misplacement of time and resource in an attempt to locate the relevant expert for the specific query. Whilst adequate communication reduces the time spent searching for information. For instance a number of practitioners mentioned the need for updated directories of disciplines and specialist expertise. This way they could simply find the individual sought through reference of the directory, which it was specified should contain contact details, and must be maintained. Therefore if material-product information is required, the expert with this knowledge could be readily identified and contacted. As opposed to the cost-practitioner needing to find the information sought via other means, e.g. contacting material supplier, researching through publications, having first identified the relevant journal: Such methods evidently take longer then contacting the appropriate specialist would take.

An automotive practitioner described product costing as working within a triangular support group, comprising of engineering, purchase and PC. Resultantly there were large degrees of interaction between the costing practitioners, purchase and at times the supplier in order to assess whether the stated costs e.g. from supplier invoice, were satisfactory; or if modifications were required. A need for amendments could lead to interaction with engineering to achieve the desired changes; hence engineering may also require supplier-interaction, and subsequently the work would go back to purchase, product-costing for clarification, and so forth recursively. Here it is evident that clear channels of communication need to be developed and maintained, in order to allow the necessary interactions to occur between the relevant parties. Stifled communication hinders or totally prevents this iteration of costs between the parties which are meant to be developing them. Additionally, the lack of process to communicate including corporate structural deficiencies, also create challenges for the costing process and the relevant interactions required for maximum costing performance.

#### 7.4.1.2 Specialisation Knowledge:

Previous sections have identified that in order to cost a product the practitioner requires knowledge of materials, design, manufacturing processes and of course to be knowledgeable about the product itself: These are explicit, tangible KTs which unequivocally contribute to PC. For each one of these knowledge-types as discussed earlier in the chapter, there are a number of constituents which comprises of the individual KT. It is therefore a large undertaking to strive to be familiar and knowledgeable completely within one of these KT; let alone in all of them. For instance, manufacturing-process knowledge is a generalisation which incorporates the need to be knowledgeable in the process most commonly employed, and to keep updated with new, potentially more efficient MPs, see Section 7.3.2 for more detail. This in itself is a large undertaking; therefore interaction with other practitioners who may be knowledgeable in different areas, is beneficial. As prior stated, a practitioner may have expertise within one aspect of one or more KTs, e.g. a specific set of manufacturing processes, if they had experience of them. Alternatively they may posses specialist knowledge about certain materials types; or even be knowledgeable in one or two components, one area of product if they had prior in-depth experience in such aspects i.e. had worked on specific projects. However it is less likely that they will have the same level of experience and knowledge about every area which needs to be included in the cost, e.g. they would not be knowledgeable about every material used on the product, for instance. Each item that the project comprises of, which affects the costs, needs to be primarily assessed in order to develop a cost-estimate. There is then potential scrutiny if cost-cutting exercises are deemed necessary, which is common; or re-addressed for product-change management, upgrades and / or general modification. Product costs are involved in such exercises in 95% of cases examined, i.e. the overwhelming majority of the organisations examined, out of the 25 contributors, see Table 6.2 in Chapter 6 for contributor list.

Therefore it is clear that knowledge exchange is a regular and essential aspect of PC in relation to all areas of the product being assessed. When an unknown domain for a specific practitioner is embarked on, it is important that the practitioner take steps to find the required information. This will include knowing who has this information, where they are within the organisation or externally; how to contact them e.g. via what media, telephone, email, meeting; and when the information is required by and available. The skills required to create and maintain networks of contacts are discussed in the proceeding chapter which addresses implementation of the research results, including training needs for the costing process.

#### 7.4.1.3 The Need to Train Interpersonal Communicative Knowledge.

A major aspect of this type of knowledge-share seems to lie within the ability of interpersonal communication. This is because if a cost-practitioner has the required knowledge, either because of prior or more experience, especially if the enquirer is a novice or trainee, then it can be assumed that the person in receipt of the knowledge is as busy and pressed for time and resource as the person asking for help. An example of this was within automotive companies where practitioners stated that close to launch dates, all contributing areas were snowed under addressing the needs of the domain. It was basically conveyed that the whole organisation effectively became very focused and involved in ensuring their areas whether aspects of engineering, production, marketing or other, where ready by the launch-date. Effective, interpersonal communicational-knowledge is essential in such situations. The request needs to be clear and presented in such a way which evokes the transmission of knowledge. Deficiency in such communicational skills can stifle essential, regular interaction; and can even create hostility and promote segregated working practices. This results in either low quality output, as the information is inadequate or inaccurate: Or a misuse of resource when seeking the information via other means, other then simply asking a knowledgeable colleague; or finding out who can help, and contacting them. Again emphasis on interpersonal communicational-knowledge and skills are essential for the production of accurate PC, when needed within the desired, often highly pressured industrial time frames. It is also necessary for the other duties commonly performed by PC such as VEVA and other cost-cutting ventures. The utilisation of such a range of KT makes the necessity to communicate proficiently, imperative.

As stated throughout this research, a lack of appreciation towards the amount of influence that the ‘softer’ issues have on the costing process has effectively reinforced the challenges by leaving them unaddressed. Such essential knowledge and skills as that of being personable and communicative needs to be formally conveyed, and should even be addressed within training courses. A systemic understanding of the organisation and the collaborating areas in which costing interacts may instill an understanding of the contributors’ role, focus and priorities. Therefore if a discipline is particularly pressed for time, e.g. R&D have overrun, and the production areas are waiting for the product verification: At such times supportive interactions and an understanding of their priorities will create productive working domains. As opposed to a lack of awareness as to other interacting domain pressures which may result in for instance the perception of information requests being ignored, and breakdowns in communication. Such occurrences will be formulated due to a lack of understanding of why requests are answered and / or why more time then usual seems to be required, or why only minimal information is made available and not detailed as perhaps would have been requested. As well as having a holistic understanding of the process, hence having an awareness of others’ roles, personable communicational skills are valuable during such regular industrial situations to avoid aspects such as fear culture or the perception of professional misconduct or lack of professional courtesy. The aforementioned will clearly create tensions within the workplace, and therefore not promote interactive working practice or the fluid flow of communication, e.g. convey the required cost knowledge, information and data.

#### 7.4.1.4. Integrated Product Teams, IPTs

This research within the 25 organisations examined (see Table 6.2 for contributors) found that IPTs are the most commonly used term to describe the integration of disciplines into one team. IPTs are increasingly common, as organisations are recognising the importance of integrated working practices between the joint areas which contribute concurrently to any one product or project. Hence on any given product or component a number of disciplines may be involved. Engineering is subdivided into areas such as electronics / avionics, manufacturing, design, QA, R&D, fascia / skin / Body in white, interior / trim, structure (ribs / sprue) and chassis. These are just a sample of the different engineering specialisations involved on a product; the range of engineering functions are primary areas involved. There is also the financial area and all other aspects of the commercial side, such as marketing and sales. As these disciplines work concurrently on the same product, it has been recognised that the work will be conducted more effectively and quickly if these areas work in as integrated a manner as possible; so each domain has a holistic understanding of the project, and of where their contribution fits into it. Hence they will have an awareness of the other areas, as well as knowing their own. This is in contrast to the more dated, but established method, which is accustomed to segregated working practices, termed as 'over the wall' working by one aerospace practitioner.

When assessing the contributors towards the products across the observed industries including manufacturing sectors, aerospace and automotive, it was repeated throughout these organisations that an increased understanding of the roles for each discipline, especially PC, is essential. This was stated as often only established when the different areas work together. IPTs are when representatives from each area are placed within one team, in order to work together. This allows representation of all areas and promotes understanding, which is a good way of ensuring some areas do not dominate the process, creating weaknesses in other areas and consequently in the final product.

Working in teams comprised of multiple disciplines leaves less room for misunderstandings and miscommunication between the expertise in question. Such aforementioned challenges can often be created via terminology discrepancies, among other inconsistencies and misinterpretations. More then 80% of organisations examined had their own version of IPTs; they were made up of a limited variety of disciplines, the core areas comprised of the various relevant engineering functions, purchase, and often PC.

Costing practitioners at times were seen to hold additional responsibilities, for instance within one large automotive organisation they each oversaw other components or areas of the product: As they may also be responsible for an engine for a specific model of a car; or for a component i.e. tensioner, or alloy wheels. In these cases they would be involved in all aspects for their particular component or area. For this type of occurrence, teams were often formed which would be company specific that focused around the relevant component, as described above. These teams would generally consists of:

- Engineer(s); from relevant areas
  - E.g. design, manufacture, R&D;
- A supplier representative;
- Product-costing;
- Buyer (or Procurement / Purchase)
- Financial representation, company-specific.

All of the above will usually converge to focus around a part. Within aerospace practice, design reviews are conducted throughout duration of project, at each phase by the IPTs; these teams include production, designers and cost engineers. It was stated that PC was involved as there is the need to determine which costs have a large impact, and which are have a low effect.

Figure 7.12 highlights the stated positive and negative points regarding IPTs. The force field representation allows the weight of each point to be expressed as well as the primary ones on each side. It can be seen from this figure which represents an amalgamation of the perceptions given from across the industrial examinations, that there were more positive points put forward in favour of IPT-type working style, which hold more weight, then the ones proposed against them.

The majority of the negative points focused around the fact that often the practitioner would be removed from their environment. This could leave them vulnerable to issues such as losing touch with their domain and any potential innovations. An absence from their specialty could even render them less influential when interacting within their peers; this is a point of culture, acceptance and trust issues. However the benefits described appeared to far outweigh these concerns, with the majority of industrial contributors. The clear communication; clarity of priorities and roles; overall, personal representation and improved understanding proved to be of value within the majority of areas examined. For example within the VEVA meetings and CCRT (Commodity Cost Reduction Teams) different areas of product were represented, designed in order to facilitate the amalgamation of perceptions and expertise within the immediate domain and wider environment, contributing to the product. Particularly for CCRTs: Each domain can represent, defend and if needs be work together with the other areas, in order to reduce costs that may be excessive.

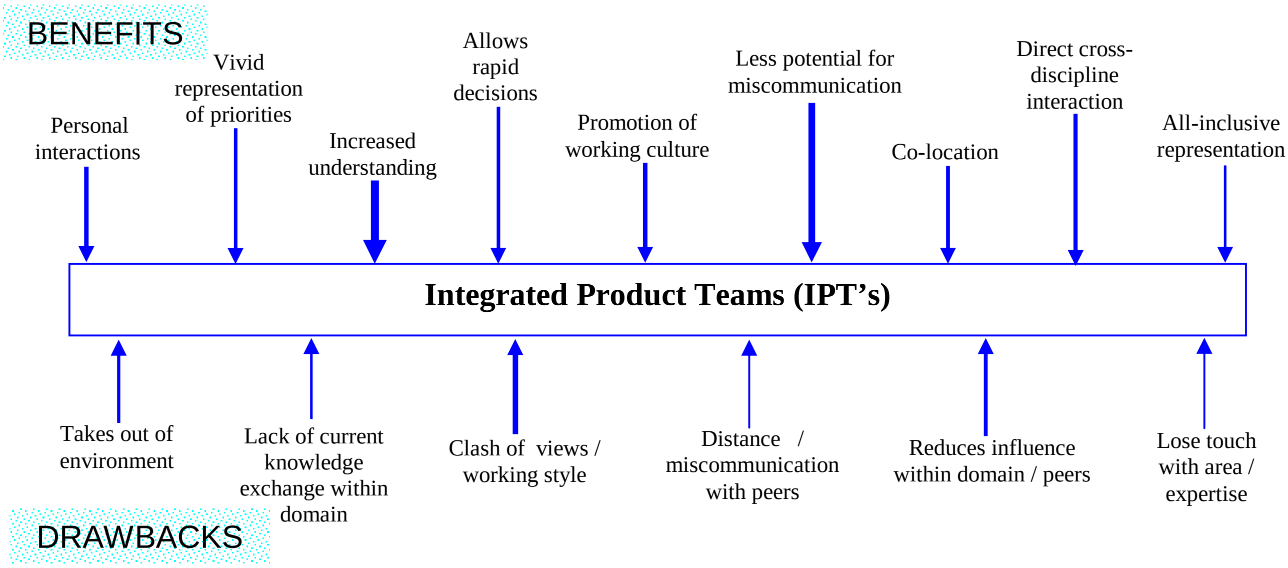



Figure 7.12: The Positive and Negative Aspects of IPTs

### 7.4.1.5 Benefits of Co-Location:

As described above there are many positive points of this type of integrative team working, but often just the fact that they are co-located allows a large level of communication. One reason for this may be due to the situation of physical practically, i.e. there is not the need for any length of commute to interact, which was highlighted by a number of practitioners to be the cause of general inadequate communications. Hence physical proximity promotes increased fluid interactions and in turn improved understanding. Product solutions derived via this type of compounded expertise are often more rounded, as all parties are involved.

Personal interaction was mentioned as being key towards the communicational process on numerous occasions throughout the research. The primary way that this could be achieved on a regular basis would be via co-location. Teams that are meant to be working together need to be within close physical proximity to each other in order to fully integrate. Therefore this is preferable, though not always possible, for the interacting departments. However, in large organisations often the engineers would be based on another site or at a different end of the plant; often not even walking distance apart, due to scale of productivity. In such cases, regular face-to-face meetings were said as being necessary in order to ensure the project ran smoothly. However this was not always an ideal solution for all parties, as constant travel to and from sites was occasionally perceived as an unproductive, misuse of time. Those involved also felt it slowed the decision-making process down, and conveyed frustration about now overly directed importance was placed on personal communications: With this said, it was still overwhelmingly stated as an essential element.

Another solution to the lack of practitioner communication was technological, where video conferences could be utilised to communicate personally on a regular and convenient basis. The observations towards this route of improved personal interaction was that it was being adopted on a very slow scale; but nonetheless was definitely increasing. Therefore co-location, where possible, was perceived as the most suitable way to ensure effective communication between relevant parties; namely the variety of disciplines which may be working on one project; and was implemented accordingly.

#### 7.4.1.6 Translational Miscommunications:

An automotive practitioner relayed an instance of what he perceived as potential misdirection of costs, from an overseas supplier.  The initial assumption was made when a cost was described by the supplier-contact as a 'utility': Further enquiries revealed that this was in fact a translational issue. This particular cost should have been noted under 'tooling', of which the user company was in fact responsible for. However, as the direct translation was utility, it was interpreted by the relatively inexperienced practitioner as supplier-machinery, which should not be included within the invoice costs for the user organisation, but covered by the supplier. Thus the order was continually refused, as it was repeatedly resubmitted in the same form and wording. When a more experienced practitioner eventually examined the situation, the confusion was exposed directly. The semi-novice had explained:

"..from an overseas supplier …when I saw it was a 'utility', I rejected the order; …kept putting it back through, and I kept declining it….

..I eventually asked Dave to look at it … he contacted the supplier and verified it was actually 'tooling' …so  was a legitimate cost after all, ..and  I could let it go through..  ...turned out to be just a misunderstanding with the translation"

[Cost practitioner, Automotive Industry, 2003]

This simple lack of effective communication which could have been addressed within one telephone call caused a substantial time delay, as the supplier continued to submit requests for this cost after each refusal, and reallocation of resource in the form of eventual intervention by another more knowledgeable practitioner. The knowledge of the more experienced practitioner drew attention to the possibility of translational miscommunications immediately, being aware that in general the supplier would not overtly attempt to charge the customer for machinery, and it was more likely to be tooling expenditure i.e. an add-on to the main machine; the latter was owned by the supplier; whilst it is understood that the former, tooling may be charged to the customer, due to wear and tear via direct production for customer item.

Such examples throughout P2 the in-depth industrial visits, further revealed as with the previous set of observations in P1, that the need for the costing practitioners to have sufficient communication across the relevant industrial contacts, is imperative. This applies both within their department, as above mentioned, with the intervention of a more experienced, senior practitioner addressing the miscommunication effectively. It is also essential for the interactions external to PC, to avoid for instance the ineffective communication between the overseas supplier and cost practitioner to begin with. Knowledge of communication is necessary to enable the receipt of information, gathered by the flow of the wide range of communication, necessary for the costing practitioner to fulfill their role.

#### 7.4.1.7 Recognising and Locating Relevant Information

There has already been discussions around the framework of 5WH within this and the previous chapters. However, the usage of this model is again applicable within the knowledge of risk. For example knowing where to find the information about weather conditions in the geographical area under development; how to successfully utilise information; and understanding the implications of different choices are all essential. Having an awareness that such considerations e.g. as weather are important, as unsuitable conditions for outdoor-based projects could create difficulties if the potential risks have not been assessed and accounted for during the conceptual-design stages of project. Similarly, being able to locate information about potential overseas suppliers proved imperative in the previously stated example; see Section 7.3.6.1. How the practitioner went about researching the company, where was this information held; could the practitioner get access to it, e.g. was it open for public reference: If not, there is a need to find alternate methods of obtaining detailed and potentially sensitive information about a company. These issues all need to be addressed, therefore 'contacts' are essential for all aspects, commercial and technical, of costing. The term contact is used to refer to a person(s) who can provide relevant information, e.g. perhaps a networking community includes personnel from marketing; they may have knowledge of the supplier-company under investigation and can thus relay it. This is convenient if information about product and company are not published, the CP could liaise with others who have the relevant knowledge; potentially allowing the evaluation of past performances, reliability, credibility and other necessary factors. It is important to check these points whenever possible and not just make assumptions, as cultural issues can surround a number of considerations. For instance part of the cost assessment may be related to whether a company has sick-days, holidays, public holiday breaks. This can vary between countries as attitudes will differ; as it does with pay-rates and the expected length of working days. Such information is important to cater for in cross-cultural interactions i.e. multinational collaborative projects. The ability to recognise that the information in question is key to begin with; before the process of procuring it, subsequent analysis and making organisational decisions based upon it can take occur. This is all knowledge required, though was said to be more commonly held by the more senior, experienced costing practitioners especially with regards to risk assessments.

What is lacking seemingly across organisations is a database of potential and subsequent established risks per project, which could be utilised for training purposes, as well as cost assessment. Such a risk-database would enable personnel of whom are novices within the costing field, but knowledgeable within the organisation e.g. for internal movement of expertise, to gain a fundamental understanding of risks via access and constant reference as required, to relevant, contemporary company case studies. This observation was made as much on-the-job training was undertaken in industry, where novices learnt from the more experienced practitioners. If the knowledge of the practitioners regarding risk analysis was documented, then this knowledge would become explicit and be able to be re-used; knowledge conversion is discussed in Chapter 5 [Nonaka and Takeuchi, 1995; Nonaka and Teece, 2001]. Thus initiating and broadening their domain knowledge, via the transferal of expert knowledge with use of case studies and historic data. The economic / commercial activities within PC in particular will need a wide knowledge of government standards and regulations, i.e. TINA, a set of regulations. This is predominant within the aerospace industry, as there are a number of rules, regulations and standards that the practitioners need to be familiar with, and to implement.

#### 7.4.1.8 Negotiations

Negotiations have been described as being both explicit and implicitly conducted, see Figure 7.9. The use of language, being accurate in what is said on an explicit level, and being assertive on a more implicit level, are important. If one has the correct facts and figures to back-up proposed cost–reductions, coupled with the correct usually technical knowledge of product and manufacturing processes, this will gain confidence from the supplier, for instance in what is being said, and establish credibility for the customers; see Section 7.2.3.3. If cost-reduction demands are made without the product-knowledge to support it, this is less credible and could potentially result in failure within the negotiations. The only other time where unsupported cost-cuts can be expected will be in strategic-level negotiations, which tend to be lead by purchase alone, where they can 'muscle' down costs strategically (see Figure 7.10), described in the earlier sections discussing negotiations. Generally speaking though technical language and knowledge are required to gain advantage in negotiations, prove competence in the proposed decreases, and ultimately lower the costs.

A major factor within such activities however is the manner of communication. Negotiations are often conducted on individualistic levels, and therefore the way in which information is conveyed can be crucial. If the supplier is assertive, loud, confident and forthright, the reciprocal negotiator needs to adopt a similar attitude. In such a case, being polite and measured may result in the perception of weakness, as being unable to argue against the stated required cuts for reasons of legitimacy, or being seen as 'a soft touch', and may result in the costs remaining under the control of the supplier; or vice versa, whichever side is perceived as weaker within the negotiations could potentially result in being pressured into a less advantageous position. Practitioners discussed the need for such assertion, whilst others focused on the quality of data over the attitude adopted in these negotiational sessions: As alternatively assertion could be perceived as aggression, and therefore communications could break down due to this unreasonable, inappropriately perceived approach. This type of adequate communicative effort is essentially linked to culture, in where it is important to understand the culture of the individual and organisation one is dealing with. If they are a large, powerful corporation, who dictates cost-reductions to the supplier, it is better to be aware of this when entering into such negotiations. This is because these negotiations will unfold in a different manner to say more equally-based interactions, where more flexibility may be settled on.

The more implicit negotiations were observed as occurring within organisations. Here knowledge around the 5WHs e.g. of contacts, knowing who to talk to, how to contact them, where they are and how to approach them and interact appropriately is essential. For instance, if one required flexibility in the budget or an increased level, a very measured communication may be required, unequivocally mapping out why such requirements are necessary e.g. more time / funds and labour. In these instances, it may need to be formalised in documentation, and explained in a meeting. However, if interacting with work-shop engineers and for example, more information is being requested on a specific product or component, then a more casual, relaxed approach may be utilised. It is essential to communicate in the most effective, suitable way, which will involve knowing 'who the audience is' i.e. formalised interactions for management; or casual, with engineers / between the regular interacting departments. The approach taken may be less obvious than this example and dependent on a number of factors, e.g. supplier communications. This may need to be formalised as it takes place between organisations; or there could be a good relationship between the individuals, who regularly interact or are even co-located. In which case formalised documented or third party reports may be unnecessary, and unsuitable.

## *7.4.2 Knowledge of Organisational Culture*

A number of the main schools of thought with regards to cultural studies have been presented in Chapter 5, Table 5.1 within the human factors literature-based discussion, in relation to product costing. The works of Trompenaars and Hofstede [last accessed 2008] have developed cultural dimensions; see Appendices 2a / b. The following analysis has drawn from these to expose a number of trends across the industrial costing process.

### 7.4.2.1 Incorporating Cultural Diversity Spectrum

An immediate observation with regards to cultural distinctions can be made when regarding the diversity of what PC is comprised of. The amalgamated disciplines, and variety of skills required have been shown to be necessary due to the nature of what the costing process entails: Namely costs about the product, which equals technical plus economic; and communicational, cultural and human factors, all working concurrently in a compounded manner. Consequently, when examined with the aim of exposing the clear diversity involved, it is not wholly unexpected to then observe amalgamations in the types of cultural dimensions at work within the process.

A primary example of where this can be seen is in relation to the cultural spectrum of universalism and particularism [Trompenaars and Hampden-Turner, 1999]. Although PC has fundamental rules and generalisations which are adhered to, there are noticeable exceptions and special circumstances which need to be accounted for. For instance, one large automotive organisation would give a generalised rule of PC to comprise of labour, material and overhead. Within these three headings, can be a number of subheadings: These can be generalised, or very specific, depending on the area, amount of research, past data related to it and type of estimate done. For example, if a rough order of magnitude (ROM) estimate is adequate, then SG&A can be approximated as 7% of the overall costs, along with a set percentage made from scrap, in the region of 5%. A similar type of approximation can be made with regard to the costs of material, placed at roughly 30% and labour associated with the manufacturing processes related to the product, at around 30%. This applies particularly when there is reliable past–project information at hand, when perhaps working on a refreshed, upgraded model of an established product. However if a more detailed estimation of the costs are required, such generalisations will be insufficient. The figures included in the more detailed cost-breakdown would need to be assessed on a more specific level. The term 'detailed costing' is an accurate description of the task, see Chapter 3 Section 3.4.2 for a fuller description and Table 3.7 for a summary of the multiple costing techniques. Namely a full examination of each element dependant on amount of time and resource available, would be performed before producing an estimate of the cost. Therefore unlike with the ROM cost where approximations were sufficient, each aspect of the item being costed would be evaluated, such as the cost of material, batch size, mode of delivery; manufacturing process, with comparative analysis between them, among the other contributory inclusions. Alternately, it has been said for an ROM, a cost from a previous project can be used, with a set percentage added on top, e.g. previous cost, plus 10% for escalations such as inflation; and this can suffice as the new cost derivation. Such generalisations are in complete contrast to the level of detail expected from more in-depth techniques of cost-derivation; unique relationships and circumstances will necessarily be incorporated, such as accounting for specifics of unexpected costs linked to innovative processes, IT or new material compositions.

The nature of PC indicates a clear need for both ends of the cultural spectrum specificity and diffusion [Trompenaars and Hampden-Turner, 1999]. The latter, of possessing a holistic view of the overall area to be costed and indeed of the complete product, the focus of organisation, market trends, and direction in which the product in general is heading are all important; as they ultimately do impact on the predicted costs. However this vision, though important needs to be completely reduced, atomised into elements in order to accurately breakdown the specific piece costs, needed to compile the final product cost. Hence the need to adopt both a systemic, holistic and specific itemised approach in order to gain a comprehensive view of the item being costed.

The different disciplines which are integrated in the process of cost assessments help shape this type of amalgamated cultural practice. It has been stated that the most harmonious balance is achieved through the use of both ends of the cultural dimensions. Although either extremes do have beneficial and detrimental consequence, the most advantageous and productive results emerged from the middle ground, or elements of both ends present in working practice. This is again overtly present when examining PC, in the sense of individualism, IDV [Hofstede 2008] and communitarianism [Trompenaars and Hampden-Turner, 1999].

A common statement given by the practitioners interviewed was that PC is a highly individualistic process, where each practitioner can deduce a similar, comparative cost for the same component via a different route. This may be true to a point, but an objective view exposes the fact that there are a finite number of tasks and elements involved in producing the cost. Therefore there will not be an infinite number of drastically different ways in which any one specific cost could be derived. Although each practitioner will not necessarily follow the same process, in the exact order as each other; nonetheless a similar set of activities will be undergone, with a confined number of variables involved, per practitioner. Therefore the individualism is limited to the task. In addition to this measured IDV, there needs to be a level of co-operation to various degrees between the contributors of the cost, and even the practitioners themselves, in order to disseminate expert knowledge. Resultantly this stance takes the dimension of individualism and communitarianism as both being necessary within the CP.

If a degree of both ends of the spectrum is not present, with all the mentioned dimensions, the quality of the results will be impaired, so it is important to have an awareness of such aspects and the knowledge of how to apply them to the process in the way which creates an equilibrium. Saying this there are clear areas where an imbalance is the norm, as with specificity and diffusion. Diffusion would be more advantageous during early and latter phases of work, whereas specificity is necessary when deducing the details of the cost. So different phases will have different emphasis of the extremes of each affecting cultural dimension; different cultural modes will be used within the actual costing process itself.

### 7.4.2.2 Diverse Interacting Disciplines

The way in which disciplines work can be observed as diverse, depending on the type of function undertaken. For instance an individual whose role is based within a workshop routinely, having little contact with other people but high interaction with machinery, would necessarily adopt a different working culture to a person who worked with people all day; perhaps being in the sales department of the product being made. A similar state of affairs can be seen with the areas that contribute towards the result of product costing. PC combine disciplines with necessarily different cultural practice in order to work towards the final cost of product. Therefore this involves:

- Different aspects of engineering e.g. design, together with production;
- Economic / commercial and engineering / technical thinking;
- The supplier working integratedly with the customer; therefore external and internal priorities and modes of thought, merged on one project;
- Management and work-shop employee and project-needs; interaction in order to determine and direct the most favourable modes of working.

As discussed previously, particularly in Chapter 3 which examined the explicit process of costing from a literature perspective and Chapter 4, which highlights the industrial AS-IS study, all these areas are included in the integrated working practice required to form costs, set budgets, manage change and product-modification.

The stated domain can often appear to be at different ends of spectrum, e.g. customer focus against management focus: Product, economic competitiveness i.e. cost / price focus; against product performance i.e. technical superiority and enhancement priorities. The commercial domains' primary concentration is around the monetary aspects of the project. This will create a certain type of working procedure dealing with finances, facts, figures; whereas the technical functions concentrate more on the physical product itself. This centres on a different type of working practice, e.g. machinery, equipment, materials, electronics. Although the engineering areas are said to be ever endeavoring to increase the financial know-how within them, due to the nature of the role, the chief concerns will always be related to the product and performance. Thus although a raised economic awareness can be sought, it will not be the dominant perspective within a technical environment. Therefore, there are still substantially different working cultures interacting, when the relevant specialisations work in an integrated way towards creating the product-cost.

When such diverse roles necessarily interact, a number of factors need to be taken into account, such as the different priorities and aims of each area. In addition to this, there are practical considerations, such as different terminologies. Recognition of the fact that each discipline tends to communicate with use of language which is often specialisation-relevant, needs to be accounted for. Such type of discipline-dependent terms and communications may not be directly interpreted, or not even understood with ease by an outside specialisation. Once this is recognised attempts can be made to align the communication between them, which otherwise could create misunderstandings and ultimately cause delays or greater challenges; a cultural example of miscommunication is given within Section 7.4.1.6, and has similarities to internal organisational discrepancies across differing disciplinary cultures.

The issues around a mismatch of priorities need to be addressed initially by raising awareness of the interacting parties' roles. If they each understand what the other roles comprise of, and their importance within the overall process, then an appreciation of their goals can be attained. This type of comprehension creates a harmonious working environment, where different disciplines can work towards the same aims, in a genuinely integrated manner with all areas represented appropriately. See Chapter 5, Section 5.3.3 for the cultural literature paradigm regarding the state of harmonious integrated working within business.

### 7.4.2.3 Cultural Context of Risk

The break through of new innovative products can be linked to an organisations UAI (uncertainty avoidance index) in relation to the level of risk a company is willing take; whether they are innovators or followers [Hofstede, 2008]. Higher risks tend to be associated with innovative products and greater investment; through the new design, innovative methods of development and rigorous testing required; along with the expense of investment towards potential failures. This is as opposed to upgrading an already established product. Risks associated with the use of new, supposedly revolutionary materials; otherwise from implementing new manufacturing processes or IT can ‘make or break’ a company. It determines whether they lead the field, or are followers of good practice which can also be beneficial as it removes much of the risk-element. In relation to the highly successful or detrimental aspect of risk-taking, new materials and processes can be either advantageous in some way e.g. performance-enhancement via lighter weight, higher heat resistance, increased durability; as well as cost-cutting. Otherwise they can be filled with unexpected challenges. These can be difficult to predict incurring huge, unexpected costs, which could result in a range of adverse consequences, the ultimate one perhaps being the downfall of an organisation or termination of whole product due to escalated, unforeseen costs. Alternatively the benefits reaped from utilising for instance a new material which may not be a safe, ‘tired and tested’ option, but may excel in performance whilst universally cutting costs, is immense. Although just as unpredictable in the potential savings as it can be for foreseeing losses, the use of innovation i.e. often perceived as risk-taking, can leave the organisation in a strong all round position. E.g. strength in the market, financially, technologically; leverage against competitors, among other benefits. Thus the UAI of a team, organisation and even society in which the organisation is situated, has relevance on the costing process. See Appendix 2, and Chapter 5, Section 5.3.1 for outlines of the cultural dimensions, summarised in Table 5.1. This relevance stems from the need to be able to account for the potential risks. For instance, if an organisation is not likely to adopt an innovative strategy perceived as a high risk, the costs may be more straightforward to predict, as could be similar to previous projects. Conversely, if a company does utilise new technology, materials and procedures, the resulting costs are predictably challenging to forecast, being unknown or needing to be derived with little actual data. Subsequently, the UAI of the environment, and likely course of action tends to effect the costing process.

### 7.4.2.4 Cultural Related Attitude Towards Risk Regarding Economic Investment: Priority and Benefits of Customer-Contractor Associations.

An example of differences in expectations, priorities and perceived and actual benefits, from a contractors' perspective was relayed by a civil engineering contractor. The case-study highlighted different working practices, standards and focus evoked due to the type of contract being offered by the customer. An ITT (Invitation To Tender) was internationally disseminated within the industrial community. From which time the contractors were given two months to submit their bid to the customer. The contractor was one of two companies selected to develop prototype-products: The cost for which was $10 million per prototype. It had already been clarified at the RFP (Request For Proposal) stage that the customer would cover these costs, because the type of contract specified was Cost plus fixed fee. This is were the profit made is pre-determined and received regardless of the design and development costs, which are all covered by the customer. The alternative was a Fixed cost / price contract, which is where the amount paid for the product is set, and incorporates development costs, regardless of what they amount to. These two conditions of working highlight a number of points with regards to focus, precedence and aspects of culture, such as propensity for risk-taking and innovation.

The contractor explained that the fact that it was a Cost plus fixed fee arrangement indicated that the issues of costs was secondary to the lucrative (in this case) customer. Therefore their main concern was to achieve a ground-breaking, state-of-the-art, high quality product. Basically the contractor bore this customer-priority in mind through the material selection, hydraulics, and general design and development of product; and as a result won the bid. As this involved the supply of a minimum of 27 units, winning such a contract was a major benefit to the established, but specialised contractors, particularly due to the terms of revenue and funding agreed. On a fundamental level it was explained how the Cost plus fixed fee meant that all innovation and new development was covered by the customer, with the rate of profit secured. The contract type conveyed this corporation's priority, of a product which fulfilled their requirements regardless of costs. It also indicated that if innovative design was the only way to obtain the requisites then the customer was willing to fund this. With any innovation is an element of risk, and Cost plus fixed fee contracts show that the customer is willing to bare at least part of the risk, if not all as far as covering costs go. If it had been a fixed cost / price contract, the supplier would have understood that cost was an issue for the customer. This would transfer onto the type of product delivered, as the contractors would be reluctant to escalate costs via innovative design or modifications, as the lower the cost from the overall payment, the higher the contractor profits are: This reveals a lower propensity towards risk particularly economic ones, and a high rating for UAI (uncertainty avoidance index), see Chapter 5. The contractor expressed the preference of the Cost plus fixed fee condition, due to aspects as difficulties in determining development risks from onset of project. E.g. contractor may not know how much testing is required, will only have a ROM if the product is novel. If each test comes out of potential profits, this causes reluctance to conduct excessive tests, which means that tried and tested products will be proposed; as opposed to innovative ones.

#### 7.4.2.5 Cultural Awareness within Negotiations:

A high level of interaction between organisations occurs during the process of negotiational sessions; and the exchanges are often conducted between individual practitioners, see Figure 7.9. Therefore it is important that the practitioners engaging in these talks have a comprehensive knowledge of the culture of the organisation in which they are interacting with, see Figure 7.10. Such knowledge is necessary, due to the fact that advantage during this process can be gained or lost in subtle, but effective means e.g. behaviours / mannerisms. For instance, it is imperative to determine whether a friendly, well meaning, 'family-type' relationship is necessary, in order to obtain the best prices from the supplier. Alternatively the soft, warm type of attitude may be perceived as a weakness, rendering the perception of a more assertive, 'bullying' approach as necessary, in order to gain advantage in persuading the interacting organisation to decrease its proposed costs; see Chapter 5 for organisational cultural differences.

An example of negotiational techniques emerged from a point made by a practitioner from a large automotive conglomerate; refer to Section 7.3.1.8 which discusses negotiation in relation to knowledge of the costing-process. The comment expressed a lack of confidence in instruction to reduce suppliers' costs, when the premises and their process had not been examined. This indicated that logical deduction of the costs due to assessed reductions, as deduced independently by the practitioner, would not be accepted by the supplier. Essentially unless all efforts of scrutiny had been approached by the cost-practitioner, then their representations would be discredited by supplier. In this case the 'mental muscle' would involve indisputable cuts, both from a cost practitioners' version of cost-assessment showing how decreases can be derived; and with use of supplier activities, showing how they can be lowered from that perspective too. In other cases it seems that regardless of the figures, costs-reductions will still be insisted on as with supplier strategic negotiations, and whether the supplier costs are fair and feasible or whether they can be detected as escalated, cuts will be demanded either way; see Section 7.3.1.8.c. This is a more aggressive, forceful approach and would have a high MAS rating, in cultural dimensions; as opposed to the more yielding, logical manner which would have a lower MAS rating [Hofstede, 2008].

The authorities, hierarchical, and family-type cultures are discussed in the cultural literatures, see Chapter 5 and Appendix 2 [Cameron and Quinn, 1999; Trompenaars and Hampden-Turner, 1999]. This is a clear example in which knowledge of the culture of the organisation in question is essential, as adoption of incorrect approaches could ultimately result in financial loss at times. For instance, if an aggressive stance is assumed during negotiations when a nurturing, trustful one is required, negotiations could fail / break-down; leading business to be lost, and contracts placed elsewhere. This could potentially be either a loss for the supplier or the buyer, depending on circumstance. For instance, if it involves a specialist supplier and / or perhaps the most convenient one e.g. in respect to location, then the buyer will be loosing the advantage, need to establish re-negotiations or accept losses. Conversely if the supplier requires the business, a break-down in negotiations will evidently be detrimental for them; therefore the correct approach is important for all parties involved.

Within the organisations examined which were generally UK based, assertion and meticulous scrutiny of the figures under negotiation where often the routes taken within the interactions. This is because the culture in which the research was grounded tended to have lower LTO (Long Term Orientation) [Hofstede 2008], but inclined towards that of quick change, higher IDV (Individualism), and more immediate results expected from shorter term investment [Trompenaars and Hampden-Turner, 1999]. Therefore it was explained by the practitioners that if lower costs could be gained from new suppliers, they would win the work over non-competitive but known companies. With this said, purchase tended to favour suppliers where relations between the companies had already been established, so there were a few examples that highlighted a degree of higher LTO; where quality, and known working practice was trusted and preferred over lower costs. So exceptions to a typically western rating of LTO were noticeable throughout this study, not unexpectedly, as the contributors were all based within the UK and US; and generally though not wholly, were western-governed organisations. So though dominantly comparatively low LTO was observed in comparison with Hofstedes world ratings, (see Appendix

3) it tended to be dependent on the specific industry in question. For example, aerospace and automotive would deal internationally and in long-term projects; whereas software were often smaller organisations with a high turnover of products such as technological developments, which peak and matures rapidly in this domain.

Therefore expertise and product-development moved rapidly and kept-up which the changes, in order keep advantage over the competitors. This is true of all industries, but in real-time the software domain were observed as being more progressive in this sense, quicker to embrace innovation, so resultantly moving more rapidly then other areas. The approach these companies pursued typically involved a lower LTO approach; as there is an advantage to invest time in order to keep updated, which is important within the software and IT markets. Within an automotive one however, the vehicles need to satisfy customer. This means that the use of such new technological advances are incorporated but the main product changes less rapidly, with more subtle changes continuously made. The aerospace industry again improves with technological innovations, but due to the predominant nature of the industry, tends to be slow to adopt major changes, as there are a number of issues to consider including safety, security clearances, with the requisite of longer-term tests. The culture within each of these industries determines their attitudes towards change management and risk.

An understanding of a degree of the culture, subsequently plays a part in negotiations, as for instance in the adoption of friendly or a 'bullying' atmosphere; the individuals involved need to recognise which approach gives advantage; see Section 7.4.1.8 about negotiations. The language used plays a part in the chosen stance, e.g. whether assertive, loud, argumentative, provocative, even antagonistic; or calm, measured and friendly, all guises adopted in order to gain credibility and acceptance within the interactions, ultimately to lower costs, if the customer of supplier; or maintain them, if supplier. As well as use of language, it was also stated that numbers in physical presence can gain advantage in the negotiations. The primary contributors within the negotiations were Purchase, accompanied by product-costing, with an occasional representative from engineering; the compounded expertise gave strength to the negotiations, see Figure 7.10.

There were occasions when it was debated to a point where the costs could no longer be reduced via the more standard negotiational techniques. These include recognition of 'tricks' from the supplier, in order to escalate costs as discussed in earlier sections; or comparative analysis, with the figures the customer derived against the suppliers costs. When such debate was undergone, but did not result in cost reductions, this my be due to the cost-practitioner being satisfied that the proposed costs are valid and cannot be further reduced via convention methods. However, the situation may be that cuts in the costs are still required, in order to keep within the budget. In these instances, it has been stated that larger organisations can demand first-tier suppliers redesign the component in order to keep within the cost-target referred to as Design to Cost, DTC. This involves a large degree of interactive working with the supplier and customer, in order to reach the cost margins necessary. The first step will be to go through costs to look for reductions wherever possible. The tricks identified relate to issues of trust (see Chapter 5, Section 5.8), not simply for willful misleading information bestowed, but also in the area of competence. For instance outdated, slower methods, when investments by the supplier in upgrading their own practices, ultimately save money for the customer; or insufficient labour-employed to save costs. Such integrated working needs to lead to an understanding of organisational culture between the external parties. This type of collaboration, including towards

'DTC' as opposed to designing, then determining the cost, is more likely to occur within large manufacturing organisations where profits are set and cannot be changed; therefore the budgets need to be worked towards, even with the suppliers.

Another area of the product / projects where change management is necessary is when overall costs reductions need to be found. A team of specialist will examine the whole product and debate the most effective cuts. E.g. whether there are any surplus components which could be omitted; selecting a lower cost material; less labour and / or hours: The necessity of each potential solution needs to be assessed. This often involves VEVA teams or some other form of IPT, including supplier. A typical IPT will involve a practitioner from each section of the product, if overall costs need to be cut; e.g. within automotive organisations, may comprise of: Body in white, engines, exterior trim, interior trim, etc; plus supplier, product-costing, (see IPT Section 7.4.1.4). This method of integrated working has proved to be an effective way of tackling disciplinary-cultural differences, i.e. via personal interaction. Internal negotiations are experienced in these type of teams, but were described as amicable with the team working towards a consensual solution, as opposed to hard-core negotiations. This is very different to the prior described strategic-negotiations which are undergone to varying degrees, often by the more powerful corporations as cuts are demanded indiscriminately in such negotiations, expanded on within the negotiation Sections 7.3.1.8 and 7.4.1.8.

### 7.4.2.6 Specific and General Appreciation of Cultural Knowledge

Within the observations of the knowledge that is required about organisational culture, there are two main aspects: One is in the need to possess a specific understanding of aspects of culture and the effects; the other is to have a general awareness of it. This observation can again be loosely linked to the diffuse and specificity research by Trompenaars and Hampden-Turner [1999], mentioned earlier in the section, and Chapter 5.

For the overall dealings of the costing process, the practitioners need to have an appreciation towards the cultural needs of those they interact with. As discussed throughout the thesis, a number of different areas contribute towards the costing process in order to create the required costs; though the primarily contributors are purchase, the engineering functions and often the supplier. There is clearly a need to understand the attitudes and perceptions of the interacting domains. When people work together it is important to not make unfounded assumptions about their beliefs and working ethos; but instead to establish common ground whilst identifying and aligning dissimilarities. For instance, determining differences in the manner of working and why these occur; the priorities, focus and preferred modes of attaining results: Identification of various actions and schools of thought behind them can lead to best practice exchange.

For one set of practitioners to automatically presume that interacting parties hold the same perceptions as themselves without finding a way of verifying this assumption, will tend to be the cause of many difficulties, misunderstandings and general cacophony. Whether between interacting organisations e.g. supplier and customer, nationally or globally; or different, liaising branches of the same international corporation, e.g. one company based across Germany, Japan, UK and US, as with a number of automotive organisations; to different departments within the same location. Whenever groups of individuals interact, there is a need to understand what the primary roles involved are, and how resultant beliefs and behaviour will be modified accordingly.

### 7.4.2.7 Trust and Fear Cultures:

The level of IDV or communitarianism between organisations can be observed through the attitudes of the work-force; see Chapter 5, Table 5.1; and Appendix 3 for cultural term abbreviations. For instance if practitioners' are reluctant to take responsibility for any action that is not strictly standardised, it can portray an individualistic culture where a hierarchical chain of command can impose penalties upon that which is perceived as 'bad practice' or even towards mistakes. However, in industries where individuals were likely to be made personally liable for difficulties, there was a greater tendency to produce evidence and reasoning behind resultant judgments and decisions made. This was beneficial for future projects, and even as a training-tool, see Chapter 8. However, areas where personal accountability was generally a lesser concern, seemed to result in a lack of documentation of proceedings; which ultimately leads the loss of knowledge via the natural depletion and general movement of experienced practitioners.

The reaction of the workforce towards such situations as taking responsibility for actions, can be a reflection on the levels of trust within that organisation. Ideally an open environment should be adopted, where constituents can voice concern about any disadvantageous implementations, with the aim of making overall improvements. Alternatively, a learning environment promotes the disclosure of difficulties and error, in order to learn from them. However, within a number of the organisations examined, a distinct fear culture was identified in general, i.e. manifested towards management, not just towards PC. For instance one cost manager summarised product-costing as:

"…the person who's the main one to understand commercial plus technical elements; whereas the buyer or purchasing are mainly commercial people, therefore they have a fear of being told that they're not doing job properly, to summarise."

[Costing Manager, Automotive Industry, 2002]

The following points were conveyed across the spectrum of companies observed, showing the manifestation of fear cultures:

- Between interacting departments, namely Purchase and PC:
  - Caused by lack of trust and misunderstanding of roles; resulting in a breakdown of communication;
- Between hierarchical levels of the organisation: Management and the workforce;
  - With regards to budget-allowances and resultant over-estimations;
  - Due to not wanting to be perceived as inefficient, through not meeting time / monetary allowances;
  - Resulting in overestimations, which work directly against the best interests of the organisation;
- Lack of integrated working between both individuals practitioners and departments;
  - Due to lack of holistic perception of area / product;
  - Plus a lack of understanding of roles, so why information may be requested;
  - Enforced by a fear of reprimands if mistakes are made, as opposed to promoting a learning environment;
  - Which is often symptomatic of a high IDV environment, where individuals can be held personally responsible;
- Lack of innovative thinking, tendency observed more within a communitarianism environment;
  - Reference made to reliance on software tools, as opposed to ground-root costing;

    - Need to be tacitly knowledgeable of at least ROM predicted costs, used in conjunction with and to validate tool-derived costs;
- Fear of voicing innovative ideas;
    - Due to reluctance to deviate from the norm;
    - Or repercussions if perceived as criticisms of current system / performance;
- Responsibility will be avoided, hence actions not taken if perceived fear culture promotes unfavourable consequences resulting from identified mistakes / deviation from protocol.

A noteworthy point is that the above listing of fear-culture experiences from within the companies examined shows that such occurrences are not industry-specific but can affect all domains; as it was derived from a combination of the contributor in-put, refer to Chapter 6, Table 6.2. PDI, (Power distance index) relays the level of equality between constituents within an environment. If an organisation has a high PDI, it can result in greater manifestations of fear culture. Examples of fear culture were evident within a small majority of the organisations examined, as included throughout the thesis, including the above cost manager quotation; and in each instance the results of these symptoms were identified as highly detrimental. The organisations within which this culture prevails would benefit from the promotion of a more positive, integrated and blame-free cultural presence. Holden, [2002] gives examples of contemporary examples of the positive effects of such changes, and case studies of how organisational culture has been modified or radically changed.

Trust issues were often seen to be linked with fear culture. Trust-concerns within working environments can have detrimental effects on interactions, perceived motives and resulting behaviours, discussed throughout this and Chapters 4, 5 and 6; and summarised below which highlights the cause and results of a lack of trust:

- Often overtly perceived between supplier and customer, with regards to cost breakdowns for service or component provided:
    - Tricks are commonly perceived to be initially incorporated, as a standard part of the costs specified by supplier;
    - Or 'bullying' tactics can be perceived as being employed by powerful corporations towards smaller suppliers in the form of the strategic negotiations which stipulate more extreme customer demands, mainly price-cuts;
    - Both sides negotiate to gain advantage for their company;
- Between commercial elements of costing and engineering, stemming from a lack of understanding towards each others roles, and resulting in conflicts:
    - E.g. Unreasonable budget-cuts, perceived by the engineering functions or the commercial / economic restrictions imposed;
    - Escalated proposed costs, as perceived by the commercial areas of the received technical work-breakdown and resultant budgets required;
- Lack of use of softwares, resulting in potentially greater time taken:
    - Due to a mistrust in the validity and performance of the tools;
    - Lack of investment towards updating the supporting databases the run the computerised costing aids;
- Insufficient use of product costing function:
    - Due to lack of understanding and subsequent appreciation of role;
    - Plus lack of formal procedure to include PC early and throughout the process;

- General lack of trust in the motives behind actions:
    - E.g. why is a breakdown of costs required; assumptions can be that are due to lack of trust in competencies
    - Or intentions behind decisions made e.g. supplier choice
- Segregated working practice:
    - Often due to limited understanding of holistic process, with concerns confined to specific function, alone.
    - Distrust of external functions regarding prioritisation, and management with regards to judgments made based on identifiable results, as opposed to overall performance;
    - Mistrust, of others taking credit for work; typically an individualistic-type behaviour.
- Lack of trust promotes 'blame culture': Fear of being accused or 'blamed' potentially enduring repercussion for unsuccessful actions:
    - This can prevent lateral thinking and stifle innovation, which is often required in areas of costing, where costs are not readily procured.

An overt example of a lack of trust among other issues including cultural, was observed within an international automotive company where an overseas, non-European and non western owner. In this case the UK practitioners were seen to be disparaging towards decisions made in countries where the owners were based, which the practitioners felt had radically different cultures and perceptions; but regularly made decisions that affected their regular activities. The reproachful attitude stemmed from the perception of the international management, being viewed as out of touch with UK company practices. Conversely, a UK branch of a large manufacturing organisation, described how best practice could be adopted from on of their European branches, following the organisations' attempts to standardise and disseminate company procedure; therefore when procedures were exchanged the former were able to learn from the latter. These two quite different examples of international integrative working practice show how the culture instilled can result in different productivity.

The former practitioners openly discussed issues pointing towards mistrust of the conglomerate owners, due to perceived lack of understanding and / or lack of competence towards the cost-practitioners role. This discord had already resulted in many of these automotive cost practitioners having left; their movement to other organisations had consequently weakened the overall PC department as they had not been replaced, perhaps expectedly, given management perception of PC. In turn the output of costing had accordingly become minimalisitic; and ultimately the remaining costing personnel, now very low in numbers, were fearful for their positions, as said because the value of their role seemed to simply no longer be valued under this relatively new management; see Chapter 4 for supporting evidence. Cultural knowledge is encompassed within organisational culture and social aspects and interactions. This is partly what the practitioners referred to when they commented on being 'institutionalised'. The former is essentially a reference to the adoption of how fully an individual employee has taken on the company-culture, and how obviously it may be seen in aspects such as their mannerisms, attitudes, opinions; and consequently in their behaviour.

Table 7.3: Summary of the Essential Eight Knowledge Types: With Associated Activities and Interlinks between other KTs

| KNOWLEDGE TYPE: | Knowledge Sub-Types | Knowledge Inter-Linkages |
|---|---|---|
| Section: 7.3.1:<br>**Knowledge of the Costing Process** | Economics<br>Including overheads, logistics and exchange rates. | Knowledge of Risk |
| | Knowledge of Negotiations | Manufacturing Process knowledge<br>Including labour hours, skill-levels, alternate process, tooling |
| | Organisational Strategy | Knowledge of Materials including cost of; and batch size |
| | Historical data /<br>Past Project Knowledge | Knowledge of interpersonal Communication |
| | Knowledge of Risk | Design knowledge (changes) |
| | Organisational Structure | Cultural knowledge |
| Section 7.3.2:<br>**Knowledge of Manufacturing-Processes** | Supplier Knowledge | Communication |
| | Negotiations | Material knowledge |
| Section 7.3.3:<br>**Knowledge of Design** | Company Strategy | Material |
| | Supplier knowledge | Manufacturing Processes |
| Section 7.3.4:<br>**Knowledge of Material** | Supplier knowledge | Communication |
| | | Design Knowledge |
| | | Manufacturing Process |
| Section 7.3.5:<br>**Product Knowledge** | Supplier Knowledge | Communicational knowledge |
| | Knowledge of company-Strategy | Cultural Knowledge (type of interactions, etc) |
| | Organisational Structure | Knowledge of Risk |
| | Market Trend- knowledge | Manufacturing Processes |
| | Historical data /past-projects | Knowledge of Design |
| Section 7.3.6:<br>**Knowledge of Risk** | Supplier | Design Knowledge |
| | | Manufacturing Processes |
| | | Product Knowledge |
| | | Communicational Knowledge |
| Section 7.4.1:<br>**Communicational Knowledge** | Negotiation knowledge | Knowledge of Organisational Culture |
| | Contact knowledge | knowledge of Product |
| | Organisational Structure | Costing Process |
| | Knowledge of Disciplines<br>E.g. expertise / roles | Knowledge of Risk |
| Section 7.4.2:<br>**Knowledge of Organisational Culture** | Market Trends | Communicational knowledge |
| | Organisational Structure | Product knowledge |
| | Knowledge of Disciplines<br>E.g. expertise / roles | Costing Process |
| | Historical data /past projects | Knowledge of Risk |
| | Negotiation knowledge | Design Knowledge |
| | Knowledge of supplier | |

As the culture of an organisation changes, the fluid flow of information would change accordingly. Many different cultures where observed to be present even within one company; these need to be understood by their counterparts, and need to understand the supporting areas around them. This is particularly valid within PC as they liaise with a number of different areas: A lack of understanding towards the cultures and mindset of those they are working with, has detrimental effects. Hence, a systemic comprehension involves knowing that cultures of different disciplines may vary; priorities and emphasis will be different.

For example, previous discussion throughout the thesis has explained the focus of the interacting disciplines within PC, principally economic functions such as finance and accounting, that has been observed to center around balancing monetary aspects; whilst physical aspects of the product were key with the engineering disciplines. The difference needs to be highlighted, disseminated and taken on board in order to allow understanding and adaptation where needed to promote integrative working processes with a lateral transfer of costing knowledge.

Table 7.3 lists aspects of each of the finalised cost-knowledge type identified: Of the eight knowledges' listed, they are summarised against the industrial areas of knowledge which they incorporate such as economic and financial knowledge required to be able to cost a product, so is encompassed within costing-process knowledge; see the middle column of Table 7.3. The KTs which are interlinked with the associated activities of the primary listed KT in the first column, are also listed; these linkages between the essential knowledge-types are highlighted in the third column.

## *7.5. Knowledge and Training*

This chapter discussed the knowledge utilised within the costing process, and established a definite list of knowledge types which are essential for product-costing. Of the eight essential knowledge-types identified, the observations disclose that all of which can and must be bestowed on novices within the domain in order to develop their skills, understanding and knowledge of PC. Additionally, it was noted that even current practitioners could benefit from the continued reinforcement of the essential aspects of each knowledge-type, as it would further enhance their understanding and performance. Plus an awareness of changing cultural environments such as international company merges / take-overs is crucial, and facilitates the adaption towards such metaphorised working environments.  Knowledge capture and transfer can be achieved via the development of training material, specific to the costing domain, and comprehensive in the diverse needs of a cost-practitioner.

Numerous practitioners, particularly from the large companies where cost-personnel were known to work within for the majority of their careers, stressed that the detrimental occurrence namely the loss of fundamental knowledge from the organisation, needs to be addressed. The observations made were that the general depletion of costing-expertise and knowledge due to the typical levels of retirement, changing personnel, and so forth, meant that elicitation and reuse of experienced practitioner knowledge was essential if quality costing practices were to be achieved, and high standards maintained.

If the organisational knowledge is lost, it was also said to have been depleted due to excessive outsourcing, with investment not being made within the organisation itself. Therefore expertise is transferred by various means, either lost personnel occasionally via departmental cuts, who then move to other companies. Otherwise via funds being plied into for instance supplier companies, as opposed to nurturing in-house practice; hence the recipient supplier, in turn develop their expertise. Over time, this gradually makes the supplier expertise superior; ultimately putting the customer organisation in weaker, potentially vulnerably position; as they may become reliant on an increasingly knowledgeable, and thus powerful supplier who can eventually dictate price. E.g. an automotive example of such was given as Bosch. Such events had occurred where high expertise was requisites from the first tier suppliers; see supplier accessibility within the previous manufacturing processes knowledge Section 7.3.2. Companies needed to initially have a systemic awareness of not only their own practices, but that of the environment in which they operated within, e.g. to understand how interacting companies impacted on them. The lateral transfer of knowledge between organisations, and across where possible, improved this systemic perception. The cost knowledge framework, consisting of the eight KTs which the research identified as being essential in order to conduct the costing process, in conjunction with the six cost themes detailed within the previous Chapter 6 require a system in where it can be disseminated within the industrial environment which it has been developed by and for. Propagation of the framework would generally serve to improve organisational practice if it was accessible.

A way in which the framework may be conveyed is to package it within customised training packages. Hence the research results have training implications for the cost-domain; the targeted development of which can then address the more specific areas affecting cost and its contributors; including the ubiquitous influences, such as communication and cultural considerations, if managed to be incorporated within the training material. See Figure 7.13 for the ICKF flow into the lateral dissemination of costing knowledge.

Given these tacit and explicit components the resultant output manifests as more then a sum of its parts; hence is not as typical standardised training but that which contains both hard, quantifiable aspects of costing, such as manufacturing process. These types of tangible elements within the process are relatively straightforward to address in respect to developing training material around them. However, ideally the training developments should also include the soft, less tangible findings of the research including all aspects related to communication, and development of interpersonal skills. This research proposes to incorporate such factors fully into the ICKF industrial dissemination, though via tacit, implicit approaches. The build up towards such propagation of the ICKF is illustrated in Figure 7.13: which shows how the cost themes are added to, by incorporation of the 8 essential cost KTs. The resultant, layering framework may be explicitly represented via specifically formulated cost-focused training, which will overtly deliver the tangible elements of PC. In conjunction to the expected training, the programmes will subtly, seemingly incidentally address the social aspects fundamental within the cost process; providing a rounded, effective training approach for the domain of product-costing, applicable across industries.

The following chapter discusses the way in which the ICKF may be implemented within an industrial domain. Chapter 9 highlights the area of subsequent training implications resulting from the research; with tailor-made training programmes having been identified as being a principal part of the cost-knowledge practical dissemination, detailed in Chapter 8. This includes training needs analysis (TNA); types of learning; plus subject and module design specific to PC. As stated, the training propositions are formulated directly from the KTs, which were derived against the primary cost themes; all of which evolved directly from the organisational studies. Therefore the following projected training proposals are expressly influenced by the industrial costing practitioners; whilst being based upon the knowledge framework highlighted throughout this chapter.

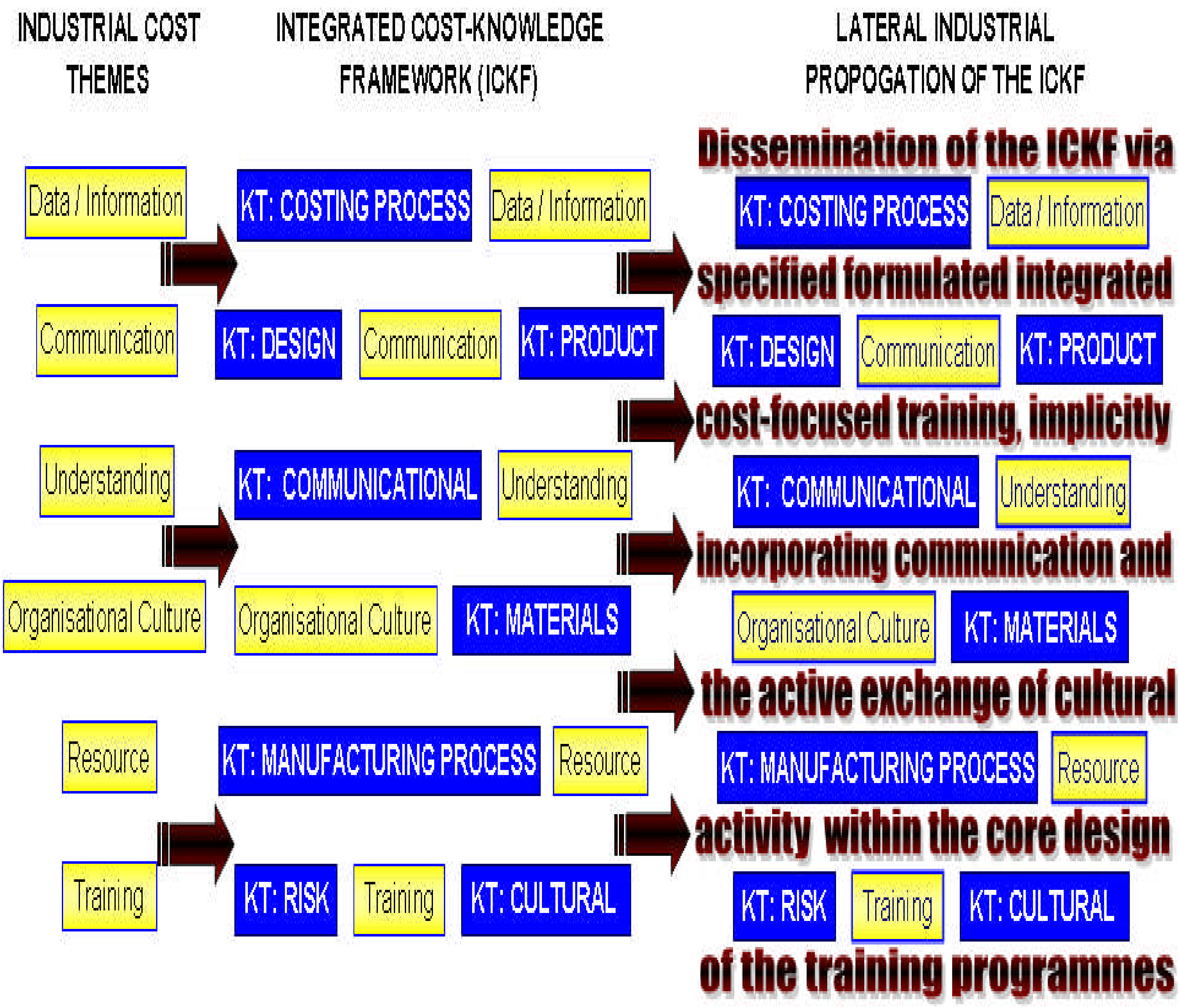
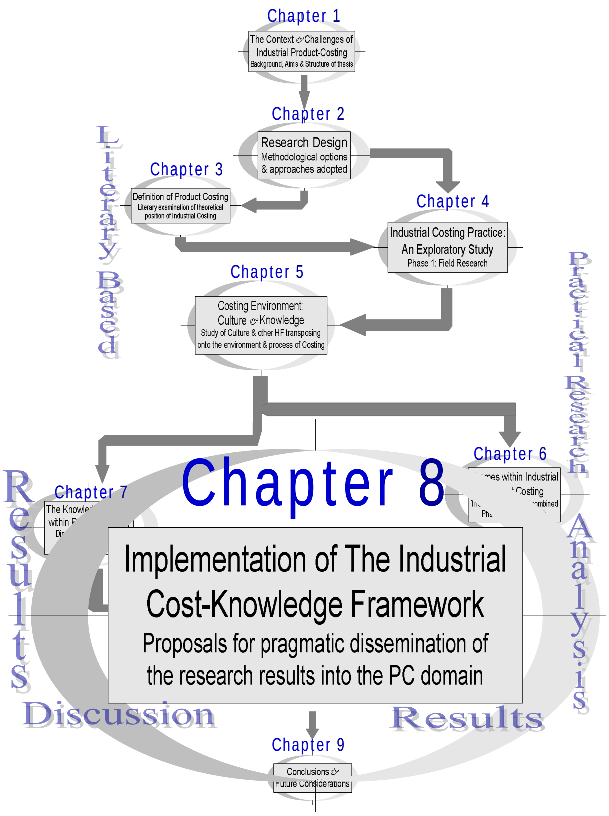



Figure 7.13: The Research Steps Leading to the Industrial Dissemination of the ICKF

# Chapter 8:

## Implementation of the Industrial Cost-Knowledge Framework




*"..organisations are rediscovering that humans are their critical resource and that a commitment to training and continuous learning is crucial for them to remain competitive".*

[Goldstein and Ford, 2002, p.14]

The focus of this chapter is on how the research may be implemented in practical terms. Emphasis is on the dissemination of the developed framework <u>into</u> the <u>industrial environment</u> of PC. For instance examination of methods that enable the formulations of this research to be practically implemented within the areas which will benefit from them namely the industrial domain of PC. Training proposals will feature in the delivery of the research findings. However, not standardised training but tailor-made specialised programmes designed to integrate the work into conveyable modules, suitable for industrial usage. Having identified the themes underpinning costing, (Chapter 6), and the knowledge types associated with them, (Chapter 7); this chapter will examine the most appropriate methods of propagation, allowing industrial sectors to acquire, customize and assimilate the industrial integrated cost-knowledge framework, ICKF.

The ICKF developed integrates the physical and social / human aspects within the costing process. ICKF was derived and finalised within the latter half of the thesis, discussing the challenges currently experienced within product-costing. The process was dissected in order to identify its components and subsequent individual areas of difficulty. The resultant themes, refer to Chapter 6 and Figure 6.5, represent the areas which the practitioners recognised as generally problematic that commonly occurred in day-to-day practice. They expose interacting functions and activities encompassing not only issues within the process itself, but the environment within which it is performed, which has marked influences on execution and outcomes. Equally the knowledge–types, KTs, explored in the previous chapter were the result of close examination of the actual cost process; and have explicitly identified what is required in order to adequately perform industrial product-costing, PC. Therefore the themes highlight the challenges within and surrounding the process; whilst the knowledge-types collectively represent how the cost-process is actually performed.

The corollary of this compiled research lead into issues of industrial implementation and dissemination in order to maximize the pragmatism of these findings. One proposal presented in which to propagate the ICKF in a straightforward manner was via that of untraditional, customised cost-training developments. Accordingly this chapter discusses areas of training, from training philosophies, e.g. the type of training dependent on application or what it is trying to be achieved, see Section 8.2.4.; to the final modules and content suggested, developed specifically for the costing domain. The focus includes the way in which skills and knowledge are learnt and retained i.e. learning needs; training needs analysis, TNA, and modes of delivery. The resultant training implications were derived with direct input from the industrial contributors, primarily from Phase 2 research, P2; (refer to Table 6.2, Chapter 6) with regards to the suggested training modules, and DIF analysis, performed as part of the TNA.

## *8.1 Potential Techniques for the Operationalisation of the Costing Model:*

The cost-model consists of the main 6 themes which impact on the process; plus the 8 knowledge types which have been deemed essential to conduct it. Figure 8.1 illustrates the developed industrial cost-model, depicting these costing-aspects of the model in cubic formation. The 6 sides of the cube represent the identified themes, T1 - T6 where 'T' denotes 'theme'; and 8 edges structure the knowledge-types, KT1 - KT8. This 3D graphical representation attempts to illustrate the concept of the ICKF showing how the themes and KT's interlink, and when considered in conjunction, comprise the ICKF.

Figure 7.13 in the previous chapter shows how the ICKF emerged, with the derivation of the cost themes being incorporated with the 8 essential KTs, a model of which is presented in Figure 8.1. This model can then be disseminated throughout industry with the intangible aspects applied liberally, but implicitly throughout, in a similar manner to cement holding the brick-components of the model in place, as depicted in Figure 7.13. Within the final Chapter, 9, Figure 9.3 is represented on more of a flat structure, showing the layers throughout the ICKF, and its subsequent dissemination.

Training has been identified as one of the main themes; and also can be a way to stabilise, promote and enhance the cost-model, as illustrated in Figure 8.1. However, the operationalisation of this ICKF may involve a number of elements, including job-share schemes, social networking, communities of practice and training [Holden, 2002].

A major aspect of job-sharing would be to promote cultural knowledge between the primary functions of costing. The emphasis of this cross-disciplinary collaboration would be centred on the economic disciplines interacting within an engineering environment, and vice-versa, i.e. the technical aspects working with the financial areas. This cross-functional working will result in shared experiences. It will provide first hand knowledge of the interacting disciplines' working-culture, enforcing priorities and perceptions which may otherwise be left unknown, misunderstood and / or mis-communicated.

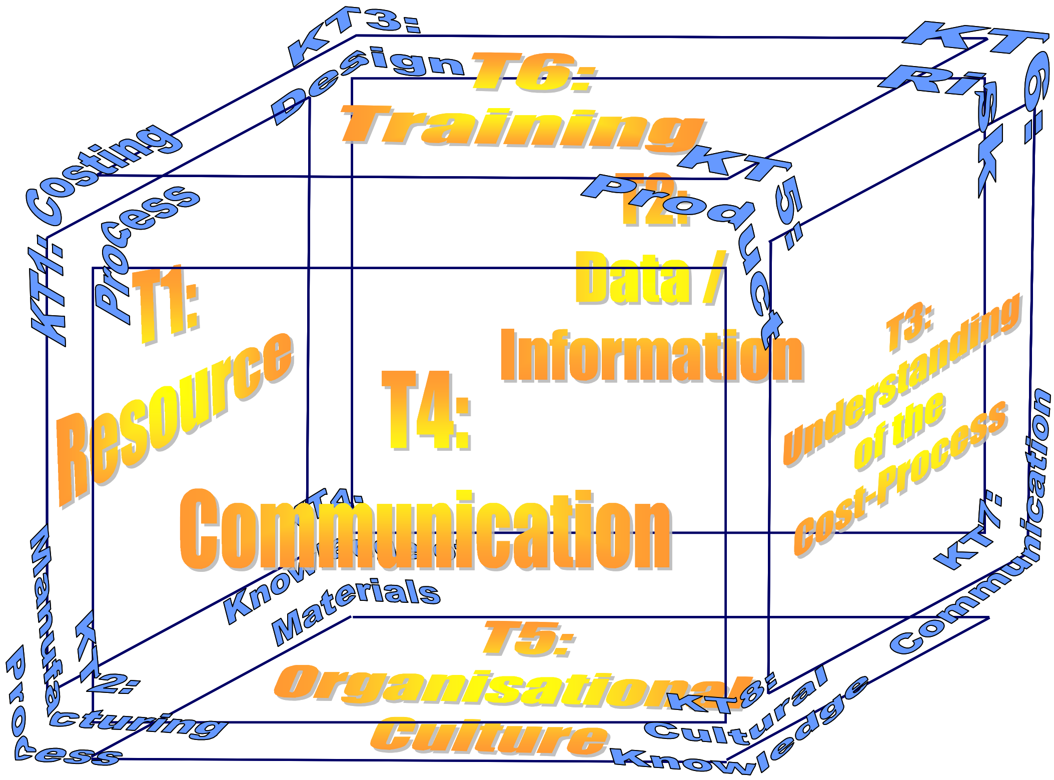



Figure 8.1: 3-D Graphical Representation of The Industrial Cost–Model Derived via the Juxtaposition of 6 Cost Themes and 8 KTs

### *8.1.1. Job-Sharing:*

Job-sharing gives actual experience of the others' roles, allowing an understanding of culture as well as the physical activities and mental stimuli involved; plus assists with communication, once roles are reverted back. The traditional perception of a job-share-type experience is that it is a useful way to integrate novices into the industrial and organisational environment. This manifests in the fact that a common framework for new recruits, particularly graduate schemes, is to place the trainee within a department for typically a 6 month period (or less), and rotate them throughout areas of the organisation. This was common practice among the examined companies, being undertaken in order to give the trainee a comprehensive knowledge of the company-structure and a thorough view of the relevant functions, whilst enabling them to determine the discipline they would prefer, and are most suited to work within. Associated with this school of thought are the personal development programmes within organisations such as Ford Motor Company, where practitioners were encouraged to move internally every two or so years. The theory behind this practice was to bestow the employees with a systemic, comprehensive knowledge of a number of areas within the company, which in turn was considered to make them more aware about many aspects of the product and environment in which they worked within. The idea was to improve their performance, making such standardised movement beneficial for both the individual who would end up being skilled and widely

experienced; which would in turn benefit the overall company, as this enhanced calibre of practitioner would be transferring their board expertise to the work environment.
The function for the type of job-sharing suggested in this instance builds upon this ideology. It expands to incorporate the view that instead of shared-functional activities being utilised as a part of introductory training only, its usage could be expanded in order to provide a continuous understanding of the environment in which any one function performs within.

Unlike the actual employee personal development opportunities presented within companies including Ford Motor Company, the job-share scheme differs in that it should be imposed for a limited period. This is because what is being proposed is not a change in role, but an education of other, interacting disciplines. Hence short periods enables it to not disrupt the participants' usual activities; but to also be conducted over a substantial enough time-frame to allow a valid experience of the others' role.  This type of active interaction could be implemented on a continuous basis, not solely for novices, but as part of an on-going performance-enhancement programme within the organisation. It could be commenced at set-periods, as predetermined by each organisation, depending on what was identified as the most beneficial time frames,  e.g. two-yearly. Plus it could be undertaken for fortnightly periods between interacting departments, in order to promote communicational knowledge, understanding of functions, needs and priorities; as well as the general updating of organisational cross-departmental cultural knowledge.

Such an operalisational technique of the costing-model may be equated to an ethnographical study. Ethnography is more commonly associated to academic purposes; refer to the description in Chapter 2 within the methodology discussions, Section 2.3.1.1. Often in order to gain a sense of the subject-area under examination, a knowledge engineer or researcher will undertake an ethnographical study [Rush and Roy, 2001]. For instance placement within a company to observe the practitioners and absorb the environment in order to research either general or specified aspects was not uncommon. It is reasonable to transfer this type of activity into an industrial domain on an ongoing basis. In other words to implement it more broadly than it currently is, i.e. which seems to be training periods only, such as that within graduate schemes, with the aim of creating and maintaining the type of integrated working environment necessary for product-costing.

The previous Chapter 7 has discussed the most common type of collaborative working, which was observed as being via IPTs (integrated product teams). This is where different disciplines work together towards a shared goal so may represent the priorities and aims of their area, whilst appreciating that of the other contributors: The industrial perception was that this was a valid method of working, see Chapter 7, Section 7.4.1.4. Job-sharing would intensify this process; including active interpersonal communication within the other methods of interaction, and bestowing a genuine awareness of the roles, priorities and general culture of the disciplines whose amalgamated contributions produce a product-cost. However a drawback to this may be in the loss of time towards their own domain, and their lack of experience within the shared role: Arguably, their use or application within it may be limited. Hence with the time and resource pressures regularly mentioned by practitioners, the research perceives that within product-costing, the activity of job-sharing on an on-going basis may be resisted for those reasons. The benefits and drawbacks of IPTs are presented within Figure 7.12 in the previous chapter; and can be equated to a degree with other integrated roles including job-share.

### *8.1.2. Networking:*

Social networking is a highly beneficial way to promote communication, though it can be challenging to promote within professional environments, particularly male-dominated ones as costing has overwhelmingly been observed as being. Refer to Chapter 5, Section 5.3.2 for gender-working influence. Improved standardised IT may support such social networks, as it could allow the transfer of information at a practical and accessible level, generally enhancing all types of communication.

An imperative element identified from the model is the need for networking, both socially i.e. between individuals; and functionally i.e. between disciplines, across the main contributing departments. This area is discussed later in the chapter, within the sphere of interactive training modules. However, it merits acknowledgement independently of the training context, due to its continued reference throughout the process, across organisations and industries examined. This was primarily related to the location of cost-knowledge and information; and towards the way in which practitioners could not only locate the required levels, but to be able to do so as rapidly and efficiently as possible: Refer to Chapters 6 and 7 for greater detail.

A critical and apparent observation throughout the cost-model was in the need for a range of communicative techniques to be implemented in order to produce the most rapid and accurate costing results. Challenges within this area have regularly manifested under a number of guises, e.g. insufficient data-transfer due to lack of procedure / systems; lack of awareness of the requisite for information-transfer, which can be recognisable as having initiated from communicational issues. This is often coupled with concerns raised which ultimately derived from cultural knowledge deficiencies: E.g. lack of environmental knowledge including not understanding the time constraints or pressures within product-costing; therefore internal users or customers of PC have been said to make unrealistic requests for the time in which the costs are required within. Evidence for which has been presented within the previous chapters.

An environment which promotes social networking between disciplines will lead to improved communication and access to knowledge, and therefore must be established and nurtured. Technical networking systems are also important in the supporting of such social networks. The information required can be readily identified, requested and supplied if adequate IT structures are in place. Such integrated working is discussed later within the chapter in relation to the integrative training modules proposed. Cross-discipline workshops with mixed experience and background, and even different organisations will enhance understanding of each others roles along with the cultural domains; ultimately promoting communication.

### *8.1.3 Communities of Practice:*

Communities of practice may be established either formally or informally. Formal structures may be arranged by the organisation; whilst informal may be allowed by the primary body in ways such as not monitoring phone calls and time in the office. This would enable individuals to set up their own communities of practice [Holden, 2002]. For instance if this was implemented, the way in which it could influence the costing practice would be via a perception of more time to personally visit other departments. Thus with regards to PC the principal ones are purchase and engineering functions, of which may be located on a separate site. Informal conversations between practitioners including different disciplines could be incorporated into the working practice of individuals, which would result in improved integrated working and a lateral transfer of costing knowledge. If an environment was created with emphasis on the quality of the job and judgment / expertise of practitioner, then the perception may be formulated that there is enough time to allocate to supplier visits. This would allow validation of their practices and even to perform more in-depth costs, including increased time to gather data / information. This is as opposed to comments regularly conveyed by a selection of industrial participants, relating to the fact that they had little time to thoroughly undertake such activities, at the expense of the quality of results; see Chapters 6 and 7 for supporting evidence. If their judgement with regards to how their time would be more sufficiently employed was allowed, then such issues such as accuracy may be addressed more often, as opposed to target impositions from the company. Chapter 3 discusses the techniques of PC including the ROM; and detailed estimate processes which require more resource including time; data and information.

However such an environment involves integrity from the practitioners, and trust on behalf of the organisations; which can be abused: As for example clearly a level of time constraint does need to be indicted. However it becomes counter-productive when there is not time for instance, for various departments e.g. engineering, to assimilate the recommendations of PC into the product as was noted at such times as product launch preparation for automotive industry activity. However the latter mentioned was an important time for the whole company and it was specified that changes even cost-effective, were considered as too late if made in the immediate lead-up to launches; see Chapter 6 for more detail. However, with this in mind, a practice which was noted as needing to become commonplace was the inclusion of costing at earlier stages; with increased integrated working to avoid late recommendations and enable them to be identified as early as possible.

### *8.1.4. Primary Operational Approach towards the Cost-Framework:*

This type of active and structured interaction signifies techniques which may be used to operationalise the costing framework developed within the research. The aim of the ICKF is to make improvements within the costing process through the development of a more integrative mode of thinking, regardless of the physical environment the process is performed within. The primary method adopted by this research, for the operalisation of the cost-model, has been proposed as being through the targeted development and industrial implementation of cost-training material. Training cannot generally be undertaken on an independent basis and is often part of a larger system, operating within an organisations' culture and structural dimensions. The prior mentioned operalisational techniques can be applied in addition to organisational training, otherwise they may be integrated and promoted within developed training; suggestions of which are presented later in the chapter the with regards to the specific cost-programmes. Refer to Figure 8.1 which highlights how issues of communication, culture and understanding are included within the cost-model; these aspects are fundamental within the above mentioned techniques e.g. networking and job-sharing. Training will often have to work within the confines of the current structure, as it will be dependent on variables such as the budgets available for development and implementation, e.g. training budgets are often cut more readily then other areas, as the benefits can be less tangible to account for [Patrick, 1992].

Selection, ergonomics and training have been stated as being beneficial when used in juxtaposition: If ergonomics are accurate, then it makes the job more simplistic and training easier; subsequently the rate of success for good results is increased. However if there are not suitable ergonomics in place throughout i.e. physical and metaphorical, then more mistakes will be made. A clear example of this can be seen with pilots: If instructions are logically situated within the cockpit, the users will be less likely to make errors then if things were positioned in a way which would not create a natural or direct use for the pilot. Similarly with selection criteria; when choosing practitioners if more time and attention with regards to the specific role against the selected candidate, then training can potentially be reduced [Craig, 1994].

With costing the physical ergonomics as such are less of an issue, due to the nature of the role. However the metaphorical ergonomics and the practitioner-selection are essential. What is meant by this is related to the 'knowing criteria' i.e. the 5WH which translated to KCs relevant to this research as discussed in Chapter 6, Section 6.3 and is referred to throughout Chapter 7. The KCs assist in the location and maximised use of data and information, which is a major part of the costing function. Selection implications are related to the knowledge-types required; see KTs in Figure 8.1. and which are individually detailed within Chapter 7: In particular, the technical / engineering knowledge and experience necessary to fulfil the PC role, and has been discussed in the former chapters.

In this thesis, although it is noted that the other points mentioned, of ergonomics and selection are important, the primary focus is upon training; as the knowing-categories [Collison and Parcell, 2008] has also been alluded to in Chapter 7 which discusses the essential knowledge of PC, and well as the previous chapters. This includes the point mentioned by practitioners, stating that certain pre-requisite knowledge and experience is highly preferable when entering a cost-role. The UK-based contributors particularly specified that a technical background was important for costing a product, discussed at length within the previous chapters including 4 and 6 which detailed the interactive research Phases 1 and 2.

## *8.2. ICKF Dissemination via Training Development*

With regards to the operalisation of the framework developed, training is the principal approach adopted within this research; within which elements of the prior mentioned operalisation techniques can be incorporated. The following statement emphasis the importance of training within the present-day organisational environment:

"Within the context of radical, dynamic change resulting from globalization and integration of businesses, corporations that turn out to be winners are those that adopt in practice and not just theory, to the fact that corporate training and development, (CT&D) is a vital strategic investment and not just a short-term expense: "A 25-year old graduate will have to be re-educated 8 times in the course of a 40 year career" (Odiorne and Rummler, 1988)."

[Odiorne and Rummler, 1988,
in Carayannis and Jorge, 1998 p.386].

This quote encapsulates the current state of the global market and the complex situations in which organisations are generally contending with. At company-level there is constant international competition for market-share, which needs to be continually addressed. Internally, organisations need to tackle their structure and processes implemented, to ensure their adaptability to the changing needs of the market. Adequate response to customer requirements and / or advances within the field are imperative, if the company is to keep within the competitive domain. At practitioner level, training-needs require regular assessment and revision to maintain their standing against competitor advances and to ensure adequate reaction towards the resultant pressures.

In order to maximise effectiveness, it is necessary for training and development to be kept relevant to the function and corporate strategy, with a structured design and execution, not simply implemented as a result of whimsically perceived or unfounded needs or 'fads' [Jackson, 1991]. In other words regular assessments of practice baring the company ethos in mind; followed by appropriate targeted training developments is essential, as opposed to implementing generalised, but widely published findings related to broad research trends. I.e. popular 'fads' or a current novel theory which whilst published, may have little evidence or short-term results linked to it.

Product costing is as susceptible to such pressures as any other element of the organisation. Organisational processes need to be flexible enough to incorporate modifications deemed necessary, to enhance performance. Practitioners require keeping abreast of the innovations within the field; and most importantly, having been obtained, corporate knowledge needs to be retained. The acquired knowledge must be disseminated between the experts, and onto the novices; it must be accessible for reuse, as required. This transferral across practitioners, and onto the novice, needs to be implemented on a cyclical basis, as it is formulated, and updated.

### *8.2.1 The Need for Training*

Learning has become a major priority in business due to a gap in the knowledge required by companies, against what the workforce has to offer. Adelsberg and Trolley [1999] explains that the gap between effective skilled workers against high and low performers in effect is at an extreme. It is close to being incomparable, with regards to the results and knock-on effects from either end of the scale, i.e. both good and bad practice [Adelsberg and Trolley, 1999]. Therefore training is merely a means to business ends. However, with this said many demands are expected of employees presently, within the general industrial environment. Carayannis and Jorge [1998] states that an entry level employee is not only required to posses specific knowledge and skills to address the work or tasks at hand, but also needs to hold a repertory of abstract knowledge that includes computing aptitude, leadership skills, teamwork qualities, ability to communicate, plus the willingness and capability to be mobile. This highlights the fact that product-costing is not the only profession that demands the utilisation of a multitude of skills and knowledge; and consequently attention to training needs, development, and the adequate administration of such is a pressing and more or less universal organisational concern. As higher education is among the entities that does not address all of these necessities, adequate, continuously updated corporate training and development (CT&D) is imperative, in order to survive what is being described as 'strategic global competitiveness' [Carayannis and Jorge, 1998].

Targeted training is essential for the continued high performance of organisations, the improvement of the workforce; and sustained, if not increased morale and motivation. Therenou discusses the possibilities of training motivation to the resultant benefits gained from the training; and also to participation [Therenou, 2001]. Not surprisingly the results supported the idea that training development and higher participation occurred when it was supported by supervisors. Coupled with this type of supportive environment, is the link that knowledge and skills gained from the training should be visibility associated with promotion, job security and pay.

Throughout the thesis the costing process has been dissected in order to reveal the components that it is comprised of. This exposure subsequently aids in the development towards the most effective training within this domain. For instance, if the elements that comprise the process are established, then tailoring training to address each relevant aspect can be achieved effectively, and as Goldstein and Ford [2002] plainly points out that although tempting, it is often futile to embark on training without having prior assessed learning needs [Goldstein and Ford, 2002].

This is particularly important for costing, as the research has shown there are a number of considerations to incorporate which stem from different disciplines e.g. economic and engineering; in conjunction with the social competencies which are required throughout the process. Therefore the formulation of assumptions about which areas are to be trained and which are not, determined without any type of TNA (training needs analysis) has proven to often result in deficient training from a number of angles including content, plus the areas or disciplines that the training has been targeted at.

#### 8.2.1.1 Current Industrial *Training* Analysis:

Prior to the development of any new training, the research examined current training schemes in order to establish their potential suitability, as defined against the costing framework. Ideally the existing material needs to incorporate the technical, economic and social issues inherent within the costing process.

In broad terms the training techniques observed followed similar patterns. These tended to stem around lecture–based modules; observation / shadowing and other types of SWN, (Sitting With Nellie) type training structures. These are valid techniques in themselves, having been repeatedly proven as effective: Lectures or 'instruction' is an established technique within educational and industrial teaching / training: Whilst the SWN method was almost universally adopted throughout the examined organisations. However within this industrial integrated cost-knowledge framework, ICKF, they were generally inadequate approaches with limited effects, commonly due to inconsistencies; as well as a lack of integration of the tangible and intangible aspects surrounding the costing-process.

The content of the courses had comparable traits, which is not unexpected due to the fact that they were catering for the same process, even if within different organisations, industries and countries. The majority of costing practitioners, approximately 90% of those examined were recruited with an engineering or technical background. This includes technical apprentices, which was a very common background for the UK practitioners: Typically two years within a technical workshop environment, and often included a section of rotation across the company to enable knowledge of a number of domains; and / or with workshop, manufacturing experience. A small minority were drawn from a financial background, with the majority of these incumbents notably within the U.S., though not exclusively. Verification of the practitioners' prior experience and basic training and discipline derivation is important, as it gives an indication of the direction in which the training being developed should focus on; see proceeding sections. The contemporary training observed within organisations included:

- Shadowing / Observation;
- On-the job training / 'Buddying'; being accompanied by a supervisor;
- Courses; primarily consisting of lectures / instruction which included a degree of video and technical slide shows.
- The subjects covered included:
    - Negotiational skills;
    - An array of Economic areas, such as Marketing and annual company-cost breakdowns;
    - Cost - techniques including ABC, parametric, traditional, FBC, detailed; see Chapter 3 for a full listing; summarised in Table 3.7.

Although a number of the companies examined had adopted comprehensive training programmes, these were often limited to technical and / or economic material. This tended to omit the social and interpersonal skills required for the regular interactions routinely performed; because as discussed in Chapters 5 onwards, these issues were not recognised within the industrial examinations as being of importance or explicitly affecting the process. For instance, there was little evidence observed of disciplinary functions being conveyed within an organisational, systemic context. This would give an idea of the overall procedures, highlighting where each process lay within the system; which would stress its function and importance as well as how it interacted with other departments both directly and indirectly. This type of training module would encourage greater communication across interacting domains, due to an improved understanding of the other processes, stemming from knowledge of the overall process and a subsequent appreciation of integrative working. This is broken down systematically within the combined eight knowledge types, discussed in the previous chapter, and related to the ICKF dissemination and resultant training implications in the following sections.

The information regarding what was currently embarked upon, and the training needs or current 'gaps' in knowledge was established via document analysis among other examinations of training presentations including course notes and practitioner interviews. Interviews, either personally, conducted on-site, or telephone interviews discussed the current training within each practitioners organisation against what they perceived as could be added, and why it was necessary. In addition trial workshops were conducted, with practitioner feedback about the content, how helpful it was and potential modification and / or validation of content. Appendix 4b presents this feedback form, with specific examples given within the relevant section in this chapter; whilst the questionnaire for part of the module development, namely the materials workbook section is given in Appendix 4a.

### *8.2.2 Training Needs Analysis, TNA*

The costing framework developed, see Figure 8.1, consists of themes and knowledge types related to the costing processes. A number of training implications result from this model, so a primary point of interest is to establish exactly which areas required formalised training, and which do not i.e. could suffice with informal: In addition to what format the training might take. This type of analysis is crucial, as it has been noted that training-development can often be attempted with a lack of such a training-needs study or assessment. If the training needs are not assessed well enough, a number of challenges from the resultant training will emerge, as discussed by Goldstein and Ford [2002].

#### 8.2.2.1 A Systemic Approach to Training

Training is treated as part of the system of learning and interacts with organisational needs and direction [Goldstein and Ford, 2002]. A systems approach focuses on the interactions and relations between each aspect of the holistic contributor to the whole; as discussed in Chapter 5 in the systemic thinking Section, 5.7.1.

When considering the introduction of any training intervention, a systematic approach is commonly employed towards the design of programme, as shown systemically in Figure 8.2. This type of framework provides a suitable way of undertaking training, due to the fact that it can be generalised in order to be applied across functions, companies and even industries. Patrick [1992] states that a systemic approach is useful as:

*"It enables us to ask searching questions concerning what a system is trying to achieve and what functions have to be performed for this to happen"*

[Patrick, 1992, p109].

This is in addition to highlighting the vital links between the contained subsystems. Training and a number of Learning and Instructional Systems Development (LSD and ISD) are discussed within the training literatures. This logical and almost simplistic approach, illustrated in Figure 8.2 allows feedback from the evaluation stages, back into the needs and design of the programme; which can be implemented, evaluated and attuned cyclically.

Such a systemic approach which starts with the identification of what training is required determines the real training needs which exist in an organisation or department. Without a systematic, logical and formalised approach to TNA, training could be provided unnecessarily. For instance it may be unsuccessful in transference to the work environment; the timing may be incorrect, so it is not of maximum (or any) benefit e.g. too early or late to be of use. It may result in a general blanketed imposition, as a tokenistic gesture, without appropriate consideration of its intention or need; and its resulting value. For example it may result in a superficial 'box-ticking' exercise or simply a requirement of the company; and consequently may be undertaken as a formality, as opposed to a beneficial need. Therefore some description of evaluation which can identify the actual needs accurately, is required. This includes an assessment to determine the most suitable time to deploy the training, and at whom it is aimed at.

The training needs identification links to the knowledge of the practitioners; the previous chapter outlined the specific knowledge requirements within costing, therefore the TNA can relate directly to these areas and assess which are lacking. The implementation of training may involve interacting disciplines in order to address previously highlighted challenges such as understanding communication and culture knowledge and themes. With the evaluation phase assessing how beneficial the training has been, discussed in following sections; and re-evaluating the various approaches taken, depending on their success; see Figure 8.2.

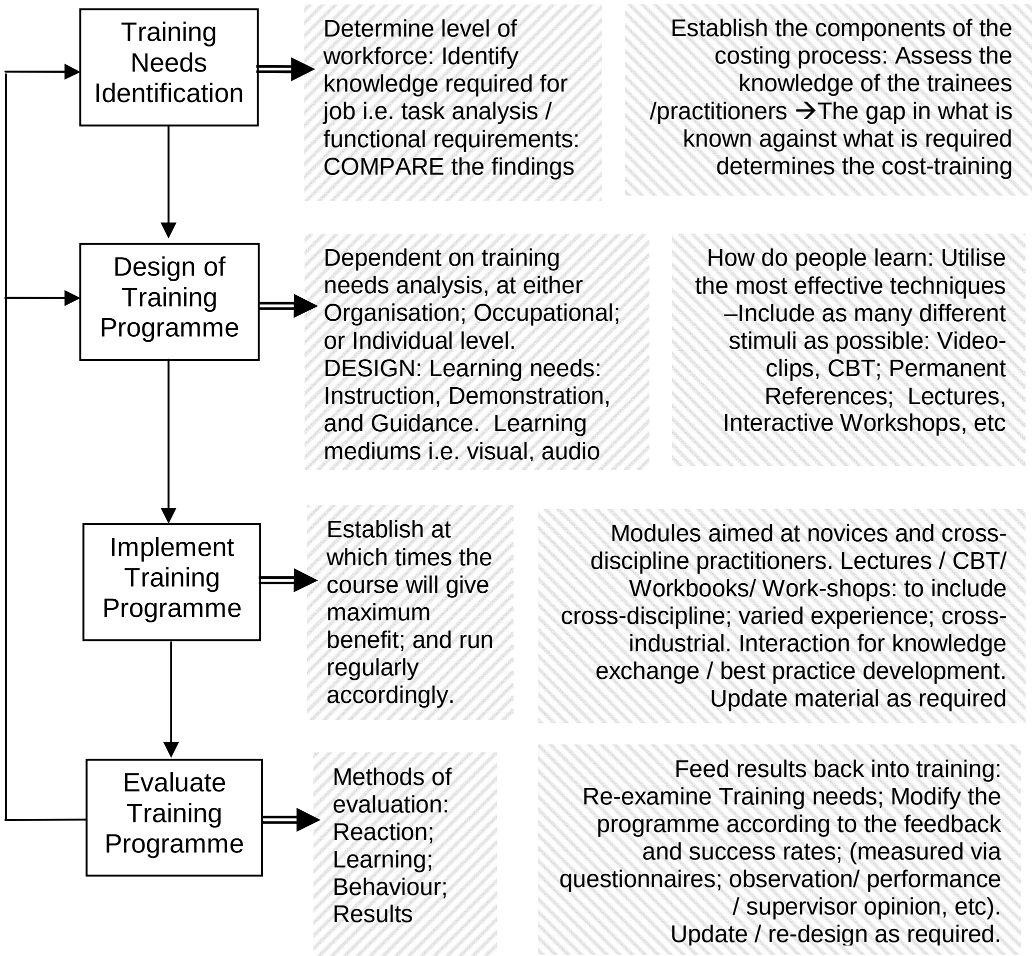



Figure 8.2: A Systemic Approach to Training, highlighting specific Costing Relevance and Adaptation

TNA is generally considered on three conceptually distinct levels: Organisational, occupational, and personal; see proceeding sections. At organisational level this will confirm that a training intervention is the most appropriate action, and allow the occupational and personal analysis to be placed into the organisational context [Goldstein and Ford, 2002]. As mentioned in the earlier sections, at organisational level training is one, among the options available for improving workplace performance and / or well being. Procuring the most appropriate individual for the role can be focused at the selection stage; as well as using training material for such use. The social and physical work-environment alternatively can be centred towards adapting the role to the person. Within costing these, and potentially other techniques could contribute towards the operalisation of the, i.e. job-share and networking; discussed in Sections 8.1.1 and 8.1.2. However within this research these appear to be most advantageous when utilised in conjunction with a structured training programme.  It can be noted that selection criteria could play a larger part in shaping training requisites; though this can be scoped more within occupational level TNA analysis, discussed in the proceeding sections.

#### 8.2.2.2 Organisational –Level Analysis:

Within an organisation, training may be instigated as a result of either a calculated, specific strategic finding; or on more of a reactive, adhoc basis, in response to a specific need. To elaborate, the latter approach will be to react to one specific area, e.g. a manager happening to notice an employee is struggling in something, or individuals make it known that they would like or feel they need training in a certain area. Therefore training in response to the observation or request is embarked on, hence the adhoc nature. Alternatively an overall organisational move may be made towards a form of training for a specific, pre-assessed need, e.g. a new IT system may be put into operation across the company, so training will commence with regards to familiarisation of it; or the organisation may decide to implement a new division or expand on its current range of product, which will involve certain training within relevant areas, hence the strategic reference. These approaches are not mutually exclusive and can be very successful when used in an integrated manner. For instance when fortuitous training occurs as a move towards a long-term strategy which the organisation is adopting, [Mintzberg, 1987, cited in Blanchard & Thacker, 1993]. ‘Leaner Thinking’, or increased global dealings are examples of strategies in where the companies examined have made attempts to implement policies and modify behaviour on an organisational scale. These two examples are among the situations in where cultural changes within the company have been focal. Others include acquisitions and merges of organisations, with a significant minority of the manufacturing companies examined having experienced a number of such developments. This type of restructuring was often accompanied by a number of humanistic concerns, including branding or company loyalty, and ranking issues observed in this research within a number of the merged organisations. As well as equal opportunity instillation; see cultural knowledge and themes Chapters, 6 and 7. Hence analysis at an organisational level is a feasible approach to TNA.

#### 8.2.2.3 Occupational Analysis:

Occupational level analysis, also referred to as ‘operational level analysis’ in some literatures, focuses on the components of the job-function, in order to tailor the training to it. This type of training which focused more specifically on the role, is more prominent then organisational type mentioned previously. In order to undertake such training, analysis of the function / job is essential, as the specific components are key aspects and shape the resultant training developed in order to produce skills and knowledge within that particular occupation.

Within this research, the costing process has been assessed across 24 organisations, refer to Table 6.2 in Chapter 6. Therefore the main elements which reoccur within the process have been identified, satisfying the job-analysis criteria for product-costing. Having identified the components within costing, the knowledge required to perform the process has been documented; see Chapter 7. Thus both interacting constituents have been addressed: The role and person to perform the role. An awareness of the essential knowledge types involved and the main themes of costing allows the gaps which need training and reinforcement to be exposed; and therefore addressed.

This is clearly a functional or occupational level analysis and approach to training development. There are occasionally situations in which occupational–level training is limited, as every member of the organisation requires the training; however these are evidently not related to any specific process or function. They are as stated in the previous Section, (8.2.2.2) where all are deemed to benefit from the general issues being adopted, regardless of specific roles; often in relation to organisation cultural change-endeavours or systemic strategic moves [Blanchard & Thacker, 1999].

### 8.2.2.4 Personal Level Analysis:

Personal level analysis centres on the selection of individuals who are to receive training, as opposed to involving an entire group, discipline or department. In these situations, each individuals' level of knowledge and competency will need to be assessed in order to determine who will benefit from the particular proposed training. However such micro-level analysis may not always be required; for instance team expenditure may be sufficiently justified by means of occupational analysis. In such circumstances it is desirable to train the entire group, regardless of the level of competencies held by individual team members. Conversely within costing, the research has observed that new members to the cost-functions often arrived at intervals, and therefore were unmistakable candidates for training, being novices to the process even if not to the industry. Therefore there are a number of different levels at which such individuals can be placed into. A novice can be new to the department, but familiar with the organisation, if they have transferred from another area, internally. They may subsequently be from a different or sub-discipline of costing e.g. purchase, financial or from one of the engineering / manufacturing domains such as the development of a specific product line. Alternatively the novice may be new to the organisation; and / or the industry; and even new to the overall work environment, being a technical graduate or apprentice without prior work-experience. Therefore spectrums of experience prior to commencement within the costing function were observed to vary widely, organisation-dependent. This would call for quite targeted personal analysis in some cases even though the superficial need for training will be apparent, the level and types of which, will require individual appraisal.

For complete novices, on-the-job training, shadowing and observation were the most common method of company training across the board. It could be noted though that novices and current costing-practitioners would often need select training, not requiring it for every aspect of the process. With this view of the novices and practitioners, it makes sense to direct training towards the individuals who will gain the most from it. For instance if a cost-novice has transferred from an engineering department, and has low awareness of financial issues, then these are the courses which the practitioner should undertake. Alternatively if an individual has insufficient materials knowledge then training can be attended in this area. Often the background of the practitioner can indicate the areas of need, in conjunction with their performance on-the-job; and occasionally even self-assessment will suffice, with regards to specific areas such as the materials example given. However it was often observed to be the supervisor / manager who determined the training needs.

With regards to individual versus occupational / organisational TNA, there are resource and motivational issues which arise from training practitioners who are already competent; making the appropriate assessment for specific candidate training even more consequential. Although the cost-training proposed for development will focus on all the eight knowledge-types identified as essential (see Chapter 7), it will be designed in modular form. This will enable personal level adaptation to allow specialised areas to be focused upon, whilst not wasting resource and time on the aspects already known by different individuals. Thus the training will be adaptable to the needs of a variety of levels, adequately catering for the variants observed across the costing community.

### 8.2.2.5. An Integrated Costing Approach to TNA:

Although there are elements distinct to each of the above areas of training-derivation such as the affects of organisational strategy that will influence TNA; the specifics occupational needs that will not apply to other disciplines; and the particular focus of an individuals areas requiring improvement, a combination of factors from each contributes to this cost-training. Companies are continually changing, for instance through unifications; this is a reality across business, with the organisations examined not exempt from this; a number had experienced such occurrences including JLR. Therefore the overall thinking or culture within the organisation will modify per merger. Companies are operating in an increasingly complex and global market and with such expansions also follows a cultural change of environment, according to new policies and working practice to accommodate and reflect the new visions and aspects of the organisation. This metamorphic environment was experienced in the research, as there are ever increasing global partners, suppliers / contractors and customers to interact with. This expanding international mode of working or 'working culture' includes data gathering with regards to costs, where individual components of product may be manufactured, designed, imported from other countries; all such costs need to be ascertained. Suppliers may be global; as is the consumer-market which requires an awareness at a company-level, i.e.  highlights the organisational aspects prevalent within the costing process.

A way in which conglomerates can maintain updated working practices among such expansions and changes to the working environment is via current training made available to its employees as and when it is required. Attention to the maintenance of such training, and its attendance, is necessary e.g. time must be allowed in order to attend the courses deemed important. For instance within product-costing, a working alliance may be formed with an overseas supplier who has not been used before, who are based in a country with a substantially different culture, and therefore possibly very different working cultures. In the event of such an alliance training and information with regards to the background, practices and priorities should ideally be provided, in order to raise awareness within the costing-community about what to expect and how to maximise effective working relations. I.e. to obtain the most cost-information, to inform of any common translational issues; as this will save time, promote integrated working and a lateral transfer of costing information and knowledge within a harmonious, open working-environment, where both parties understand each other. In relation to supplier translational miscommunications, an example of miscommunications and lack of comprehension was conveyed from a large, international automotive conglomerate: A cost-practitioner wasted time by repeatedly not signing off a work-order for a piece of equipment which he had understood to be machinery (supplier cost), not tooling (customers' cost). It took the assessment of a more experienced practitioner to identify the misunderstanding and rectify the confusion; see Chapter 7, Section 7.4.1.6 for a detailed account of this example. Training with the intent of raising cultural awareness would have avoided the time loss of such an occurrence; not to mention the incidences which may not be resolved so directly, possibly creating discord or permanently damaging trust, and consequently the level of interactive working between the relevant parties.

The individual-level of analysis is as mentioned with novices and cross-practitioner knowledge and competencies requiring assessment, then training to develop in compliance with the needs of the role: Linked to this is occupational level analysis. The costing process has been established and the individual knowledge types required has been designed into a training framework, as deemed relevant by the industrial-experts, detailed in the proceeding DIF analysis section.

It has been stated that task analysis protocol has allowed managers to observe highly skilled workers, and identify the precise activities required to perform the variety of jobs performed in manufacturing, [Gael, 1988]. Once a specialisation and its components had been analysed and documented, it could be utilised to aid in the training of the domain novice, [Clark et al 1997]. Prior to this job breakdown, training was undertaken almost exclusively by observational, on-the-job learning, in conjunction with formal apprenticeships. This type of shadowing is firmly established as a primary form of training within industry. However although it has a degree of success, there are a number of detrimental aspects to it which should not be overlooked, especially as it is so widely implemented. On-the-job type training can be:

- Time consuming: It is effectively one-one training, so involves another experienced practitioner.
- Inconsistent; as it is often not a particularly formalised process, so tends to cover whatever happens to occur on-the-job, when the novice is in attendance.

SWN, Sitting With Nellie is a term derived which refers to the observational, on-the-job techniques of training. As listed above SWN is not only a time consuming method of learning, as it requires a fully trained practitioners continued time, along with the trainee; but without standardised procedures, inconsistencies in the training outcome would inevitably occur. This is due to the fact that SWN -types training techniques including shadowing, are often informal practices. Though considered effective and commonly employed, other more standardised training is also required: These can be used in conjunction with SWN.

Prior to embarking on proposed training, it was considered relevant to establish which areas of the costing process were perceived as requiring some type of formalised training, against those which could suffice within this informal approach (SWN). For this purpose, DIF analysis was implemented: It is a subjective technique, which allows flexibility for practitioners of different organisations and industries to contribute, whilst being able to directly compare the results in a straightforward manner. The procedure allows all elements to be taken into consideration, whilst the most consistent industrial outcomes can be adhered to.

### *8.2.3. DIF Analysis:*

The tasks within PC have been analysed and detailed within Chapters 3 and 4. The main themes which emerged from the industrial examinations have subsequently been investigated, and are discussed in Chapter 6, having been supported by the social and human factors researched and fundamentally presented in Chapter 5. An amalgamation of these themes, in conjunction with the components of costing, were effective in determining the primary knowledge-types within this area (Chapter 7); which leads aptly into the domain of the propagation of the developed cost-model or IKCF in turn leading to training implications for the cost domain. Refer to Figure 9.3, in the following chapter, which pictorially links the cost-model of themes, KTs and training.

As a consequence of the identification of the need of some form of industrial dissemination for the ICKF, and the focus resulting on the evolution of innovative training programmes, the previous section then discussed the training needs analysis, TNA, in a more philosophical and generalised way in preparation for these training developments. This section deals with the specific training needs of costing process, and describes a suitable quantitative technique of analysis, with direct in-put from a range of costing practitioners, across a number of industries. The main technique employed to help determine the content and design of the proposed cost-training material was DIF analysis. In conjunction with DIF were interviews, workshops, questionnaires for specific areas of training development, such as the materials workbook and documentation / organisational analysis of current training methods and perceived needs.

DIF is fundamentally an assessment of the difficulty, importance and frequency of primary aspects within the cost-domain, as determined by the cost-practitioners in this instance: Its outcome contributes largely to TNA, which may then be embarked on accordingly. Though the results of this technique may be quantifiable, it is definitely more of an art then exact science, as explained in the proceeding sections.

#### 8.2.3.1 The Theory of DIF:

As all of the identified knowledge types (KTs) were deemed essential for the process of costing, discussed in Chapter 7, see Table 7.4; and Figure 8.1 for an illustration of the integrated cost-model, the next point to confirm was which, from the spectrum of KTs, required formalised training; and which, if any, were perceived as sufficient with informal. DIF analysis was considered an effective technique for this purpose. DIF denotes Difficulty, Importance and Frequency [Buckley and Caple, 1995]: The levels of these three points as judged by the practitioners, were used in combination to gauge the training outcome for the costing process. DIF analysis was selected for TNA, as it appeared to be a technique which was general enough to be able to cater for the costing practitioners across a range of industries: Whilst still producing a useful indication towards particular cost-aspects that the practitioners determined as in need of training.

The way in which the DIF analysis technique is executed was very straightforward, acting as further positive validation in its selection for use within this research. The experts simply need to judge whether each aspect in question has a ‘high’ (H) or ‘low’ (L) value: For example the level of difficulty is either determined as H or L; how important it was, high or low; and how frequently it was required, again, either high frequency, or low, as described in Table 8.1, with actual industrial response examples contained in Table 8.2. The results of the contributors’ answers lead directly to the training analysis with use of the grid shown in Figure 8.3.

Table 8.1: DIF Analysis for Training Selection Criteria, with Costing-Relevance Adaptation:

| | | | |
|---|---|---|---|
| **D** | Difficulty | Difficulty in learning / performing task. | E.g. The difficulty for costing, may also lie in the location / procurement of data / information |
| **I** | Importance | Level of criticality of task to job performance; or consequences of error | E.g. Cost implications including added expense if errors are made; or cost estimates are inaccurate or delayed. |
| **F** | Frequency | How often task has to be performed | E.g. Is it only performed at the beginning of project; or required throughout? |

Before further examination of the subject, it must be noted that when discussing the matter of training requirements for various areas, there are certain elements which are considered achievable via informalised, less structured training techniques. In others words, although a novice may initially appear to require some degree of training towards all aspects of the job or costing process, it is often assumed that a certain percentage of the role can be mastered via observation, or some type of informalised, tacit progression. This is often developed through on-the-job training processes e.g. SWN, as discussed in Section 8.2.1.1 and Chapter 6; plus later in this chapter. For instance a degree of contact and communicational knowledge regarding the most experienced practitioners within the department, and hence of whom may be of greatest assistance when seeking various cost-information or knowledge, may be revealed by means of observation and simply taking mental notes of whose expertise is within which domain. Informal interactions including something as seemingly straightforward as a conversation are invaluable for novices in ascertaining such points for future reference. Therefore, though it can quite be feasibly inferred that such activities are new to the trainee, it can be assumed that an unstructured approach to the training will suffice in gaining competence with activities placed into this type of category.

#### 8.2.3.2. Application of DIF Towards Product-Costing: Knowledge Assessments

This section of data-collection was the final validation phase that required direct industrial input. The results of DIF were used as validation for the other phases of research. These included the interviews, questionnaires, document analysis and training examination conducted within organisations, towards the training proposals.

The way in which DIF analysis was applied towards the specific research area was directly related to the knowledge types identified, discussed in Chapter 7. Therefore for the DIF feedback each of the eight knowledge types were broken down into appropriate, related functions i.e. points that had been classified as activities within each main knowledge-heading, as within Table 8.2. The eight main headings subsequently had between four and nineteen sub-headings. An example of how the knowledge-types were sub-divided is presented in Table 8.2. Here, a list of costing–related activities within the knowledge of the Costing Process is presented, with a sample of typical practitioner responses. Table 8.2 gives an example of one KT completely; but for a more detailed example of the full DIF results of all eight KTs, refer to Appendix 10.

The contributors towards this part of the research, i.e. the training requirements, P2-C as depicted in Figure 4.1, are listed in Table 6.2, Chapter 6. The practitioners were asked to evaluate each subheading as to its Difficulty (D), Frequency, (F) and Importance (I); to be assigned either High or Low values. The contributors were given loose guidelines regarding the parameters of judgment per section, though were largely left to determine the results based on their experience and informed opinion of each sub-section. Table 8.1 highlights the guiding principles which were specified, under which the high or low values were to be determined. Table 8.2 presents a typical representation of the feedback received from the DIF exercise in response to the knowledge of the costing process. As can be seen, there have been a number of comments made supporting the final choice, of either high or low; though not every contributor gave particularly extensive reasoning behind the selections, occasionally opting to denote the basic judgments alone.

Table 8.2: An Example of DIF Analysis Industrial Response, Regarding a Selection of the Components Encompassed within the Costing-Process KT.

***1. Knowledge of the Costing Process:***

| ACTIVITIES / Functions | Difficulty | Importance | Frequency |
|---|---|---|---|
| | HIGH or LOW | HIGH or LOW | HIGH or LOW |
| Direct Costs | LOW<br>Comments: Fairly straightforward for single tiered contracts | HIGH<br>Comments: Large contributor to overall cost | HIGH<br>Comments: Particularly in long projects. |
| Indirect Costs | HIGH<br>Comments: Difficult to understand indirect costing standards | HIGH<br>Comments: Can have a large impact on costs, particularly for specialised products | LOW<br>Comments: Unstable business base and frequent order changes may influence costs more frequently than for stable, low volatility businesses |
| Supplier cost breakdown | HIGH<br>Comments: Programmes with multi-tiered structures may have a very large number of tiered contracts, particularly in spacecraft. | HIGH<br>Comments: Multiple levels of suppliers may have large fee components to overall project cost | LOW<br>Comments: Tend to be more stable |
| Overhead Allocation | HIGH<br>Comments: Difficult to understand indirect costing / overhead accounting /can vary per project | HIGH<br>Comments: Large effect on costs | LOW<br>Comments: Usually once throughout project |
| Logistics (-overseas or not?) Difference in costs | HIGH<br>Comments: | HIGH<br>Comments: | LOW<br>Comments: Not required often, usually determined early in project |
| Legislative Effects | HIGH<br>Comments: If pollutants, contaminants or radioactive materials are involved. Difficult issues with International Trafficking and Arms Regulations (ITAR) and Export Licensing. | HIGH<br>Comments: Can add significantly to schedule. | LOW<br>Comments: Infrequent |
| Annual cost breakdown | LOW<br>Comments: Fairly straightforward; (company can provide) | LOW<br>Comments: Important for programme budgeting process | LOW<br>Comments: Conducted annually |
| Depreciation | HIGH<br>Comments: | LOW<br>Comments: | LOW<br>Comments: Conducted once throughout project |
| Competitive pricing | LOW<br>Comments: | LOW<br>Comments: | LOW<br>Comments: |
| Product profits -future trends of market | LOW<br>Comments: Data is easy to obtain and regress. | HIGH<br>Comments: | LOW<br>Comments: Depends on type of product. Software (low) Electronic hardware (high) |
| Market trend knowledge and information | LOW<br>Comments: seen more to be remit of buyer (not estimator) | LOW<br>Comments: | HIGH<br>Comments: Depends on type of product. Software (low) |

| | | | |
|---|---|---|---|
| | | | Electronic hardware (high) |
| Outsourcing Vs In-house development (-cost of developing long term, or short term gains by paying outside companies) | LOW<br>Comments: | LOW<br>Comments: | LOW<br>Comments: |

The practitioners were asked to respond to each of the eight KTs, which were represented in separate tables; and example of practitioner response to all eight is given in Appendix 10, including additional comments. Table 8.2 gives only an example in respect to Costing Process knowledge, but showing how each KT was sub-divided into specific attributes, against routine industrial activities related to them. This technique allows the collaboration of the various activities under each main heading to gradually build up a general composition of what formulates each knowledge–type. The primary significance of the area is also more comprehensively derived via a median of the compilation of all inclusive judgments made. Thus when a spectrum of functions within the KTs have been considered, the dominant value can be ascertained; as opposed to it being considered within a specific, and thus more limited context. In other words instead of just asking for the DIF assessment for the cost-process knowledge alone, in this example the KT has been split into 13 different activities performed within that knowledge heading. A compilation of the responses to all 13 points subsequently provides a more accurate assessment of DIF for that KT. Evidence is also given in Appendix 10 via practitioner response to the other KTs; which as mentioned earlier all had a number of subheadings per KT, both broad and specific. Hence when asking more generalised questions, the respondent may defer to one isolated area of the KT in attempts to make the answer relevant to their experience. Otherwise if the queries are too specific, they may not cover the full range of activities contained within; either way resulting in an incomplete or bias response. Therefore gaining feedback about a range of functions within each knowledge-type produces the most comprehensive insight with regards to each of them and the resultant training required.

### *8.2.3.3 TNA Deductions:*

Once the data had been gathered from the participating organisations, see Table 6.2 in Chapter 6 for list of contributors; it was analysed: The comments were considered individually. However the way in which the immediate values were assessed was with use of the grid shown below in Figure 8.3. The high or low valuations placed against each sub-section within all eight tables were analysed as per the matrix in Figure 8.3: The use of which is evident, when following the indicators, as dictated from the results (H or L) within the DIF analysis configuration. The outcome of each activity could plainly be determined, and the most dominant per KT resulted in the training outcomes for the area; Table 8.4 presents the final results.

#### *8.2.3.3.a) The Outcomes from DIF Analysis*

The outcomes of DIF are presented in Table 8.3, resulting in either ‘Train’, ‘No Train’ or ‘Over Train’. To elaborate on these terms, if ‘Train’ emerges, this is quite straightforward: It indicates that some form of structured, formalised training intervention is required for the area in question. Therefore if the option of training occurs, this means that the knowledge type should have a training programme designed and developed for it. This can then be undertaken in accordance with the requirements e.g. its prominence and timing most advantageous for the success of the training material.

If the outcome is 'No Train' this does not in fact imply that the area does not require some form of training; but instead is indicating that a more informal, unstructured approach would suffice. This may be in the form of observation, shadowing, and other similar forms, known collectively as 'Sitting with Nellie' SWN; referred to earlier within the section (8.2.3.i). SWN is fundamentally an informalised mode of training, where the novice will basically learn directly from the more experienced practitioner within a work environment. This type of technique has already been noted as being favoured within industries. On-the-job training was found to be commonly employed and held in high esteem by the contributing practitioners, as an essential component of the training process. SWN is discussed further, later in the chapter when considering the specific proposed cost-training formulations.

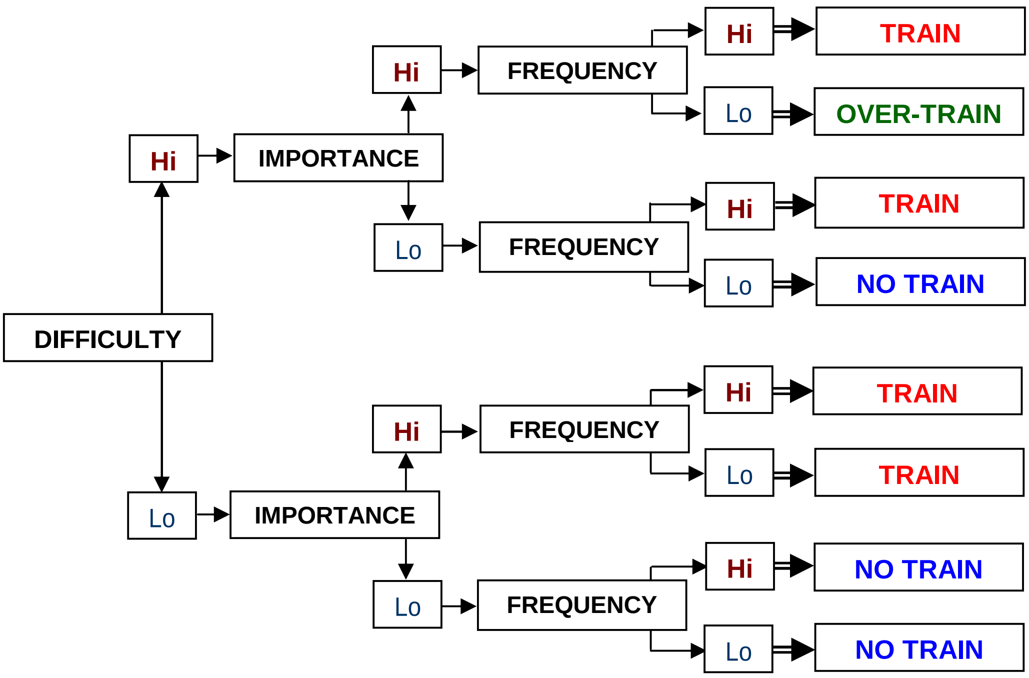



Figure 8.3: DIF Analysis; A Technique to Determine Training Needs
[Adapted from Buckley and Caple, 1995, p86].

The final option emerging from DIF may be to Over-Train. This basically signifies that the area in need of training must be able to be performed adequately at all times. Therefore the recommendations are that training should continue even when the trainee has reached a sufficient level of knowledge and competence towards the tasks. This need tends to occur when the activity is deemed to be of high importance, but is utilised infrequently. Thus the general principle behind over-train is focused upon reinforcement, so that the implementers do not forget what is required, due to a sustained absence or substantial breaks in-between performing the required procedure.

An example of such a task can be seen in safety critical issues, including first aid activities. Often first aiders are obliged to be re-trained at specified intervals, in order to maintain and update their skills. This is because, although they are rarely utilised in routine situations, on the occasions when they may be required to implement them, it is clearly essential that they are able to carry out the learnt skills to a proficient degree.

Table 8.3: Elaborates on the Range of Outcomes from DIF analysis:

| ***TRAINING DIRECTION RESULTING FROM DIF ANALYSIS:*** | |
|---|---|
| *NO TRAIN* | No formal training required: SWN variant methods will suffice. |
| *TRAIN* | Requires a form of structured training intervention:<br>i.e. the development and implementation of training is necessary. |
| *OVER-TRAIN* | Training continues beyond the trainee reaching competence in the area: To continually reinforce the requirements / knowledge needed to perform the task(s). |

In theory such occurrences could happen within a costing situation, as practitioners have commonly stated that they frequently work under time pressures which can create a sense of urgency. Such situations will occur whilst they are expected to be performing to a high standard, being able to draw on techniques not regularly used, if required; and still be competent in using them. For instance rules and regulations with regards to toxins and gas-emissions and the associated costs may only need to be cited, and included within the costing-analysis once per project, possibly within the overhead allocations. However, it is important that such information is known including the awareness of updates, to incorporate into the costs; particularly with government-related projects e.g. in the aerospace industry: As lack of such knowledge will result in escalated, unaccounted costs and potential penalties if overlooked until the later phases. This is one of the many examples that may only need assessment once throughout the duration of the project; however their cost-impact is high, as is the implication of omission i.e. forgetting to include them or inaccurate assessment. Hence their importance is high, even if the frequency of use is low; and the difficulty level may be considered high, if it is in relation to a complex system and / or which regularly changes so may be difficult to obtain and maintain accurate, current information regarding the area. Table 8.3 lists the three potential outcomes of DIF, and what each one signifies.

### *8.2.3.3.b) Cost-Training Outcome:*

The outcome from the DIF analysis for the eight knowledge types are presented in Table 8.4. To summarise how the content of this table has been derived:

- The individual industrial contributors as specified for P2-C research, can be found in Chapter 6 listed within Table 6.2.;
- Each participating practitioner when through the eight KTs, considering them separately;
    - Which in turn had been subdivided into specific tasks which comprised the KT;
- They gave their assessment of whether DIF was high or low in each case;
- Refer to Table 8.2 and Appendix 10 for the supporting evidence of this part of TNA;
    - A noteworthy point is that these examples have been presented within the thesis;
    - However it was impractical to include the raw data for all KTs from all contributors;
- The results were then converted directly to training needs;
    - Via the grid presented in Figure 8.3.
- Evaluation of the raw data via this grid resulted in an almost unequivocal determination of training needs;
    - Which is fundamentally why this method was selected i.e. due to its straightforward nature;
- Each KT could therefore be evaluated for training requisites;
    - Results of which are listed in Table 8.4.

Within Table 8.4, the Training Outcome column shows that the decision of 'Train' noticeably applies to the entire list of KTs, with two broader-line over-train classifications, which fundamentally signify that formalised training is required. The table also shows the average results per criteria of Difficulty, Importance, Frequency; these are the median of the raw data, prior to grid analysis (in Figure 8.3). Table 6.2 show that these results were derived via feedback from a range of industries including aerospace, automotive, food, manufacturing with contributors from the UK and USA; so have been deemed as being of a comprehensive and wide enough level for this study.

A complete TNA result of 'Train' gives a certain degree of contemplation for the costing community, in where it may re-evaluate its traditional perception towards the attainment of proficiency and skill within this field. Across industries, it was observed that the emphasis of the costing practitioners' knowledge, competency and skill-level tended to be placed on experience or judgment of the costs towards any given component, project, or product. This research has to a degree observed that product-costing is perceived as a technical, physical domain; this perception seems principally due to the widely observed pre-requisite knowledge requirements of a technical background for entry to the costing domain. Hence PC appeared to be founded in ostensible 'hard' issues. However an attitude adopted towards the acquisition of the essence of its fundamental level of expertise, transpired as overwhelmingly evolving from intangible, 'soft', tacit elements. I.e. the training focused on SWN-type approaches including observation, on-the-job training or learning-by-doing; discussed in Section 8.2.5. In other words the tangible elements which largely comprised PC where broadly accepted as being learnt and adopted via intangible, generally immeasurable means through the manner that it was trained.

Therefore, the result as it stands of TNA via DIF in this research, conversely bestows an unequivocal direction of all individual components within the costing process; and subsequently from a holistic view the need for explicit, tangible direction e.g. formalised training within all areas identified as fundamental to the costing process. This position delivers clear indication that there is the opportunity to impart costing-knowledge and expertise with the use of structured training to a degree, in conjunction with the more established, traditional on-the-job procedures.

Table 8.4: Total Outcome of DIF Analysis,

Including the Average per Individual Components of DIF.

| **KNOWLEDGE TYPES:** | **AVERAGE** | | | **TRAINING OUTCOME:** |
|---|---|---|---|---|
| | **D:** | **I:** | **F:** | |
| Costing Process | H | H | L | (OVER*) TRAIN |
| Manufacturing Process | L | H | L | TRAIN |
| Knowledge of Design | L | H | L | TRAIN |
| Knowledge of Materials | L | H | L | TRAIN |
| Product Knowledge | L | H | H | TRAIN |
| Knowledge of Risk | H | H | L | (OVER*) TRAIN |
| Communicational Knowledge | L | H | H | TRAIN |
| Knowledge of Culture | L | H | H | TRAIN |

Although the TNA has classified all components of costing as being in need of formalised training, the actual training proposed will take into account the strong opinion held within the industrial sectors, regarding the intangible aspects towards achieving cost-expertise and 'know-how'.

Subsequently the resultant training will in fact be complimentary to this viewpoint, endeavouring to encompass SWN techniques, and learning via direct expert-novice interactions and communication. A large factor of the proposed training programmes will focus on techniques which ultimately promote knowledge capture and transfer via direct interpersonal strategies. Refer to later sections which include proposals towards the cross-experience practitioner and interactive workshops to laterally exchange cost-knowledge. This type of targeted training tailored towards specific cost-training needs as identified throughout the research, has the intention of facilitating improvements regarding the speed, quality and level of novice performance within the costing process. It will also assist in enhancing the current expertise and practitioner ability through addressing the current inadequacies identified in costing. The holistic training will develop through means of incremental training-design which will address each element of the process and knowledge required. This will enable specific training requisites of individuals to be catered for; as they will be able to select areas which they are less knowledgeable / experienced in, and undertake the training for it. Such targeted training ultimately will advance the overall practice of costing through improvements with procedures and interactions among others. Plus it will enhance the knowledge of the practitioners working within the area; discussed in detail later in the chapter.

In order to address the range of KTs in the training, the programmes will be designed to incorporate the ‘soft’ and ‘hard’ issues within costing through sessions such as interactive learning, group workshops and other techniques designed to promote communication and interactive learning i.e. knowledge transfer between the participants. This will add value for the novices, plus expand on the knowledge of the more experienced practitioners attending the course. These training techniques will be in addition to the more traditional methods including lecturing or instruction and demonstration; (see Section 8.2.5 and 8.3.4): The development of a multi-method training programme is proposed as being the most beneficial approach towards addressing the spectrum of costing aspects.

#### *8.2.3.3.c) Validation and Rigour of the Cost-Knowledge Model*

The DIF analysis within this research has been based on the finalised 8 knowledge types, which have been detailed in the previous chapter; also refer to Figure 8.1 for their incorporation into the overall cost-model. Prior to these concluding results, DIF had been performed on the initial set of KTs which were subsequently refined, basically from a draft version of 10 [Mishra et al, 2002b], to the eight essential knowledge types used within the ICKF. See Appendix 9, for reasoning behind the finalisation of the KT list; plus specifically Section 9.6 for the TNA implications attached to them.

DIF analysis was partly utilised within this research as a validation technique. The eight essential knowledge-types were determined via conclusions drawn from the first, but primarily second phase of research, discussed in Chapter 7. The areas of knowledge contained within the final selection are there due to their invaluable contributions, necessary in conducting the costing process. Though the combined areas of research had already established this, it could be further validated via DIF; if they continued to emerge as consistently essential throughout the approaches within all the research phases. The results in Table 8.4 show that each of the identified KTs are considered by the experts as in need of formalised training.

As well as the overall training outcomes, Table 8.4 contains a more micro-level of analysis, with the average of each section of DIF per eight KT, prior to the grid-analysis, in Figure 8.3, being displayed. What is noticeable due to its consistency, is that 'I' (Importance), has on average emerged as a High rating, universally. The other areas of assessment are less uniform in the practitioners evaluation of them i.e. Difficulty has two KTs which are high, and frequency has three. However the fact that the Importance of each of these knowledge's was deemed on average, as high in all cases, reinforces the unequivocal value of each of the essential KTs within the costing process. This validates the costing framework, even further; as diverse angles of testing prove consistent outcomes, of all 8 KTs being important, making the ICKF increasingly credible.

With regards to the variations towards the approach of analysis of the data, it can be seen that if the average of the individual components of DIF were utilised per KT, prior to each being assessed via the grid and then deriving a mean. The outcome then of the average D's, I's and F's per KT, when processed would emerge as a mixture of two training propositions. The 'train' result would be mixed with two 'Over–train' outcomes, which have been denoted with an asterisk (*) in Table 8.4*, which would fundamentally still enforce the need for formalised training in all areas. In other words which ever way in which the results were analysed, the main outcome remained constant, namely to develop training for all eight knowledge-types; see Section 8.2.3.3.e) for further discussion on this specific observation.

#### *8.2.3.3. d) Costing-Result Validated Expectations:*

Table 8.4 is not an unexpected outcome from the DIF analysis, as discussed within the previous section. Each of the knowledge-types were identified as essential components of the costing process. The DIF analysis collective result has essentially acted to reinforce the importance of each KT; as was established in Chapter 7.

Appendix 9, Section 9.6 explains DIF results in relation to the initial KT considered, prior to refinement of the model. A clear result within this preliminary phase confirmed that the 'Train' mode is not a default state, but has occurred due to genuinely perceived specific benefits of training needs, within the areas in question. Insights towards this potential spectrum have been bestowed by a cross-section of industrial practitioners, (see Chapter 6, Table 6.2); as was undertaken with the finalised list of KTs. The preliminary outcome, which results in mixed training requisites, gives credibility towards the TNA technique employed. In other words it does not simply default to the Train mode, but is lead to any of the three potential outcomes, directly via a combination of the feedback inputted into the system.

A study of the training-needs grid, in Figure 8.3 shows certain trends in the outcomes of training needs. The primary observation is in that if the Importance of the specific knowledge activities were deemed as high, the recommendations towards some type of formalised training are significantly higher then if the importance is classified as low.

The final outcome of the eight KTs did not unequivocally indicate an 'over-train' result. This is as expected because it can be deduced that the Over-train outcome would occur when the majority of aspects within the KT had been classified as having high importance, high difficulty, but being required for use infrequently. Therefore to a degree it could be predicted that these knowledge-types would not fall into that category from their theoretical identification, which was that they are all essential components of costing which are necessarily utilised on a regular basis. Given this, the fact that the Over-train option, though alluded to, (see Section 8.2.2.3.c and Table 8.4) did not prevail in the overall average outcome of any of the KTs when scrutinised, was not unexpected. This is because though individual aspects within a KT may be very important, difficult, but rarely used resulting in an 'Over-train' outcome, when the total components involved within any given KT were collectively assessed to summarise the particular KT, the over-train result tended to be in the minority, so was averaged out; see the previous section.

With regards to the No train option, its lack of occurrence when determined through the industrially validated research similarly to the above stated, can also be predicted from the theoretical reasoning behind the identification of the KT. This is due to the ubiquitous nature of each of the KTs highlighted. Chapter 7 discussed the results of the P1 and P2 industrial research, which had examined the contributing practitioners assessment of what knowledge is required to cost a product, and the ICKF was formulated accordingly.

To briefly recap how this was arrived at: The Knowledge themes, KCs and KTs have been presented in Chapters 4, 6 and 7 with examples of the data used to derive them being included throughout. This is in juxtaposition with analysis of this data, including summarises via the statistical package, SPSS, as well as regular supporting descriptive narrative. Subsequently the research detailed within Chapter 7 identified that the process would be very challenging to conduct without each KT being mastered beyond a basic level; or to have ready access to a required knowledge-source, e.g. an experienced cost-practitioner, working alongside a relatively inexperienced one. Therefore it makes sense that the industrial practitioners themselves would resultantly identify that it is critical that every KT involved requires formalised training of some description, which is to be determined; see proceeding Sections. When examining the responses, the fact the 100% of the respondents gave a greater level of 'high' ratings to the Importance category than low, quantifies the significance attached to the identified KTs. This not only validates the previously discussed results regarding the essential aspect of the eight KTs, but it also helps determine the training needs.

Formalised structured training has been clearly identified for each area in question. Therefore although regular reinforcement of the training has not been specified i.e. through the 'Over-training' outcome, the practice of training conducted solely or primarily via on-the-job modus operandi with little structured intervention is not supported here. Therefore the training proposals will incorporate formalised targeting of all identified areas; although they can be performed in conjunction with the use of the unstructured techniques. A point to note is that it has not been recommended that the SWN-type shadowing / observational approaches are either discontinued completely, or implemented alone.

#### *8.2.3.3 e) Expanded Outcome of the DIF Technique*

An interesting consideration emerges on examination of the average DIF values, in Table 8.4. If the average values as are presented within the Table were used to obtain the final outcome, it would include two over-train results, under knowledge of the Costing Process and of Risk, denoted with (*). The study required that the individual components of the data were processed using the grid-analysis prior to assessment of the average values, which resulted as Train for all KTs; these are the accepted results within the research. However if the raw DIF averages had been adopted, this would have created a change in the uniform 'train' outcome, to a mixture which included 'over-train'. This result would be particularly relevant for the Risk knowledge type, as there will be instances of risk which do not commonly occur, hence them falling into the 'risk' category to begin with and not accepted as common activities within process. In other words if the event was commonplace, it would be known, expected and could therefore be adequately catered for, so not pose a significant risk. In this light it makes sense to over-train various elements related to risk analysis, as the consequences for inaccurate estimation can be severe i.e. incur high costs. Over-train relates to an on-going training system, where various aspects which fall into the Over-train classification are regularly re-trained, regardless of perceived competence. The repeated though updated training may be implemented at regular pre-specified intervals, for instance Risk analysis courses may be attended annually or two-yearly, where each course is updated and principles are applied to current situations. However, as prior mentioned, adoption of results from this type of micro or compartmentalised manner, without procedural processing of the raw data was not deemed the most accurate route of analysis. Therefore the data was fully processed, prior to extraction and utilisation of the average outcomes.

#### *8.2.3.3.f) Elaboration, Merits and Drawbacks of DIF Analysis:*

Within the theory there are expansions on the TNA available, where techniques have added complexity, in comparisons to the DIF grid applied within this research [Buckley et al, 2000]. The reason these were utilised was because it was decided that a basic increased intricacy was not required. The outcome that was desired was either train or not: Over-train added a dimension to the results, with regard to the level; and the rest was determined via more qualitative methods such as interviews, and more targeted, specific questionnaires to discuss levels and more specific needs of training requirements. Refer to Appendix 4a and 4b for training–related questionnaires.

Although the manner in which DIF was implemented within this study does not give much room for indecision, there was the opportunity for practitioners to add to their valuation. As can be seen in Table 8.2, there is a comments section by each assessment–point within the knowledge types. Therefore if the contributor felt compromised in placing a definite judgment against a situation which may have been experienced as fluid or changeable under a variation of circumstances, this can be stipulated in the response. In such cases the alternate judgment has also been taken into account within the final analysis. See Appendix 10 for further evidence of DIF analysis data expansion, including the final 'additional comments' example of practitioner feedback.

The DIF method employed was selected due to its simplicity of implementation, uncomplicated practitioner in-put and generalistic format: In combination with the other TNA data-collected the results were adequately inclusive. The method simply broke-down the required areas, in order to make them straightforward to answer and understand. The separate areas are then brought together in the final stages of analysis. Appendix 5 lists the drawbacks and positive points related to the use of this level of DIF analysis for the TNA. The DIF analysis shows that the theoretical deductions behind the research were validated by the industrial in-put. Therefore having determined the TNA for the costing domain, the more specific elements of the training development could consequently be addressed.

### *8.2.4. Primary Trainings Needs Analysis Techniques: Interviews, Questionnaires and Document Analysis*

DIF analysis supported the main data collection technique with regards to training requisites, which were interviews, questionnaires and organisational-document analysis. Chapters 3, 4, 6 but primarily 2 discuss the literature presenting the broad methodologies for conducting research; and the specific method and techniques utilised within this thesis. Whilst Chapters 4 and 6 discussed how the selected techniques for industrial data-collection / knowledge elicitation were more practically employed. Table 6.2 (Chapter 6) breaks down the organisational involvement per phase of research, with the concentration of training development issues being addressed primarily across the sub-stages of Phase 2.

Due to previous descriptions, no more then a brief recapitulation is required regarding the techniques and methods applied within this section of TNA. Across the participating industries a range of cost practitioners and those who interact with them were interviewed with regard to the aspects of the costing-process in need of formalised training. The essential knowledge-types identified were targeted throughout the interviews as areas which required comprehensive knowledge. In other words, due to their prominence throughout the process, the KTs could not be left to chance, for a novice to attain during on-the-job training; the large majority of interviewees acknowledged that some standardised procedures must be implemented; or reliable means of accounting for their implementation of the less formalised techniques, must be established. Questions asked throughout the interviews would often follow the basic format for DIF assessment per KT; see Table 8.2 and Appendix 4 for training questionnaire: This would ensure consistency throughout the interviews. Organisational and subsequent industrial training–gap analysis was identified via the use of current company documentation and other explicit training material. The fundamental procedure of gap analysis, was undertaken by a thorough examination of the organisations training programmes, then preceded by discussion focusing on training requisites. This was able to highlight unequivocally the areas in which training would benefit from being developed within; details of which are presented throughout the following sections which examine the specific areas of training development; plus see Appendices 6 and 7.

#### 8.2.4.1 The Recognition of A Need for Targeted Cost-Training

A general but important revelation of the industrial examination emerged through a lack of targeted cost-training. Though there tended to be training of sorts in place, the bulk of observed training programmes within companies appeared to be ‘pulled together’ i.e. created with use of elements of training sections from other areas. The domains from which the costing courses were compiled were perceived as more established or more tangible domains. The main disciplines of contributions were from within the engineering training programmes; which given the list of KTs was not unexpected: These were often vast and very comprehensive, particularly within the medium to large organisations, where the engineering training was well established and generally of a good quality. The economic areas also contributed towards a costing course in a number of organisations. Therefore a very apparent conclusion from these studies was in the deduction that part of the inadequacies observed within current industrial costing may be due to a lack of focused training, developed for the costing community.

The reason why it was deemed insufficient to simply utilise other seemingly relevant areas where training had already been developed within, was due to the fact that product-costing does require a combination of knowledge specific to its process. Although this knowledge is comprised of engineering and economic areas, there are also essential components that are less tangible that appear to act as a catalyst for the production of a successful cost-practitioner. The more tacit elements have been discussed at length throughout the thesis, see Chapters 5, 6 and 7; and stem from the requisite of possessing communicational and cultural knowledges'. This requirement is because of the degree of interaction that is required for costing, which is less so with the other aforementioned disciplines. In other words as they are independent functions, their output does not rely on the integrative working between departments to anywhere near the same level as PC does. Therefore these 'softer' aspects are important within PC and should be trained.

Additionally although aspects of engineering functions are essential components of the costing practitioners' knowledge repertoire, there is a limit to the depth of technical knowledge required to conduct the cost-process. However the vital aspect of this knowledge is in the identification of the associated costs. The essential element of a cost-practitioner was described as their possessing: *"..A hunger or natural curiosity that compels them to gnaw away until the costs are established*"

[Senior cost estimator, Aerospace industry, 2002].

This 'natural curiosity' was expressed a number of times as a critical characteristic, which was looked for in a costing trainee; having been referred to in over 50% of the interviews conducted within P1, which was focused more on the fundamentals of PC; see Chapter 4. As the engineering knowledge types were important, there was not a specific need to re-develop for instance training within manufacturing processes or design, as a degree of which could be adapted from current company training if it was already up to a good standard. However it must be stressed that this could only be part of the training material, which needed to be focused on the specific needs of the cost-practitioners. Refer to Table 7.4, Chapter 7, which have identified over half of the KT as being pragmatic, 'hard', technically-based knowledges'; the rest, i.e. the softer KTs require different independent development from that which is used via the technical areas of the companies. Subsequently although there are aspects of other disciplines within product-costing which may be learned via external disciplinary training material, the cost-process would benefit from a programme which systematically identified the core elements involved, and designed training which holistically worked towards developing these skills and knowledge types within novices.

*"Basic costing knowledge, 101.."* [Marketing manager, software industry, 2002] was also quoted as a major training requirement, i.e. fundamental principles of the costing process were often referred to as deficient within the costing domain. As discussed within Chapters 4, 5, 6 and 7, the knowledge required for PC is a combination of economic, technical and the more tacit areas, like communication. Therefore the observation that the costing process hinges on this blend of knowledge domains, as opposed to sufficing with any one of the areas, highlight the need for specialised training for these practitioners. Knowing what the cost-process consists of, and subsequently how to develop a cost i.e. this, with an amalgamation of all the other knowledge types, reveals the uniqueness of the process when considered systemically. Costing does not comprise of a sum of its explicit components, but is evidently more then this, being a sum of its explicit and implicit elements, when used in a comprehensive, systemic manner. Therefore due to a common theme which reoccurred throughout the organisational TNA, where the practitioner was unable to articulate the component which distinguished a practitioner from a novice, cost–

training which combined the 'soft' and 'hard' contributors towards the process was firmly elucidated.

### *8.2.5. Theories Related to Learning*

A major school of thought within learning and capabilities centres on the original ideas and extensive subsequent work and revisions of Gagné [1965; 1985]. Gagné's hypothesis incorporates the supposition that different types of learning require different environments or conditions to evoke them: Which leads logically into the subject of training design. Gagné's hierarchy of learning attempts to integrate behavioural and cognitive learning approaches [Blanchard and Thacker, 2006]. The concept discusses internal and external conditions for learning, the former being derived from within the learner themselves; whilst the latter, (external learning conditions) is concerned with the training types employed per organisation [Patrick, 1992]. An adaptation of this paradigm within the costing realm can be explained via the background required of each trainee, primarily technical / engineering knowledge ranging from apprentice level onwards. This is not the sole background requisite for a costing novice though, with a small minority of candidates emerging from purchase and financial origins too.

The discussion within previous chapters on the subject of tacit and explicit knowledge can be related with the theory that: Tacit or internal knowledge is centred within the individual. This can thus be linked to the prerequisite skills learnt, before training for the costing process can be commenced. For example a technical apprentice acquires tacit knowledge via the experience gained throughout their apprenticeship. Whereas the explicit knowledge is a more tangible, external manifestation which may be classified and theoretically disseminated through such means as documentation, instruction manuals and other types of tangible, formalised training material. A description of these knowledge types has been given as:

*"Explicit knowledge equals the sum of the parts; whilst tacit knowledge equals more then the sum of the parts."*

[Research Methods lecture notes on Organisational Culture, Cranfield University, Lemon, 2008].

Therefore although external aspects or explicit knowledge tend to be readily identified, classified and disseminated, generally elements of tacit knowledge are more difficult to pinpoint. For instance, a cost-practitioners' knowledge consists of tangible and intangible types; the tangible can be described as being consolidated by the intangible. Hence the cost-process knowledge together with the manufacturing, product, materials and other engineering-based KTs are established with use of the more tacit communicational knowledge which allows the tangibles to be ascertained or 'gathered', along with an awareness of the appropriate cultural considerations. This relates to how the tacit knowledge is comprised of more then the sum of the tangible elements which contribute towards it. To elaborate, a costing practitioner may be able to produce an accurate cost of a component of which they are familiar, by simply studying that actual part for a short time span i.e. a few minutes. When attempting to explain the process to a novice, the explicit knowledge and information employed will be conveyed; however this tends to result in a less accurate outcome when the novice attempts to reproduce the communicated process. The difference between their internal, cognitive processes will be difficult to identify. In other words, the experienced practitioner will often be unable to explain explicitly what tacit knowledge was used in addition to the externally imparted aspects which can be readily bestowed. This seemingly intangible tacit knowledge would ultimately be responsible for the difference between the experienced and novices' results.

Similarly, there are prerequisites of learning which involve concepts, rules, discriminations and associations to be made, in order to learn and be able to perform tasks successfully [Patrick, 1992]. A costing example of such prerequisites may be observed between an engineer and an academic graduate. The difference between the former mentioned or any individual of whom has a level of technical experience even if basic, within an engineering and product-related environment; and their resultant performance within a costing domain. This compared against a graduate, even a technical one, but who does not have any engineering industrial experiences within the processes and product in question. The latter may have complete theoretical technical knowledge of a generalised, hypothetical engineering foundation. However their chances of becoming adequate as a result of undertaking a preliminary cost-training programme will be minimal, due to an insufficient background or prerequisite knowledge of the engineering processes, and the products being assessed. Alternatively fundamental aptitude in industrial knowledge i.e. economic and / or technical will suffice as preparation for a costing novice candidate. An academic (theoretical) background alone will need to be reinforced with technical, practical knowledge to apply to the cost process. Consequently internal and external learning conditions are interactive; for instance, certain assumptions can be made by the trainer and within training material, due to the prerequisite-background of the trainees. Refer Chapter 2, Section 2.6.2 plus Chapters 6 and 7 for discussion of pre-requisite cost-knowledge, i.e. suitable candidates for cost-novice.

In order to enable learning, analysis of the subject domain is required which this research has addressed in prior chapters; and as was performed in great detail within Gagné's work. However, criticisms of Gagné's model include the observation of distinct challenges when attempting to recreate such dysectioning of tasks, as would fit into Gagné's types of learning. The corresponding suggestion to this apparent oversight was that more information should be provided on the subject of how tasks can be sectioned, in order to reveal the necessary sub-skills which relate to the stated learning categories [Patrick 1992]. This research can corroborate this aspect of criticism to a degree, via an element of complexity experienced whilst analysing tasks and activities which in a number of areas had not been previously scrutinised. As Patrick explained:

*"..it is unlikely that a unique solution exists in the analysis of any one task, and also the sub-skills identified by an analysis do not always fit neatly into Gagné's categories."*

[Patrick 1992, p291].

With this said, the costing tasks, activities and relationships examined within this research were successfully assessed, see Chapters 4 and 6. Additionally much of the general hypothesis presented by Gagné seems logical within this research context such as the identification of skills required against those held, minus those deemed as a prerequisite of the domain. I.e. general technical / commercial knowledge possessed by novice on commencement of training. The sum of such evaluations allows the trainer to distinguish what needs to be learnt and included in the training content [Gagné, 1985]. On a fundamental level the skills needed by the novice which are lacking formulate the basis of the training, dependent on the level the training is aimed at i.e. Basic, Intermediate or Advanced.

Merrill presents an instructional framework which has emerged via the integration of a number of accepted instruction-concepts. Having been influenced by Gagné's work, it follows the notion that learning types are affected by two dimensions: The required performance, and the context of the training, [Merrill, 1988]. With regards to the former criterion this research again relates to the initial analysis of tasks, functions and interactions within organisational costing; see earlier chapters including Chapter 3 for literature definitions and breakdown of the costing process; and Chapters 4 and 6 for industrial cost practice observations. This then exposes the expected levels of performance; and can accordingly be addressed within the training design and context.

#### 8.2.5.1 Types of Learning

Much has been written on the ways in which trainees learn; and accepted techniques include: Direct experience, experimentation, seeing and doing, mentoring, shadowing / observation, through receiving verbal instruction, sharing ideas, self discovery, easy access to information e.g. world wide web. The General Electric field engineering training programme, for instance (FEP) focuses on strategic learning from experience, tacit learning and 'how-to-learn' skills within trainees. This incorporates encouragement towards establishing new ways of confronting and resolving involved technical problems [Carayannis and Jorge, 1998]. This type of philosophy is aligned with the General principles theory, where emphasis is placed on 'why' things are done; as opposed to the identical element, which centres on 'what' to do (or 'seeing and doing' -type learning). This requires the maximum similarity between training and the work environment [Patrick, 1992], and is useful for technical and motor skills. The former, focusing on 'why' is more pertinent for managerial positions, fault diagnosis and product-costing, as it focuses on the principles underlying the actions. Therefore the training is designed to develop an understanding of why actions are taken, not simply what actions to take.
The basic high-level outline of the training instruction is:

- Direction or Instruction, telling trainee what to do i.e. via lecture form;
- Demonstration, showing trainee what to do;
- Application or Guidance, allowing trainee to perform the task under supervision or with instruction.

Direction or verbal tutoring / lectures is a highly established training technique. It is a core element within education and commonly adopted across the spectrum of training domains. However though thoroughly tired and tested, it has long been accepted that used in isolation, this technique can be insufficient. An actual demonstration when accompanying a lecture can reinforce the subject in question: For instance, a biology or medical lecture followed by the witnessing of an actual autopsy is more likely to provoke learning, then a lecture alone. Further enhancement of this pursuit of learning would be to allow the trainees to conduct an autopsy having academically learnt the discipline via instruction, and observed the fundamentals of the process through demonstration. The costing process currently relies heavily on 'on-the-job' learning; which tends to primarily constitute the latter mentioned techniques, shadowing or Sitting with Nellie, SWN, and performing costing activities under supervision; with guidance from experienced practitioners.

### *8.2.6 Aspects of Training*

It has been stated that task analysis protocol has allowed managers to observe highly skilled workers with the aim of identification of the precise activities required to perform the variety of jobs undertaken in manufacturing [Gael, 1988]. As mentioned within the previous section, once a specialisation and its components had been analysed and documented, this could be utilised to aid in the training of the domain novice [Clark and Estes, 1997]. Prior to this job-breakdown, training was undergone almost exclusively by observational, on-the-job learning, and formal apprenticeship; see Chapters 4 and 6. Although technical apprentices were observed industrially as a common background prerequisite for entrance into PC, such workshop-type placement and experience does not act as cost-training.

As previously discussed on-the-job training is commonplace within the costing domain. However, this is not only a time consuming technique, but without standardised procedures, inconsistencies in the training outcome would inevitably occur as it involves observation of whatever crops up within the period of shadowing. This may result in bias around one area, and neglect of others which do not happen to occur during this phase. However, SWN-type techniques tended to be perceived industrially as low-cost training options. Although this can be the case when compared against costs of formalised training design, development and regular implementation; it must be noted that SWN involves the full time commitment of an experienced practitioner, in one-to-one novice-training interactions. Hence it being described as 'time consuming' due to the potential situation where it may monopolise two employees including the trainee, on a full time basis, wherein the associated cost implications are evident. With this said, the 'seeing and doing', mentoring, and other on-the job techniques seem to be an ingrained component of organisational cost-training. The results particularly through P2 confirmed this industrial observation in relation to training approaches.

The substantive contribution of the research is via suggestions towards the industrial implementation of the ICKF; through which this research acknowledges the role of an expanded type of tailored cost training development.

The research recognised within such training is the importance of utilising SWN-techniques, due to the themes and essential knowledge types identified in Chapters 6 and 7. Refer to Chapter 6 for the themes-knowledge relationships; and training-theme to cost-knowledge framework, Table 6.9. The element of being able to interlink all the diverse but related aspects within PC, benefit from direct experience of such events; see the final sections of this chapter for specifics. With the considered benefits of SWN, the research proposes that this aspect of unstructured training remain as part of cost-training, being incorporated into the overall training methodology; bearing in mind that this is the primary approach adopted for the pragmatic dissemination of the research results. A suggestion would be to identify crucial areas which need to be addressed during this phase, which will tend to be organisation-specific, and add an element of formalisation to this generally unstructured technique. This should be in respect to documenting the areas which are important to address during this training period, within some type of check-list e.g. 'Must-be-covered' activities, which can be as detailed as necessary. For instance it could encompass not only areas that have been broken down and listed as necessary for inclusion within the SWN training, but also sections which record the levels that each one was able to be experienced at, whether briefly or in-depth. This type of detailed accounting of disciplinary functions covered, can assist in enhancing the individual training needs at a review date or some other time further into their occupational development. It can also act as a check-list when embarking on the more informalised training techniques; making them more standardised and with less of an adhoc approach, which can result in subsequent inconsistency in the on-the-job type training outcomes.

### 8.2.6.1 Training Delivery, Mechanisms and Materials

Training participants of all echelons will respond most positively to a variety of stimulus. In other words each individual within the training groups will have specific responses (high or lower levels) to each mode of delivery used. In order to enhance and maximise learning, the proposed training will encompass a number of media to address the spectrum of these learning needs, see Figure 8.4. The modules will be founded on lecture–based material initially. All elements of the knowledge-types (see Chapter 7), and themes (see Chapter 6) indicated for training will have lectures designed to convey them within the programmes. These constituents will be reinforced by other types of stimuli including audio and visual material, e.g. videos on product or component. Computer-Based Training (CBT) will be developed for areas deemed most appropriate. For example where visual elements need to be stressed such as manufacturing process; see injection moulding and joining as specified for CBT development, Section 8.3.6, the relevant components will be provided for demonstrations within the training courses. There will also be permanent reference material designed to reinforce the training, and fundamentals of costing; which can be referred to, when within the workplace to guide and / or stimulate memory when required; see Appendix 4a and 6. The lectures available will be on a broad range of disciplines, and conducted by a selection of industrial expertise; thus providing state of the art guidance, information and knowledge. Along with the reinforcement of lectures via other sensory stimulation i.e. audio and video, and demonstrations; there will be opportunities to perform costing exercises on actual relevant components under expert-guidance. Figure 8.4 gives a systemic illustration of the modules intended for development, and their relevance and relationships with each other.

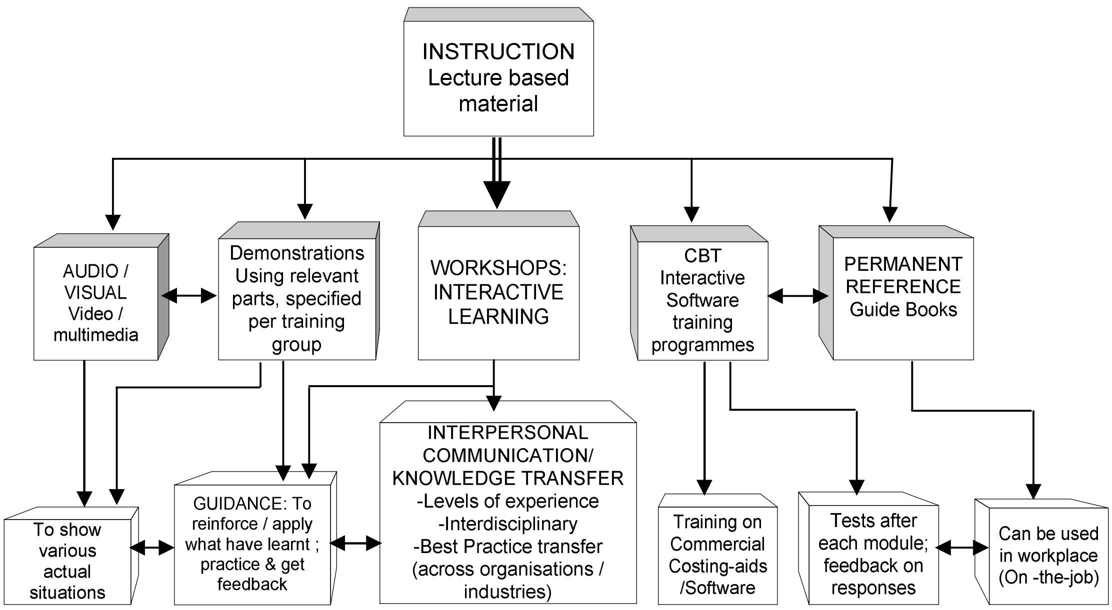



Figure 8.4: The Different types of Medium which will Encompass the Proposed Cost-Training

The content and other details of each of the training mediums given in Figure 8.4 will be discussed in the following Section 8.3. The widest variety of delivery modes have deliberately been selected for incorporation within the programme to engage the trainee via different stimuli, and thus cater for the diversities involved in the ways individuals' learn. The theory of encompassing a range of delivery in the manner in which knowledge and information is communicated throughout the training, is in order to utilise different senses of the learner. This will allow a greater impact of the training received when absorbed by different senses, with the intention of ensuring the material is learned, retained and adopted for use by the recipient. This will help to simulate the real environment. For instance if workshop experience is lacking, as has been discussed with regards to cost pre-requisite knowledge, then audio and visual aspects incorporated into training also consisting of lectures (instruction) and interactive discussion will aid in the transfer of practical knowledge. The ways in which the training can be validated and evaluated i.e. if it has had a positive effect, is discussed further in the following section.

### *8.2.7 Validation and Evaluation*

With regards to training within organisations, there is the issue of how to measure the results and account for the benefits of investing in such training and development (T&D). Companies need to have justification for disbursement towards T&D. Although it can be subjective and evasive to procure the benefits in 'hard-cash' terms, a number of studies have been conducted which generally examine the level of expenditure towards training investments of sorts, against company performance and subsequent profits. The ASTD (American Society for Training and Development) conducted a substantial survey in 1998, with a sample size of 540 American firms, of diverse size and covering a range of industries [Bassi and McMurrer, 1998]. Though it was stated within the report that the results were not definite, it provided in-depth results, concluding that:

*"Companies that use innovative training practices are likely to report improved performance over time and better performance then their competitors"*

[Bassi and McMurrer, "The 1998 ASTD State of the Industry Report" Training & Development, January 1998; in Adelsberg and Trolley, 1999, p14].

As mentioned, a number of industrial studies have been undertaken with similar findings [Welbourne and Andrews, 1996]. Nonetheless, it can still be challenging for corporations to determine exactly how much investment should be placed into T&D, and what type should be implemented [Bassi and McMurrer, 1998]. Therefore, there needs to be some method of effective validation and evaluation of the training in order to allow organisations to justify their expenditure towards training; and to provide guidelines as to the level of expense that should be allowed for T&D [Adelsberg and Trolley, 1999].

#### 8.2.7.1 A Criterion for Evaluation

A number of criteria may be employed for the function of training evaluation. However a widely used model is that of Kirkpatrick [1998]. Originally published in 1959, Kirkpatrick's training evaluation model has been further developed and revisited extensively: Though it essentially consists of four main levels:

- Reaction: Trainees perception of course
- Learning: Whether skills have been learnt
- Behaviour: Proximal or Distal
- Results: Organisational measure of the benefits of training

[Kirkpatrick, 1998]

A reaction-measure to the training is fundamentally just that, the trainees' perception towards it; and is generally procured on immediate completion of the course. This approach to evaluation is commonly employed, with the standard techniques being in questionnaire format which may involve 'rating scales'. There are a number of pros and cons to this evaluation method. A positive point is that it can provide immediate data from all trainees, relaying some measure of feedback from their training experience. A negative impact manifests in the fact that this type of rating can be subjective to the trainees' opinion of extraneous factors, unrelated to the course. For instance they may rate the trainers' style, or even some element of the environment, e.g. the quality of the social life. Therefore the trainees are not necessarily in a position where they can objectively rate the effectiveness of the training, as 'Liking does not equal learning' [Tannenbaum & Yukl, 1992 p.425].

Learning criteria assess whether the knowledge and skills which the training course was designed to transfer, have actually been learnt and retained by the trainee. These learning outcomes will often be specified within the training itself; and there are various measures which can be used to evaluate whether the targeted-learning areas have been successful. These include tests about knowledge of the job, or simulations; and are typically procured from the participants directly after the training. Although this can provide an idea of the success of the training course, the fact that such learning measures are by definition, procured within test-environments denotes that it does not give an indication as to whether the training has been learnt in a manner that subsequently leads to retention and adoption of this learnt practice within the workplace.

Therefore a Behaviour criterion is designed to measure the transfer of training (TOT). This aspect of evaluation is to assess the degree to which the knowledge and skills learnt from the training are subsequently implemented within the work environment. These measures can be Proximal i.e. taken on immediate return to workplace; or Distal, i.e. measured some time after the training which assesses the long term retention of the course. The most suitable manner in which the behaviour criteria are measured is a subject of debate.

Difficulties in this area can occur as new skills / knowledge can be learnt and retained, though not transferred to the actual job. This may be for reasons including the requisite of change to routine actions which if habitual, may prove difficult to modify so that the tasks are performed in a different manner then they have always been done within the environment. Plus it may be this environment which triggers the familiar actions, as opposed to implementing the re-trained ones.

On a practical level it can be challenging to assess behaviour criteria, due to the fact that it needs to be appraised outside a controlled, experimental environment; but instead within the regular working one. This is highly time-consuming for a researcher; but would not necessarily be accurate if left for trainee to self assess. One possibility is for the supervisor to evaluate the affect of the training and improvements or progress, when the trainee returns to work. This technique would depend largely on the skills and experience of the supervisor, in order to understand how the job should ideally be performed. The evaluator would need a degree of observatory skills and judgment to assess performance before and after the training.

The challenges involved in assessing the degree of learning from formalised courses are partly the reason why the preference within industrial costing was towards on-the-job training. It was deemed that rates of progress could be observed more readily when trainees learnt and executed new skills within the work environment. In accordance with this inclination the training implications arising from this research incorporate on-the-job training within the structured, developed programmes.

Results measures are the way in which an organisation would endeavour to account for the benefits of implementing the training. This includes examining the costs as well as the economic advantages of investing in the training, highlighted in ‘hard cash’ terms: Such practical measures were stated as preferable by managers within the industrial interviews; see Chapters 4 and 6. To asses this, a straightforward comparison of profits before and after may be made with the difference being accredited, at least in part, to the benefits resulting from training. However, more indirect attributes may be due to such, though are less clear to distinguish, as actions may be a consequence of course attendance; equally they may have been carried out  in similar manner, regardless. This makes any monetary gains which may result as a direct consequence of workforce training a difficult investment to measure in cash terms, especially to absolute degrees.

Although all four of levels of the evaluation criteria have merits and drawbacks, ideally all should be utilised; though this is rarely the case [Adelsberg and Trolley, 1999].  The reason why they all would not typically be implemented in the costing field would be primarily due to resource. Such assessments would be time consuming, within an area which is already persistently pressed for optimal results within minimal timescales. With this said, these main evaluation themes of Reaction, Learning, Behaviour, Results will be used in part as guidelines to assess the success of the proposed training coursewares' derived from this research: Having been established as a credible, and seemingly logical framework development for training appraisal; of which will be implementing the ICKF.

#### 8.2.7.2 Costing Assessments:

Proposals made within the cost-training programme towards evaluation of reaction and learning will be undertaken via both Pre- and Post-Training questionnaires. These are typically completed a week in advance of the course; then again on direct commencement i.e. for pre training assessment; followed by completion on the final day of course and once again a week or so after, for post training evaluation.  Although these will act as a guideline to a degree regarding the trainee’s reaction towards the course, care must be taken to ensure it is not what has been termed as ‘happiness sheets’, which can simply reflect the participant’s preferences. For example a number of costing practitioners typically stated that having an actual part to compile an estimate from was preferable to a designers drawing alone. Whereas others stated that a drawing often contained a lot of required information, thus saving time and enabling the cut-back on the effort which would independently be placed into obtaining such requirements in the absence of having been initially presented with them. Therefore if both were offered within the training programme there would be the highest levels of positive feedback towards this element of the course.

However, if one or other (either part or drawing) was used, it would reflect in the preferences, though not necessarily in the quality of training it had provided.
Therefore the type of questionnaire developed should be related to the job, function, activities and generally the knowledge and skill linked to these aspects. In order to conduct what is essentially a before and after evaluation effectively, the questionnaire must cover the subject-matter addressed within the training programme. If the questions are directly related to the course content, it will give both a guideline towards the reaction of the cost-trainee, as well as an indication towards the level of learning, following the course.

An awareness towards whether the course has influenced the behaviour of the trainee once returned to the work environment can be procured by a similar performance-related questionnaire, which is completed after a suitable delay. Following the training programme, the cost-participant can be given enough time to settle into the role, allowing them to have performed the tasks addressed within the training, whether related to risk analysis, manufacture, product, and / or communicational interactions. At this point a job-related questionnaire can be answered, which has been designed to assess the actions within the tasks and activities in question, i.e. around the subjects covered within the training course. This can provide an indication towards the degree from which the learning has transpired into behaviour within the work environment, and thus been transferred into the actions. In accompaniment or independent to this measure can be some type of on-the-job feedback where possible. This evaluation should ideally be derived from a supervisory figure, able to monitor the trainees' progress on a regular basis. Otherwise it may be conducted by the trainer from an on-site observation session: Though in reality this level of follow-up involvement is likely to be rare, but is possible; particularly if a training session was conducted around one organisations' needs, where a large number of trainees, e.g. whole department, were trained; see cost-centre Section 8.3.8 for further explanation.

As alluded to earlier in the section, when on-the-job progress is evaluated the assessor requires a high level of observational skills, and needs to be able to execute judgement as to the most probable derivative of the actions displayed by the trainee, in this case the costing practitioner. Evaluation from questionnaire feedback is more straightforward, though still involves a degree of judgement and contextual knowledge when assessing the responses, particularly when open questions are included in the format. Refer to the research methodological options in Chapter 2, for open / closed question description.

Interestingly enough the results measure may be deemed clearer to establish due to the nature of costing, then within other domains. This is because a basic technique within this area could be to track the revenue saved as a consequence of the cost-practitioners evaluation, and compare against the original situation, whether quote / bid, design-change-management or some other cost-assessment requisite. The difference in costs can be taken as a direct result in monetary values achieved (or not) from the training programme. With this said, it would be highly time consuming to conduct such comparative analysis for each process performed per participant. However observation at suitable intervals with regards to the progress and performance, proceeding the training will be sufficient towards evaluating a reasonable cost-assessment related to the training effectiveness.

## 8.3. Training Developments

This section discusses the specific training proposed for the costing domain, as deduced via the cost-model illustrated in Figure 8.1, derived directly from the research findings detailed within Chapters 6 and 7. The primary components have been presented in Figure 8.4, and consist of:

- Lecture based material:
    - The foundation of the training;
    - Lectures will be designed around all the essential knowledge-types, discussed in Chapter 7;
    - Industrial expert-design and -delivery of the lectures*
- Interactive Workshops:
    - To promote communication and disperse cultural knowledge throughout the working domain;
    - Can involve cross-discipline practitioners, varied level novices, and cross-functions who can learn from each other i.e. knowledge-share;
    - Will disseminate best-practice and improved integrated, systemic working practices.
- Computer Based Training Tool (CBT):
    - To lead the novice through modules at their own pace;
    - Can be used on-the-job;
    - Can select specific required areas of training, out of the whole.
- Work Book:
    - Permanent reference for users;
    - With fundamental knowledge and information;
    - Best practice tips for novices, and example case-studies included.
- Cost-Training Centre proposal:
    - State-of-the-art centre designed specifically to meet costing needs;
    - Can be built to purpose: Customised training programmes may be compiled as per customer-requirements;
    - All necessary training elements may be integrated within courses held, which could be conducted on one central site;
    - Incorporating all the techniques proposed, including commercial software access, demonstrations, guided costing processes, lectures*, video / audio information, and group interactive workshops.
- Interactive Training Modules:
    - Caters for mixed training groups, or single organisational-specific courses;
    - May incorporate all other learning material and training techniques into one programme, which through specific customisation the multi-method approach can tailor for exact needs;
    - Course compiled by industrial domain- / discipline -specific experts.

Industrial feedback with regard to content, coupled with academic research into the most suitable modes of delivery, produced the above methodology of training development. This was derived by:

- Direct practitioner in-put:
    - From the interviews;
    - Phase 2 research questionnaires; see Appendix 4a for training development questionnaire;
- Feedback from trial workshops incorporated within university industrial-focused courses; see Appendix 4b for an example of a completed workshop response feedback form.

Each section of training development as listed above is described throughout the remainder of the chapter. This includes the reasoning behind the training-technique selection, and details of how it may be employed. Industrial studies into the types of media in which the training material may be delivered, has been undertaken. This user-requirements information was primarily gathered by interview and questionnaire in addition to the workshop-response; see Chapter 2 for research methodologies and Appendix 4a and 4b for survey and an example of participant feedback respectively.

Lectures are widely used on industrial training courses, and therefore were accepted by the contributors as a standard base for the programme. Practitioner input gave force to the other general considerations towards the finalised training listings, including that 'workshops' are required in order to promote industrial interaction, propagating best-practice costing. The CBT (computer-based training tool) was specified as convenient, as it caters for own pace, as well as distance learning. CBT via CD-Rom or web-based, or internet / intranet was mentioned by approximately 90% of those interviewed. Though a minority of those (~30%) added that interaction would be required from an actual expert, in addition to this learning aid. A hard copy reference guide book was highlighted by about 80% of the questioned industrial practitioners as useful for regular reference, for use on an 'as and when required' basis. Less then 10% mentioned that this could get outdated and / or would be difficult to keep current.

Other areas of training access, which were highlighted within the study were:

- On-line (–direct access)
- Intranet (–for easy updates )
- CD Rom (– simplistic use / access)
    - (-can host CBT tool delivery*)
- Web page* (– direct, instant access; plus also could host CBT)

Intranet training, for reasons of ease of updating, was mentioned by 10% of experts. This and on-line techniques are suggested within the proposed training design as being directly facilitated by individual organisations. This is due to the fact that there are areas of costing which are highly specific to each organisation, due to the intricacies of the different products in question, as well as issues like company policy, size, resource, location, consumer base. Such company-specific and highly specialised elements for which mediums such as intranet were recommended as the most suitable medium of dissemination, seem logical for this training to be developed in-house. This is due to the fact that it can be tailored to each specific organisation and updated by the internal experts, knowledgeable about the company's practices, as and when required.

On-line and web-based training would entail a high level of maintenance and therefore are not prominently featured in the training proposals. This is similar for CD-roms, which would require regular updates and reprints; therefore it was decided that CBT tools are better placed to cater for these needs, which could be accessed via an internet address, maintained by the programme developers. Alternately it may be made available on a CD, though would be supplied with the knowledge that the discs would require updates at regular intervals from the live web-address.

Due to the revisions and updates which are predicted to be necessary on a regular basis as with most industrial training, it was deemed more appropriate within this training programme for courses to be held in one centre. The listed techniques would be incorporated within this centralised training-domain, of which may be readily updated; tailored as required per training course; and conveyed via a spectrum of media within the centrally run sessions. The content, delivery and general technique of these sessions were determined via the organisational studies into types of training: Hence the preferred techniques that emerged are summarised as that which supports a combination of the following:

- ✓ Lectures; A wide range; for details of the topics refer to Appendix 7;
- ✓ With CBT tools, that user could take at own pace; see Section 8.3.6;
- ✓ In addition to the support of a guide book which could be kept with user, thus acting as a permanent reference; see Appendix 6 for extracts from the prototype developed;
- ✓ Plus interactive learning sessions, such as workshops; and integrative modules, covering a spectrum of cost-based subjects including training about the interactive disciplines; partly covered with use of these interactive workshops; see Section 8.3.5.

Stewart et al [1995] states within the Cost Estimators Reference Manual that the process of costing is moving forward, from on-the-job training to having an array of education and training activities available for product-costing, PC. This view is more commonly accepted to be the case within American practices, which emerged within industrial studies as being perceived as marginally more progressive than the UK with regards to issues including maintenance and furthering industrial PC. An example of this commitment was observed from a large, international automotive corporation, (USA-founded) which invested the highest level of finance into a computerised-cost model. This was noticeable due to it clearly surpassing both financially and via the time commitment to its development, other endeavours into the formulation of costing-aids: It was also noted that this formalised cost-tool was revered within a number of other organisations. In addition to this point the majority of commercial cost-softwares professionally developed, stemmed from USA founded companies.

In contrast the findings of this study show that the essentials of cost training are still performed dominantly within the UK companies by SWN-type activities including shadowing, observation and mentoring such as on-the-job training; see following Section 8.3.1. Not only is this type of training widely employed; but the encountered experts provided a fairly universal attitude in that these informalised techniques were the most preferred, and considered the most efficient and reliable means of achieving proficiency within costing. Therefore the visions of cost-training which Stewart et al [1995] allures to tends to be more theoretical as opposed to operational within the observed UK-based practices. Subsequently the need for improvement within cost-training, including actions taken towards the implementations of the integrated cost framework presented in this thesis, is a pressing, current industrial concern. Hence the substantive contribution of this research consists of potential proposals towards the pragmatic propagation of the industrial cost-knowledge framework, ICKF.

### 8.3.1 On-the Job Training:

On–the–job training has been discussed earlier within this chapter, where although the importance of situational experience has been acknowledged, there can also be distinct inconsistencies within such techniques. For example the type of training received can be dependent on each different expert conducting it, and whatever they happen to cover during that period of training. These informalised techniques can be time consuming: It was widely accepted across industry that two years was the acknowledged time that it takes to develop a novices cost-knowledge and experience base, before they can perform to a suitable degree of independence. This included gaining workshop knowledge, whilst being placed or rotated across other areas of the organisation:

- Potentially including financial placement;
- With definite exposure to the various product-engineering functions;
- Including manufacturing, development, design;
- Placement within the various vehicle-models / product-lines;
- Including engine-types; avionics / hydraulics / electrical; interior / exterior trim among other areas.

This was typical of apprenticeships which were often a couple of years in themselves; and once within PC the targeted learning would be conducted:

- Involving on-the-job training;
- Observation; including negotiational interactions;
- 'Learning–by-doing' with supervision / guidance from more experienced practitioners;
- Familiarisation with historical data, sometimes referred to as past projects;
- Gaining competence with the formalised cost-models and data-bases;
- Awareness of suppliers, OEM, material-journals: Any other source where cost-data may be obtained;
- Rotation throughout the department, where necessary / appropriate;
- Along with the formalised courses made available.

Hence approximately two years was the accepted time from which a novice would be expected to have developed enough aptitude in the domain to perform the cost-process independently. Despite this acknowledgement, the (typical) two-year period was also stated as being an excessive time-frame for the discipline to continue to contend with; as it was not quick enough to replace the natural depletion of expertise from the cost-community; as discussed within former chapters including 4 and 6. This loss tended to manifest diversely: A number of organisations had policies which involved moving personnel around the company as a means of personal development. This could happen as frequently as two-yearly intervals. Hence the absolute need in this instance to train newcomers into the process more rapidly. Coupled with this state of affairs, were a noticeable number of organisations in where it was openly claimed that there were challenges in keeping practitioners within the discipline of costing. This was due to a number of reasons, though the prime ones inferred were:

- A lack of status;
- Issues surrounding wages;
- And chiefly, the lack of room for personal development within the department
  - i.e. it was arduous to get promoted.

In such cases as career-enhancement concerns, scales or ratings generally spanned from:

- ✔ New recruits;
- ✔ Costing practitioner;
- ✔ Senior practitioner;
- ✔ Supervisor;
- ✔ Management.

The latter of which had very limited openings, and excessive suitable contenders. Therefore the continuously stated claim encountered industrially i.e. that there is a current and increasing shortage of competent cost-practitioners was reinforced through the acknowledgement that PC takes two years to become competent within. This is in conjunction with the evident challenges observed across industries in both attracting and maintaining cost personnel, including the low profile and / or lack of understanding of the role and hence contribution of PC; along with unawareness of knowledge and skills required; all as discussed in Chapters 4, 6 and 7.

This was further enforced by the decline in what was termed as the 'traditional sources' from which the cost-novice has been typically procured from. I.e. primarily technical apprentices, given the prerequisites required within the costing domain, including a wide range of technical competencies; see the list earlier within this section for elaboration. Whilst a majority of those interviewed held these views, a significant minority stated that the costing practitioner was a position of some weight, and therefore required an experienced candidate. For instance the ideal candidate was specified by one senior aerospace / defence industry practitioner as needing to be towards the end of their career; preferably, though not exclusively from within the industry, and even more preferable to be from within the same organisation, (medium –large); having first gained experienced across it. Though in such positions the practitioner was less likely to leave the position within a relatively short time frame, suitable replacement-candidates when needed, were given the requirements encountered rarely. Therefore in either of these scenarios effective, efficient training plays an important part within the costing domain. With this said this type of cost practitioner was a minority; and most costing departments examined could recruit trainees on completion of either a technical apprenticeship, and very occasionally from technical graduates. Both of which would be primarily trained via on-the-job techniques, as observed via the vast majority of industrial examination.

However, as prior discussed, this approach to training had its drawbacks. As well as potentially being inconsistent and time consuming, SWN can also be resource consuming, in the fact that another experienced practitioner may be required to devote a large amount of their time towards the novice. Even when the cost-practitioner is concurrently performing their usual activities, which is generally the case with the trainee observing and having the opportunity to ask questions; this can take its toll on the output of the department when work demands are high. Alternatively the training may be affected detrimentally, by being regularly postponed (other then pure observation), and thus completed too slowly, if the mentoring-practitioner has a high workload, and subsequently is unable to dedicate the time towards training the novice.

However the general industrial belief of SWN techniques as preferable maybe due to the engineering knowledge required. It was widely stated by the UK practitioners that financial acumen could be taught or learned on–the-job: However technical knowledge was perceived as being unable to be. A key reason why, was due to the belief that engineering fundamental elements were stated as difficult to understand outside of a suitable spell within a workshop-type environment, technical apprentices being typically two years. An understanding of the engineering aspects involved in the product was considered essential in order to be able to assess the costs which contribute to that product. At a fundamental level, financial know-how was thought to be a lot more theoretical and therefore could reasonably be attained within a cost-environment; whilst engineering was considered practical, hence pragmatic experience was deemed necessary to develop proficiency in the area. Even within the U.S. where the main minority of practitioners with commercial / economic backgrounds were encountered, it was noted that a lack of engineering experiences (primarily product-knowledge) was stated as a major drawback in the pursuit of effective costing-skills.

Therefore the need for fundamental shop-floor engineering experience has been assessed as a precondition of PC. Proceeding this, economic knowledge can be acquired on-the-job i.e. from other experts; but a novice would generally be disadvantaged if they commenced without any engineering background knowledge.

This perception has resulted in questions towards the suitability of academic graduates as an alternative source for novices from technical apprentices, which was said to be a depleting resource of the costing trainee recruitment pool. The concerns for those initiating with a sole academic background is that there may be insufficient prerequisite-technical experience, to effectively manage the costing process. See Chapters 2, 3, 4 and 6 for knowledge required prior to entry into PC. With this said a limited number of technical graduates were observed within the organisational studies. They were seemingly trained by the traditional on-the-job technique, though with additional technical-department placements or 'visit's incorporated when required. Whilst there was a small number of trainees with this background, addressing the change in focus within the training requisites was a marginal concern. However it was predicted that the level of trainee with an academic background, as opposed to a practical one, may increase; indicating that the training structure needed to be adapted accordingly. Hence the training proposals in this research; presented in detail towards the end of the chapter, from Section 8.3.4 onwards; plus refer to Appendices 4, 6 and 7.

## *8.3.2 Training Recipients*

Before embarking on further elaboration of the training proposals, an examination of precisely who will benefit from the programmes is required. Although the developments are aimed at the costing community, a more defined statement of the specific recipients within this domain is necessary, in order to be clear about whom the training is focused towards. It is worth noting that the training developments will consider new-entrants to the domain, from various backgrounds / experience-levels; as well as addressing on-going cost-training needs.

This section briefly outlines the meaning of the term 'novice' (or trainee), as it is used within this research. It is especially significant to clarify who the intended users are at this stage of the thesis, as the training is not being designed to cater for only one type of level: Therefore the implication of 'novices' in the study encompasses a broader range of potential cost-practitioners, primarily three main derivatives of trainee; which have been identified from the research detailed within Chapters 4, 5, 6 and 7. The reason for this spectrum of recipients is fundamentally associated with the prominent aspect of the prerequisite-knowledge; discussed in earlier chapters. This is in reference to the difference between an inexperienced novice, against a practitioner who enters the costing department with an array of experience e.g. within other industries or organisations; the same company, but different departments. The issue of what are considered suitable prerequisites for costing has been observed as being influential on the cost-process widely i.e. through how it is conducted, how it is perceived within the organisation and by its internal customers.

#### 8.3.2.1 What Is a Cost-Novice?

The PC background or experience and general essential prerequisites have been explained earlier in the thesis, mainly in Chapters 4, 6 and 7; so are considered as being prior established within this research. The implications leading from these experiences or knowledge foundations towards the cost-process lead into the type of knowledge employed, and have resultant effects on how to disseminate the ICKF; which in turn impacts on the design of the training.

A cost-novice can vary from an individual who is inexperienced basically due to youth, hence are relatively new to industrial environments / the world of work in general; to someone more mature in age, and possessing a range of other (non-cost) industrial experiences. In other words, whether the novice has had previous industrial interactions or not, if they are new to the domain of product-costing, they are considered as novices, refer to Table 8.6 for more detail.

Therefore the question of whom the proposed training is envisaged to cater for can fall within four main categories:

- Novices with no-little prior experience: Those observed as new to industry, though have undertaken a fundamental level of domain experience, for instance in the form of an industrial apprenticeship and occasionally a technical / engineering academic graduate.

- Novices to costing, but with prior industrial experience: Experienced practitioners within industry, perceived as knowledgeable when they move into the area of product-cost having worked within the industry and / or organisation, but within other disciplines. Therefore they need to learn the specifics of costing and / or how their experience relates and can contribute to the costing process.

- Current practitioners, updating / expanding their knowledge: Those who may endeavour to gradually become proficient in a range of areas, so may need training in other specialisations. If knowledgeable in one area of product, they can receive training on another area. For example the individual may be knowledgeable in materials but less so towards manufacturing processes. Alternatively and on an even more focused level: They may for example have an awareness of steels, but not polymers. Along with expansion, regular training can ensure the updating of knowledge too. Plus interactive training between experienced practitioners can disseminate best-practice, discussed in Section 8.3.5.

- Interacting domains: Contributors and / or ‘internal customers’ of costing: Those that have frequently been referred to as ‘cross-discipline’ practitioners within this research, essentially describes the interacting areas of whom are the primary contributors to producing a cost, namely commercial and technical disciplines. Training can raise awareness towards the cost process, how it is conducted and what information, data and knowledge is required by the contributors; including aspects such as the internal customers being aware of the required time scales that they should be allowing the cost-practitioners to produce results within.

Of the four points, the former two are relatively straightforward; whilst the final points require further clarification. A major element of the original focus of research was between two disciplines of which the costing process was mainly derived from. These were the economic / commercial domains, which interacted with the technical / engineering aspects of the product. From this relatively tangible perspective, a cross-discipline integration could be perceived as the financial, liaising with the engineering departments. The resulting training would thus be focused upon each area developing a healthy understanding of the other; including the aims, functions and priorities within the corresponding party; points regarding novices are listed in Table 8.6., Section 8.3.5.2.

As the research has progressed, these main areas of enhancement evolved to incorporate the findings throughout the industrial examinations. A focal point of which has been in the observation that social and human factors have an impact on product-costing: Such disclosures influence the general approach to the training developments. For example cross-discipline areas will involve development of modules aimed at integrating different disciplines of whom may have diverse cultures, but who regularly need to communicate. Hence the aspects of communication and cultural awareness is raised when considering the need for cross-discipline interaction and how to promote the lateral transfer of cost-knowledge. The intangible elements within the cost-themes (see Chapter 6), and those within the knowledge–types (see Chapter 7) will be ingrained across the training programmes, reinforcing the intangible components of costing.

Subsequently the training for these implicit aspects will be embedded within interacting training modules, in which the explicit focus will be on the participants learning via means of active, actual physical communication. Such knowledge–transfer sessions enhances systemic thinking: It not only aspires to promote a greater holistic understanding of each others roles, and comprehension of how and why they work together; but also will naturally increase and enhance the quality and frequency of communications. This will be achieved basically by allowing a forum for open communication, to begin with. The following sections particularly Workshop Development and Cost Centre will discuss the specific training components in which this type of group interaction will be engineered.

### 8.3.3 Modules Development

Having confirmed all of the knowledge types as being in need of formalised training via the TNA, specifically DIF analysis, see Section 8.2.3; and after identification of the recipients and consequently the focus of training, i.e. the cost-novices, the emphasis moved onto the design and delivery of such programmes. As instruction is an established, effective method of delivery, all elements identified within the training were to be lecture-based. Therefore lectures would be designed around the areas being learnt and would be the foundation of the training; with the other techniques of delivery considered as reinforcement of the information and knowledge outlined within the core lectures. Table 8.5 gives an example of what may be incorporated into the main body of lectures and Figure 8.5 gives the knowledge classifications which the practitioners grouped the KTs within for training development.

In order to structure the knowledge into lecture modules, they needed to be suitably grouped into relevant areas. The costing practitioners not only identified which aspects of the process required formalised training, see TNA and DIF analysis sections earlier in the chapter; but also applied their experience to the manner in which the knowledge-types would most appropriately be classified into training modules. For instance the most readily identifiable knowledge-grouping was derived from the knowledge of manufacturing process. The primary knowledge associated with this was materials; the secondary knowledge types were design and product knowledge. Therefore it was deemed that 'Manufacturing' would be a training module which would comprise of these four knowledge types, all of which are linked clearly from a practitioners perspective; refer to Figure 8.5 to an illustration of this grouping. Manufacturing processes can be projected, animated visually including sounds of machinery, moving parts and scale, to compensate for workshop experience as much as is possible; assisting for instance technical graduates with potentially little practical experience. Directly associated are the materials which go into the manufacturing processes which can be evaluated and classified, and how the products are developed; which interlinks component and product-design. Formalised documentation, imagery and lecture-material will fundamentally comprise the training module; see following sections.


Figure 8.5: The Grouping of KTs, Classified Collectively for Training Development

With this said, as previously discussed all the essentials KTs are interrelated as a systemic vision of the cost-process can clearly distinguish; discussed at length in Chapter 7. Therefore of the eight, the remaining four knowledge types outside of the Manufacturing module were ultimately grouped around these initial four; and could subtly for the tacit ones, and overtly for the others be incorporated within the associated training programmes. For instance risk is linked with material, manufacturing process, design and product; see Chapter 7, Figure 7.11 and Sections 7.2.3.4, 7.3.1.9, 7.3.6 and 7.4.2.3. The communicational and cultural aspects, along with Costing Process knowledge apply across the whole, (see Chapter 7, Section 7.4) and are discussed more within the proposed interactive learning sessions. Other types of module sectioning were adopted from perspectives other then knowledge types. These included industrial relevance of the areas; disciplinary-relevance; and the level of participant whether beginner, intermediate or specialised courses: Discussed further in the Cost Centre section.

Industrial in-put was procured at each step of the TNA (training needs assessments), and the generalistic and specific developments were made; see Appendices 4a, 4b and 10 for supporting evidence, plus throughout the chapters. As prior mentioned, this perspective was obtained largely by taped interviews with the practitioners i.e. via audio and occasional visual recordings, questionnaire response and document analysis of existing company training material. These techniques tended to be accompanied by industrial-opinion, with regards to issues such as its effectiveness, suitability, how current, or regularly the programme was updated. A vivid perspective into the opinion of adequacy and what improvements could be made were frequently conveyed. These techniques apply to a generalised overview of company training programmes.

Table 8.5: Subjects to Include within the Core Lecture Training Modules:

| | |
|---|---|
| • Costing process: Generalisations and specifics | • Company strategy |
| • Communications: Interpersonal and networking skills | • Product knowledge requirements |
| • Contact development and maintenance | • Design change management |
| • Supplier costs / quote Breakdown: Management of | • Cost forecast techniques: Awareness of |
| • Organisational financial breakdowns | • Non-cost interactions: Working practice; cultural awareness |
| • Manufacturing process: Fundamentals e.g. depreciation; tools and equipment | • Uncertainty and risk analysis: Tools and techniques |
| • Material cost assessment | • Statement of Work (SoW) |
| • Labour and skill level | • Bid preparation |
| • Market trend appreciation | • Costing commercial tools: Training of |

Part of the developments towards the training, both in respect to covering all KTs and towards employing a range of medium, included the design of a Materials workbook. The development of which involved a specialised questionnaire to establish fundamentals of required content for workbook among the other factors surrounding such a document. See Section 8.3.7 for detailed explanation. The materials questionnaire can be found in Appendix 4a; and extracts from the workbook prototype based on the manufacturing industries, can be accessed in Appendix 6. CBT prototype modules for the manufacturing process may be examined, as were developed by MSc project related to this research; reference [Thilakawardhana, 2002] for injection moulding module; and [Kwok, 2003] for metal forming. Though initially a breakdown of the manufacturing processes were required, see Figures 8.8 and 8.9.

### 8.3.3.1 Programme Consolatory Host

Before further elaboration on the developments regarding the specifics of the training components, a brief introduction is appropriate towards the area which may act to consolidate the proposals, encapsulating the highlighted training mechanisms. A way in which the training may be kept current and at the forefront of industrial requisites is to develop it within one centre, for the costing domain in general. This is as opposed to making it relevant only for a specific industry or even organisation.

This point has been identified, as generally cost -training tends to not only be industry-specific, but even more limited to being organisational-focused. Therefore an independent, potentially academically based Cost Centre would be able to transfer knowledge across disciplines, companies and to an extent, industries, on an international level where applicable. This is a key consideration if the issue of standardisation within this process is ever to be attained. Refer to the earlier chapters' discussions on terminology including Chapter 3, Section 3.1.1 for a theoretical perspective and Chapter 4, Sections 4.4 and 4.7 for industrial observations.

A centralised type of Cost Centre can act as a channel to disseminate the industrial research findings, propagating the results in a pragmatic manner having established them academically; see earlier chapters where this development has evolved throughout the thesis. Therefore again in reference to the title of the this thesis, the integrated knowledge framework has been developed and discussed particularly in Chapters 6 and 7. Subsequent issues of implementation of this ICKF into the industrial domain of product-costing needs to be addressed practically to fulfil the research requisites.

Such a Cost Centre would aid in the design and implementation of an array of training activities specifically for the domain of costing. Figure 8.12, (in Section 8.3.8, Cost Training Centre), depicts the type of facility described, including all the specific functions that would be available. This includes a cost-table which will contain various components, as relevant per trainee participants, e.g. automotive and / or aerospace specific components, which can be costed with guidance if required. Plus workbook aids, see Figure 8.11 for an extract from a prototype material workbook and Appendix 6; and general physical / visual information. This would be in the form of running videos, CBT availability, and a cost-library with the latest developments and publications. Workshops and lecture modules can be run within this centre; current commercial software can be made available with training and the opportunity to demonstrate the softwares; see proceeding sections and Figure 8.12.

The training discussed within this thesis is largely, though not exclusively focused around such a centre with use of its facilities. Therefore an ideology of this element, the consolidation of the individual training proposals to be developed within one centralised domain is given now, prior to the individual descriptions, so that there is reference for the structure of the programmes. More details about the concept of such a centre are presented after the other main developments have been discussed, in order to place them within a context: The reason it is described in Section 8.3.8 is to show how the facility may be fully implemented with the other training tools and techniques, having highlighted them, as follows.

### *8.3.4 Training Delivery: Expert Lecture*

Lecture based training material will be developed for all areas established as relevant to costing; such sessions will be the core of the training delivery. As prior discussed in Section 8.2.5, the key aspects of delivery are:

- ✓ Instruction i.e. telling trainee what to do, e.g. via lectures;
- ✓ Demonstration i.e. showing the trainee what to do;
- ✓ Direction or Guidance i.e. allowing them to learn by doing it under supervision or with guidance.

The training within this research implements all these techniques in a multi-method approach to training delivery, with the aim of reinforcing each aspect of the course through communication on the training programmes via as varied a medium as possible. For example visual stimulants either video or demonstrations will reinforce the lectures; and guidance will further permeate the presented information initiated by the lectures, as discussed earlier. Pus greater detail of these points are bestowed later in the chapter in relation to the specific training proposals for the research dissemination.

In relation to the first point of delivery, expert-lecture modules are termed as such due to the proposal that industrial experts may be employed for the purposes of lecturing, on a type of consultant basis. The costing centre may design courses of components specified for each training course; see cost-centre section. Therefore the appropriate expert can be selected to lecture on their specialised discipline, as and when required. This will result in the highest quality lectures due to current, regularly updated industrial relevance, and domain-specific lecturers. These taught courses need to be interactive with demonstrations along with tutorials, for question / answer novice-expert interaction. It was noted that video footage may play an important part in conveying the visual knowledge that is required in the absence of first-hand experience. This was highlighted in the context of novices from a more economic, commercial background, who would benefit from having a more direct, visual knowledge of the product they were costing, e.g. a military ship, noted by a cost-practitioner from a U.S. manufacturing corporation. Therefore as viewings of such product-types are not always possible, the proposal of relevant video footage being integrated into the training material was suggested. Visual images similar to the video-learning techniques are also proposed for inclusion within the CBT, in conjunction to supporting the content of the expert lecture sessions, see Section 8.3.6.

Expert-Lectures were highlighted by more then 90% of the interviewees as necessary within cost-training; mainly due to the fact that interactive learning would be allowable in this way. Refer to Chapter 4, Table 4.2 for P1 participants; and Chapter 6, Section 6.1.4.1 or specific detail of all industrial contributors across P1 and P2, including numbers interviewed; plus a list of the 24 organisations that participated within this research within Table 6.2. A small minority of practitioners (less then 10%) indicated that in an industrial environment, time to attend lectured courses or to travel off-site for them, may reduce the numbers that attend or generally just be inconvenient. However a clear majority expressed that lectures, with scope for question-answer sessions, was a preferred method of training. Based on this feedback, coupled with the academic, documented validation of this technique, lecture-based material was the foundation of the proposed training programmes. Table 8.5 gives an indication whilst Appendix 7 lists the type of subject-matter which can be included in the training programmes; also refer to the Cost Centre Section, 8.3.8.

The lectures may be sectioned into modules, according to subject. The intention, which as already indicated can be developed within the scope of a cost-centre, is that an industrial expert, accomplished within their field can design the lectures preferably together with a contributor with some academic knowledge, to assist in aspects of teaching. Ideally the specialist should be from each industry utilising the training, so every course may be slightly modified around the essential core elements i.e. the cost themes and KTs, (see Chapters 6 and 7) to suit each set of attendees needs. The latter mentioned can be determined by straightforward techniques such as pre-training questionnaire, discussed in Section 8.2.7.2. For instance if primarily automotive personnel will be attending a course outside their organisation, the lectures, examples and general content can be automotive-focused. If mixed industries, it can be designed to cover areas which can be transferable between the organisations represented, or generally enough to be valid for all trainees.

Initially however, lectures should be designed to adequately present the fundamentals of all components of costing, i.e. convey the knowledge types identified in Chapter 7. and to address the themes (Chapter 6). Subsequent industry or even company-individualisation around these fundamentals may be designed accordingly. Therefore these initial lectures can be a core for which the continued subjects are trained by. However, they should be updated regularly, e.g. annually; or more frequently if assessed as necessary, with contemporary supporting examples and the latest industrial information.

For example, if lectures are on an element of risk analysis, then any relevant dominant occurrence that are current within that industry or even globally may be lectured on, with consequences included in the training for these trainees. This could include the resultant risk as a consequence of regional of international recessions; the affects on materials for instance of depleting natural resources, and the risks caused by fluctuating prices, economically crippling to projects if not foreseen and accounted for: Such events would impact on supplies i.e. availability. Anything a broad, current and relevant, such as the terrorist attacks in New York, now widely referred to as 9/11, to recessions or 'credit-crunch' to local strikes, cuts, closures, and international holidays affecting productivity. These include Thanksgiving (U.S.), Christmas (UK), Chinese new year; all such cultural considerations which may act as a risk if not factored into any global transactions.

To summarise, the core information and knowledge portrayed within each lecture module can be developed by industrial experts, and modified to be industry specific by again the most suitable industry training representative. These lectures can then be updated as and when required; and the database of expert-lectures can be redesigned per course, to suit the specific individuals that will be attending each time.

If it is demanded, an organisation (usually medium to large) may request such lectures to be part of an in-house training programme. The use of comprehensive training developments as discussed throughout this chapter indicates that such on-sight training requests can also be catered for, redesigned as appropriate together with the cost centre specialists and the company's internal expertise. Whether organisational-specific or an array of cost-novices from across industries and countries, the lectures can be modified and updated, with contemporary, relevant examples as required, once the core expert-lectures have been established.

### *8.3.5 Workshop / Interactive Training:*

*"Training is a people-to-people activity"* [Goldstein et al, 2002, p4] is a brief description of the attitude that should be adopted towards organisational training. This point supports the outcome of the research as described within Chapters 6 and 7, which is why a major element of the proposed programme incorporates sessions designed primarily to promote personal interaction; see Figure 8.8.

This type of interactive learning is commonly referred to as a workshop, and was deemed as a core component of the research findings, due to the initial perception that addressing such issues originally appeared quite complex and / or intangible. It seemed that training towards communicational interactions, recognition of cultural diversities and subsequent improvements of liaisons, basically general interpersonal skills, proved as challenging as design, product, or any other more physical-based training. Saying this, the task needed to be tackled from a systemic perspective; this issue is particularly prominent due to on one level, the diversity of people currently comprising the workforce, i.e. the differences in culture, backgrounds; even issues as gender, age, experience, but all of whom need to interact. Additionally, it is not uncommon to encounter products of which elements are actually produced in different countries, e.g. Eurofighter, developed between four European nations, including Germany and UK. In such cases a thorough understanding of cultural influences, for instance assumptions that may be made; as well as accurate communication can be essential to the success of such products. A prominent example of the need to be vigilant towards even seemingly obvious or insignificant diversity of practice due to culture was highlighted during a aeronautical mission, where the fatal flaw within the product was ultimately isolated as being due to the concurrent use of two different units of measure. Essentially the metric and imperial measurement systems were being implemented in juxtaposition. Although the interacting expertise within Lockheed Martin and NASA were working in parallel on the same product, there was evidently insufficient attention paid to the detail of cultural multiplicity. Hence resulting in the failure to identify this mismatch, where two dissimilar systems where mistakenly implemented, assumed as working within the same one. Lack of conversion is a typical but significant error, in this case ensuing in eventual disastrous consequences for the entire project through the loss of the NASA orbiter, reportedly incurring financial losses of $125 million [Lloyd, 1999].

Figure 8.6: Individualised Graphical Aids Developed as Guides Through Workshops

[Grove Consultancy, 2008]

There are wide global concerns for organisations that may thrive via the employment of workforces within vastly diverse cultures. Differences include that of wages and working conditions, though ultimately the personnel may need to interact across different countries but within the same company or between different ones, [Holden, 2002]. Training concerns need to be appropriately addressed to ensure all diverse communities involved are suitably catered for, [Goldstein et al, 2002]. Within many of the organisations examined such issues where prevalent; though evidence pointed to it rarely being tackled adequately as difficulties were created periodically due to essentially ineffective interactions and general miscommunications and / or misunderstandings. In addition to the previous example related to the use of segregated whilst paralleled inter-related working between organisations towards the Mars orbiter, and the subsequent overlooked modes of measurement used, there were more specific instances throughout this research, related to issues which turned out to be basic translational misunderstandings. This included between UK automotive-costing and supplier invoices; mismatch of priority focus e.g. between interacting disciplines, including purchase / engineering and costing. This even applied with regards to the value of the function or role of product-costing itself, by the new management in the case of an international automotive company take-over.

The workshop approach implemented to address these concerns is essentially a ‘structured discussion’. It can be focused around a spectrum of organisational issues, being able to include those directly involved in the topics under examination. These sessions are facilitated ideally by a trained impartial facilitator, and designed so that discussion is centred on the areas in question though with scope for elaboration and encouragement and guidance to analyse the key issues, with room for expansion upon current perceptions.

The workshops employed both this research and that intended for the proposed training, hinges on the graphical aids developed by The Grove Consultants, International [Grove.com, 2008], see Figures 8.6 and 8.7 for a general idea of the technique. There are other types, [Delta 7, 2006; Root Learning, 2002]; but the particular graphical tool selected for this work stemmed from its suitability to convey the types of challenges identified. For workshop implementation the time frames required ranged from half a working day to two day-sessions, with the discussion-commencement and propagation being directed with use of these graphical facilitations; see following sections including 8.3.8.2 and Appendix 7.

The material used needs to generally be adapted per programme; with the Grove techniques being based on hand-drawn large scaled imagery, sized approximately 2.5 metres by 1.25 metres. The basis of this individualised visualisation adds to the impact of the session, personalising the process to assist the promotion of clear, amenable conversation. Importance is placed on issues surrounding 'trust' within such open forums of discussion with guilt, blame and any type of fear culture being eliminated from the on-set. Refer to earlier in thesis, including Chapters 2, and 4, Section 4.3.4 regarding confidentiality issues, plus Chapter 5, Section 5.8 which examined the different types of trust. This is attained with use of ice-breaking techniques, one of the main purposes for which is to coax all participants into contributing freely. Having created a relaxed environment, the facilitators role is crucial in guiding a highly structured process in a seemingly unstructured way when within the actual setting; promoting a naturally emancipated environment essentially of 'conversation' or a group discussion, to flow to a pre-designed and constructive conclusion. Figures 8.6 and 8.7 show the facilitator guiding the participants through the layout of the workshop and subsequently through the results; which are displayed within the surroundings as they are procured. The function of allowing this visual presence of the ensuing outcome is to enable them to be built upon, expanded and absorbed.

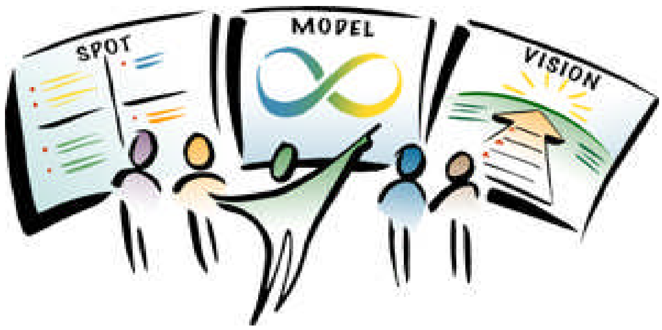



Figure 8.7: Visualisation of Workshops, to Guide Participants and Facilitator through the Personal Interaction and Knowledge-Transfer Sessions

[Grove Consultancy, 2008]

These interactive learning sessions are intended to be embedded within the training programmes, with knowledge exchanges, development and enhancement from regular intervals of interactive learning being dispersed throughout the courses. The essence of such a course-layout is to create a personal interactive environment which is ubiquitous, throughout these training programmes. To elaborate, group discussion between the attendees which may include a range of background-specialisations and experience-levels, will be continually encouraged. This facilitates interactive learning, from each other as well as the expert-lecturers running the sessions, throughout the modules. This is in conjunction to the active skills gained within communication and networking, promoted by both targeted training via instruction in these areas; and reinforced by the programme-environment being a deliberate forum to subsequently practice with the aim of retaining such knowledges'. Therefore not only will there be physical components of the knowledge-types, primarily communicational and cultural, but there will also be the development and continued practice of these elements. This will firstly teach the trainee about where and what these issues are, and then allow practice through the demonstrational and guidance costing mixed-group sessions coupled with the workshops. This conveys from a first hand perspective the aspects of why, how and with whom such interactions are to be conducted with; with the intention of the trainees acquiring the skills so as to be able to embark on such interactions with greater ease, once returned to the working environment. Hence, a general formula for such workshops is as follows:

- ✓ Run by a non-contributory neutral facilitator;
- ✓ Between 6-12 participants;
- ✓ Between ½ day - 2 days in length; predetermined with the users, prior to course;
- ✓ Key issues addressed via questions designed around them;
- ✓ Questions discussed / debated, with responses noted, openly captured and displayed for reference and re-examination if necessary;
- ✓ Implementation of visual aids of which are individualised (a general requirement), per workshop;
- ✓ Sessions create an essential element of trust; a relaxing and non-threatening open environment in which all necessary domains can be conversed about in an uninhibited manner; this can be created via initial ice-breaker activities, with subsequent facilitator intervention, if required;
- ✓ Workshop highly structured, with 'beginning, middle and end' designed and enforced throughout the session, i.e. timetable of entire session, displayed and followed;
- ✓ Therefore conclusions to the issues can be deduced, having been derived through agreed group in-put;
- ✓ Workshops will be recorded in unbiased and all-inclusive way; and made available to participants, for general future reference i.e. potential guidance through future challenges;

The workshops are discussed with specific detail behind the concepts session design, and content in the following section which examines interactive learning.

#### 8.3.5.1 Physical Interactive Learning

The workshops are designed to impart not only the 'hard' or more tangible knowledge types, i.e. product, manufacturing-process, materials, design and to a point, risk. They will also infer such 'softer' issues, i.e. culture, communication, (risk); along with the systemic perspective of the overall process of product-costing. This will be done in both a targeted and an amalgamated way, with the hopes of evoking the manner in which such knowledge-types are naturally mixed within routine working practices. Thus although the theoretical need for the enhancement of the softer issues will be stressed through the lectures and other more tangible forms, it will be actually implemented when the diverse groups are thrown together in the practical costing situations, e.g. demonstrations / guidance or learning-by-doing sessions, plus the facilitated group discussions.

Through personal interactions, knowledge and information will be transferred freely. Figure 8.8 shows how personal interactive communications can start cognitive learning processes across the discussion groups; where the knowledge pool is ever expanding due to the numerous continued contributions; and which can be accessed throughout, by all. The workshops will be designed around the knowledge-types (see Chapter 7), including KT structure into training modules, such as manufacturing processes being supported by CBT learning sessions; and materials, being reinforced with a permanent work-book reference. Whilst focusing on the explicit training area, discussion will be promoted; as the participants of the courses can include a range of trainees (see Table 8.6), the interactions will potentially be between:

- Expert and relative novices;
- Cross-discipline specialists e.g. different engineering functions and / or economic;
- Best-practice share across organisations / industries, when attendees of the course comprise of several organisations.

The learning occurs as workshops create the opportunity for different disciplines, specialisations and levels (experiences) to interact and learn from each other; whilst promoting and enhancing their own knowledge. It is designed for the different novices to interact; this includes the inexperienced trainees, with little prior industrial experience. This category will benefit from all other interactions. Those who are experienced in other disciplines and departments, but are new to costing, can transfer knowledge to all other participants, as they will tend to have knowledge in areas which are relevant to the costing process, i.e. engineering design, manufacture, component or product–specific, otherwise financial departments. In addition to transferring their prior expertise, they will develop their own knowledge base further, as the act of relaying it to others will help them understand how it fits into the costing process whilst bestowing a more systemic view, which will positively deepen their insight. Though the non-cost expert will posses industrial knowledge, they may not understand or be aware of all aspects involved in PC; therefore such courses will be of benefit to them.

Therefore whilst novices and more experienced practitioners are partaking in the training, interactive discussion will reinforce communicational awareness and the need for networking. Cross-functional awareness will be raised when different disciplines contribute to discussions and contributors from different organisations and even industries will provoke thought, through best-practice costing exchanges. Although care will need to be taken by the course organisers to ensure the participants are not compromised competitively: This can be addressed through pre-attendance selection, of the trainees.

On this note, training of the trainers is essential, during the development of such interactive, multi-method training courses. The experts running the sessions will ideally be from industry so have current, specialist expertise; their training will involve workshop facilitation, to promote discussion and maximise in-put from the attendees; whilst also lecturing during the more formalised sessions. Figure 8.8 symbolises how a range of participants, ideally between 6-12, can interact with each other and collectively contribute towards the broadening of each others knowledge, understanding and learning via interactive communicational workshops.

### 8.3.5.2 Diversity of Participants:

Where possible, interacting domains will participate: This is predicted to be more common if courses are held on-site at a specific company, which may have requested targeted training with the content adapted for organisational relevance i.e. for solely its work-force. In such cases purchase / economic, engineering functions can attend appropriate sessions. The interaction of contributory functions towards costing will be an added dimension to the knowledge base: This will not only give a more systemic, holistic visualisation across the process. It will also aid in eliminating cultural barriers which often exist between different, but interacting disciplines; as discussed in Chapters 4, 5, 6 and particularly 7. The in-put of areas which predominantly work independently of product-costing, but are still directly relevant to the output in the large majority of organisations, will aid in the strengthening of integration by improvements towards understanding from all areas. Once the practitioners have clarity of each others roles and understand how the other works, what it does, why, when and where, they will be clearer on why they should be working together, when they need to and how this can be done effectively. Interactive discussion (see Figure 8.8) highlighting roles in conjunction with more structured, instructional delivery modified as required per programme, will aid this process of understanding, integrative working and the lateral transfer of cost-knowledge.

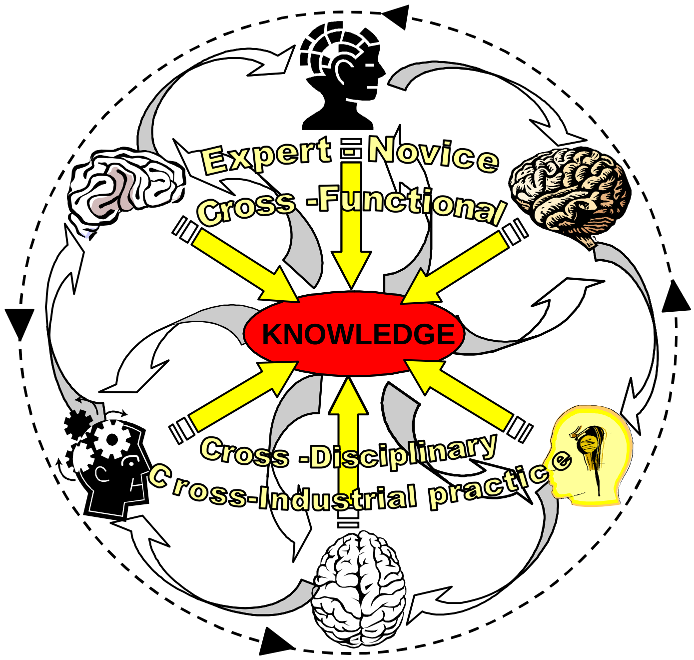



Figure 8.8: Workshops Promote Interactive-Learning / Knowledge-Transfer Between the Participants: The Action of Communication Stimulates Learning.

When different organisations from within the same industry interact, best practice can be exchanged, and improvements to external relations can be forged; though as mentioned, this is a delicate area which requires informed selection from the trainers. Consideration is dependent on type of course being run e.g. whether unspecific, around the KTs generally; or whether more focused; along with the selection of potential participants per training programme. For interaction between trainees from different industries standardisation in practice may be attained and thus propagated across them. This can be developed over time, with the course designers being in a position to work with industry in developing and disseminating standards via training programmes, plus through supporting material which can be made available: And eventually publications, which as derived in conjunction with industry, can anticipate their being accepted more readily. Such publications can be collectively developed with any official cost-body too; including endorsements from entities as SCEA, ISPA, AACE. This may aid in establishing industry standards and a general higher profile for the costing-process, which was regularly stated as being inconsistent across organisations, throughout the research; see previous chapters discussion of terminology and lack of consistent cost terms, particularly Chapters 3 and 4, Sections 3.1.1, 4.4 and 4.7. This aided in the lack of credibility displayed by external users of the process, as experienced within product-costing. The interaction of industries also will expand the knowledge of all participants through idea-exchange. Transferral of practice from one product–type to another which may not have been prior attempted or realised, can occur; this will help further the process overall.

Table 8.6: Lists the Types of Participant Integration, and the Results that Workshops / Personal-Interactive Group Sessions can Promote:

| TRAINEE TYPE: | INEXPERIENCED | EXPERIENCED | CROSS-DISCIPLINARY |
|---|---|---|---|
| SAME ORGANISATION | Gain insight and knowledge-transfer benefits from all other quarters. | Transfer and enhance current knowledge. | Improve understanding of roles, and therefore enhance Culture and communication |
| DIFFERENT ORGANISATION | Observer wider observations then one organisational practice alone: Broaden knowledge / reference -base | Develop and propagate consistencies in knowledge; and thus establish best practices | Establish industrial commonalities and industrial best-practice processes: Improve understanding and interactions. |
| DIFFERENT INDUSTRY | Gain best-practice knowledge and understand consistencies and peculiarities of the process. | Identify industry-specifics; and differences; therefore further establishment of best-practice among commonalities | Identify common traits; transfer best-practice and determine process-constants, plus industrial specifics. |

Although in standard working conditions regular miscommunications and misunderstandings may occur due to a number of prior discussed reasons, including lack of resource, so low time for adequate interactions, etc (see Chapters 6 and 7). It is however, less difficult to mis-interpret a purchasers role when directly expressed by them, personally in a neutral, ‘safe’ environment; a situation which has been designed for such roles to be clarified, discussed and subsequently debated around issues such as its validity, importance and relevance to another role. The benefits of mixing the participants for these sessions is summarised in Table 8.6. The interactive section later in the chapter highlights the way in which such workshops can fit into the overall programme.

This research will suggest an initial means of validation of the training programmes via a questionnaire-technique; the basic theory behind which is relatively straightforward. The participant will answer a questionnaire before the training commences, then directly afterwards, and again after a slightly prolonged period. Direct comparison of the results can provide some indication as to the basic success of the course, from the initial before and after questionnaires; followed by the retention of knowledge being indicated by the delayed questionnaire. This type of evaluation can be accompanied by various on-the-job monitoring where possible, plus follow-up courses to reinforce and enhance the learning process; see Section 8.2.7 on Evaluation and Validation.

## *8.3.6 Computer Based Training tools (CBT):*

The majority of published results with regards to CBT development and usage is in the area of health and educational sectors: It can be noted that much of the reported developments have been favourable. Veldenz and Edwards [1999] concluded that CBT modules offered a promising training supplement towards the decision making skill development for surgical education. It allowed interactive CBT modules that were compatible with windows, whilst being flexible enough to incorporate sophisticated multimedia; allowing the modules to act as both testing and teaching, [Veldenz and Edwards, 1999]. Further development into the area of surgical education will require more exposure, experience and investment. However when utilising CBT within training, consideration and additional provisions must be made towards the fact that it will be limited in its responses, i.e. not all possible answers will be incorporated; thus it should act only as a support to any particular area of training. Knowledge representation in forms as concept mapping and semantic networks, integrated with a training tool has been a successful development within secondary education [Rye, 2001]. The computer based concept mapping responded to a concern that many potential users would not consider CBT's due to conceptions of high difficulty levels. However the study concluded that both teachers and students were enthusiastic and enjoyed using the software, encouraging the students to learn 'with' the technology. A drawback of this development was that the software was validated only within the school-environment; and the prior-stated, within a surgical one.

Miles et al [2002] state and continue to confirm that the level of complexity of a design system should be matched to the task undertaken [Miles et al., 2002], regardless of application domain. Similarly the depth of detail and information presented within the costing CBT should be matched to the needs of the cost practitioner. For instance, the material knowledge module will only need to cover the aspects of material that effect cost. This does not include aspects as molecular composition of material (see proceeding section). The author has observed that few publications have specified how knowledge was elicited, and then subsequently transferred that knowledge into a training tool. The publications generally discussed the results and impact of the training and CBT; which frequently highlighted the need for further development of the tool; and the presented cases were often limited in the domain application. This research has elicited the costing knowledge, identified the domain themes and derived an ICKF from the practical and theoretical examinations; see earlier chapters. As a proposal of dissemination of these results into the industrial costing domain, the training developments should be adequate for purpose, particularly tailor made programmes, i.e. not the standardised types of training currently available, but enhanced training material integrating all aspects of the research findings in order to address PC requisites.

### 8.3.6.1 CBT Development

Within the research, the subject domain for the CBT module was focused around the knowledge-type of Manufacturing Process (MP) Knowledge. This was selected due to the fact that a number of issues arose with regards to this KT, and key point related to the training of manufacturing processes was in the fact that they, the MPs needed to be experienced in motion. In conjunction with lectures and theoretical facts, if MPs were able to be visualised in progress, a sense of scale, speed, results i.e. output of machinery could be experienced; and even to the degree of incorporating elements such as the sounds produced. All this may be relevant in order to recognise a properly running, efficient piece of equipment where the costs will differ to that of a slow, outdated, inefficient one. As the CBT can incorporate moving images as well as still ones, it was deemed ideal for the training of MPs, and thus the transferral of such knowledge.

The CBT will incorporate video clips from industry. These clips will be either in the form of interviewing an expert, with 'frequently-asked-question' explanation options available for the user. This will be more for the commercial knowledge transfer to the engineering user. Additionally it can be from the videoing of the processes angle. This can be made relevant for costing novices from mixed backgrounds.

The costing CBT proposed will produce two types of training: One which can take the user through a complete costing-process or through a number of case-study type real life processes in a step-by-step process. The other will focus on one aspect of the costing KT required, as prior mentioned. The CBTs developed in response to this research can be referenced in [Thilakawardhana, 2002; Kwok, 2003], MSc thesis detailing the manufacturing processes of injection moulding and metal forming respectively. Figure 8.10 gives an example of how the manufacturing processes as derived from a large international automotive corporation and an aerospace organisation: The figure is highly detailed, and shows the complexity involved in such a CBT.

### 8.3.6.2 Training within a Specific Knowledge Domain

Once the area of development had been selected, the process of developing the material of which a CBT may be based upon was undertaken. The initial and fairly generalised approach taken is illustrated below in Figure 8.9; and in-depth finalised breakdown of activities is presented in Figure 8.10 which as mentioned above is taken from research which focused on developing manufacturing-process modules of the CBT; which was a derivative of this research project.

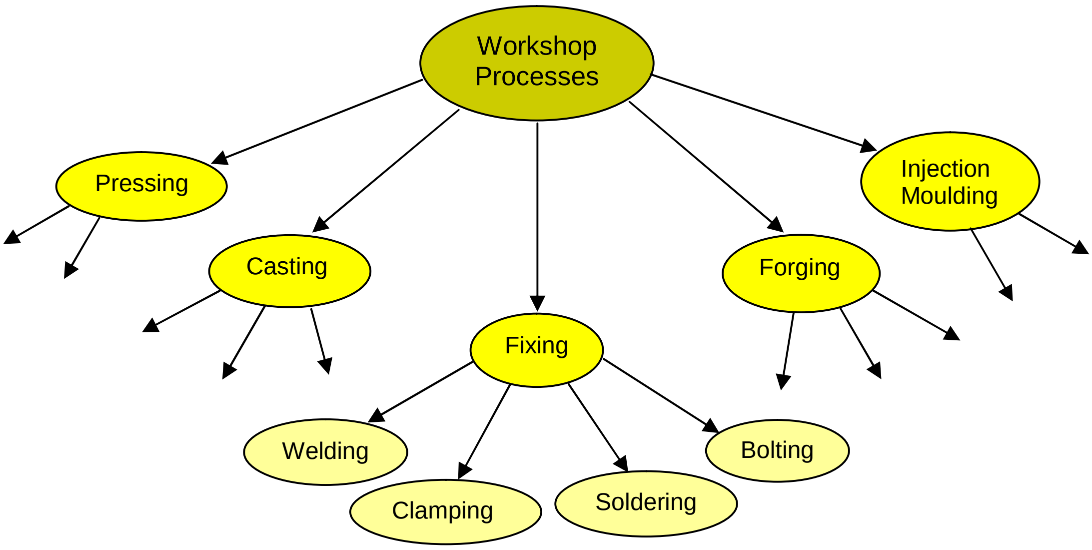



Figure 8.9: The Basis for CBT Subject-Matter: Modules developed will be per Manufacturing Process types: Structured down using this System.

Figure 8.9 illustrates the basic concepts behind the manufacturing process CBT, showing the theory behind the design. The first development towards any given CBT modules was to initially establish a detailed map of all the manufacturing processes commonly employed within industries, see Figure 8.10. The industries used to base this information on were primarily that of aerospace and automotive. It must be noted that the bulk of this work i.e. the individual design of two of the proposed CBT modules were undertaken as part of sub-research projects, associated with this one [Thilakawardhana, 2002; Kwok, 2003].

Initially, in the first year of this extended area of research, a thorough manufacturing process map was designed of the processes undergone within large, international organisations within the prior stated industries. Having established a chart illustrating the broad level of processes, showing links between them, it could be seen that such developments will be a large undertaking, as the complexity in detailing the high level of manufacturing processes showed. In other words, there are numerous processes involved, so developing training to depict each one in detail would be an in-depth undertaking, though highly beneficial for all levels of trainee and even practitioners when completed. It was decided that a prototype would suffice to give an idea of what the research was suggesting and injection moulding was the manufacturing process, MP, selected for development into industrial CBT prototype.

The primary focus was on polymers, due to the fact that they are the main material for the MP of injection moulding. The CBT tool covered the fundamentals of polymers, including an exhaustive list of them. This was proceeded by a separate terminology section; and extensive detail including film footage of processes in motion. The prototype highlighted all the main mouldings techniques within industries, and included visitation and input from suppliers as well as major manufacturers. The issue of costs was addressed; and the CBT concluded with 'tips' from the actual experts themselves, see [Thilakawardhana, 2002]. Figure 8.9 presents an idea of the layering of manufacturing processes; the actual map developed based on these organisations MPs is highly complex, with two separate ones being produced per model-company, for simplicity. Figure 8.10 illustrates the different processes involved just within one module of the injection moulding.

This particular section of development, given in Figure 8.10 of the CBT-derivation is based on a large automotive organisation. The process model has been subdivided into four main areas, to breakdown the processes and address them accordingly. It has been apportioned into materials and the relevant processes, so the level of detail may be incorporated into such CBTs is evident from this starting point. An aerospace organisational manufacturing-process (MP) model, in a similar level of detail was also produced; then the finalised version was derived via an amalgamation of the two [Thilakawardhana, 2002]. Two models were then developed from this initial MP-model, over two years, as stated previously, [Thilakawardhana, 2002; Kwok, 2003].

This research also suggested that the CBT usage be extended, in order for it to take a novice through the entire process of costing a component. The component selected will need to be a relatively straightforward one as far a costing goes, i.e. not an entire engine. Although the breaking down of an entire Rolls Royce or Puma engine could have similar themes throughout, relevant for both automotive and aircraft industries, it would be highly time consuming to develop such a CBT to cover such a large process, as there are so many components involved. It would be an ambitious undertaking for a CBT training programme of this scale, and would thus risk not being completed before major changes occur; becoming outdated and thus being less relevant too quickly when considering the time and resource that would be needed for its development. However based on the prototypes produced here, such a CBT could be developed on more of a long term basis within the extended resource and expertise levels of organisations themselves, with a focus point which would be relevant for both aerospace and automotive. Thus components of which could be transferable across the two industries, and achievable to breakdown and document within a CBT within the project timescales is as stated below.

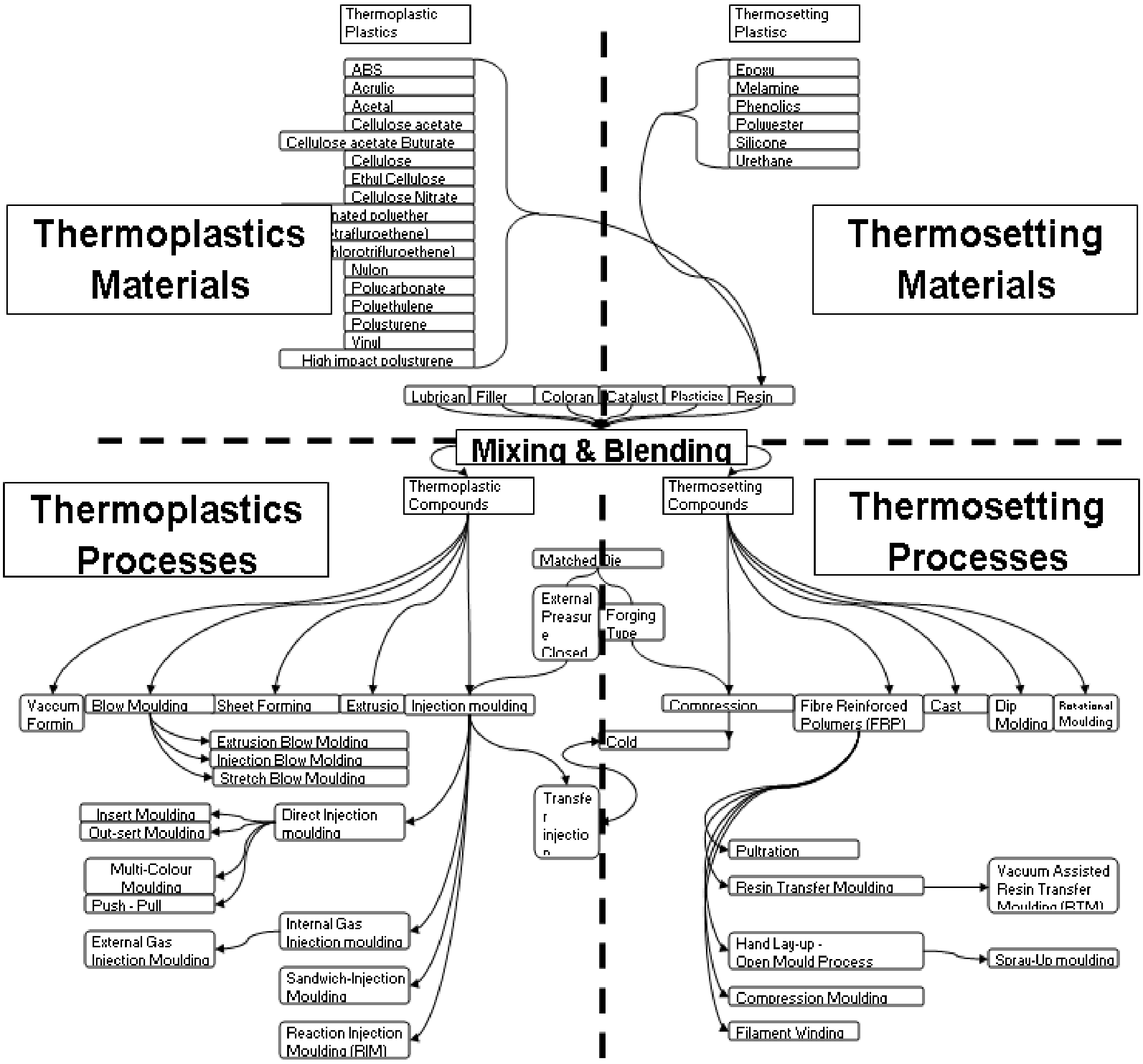



Figure 8.10: Development towards the Industrial Manufacturing Process-Model on which the Prototype CBTs were based on [Thilakawardhana, 2002, p85]

The possibilities for this subject are:

a) An Axel: On which to balance wheels; see following example of step-by-step CBT;
b) Windows: Although the properties of the windows will need to be different for an aircraft then for a car, i.e. greater strength and heat resistance for an aircraft; shatterproof for car; however the material used for both vehicles will still be based on glass.
c) Seats: Car seats will vary according to model i.e. upgrades will have leather, otherwise plastic and fabric, but structure will be very similar. Aircraft will differ from cars in the area of design, i.e. to fit the cockpit; also the add-ons, such as ejecting the pilot. Though the basic structure and materials may have a similar starting point with regards to costing.

d) Body in white: The shell of an aerospace or automotive vehicle prior to coating is also a potential for cost estimating.
e) Steering wheel: May be based on similar properties, mould types, and so forth; as well as other components within the car / cockpit.
f) Air-conditioning system: Whether in an aircraft or car, these systems will fundamentally be based on similar types.
g) Wheel rims: Again would differ in properties as heat resistance and strength, e.g. regarding the projected load to carry; but based on basically similar properties as far as consideration of aspects such as processes for mould.

The prior list contains proposals for CBT development, which would follow the lifespan of any of the stated components, among others, from conceptual design through to disposal, with the cost implications highlighted throughout the module. This would assist particularly those who have little engineering / technical knowledge. This is because they can visualise the component from beginning to end, so will help with their costing of it.

The selection of subject matter that is relevant for a cross-section of industries for training development including both aerospace and automotive relevance, as compared in the previous list, was preferable. This was because the knowledge types identified as being necessary for use within costing have been revealed to be similar within a number of industries observed; see Chapters 4, 6 and particularly 7 for cost KT listing and discussion. Therefore theoretically a cost-training package may be developed, which would be of benefit across industries, as it will consolidate knowledge which is utilised within them. Such LLC (life-cycle costing) can show how components fit into the product, systemically; given an awareness of product-knowledge, and how elements of the costing-process fit into the whole; this is important as costing of entire products may often only need to be performed once per project, i.e. at the beginning, to set budgets, time scales, labour allowances and bid-submission.

#### *8.3.6.2.a) The Recipients of CBT Modules:*

The recipients of the costing training development have been discussed within Section 8.3.5.1, (see Table 8.6). However, the CBT module is particularly flexible in its applications, being able to be accessed by novices whilst within a company, and on-the -job; so will benefit novices who are new to industry i.e. apprenticeship candidates and academic graduates. It will also help practitioners who are experienced in other areas of industry and moved into costing, as the CBT may be adapted, tailored towards the industry they are in, by modifying the components studies and the visual images to suit the environment.

The training will ideally make provision for industry specialisations and as discussed earlier even organisational ones e.g. companies including Ford Motor Company have worked with academic institutions to develop company-specific, and certainly industry-relevant training programmes. The CBT will be ideal for those with cross-disciplinary backgrounds, as they can experience aspects of manufacturing process, which they may not have had the opportunity to view before. The following section discusses development of permanent reference material in the form of a workbook relevant to the cost knowledge types identified.

### *8.3.7 The Materials Costing Workbook:*

The training is designed with use of multi-method techniques, to promote learning via a variety of stimulants in order to cater for different learning needs e.g. audio, visual, lecture-based, reference materials; and to reinforce the training content on the trainees. As CBT development had been deemed appropriate for the manufacturing-process module, a workbook was subsequently decided on, as the participating cost-community stated the usefulness of a permanent reference guide. The most suitable subject was materials, due to the comparative stability of this area in reference towards various the fundamental material properties and compositions; plus its relative ease to depict via two-dimensional visual-imagery. Refer to Appendix 4 for training materials workbook questionnaire development.

The criteria for materials knowledge being propagated via the design and use of a permanent reference workbook is as opposed to a knowledge-type like manufacturing processes which would for instance benefit from visualising the physical moving parts of machinery. Similarly design knowledge would be challenging to classify and summarise within one publication, no matter how broad. Hence materials knowledge was deemed as most suitable for capture into a publication, out of the 4 KTs within the manufacture module (see Section 8.3.3. for module development and Figure 8.5), with the intention of not only reproducing information such as typical costs per kg; and international rates whilst highlighting the reasoning behind any differences including logistical considerations. It would also include case studies of costing processes, industry-relevant; which can assist the learning process of novices via reference to actual industrial occurrences.

The materials reference work-book (see Appendix 6) discusses issues of costing, but is focused around material costing. It is split into two parts: Part 1 is more theoretical; whilst 2 relays actual industrial case studies and examples.  Extracts from the prototype proposed draft version of the materials handbook can be found in Appendix 6; and see Figure 8.11.

The prototype materials guide book which has been split into two sections as mentioned above, has been further divided into two main subsections within each part 1 and 2; as illustrated in Figure 8.11.  The Introduction details the need and uses of such a publication; and the necessity for its derivation. It highlights necessities such as key areas of interaction, primarily: Purchase, Designers, Engineers and Suppliers.

Part 1A presents background work toward the cost, giving the general theory behind what must be required to derive it. The preparation process, essentially of: Material selection; Material quantity; and the time schedules which need to be planned around e.g. when the material is required by, are examined. The key components and considerations to material costing are:

- ✓ Cost;
- ✓ Delivery;
- ✓ Properties;
- ✓ Quantity.

Section 1B subsequently discusses the questions which need to be asked and suitably answered within costing. These hinge around who has the materials required; and whether they can deliver to specification and time schedules; (see Chapters 6, 7 and 2, Section 2.6.2.1 for 5WH, KC). Hence, issues surrounding supplier reliability and capabilities are examined.

The guide book will give 'Best practice tips' regarding materials cost, throughout plus 'Key points' to remember. Please note: The following example has been reproduced below in as similar a form as possible to the actual format of the workbook prototype:

**Best Practice Tip ➔** *Contact the Original Raw Material Manufacturer*
*-to obtain a cost of material from source- if necessary / feasible.*

**→Key Point:** Original Material Manufacturer may be reluctant to spend time compiling a quote for a non-serious buyer: Therefore be prepared to accept an approximation, which can be used to develop a more accurate estimate.

**→Key Point:** Material Price is Greatly dependent on Quantity Purchased!
Material Price is also dependent on exact grade of material required

**Best Practice Tip ➔** Remember to Compare the contractors' material and labour costs, against current official indices e.g. DASA

Part 2 is more industry-focused then Part 1; the latter giving more generic guidelines and procedures. Part 2A discusses industry specifics and general commonalities of costing. For instance the material weight, batch size, and form or shape it is delivered in will affect the cost regardless of what industry it is within. Issues particular to industries are then examined, with the two selected within this guidebook being that of aerospace and automotive. Supplier assessment, cost-breakdown and bidding processes are included in the analysis; plus types of bid e.g. competitive and non-competitive; and the main categories of material cost-breakdown, primarily:

- Raw
- Bought-Out Finish (BOF)
- Subcontracted

The initial section of Part 2B contains highly detailed examinations of the breakdown of costs for specific components. The case studies used have deliberately selected common parts, namely the 'bolt' and a 'door panel' so they may be straightforward to relate to and understood across industries.

An in-depth look at a supplier bidding and contract procedure is then followed, with the company WFEL being used as a typical case study. This ensures the workbooks have both generalised and specific components, theoretical and actual applications, and user plus supplier in-put into the content. The costing guide concludes by providing examples of materials determined as widely used within industry; and a substantial list of Material Information Tables. These tables include terminology, both the abbreviated and full technical names; the processes which these materials are typically used for; the type of end product that they are used for e.g. parts / components; and a number of the main suppliers of the materials, i.e. were they can be located.

The structure and content of the Costing Guide is intended to aid in the material cost-endeavours on a continuous basis. The user should have a wider understanding of principles, challenges and range of solutions having studied the Guide; which can subsequently act as a permanent cost reference, accessed on a regular basis as various complex and intricate costing situations arise. The fundamental layout of the guide is given within Figure 8.11. If this initial costing prototype proves successful in its original form within industry, it can be expanded, producing a number of volumes with equally high practitioner contributions from different industries, and detailing different components for case study. This can ensure that elements of development can be conveyed in the book, maintaining its relelvance and keeping it current. This can be done whilst compiling a vast source of reference for users to acess as and when required, both whilst on-the-job and in the training stages.

Appendix 6 contains extracts from a prototype of the proposed type of document intended as a permanent training reference towards the industrial costing of materials. The Guide may be kept at the practitioners' place of work and can also be made available for guidance during training programmes within the prior mentioned Centre. The following section discusses the Cost Centre proposed facilities, and the general interactive learning that will be able to be designed and implemented within it.

### *8.3.8 Cost Training Centre:*

Within this research, product-costing, PC has been exposed as having a number of inconsistencies, from terminology to general practices. The reasons for these variations are dominantly due to a lack of standardisation across the cost-process. Although a degree of this is due to issues such as inherent differentials between industries and types of product. The research has identified a number of areas within costing where there could be standardisation and an exchange of best practice, which would raise the overall quality of costing as a whole. To an extent this observation has been validated within the literature, though as prior discussed the cost-focused documentation tended to have omitted what this research identified as a contributor to the causes of much of these inconsistencies: Namely via a lack of examination into the aspects of  social and human factors which tend to influence the costing domain.

Due to legitimate industrial differences, and natural organisational / market competitiveness, there seems to be few bodies which could successfully integrate such process-discrepancies holistically. With this said, the research does acknowledge institutes and industrial groups as SCCAG, SCEA (Society for Cost Estimating and Analysis), ISPA (International Society for Parametric Analysis), AACE (~The Association for the Advancement of Cost Engineering International); and it seems that the US is noticeably more proactive within the domain. With this said a number of the French automotive organisations having been reported throughout the (UK) industrial interactions as being noted for successful practice, namely Renault and Peugeot. Nonetheless, there is still little if any current industrial publications which acknowledge the communicational and cultural effects on PC with the more physical, tangible elements of costing in an integrated manner, in order to address both the long-standing and continually developing challenges within the costing field; see Chapter 3 for analysis of the published work related to PC. What is therefore required is two-fold: Firstly an independent, international establishment which has influence and preferably endorsements from all other costing bodies combined, to promote consistency; and that could examine issues of best practice and propagate them in an objective way. Additionally for this to be implemented with use of the more unconventional perspectives, as well as the general widely accepted ones within PC which focus unequivocally around the tangible elements. In other words to ensure costings integration of the intangible elements with the tangible ones, respectively.

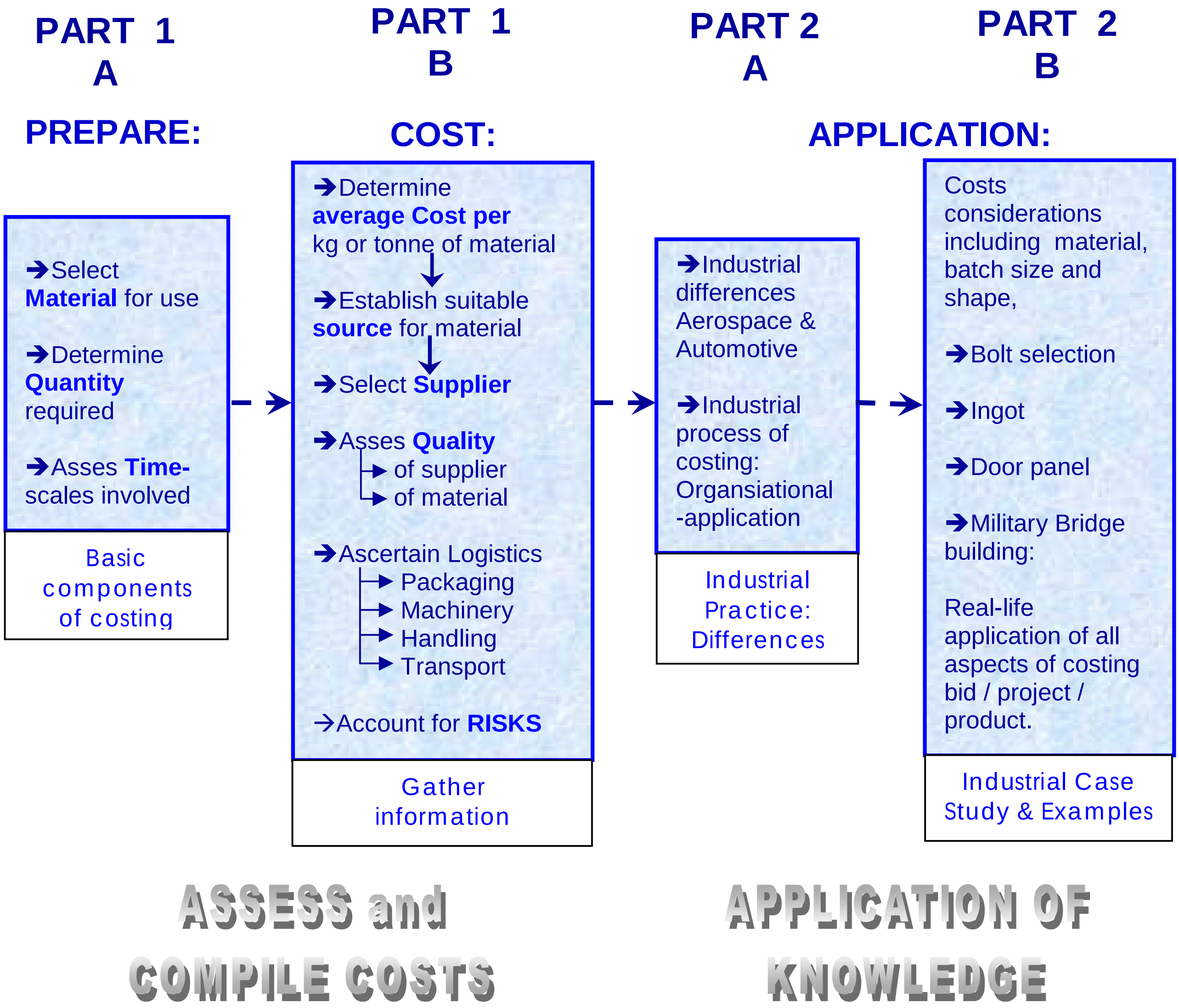



Figure 8.11: An extract from the Materials Costing-document showing the layout.

A centre which focused solely on costing aspects, which was independent of any direct industrial association, but was capable and acquiescent towards the development of costing within all industries would successfully aid the identification and dissemination of standards both across and within industries. Consequently training would be a key issue within such a costing-centre; therefore the training proposals (see Appendix 7), Figure 8.12 highlights the need for the development of such an establishment. Ideally the centre would be academically based, both to avoid the direct association with any one industrial body; and to promote the highest quality development of training programme design and implementation. The long-term goal of such a centre would be to accommodate cost-trainees (see Table 8.6) and specialised programmes internationally, being dedicated towards the continual update and improvement of the training, in accordance with industrial developments and advancements. The status of such a centre would clearly need to be built gradually with focused marketing towards the costing community, disseminated broadly, gaining credibility through performance and results. Therefore the design and maintenance of the coursewares is key to its success and value across industries who are intended to be contributors to its derivation and preservation. Figure 8.12 illustrates an overview of such a cost-centre, via a floor-plan view; it can be seen to have provisions to provide practical-example sessions, changeable as required, per session. It can also incorporate lectures, workshops, CBT usage, commercial cost-tool training, video footage, among other training and learning stimulants, see sections within Appendix 7a-g.

The training described throughout the chapter has been intended for primary implementation within such a Cost Centre. However, they will need to be designed into course modules in order to be efficient comprehensive cost-training. Table 8.5 gives an example of the type of lecture subjects; though this would be supported with manufacturing-process CBT sessions and work from the materials costing-handbook; see earlier sections for development plan of these training mediums.  Appendix 7c-7g gives detail of the subjects and how they are approached, including an example of a timetable for a weekly course (Appendix 7g). The 'softer' elements would be primarily conveyed via the interactive modules such as workshops and the active discussion sessions placed within the week, particularly included to promote communication and understanding of culture through the dialogue promoted, which will be focused on a number of the topics being trained.

The type of inclusive training which is intended for the centre would include the active recognitions and promotion of the more tacit contributors to the process, which have been identified throughout the research; summarised in cultural and communicational aspects within Chapters 4, 5, 6 and 7. As the process is fundamentally performed by individual practitioners, the way in which their humanistic features contribute towards the manner in which they cost a product, even when they are implementing industrial commercial software or any other type of programme / computing cost-aid, is important to the outcome. Therefore it must be considered along side the more overt contributors, of which comprise the first five knowledge types, (see previous Chapter, 7), which include design, materials, product and manufacturing process know-how.

### 8.3.8.1 Training Course Development and Delivery:

The centre should ideally strive to develop and implement integrated knowledge-transfer sessions, which can be modified to suit the attendees; and will be designed to cover all aspects of the research findings. The initial approach towards addressing this will be via gathering information about the prospective attendees and the company and environment that they are from, before they attend the course so it can be modified accordingly if necessary. This can be tackled via questionnaires being forwarded to them with instructions to complete and return, along with follow-up enquiries by the training organisers, among other types of research they can conduct' (see Section 8.2.7). For example web-based, direct contact with the organisation via formalised or informal means, even via telephone calls, to establish their needs from the courses. To a degree this type of activity will be conducted as part of the general updating of the courses anyway, through exercises designed to address the continually changing industrial requisites, whilst refreshing the training material. See Appendix 7b for pre-course attendee assessments.

The content of the course will incorporate sessions to induce the transfer of knowledge from expert to novice; see novice-types described in Table 8.6; between interacting disciplines; and towards all practitioners who are involved in product-costing, regardless of title and or role definition, the department they fall under, and their background knowledge. The pre-requisite course-structuring can assist the formulation of the programmes in order to ensure the required mix of trainee; whilst the marketing of the general training programmes will raise industrial awareness, so that they apply for the course with enough flexibility to be able to be allocated suitable dates for attendance. This allows the correct selection of training participants to be determined by the course developers. It is clear that the latter mentioned will need to be skilled organisers, ensuring that the training modules are planned in advance; along with the types of course available and the information necessarily sent and received from the trainees.

The ideal proposition is that there courses are run by a mixture of academic implementers but with regular use of industrial personnel, perhaps consultants or highly experienced practitioners who have perhaps (officially) retired, and are using their expertise via consulting. This was noted to not be uncommon within the organisations examined: Industrial consultants will not only run some of the modules, specialisation-dependent; but will help design and maintain them i.e. keep them current and relevant to the recipients of the courses. The industrial contributors will also need to be trained in the latest modes of training-delivery; see earlier Section 8.2.5. The academic aspect can facilitate such training and ensure it is updated per course contributor i.e. those who run modules of the courses. It is envisaged that a number of individuals will participate in the courses including industrial guest–expert speakers. The following sections discuss in more detail some potential content and compositions of the proposed training courses.

### 8.3.8.2 Knowledge Transfer Training Sessions:

This aim of this module is to transfer relevant cost-knowledge across the interacting cost related-disciplines; and to transfer cost-knowledge to the costing novices, see Table 8.6. The ways this may be achieved has been discussed throughout the chapter and is elaborated on within Appendix 7. These sessions will incorporate all the main techniques of training; and use a wide range of medium to relay the knowledge and information. This means the knowledge transfer module will include: Instruction i.e. lectures; demonstration and direction which is allowing the trainee to perform the task with supervision; as discussed throughout the chapter including Sections 8.2.5, 8.3.4; also refer to Appendix 7. The training will incorporate as wide a level of delivery as possible including CBT, workbook and interactive workshop. The former two developments will be incorporated into the Cost Centre training programmes, or may be utilised externally by trainees at their place of work, thus enabling individuals to progress at their own pace.

The cross-discipline, expert-novice interaction will be promoted via the interactive learning sessions, namely the tailor-made workshops. The varied approach to transferring knowledge to the cross-discipline experts and the novices is in order to access mental stimulus of the training recipients at all levels i.e. people learn at different rates, and via different methods; see earlier chapters. Therefore if as broad a spectrum of training techniques is employed throughout the module, all aspects of participant-learning will be catered for.

Nonaka's [1995] SECI model discusses knowledge conversion, tacit / explicit: Between the expert-lecturers or facilitators and the designed trainee-interaction. The type of knowledge conversion described may be applied to the proposed costing-courses; see Chapter 5, Section 5.5 and illustrated in Figure 5.2. This is in conjunction with aligning 'the audience' in this case the cost-trainees, with the message e.g. the course context, as deemed appropriate by the module–developers.

All proposed training developments may be incorporated into specialised Cost Centre programmes, designed for the course attendees; in other words modified per session around a core learning content which is based upon the industrial cost-knowledge framework, ICKF, compiled throughout Chapters 6 and 7. The studio will also have the commercial software courses and support available for those who opt to add the knowledge of use of commercially available tools to the cost-course; See Commercial software, Appendix 7e; and Chapter 6.

Figure 8.12 illustrates the cost centre, which will thus specialise in costing requirements; facilitating multi-method training programmes tailored for costing-needs plus associated functions: With the aim of applicability across industries, and internationally. Elaboration into the interactive workshops / knowledge transfer sessions is also given in Appendix: 7a-g; including a detailed timetable for a weekly course, (Appendix 7g).

Further details of the proposed cost-training is presented within Appendix 7; including how the up to date training may be adapted per course with use of pre-course assessments, determining which course will best suit the type of participant. Such information can subsequently be included in the training marketing, which will ideally be disseminated industrially, as appropriate i.e. targeted to cost and cost-related departments, eventually on an international scale. This will promote world-wide standardisation of training in time, which may be developed in conjunction with the participants where necessary and possible. The training will subsequently develop into increasingly sophisticated and beneficial programmes which, the more they improve, the more they will be implemented by industry. Ideally the industrial users will in turn be encouraged by the training designers to work with them instead of endeavouring to independently develop their own in-house courses, some of which may still be needed in-house, mainly product- and / or company-specific programmes.

## *8.4 To Summarise:*

The training programme proposals within this chapter have been directly derived from the cost-knowledge framework ICKF, discussed in Chapter 7. The issues that arose from the Themes (Chapter 6) have been incorporated; see Figure 8.1 which illustrates the cost themes and KT within an integrated cost-model. Additional array of cost-novice types and other contributory functions have been catered for within the proposals, defined throughout the chapter and summarised in Table 8.6; with these classifications being elaborated on in Appendix 7a. As a result, the training scheme outlined will improve the costing process due to its inclusive approach which stemmed from the recognition of process-wide deficiency. The omitted elements include the largely unacknowledged and hence unaddressed social and human factor based challenges within the costing-process; see Chapters 4, 5, 6 and 7.

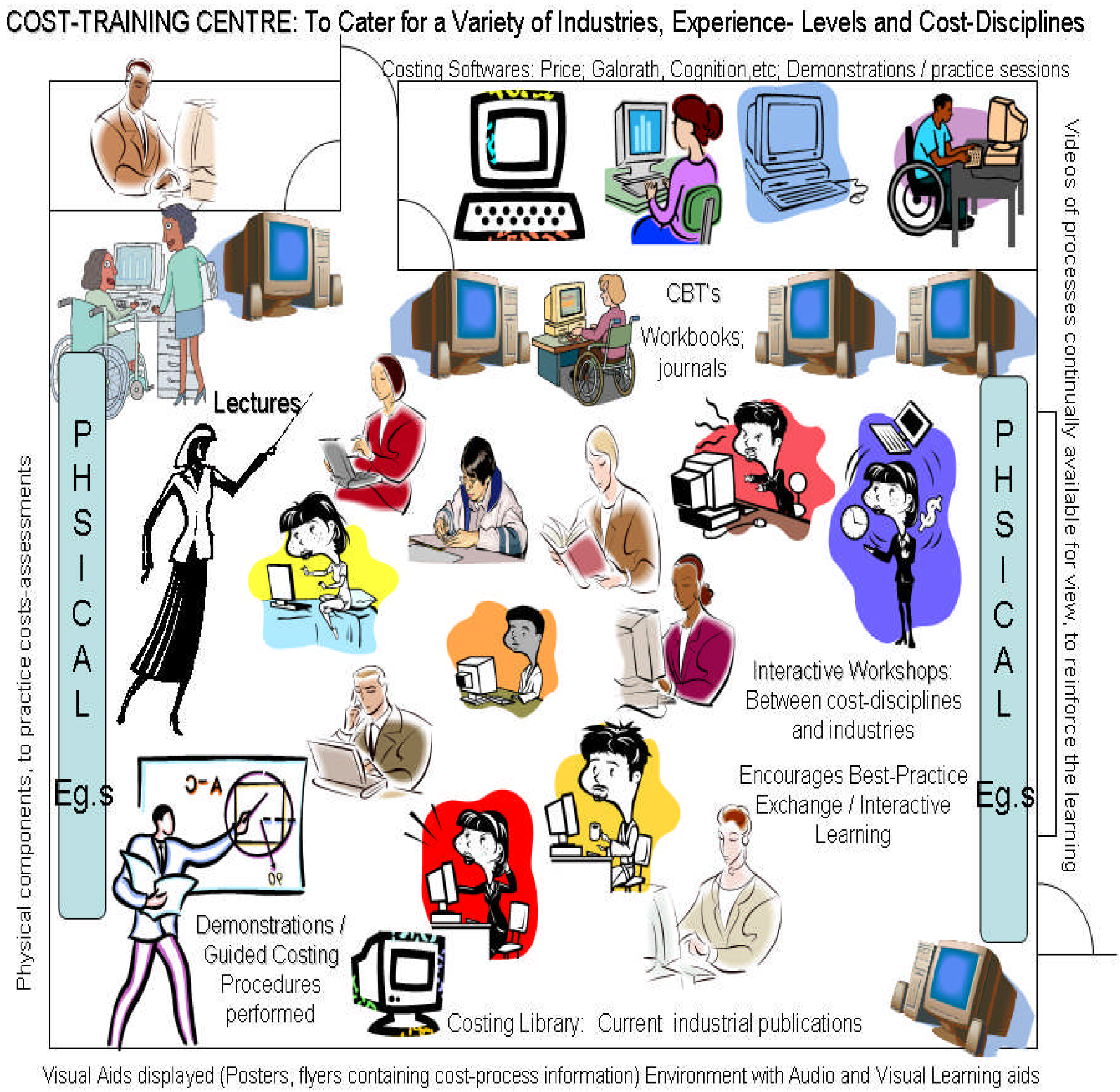
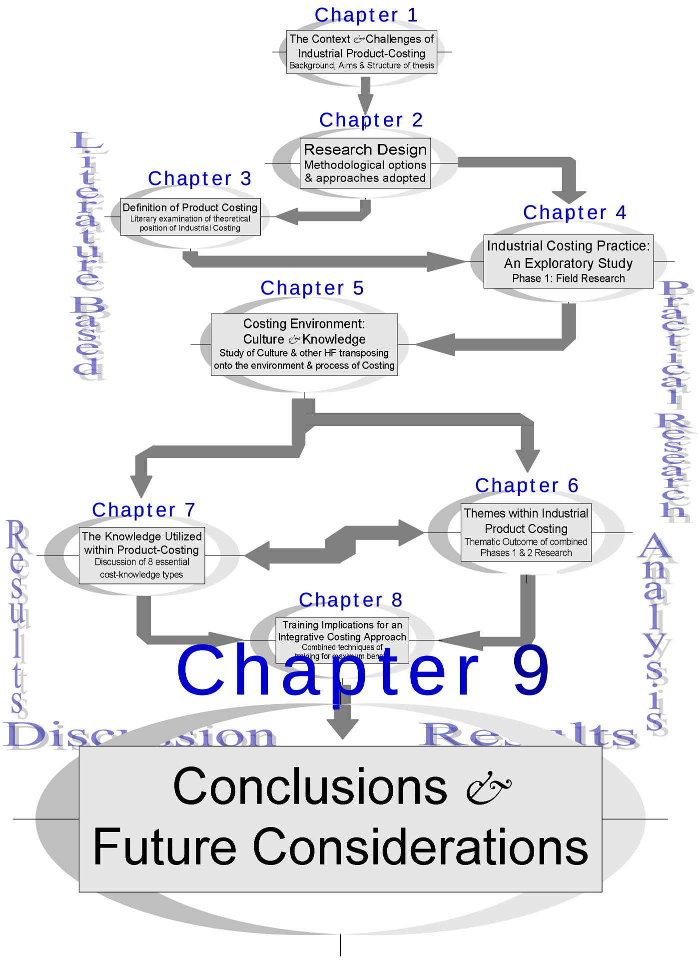



Figure 8.12: A Dedicated Internationally Focused Cost Training Centre

The types of training-developments presented have adopted a systematic systemic approach. To elaborate on this term: A systems view examines 'the whole', as opposed to isolating particulars of the system. Therefore when elements of the training material, e.g. the lectures, workshops, CBT tool and workbook are designed into programmes within one interactive training course, it holistically addresses all areas in need across the process, within industries and across them. The interactive workshop particularly promotes the type of communication and cultural exchange currently neglected within the formalised approaches toward cost-training. The training programmes need to be designed with this need in mind, so open discussions, networking and other communication may be incorporated into the framework of the training programmes, fundamentally with the aim of transference to the workplace. Hence the substantive contribution of this research: The dissemination of the cost-knowledge framework, on an industrial level.

Thus the ethos of the training should be to address these 'soft' issues, via the explicit subjects undertaken e.g. product, materials, product and design instruction, followed by discussion sessions, for interactive learning. This creates an improved knowledge of the costing process, and enhances the complex interactions which are key components. Training derived from the cost centre should be modified to suit each course; a pre-course questionnaire will establish the appropriate recipient-selection per course; and post-questionnaires and / or observations will determine validity and evaluate the effectiveness of the programmes; as discussed in Section 8.2.7. An aim of the developed training from this research is not solely to transfer and improve existing knowledge; but also to change the culture of the users. This is in the domain of changing the thought processes of interacting cost-disciplines, and consequently change their actions; see SECI model [Nonaka 1995], Chapter 5. The attempted changes will be in order to promote communication, systemic integration and understanding; in other words, a lateral transfer of cost-knowledge and integrated working within and across disciplines, as opposed to a culture of autonomous working practices, and infrequent, low quality interactions and understanding. The following final chapter concludes by outlining the main essential elements of within the thesis and discusses its lead to the resulting training proposals; as well as highlighting the contributions to knowledge of the research-areas; and potential further work which would benefit this domain.

# Chapter 9:
## Summary; Conclusions; Future Work




This investigation was initiated via an industrial need to improve costing outcomes: Product-costing had been identified as being less accurate then it could be. It was recognised that the process was a knowledge-rich domain, and the practitioners tended to have high expertise. This was due to the very nature of costing, which involved the need for knowledge-application from more then one discipline: Commercial or economic and technical e.g. engineering. However in order to enhance the cost-process, making the results more accurate within tight time schedules, a lateral transfer of knowledge was required via integrated working practices.

### *9.1. Research Focus:*

The research initially focused on the tangible areas of PC; principally the engineering, technical disciplines which interacted with the economic, commercial elements: Perception of the practitioners, particularly within large aerospace corporations was that this interaction traditionally formed the basis of costing. The emphasis of the study began with the intention to thoroughly examine this spectrum of functions, activities and interactions between the explicit cost-contributors whilst assessing their input, both expected and actual (see Figure 9.1). This is discussed in Chapters 3 and 4, the literature survey and the Exploratory / AS-IS organisational study, respectively.

Figure 9.1 depicts the initial research scope, which as mentioned was to transfer knowledge across the relevant disciplines namely commercial and engineering, via some form of industrial research dissemination, see Chapter 8; having identified the necessary areas of transferral, see

Chapters 3, 4, 5, 6, and 7. Within the original research perspective these tangible aspects were seen as straightforward to identify in themselves, therefore the main pursuit of the study was to establish:

- What was involved in the process of product cost estimating;
- Which areas required dissemination across the interacting disciplines;
- Subsequently, how to implement this knowledge / data and information transfer.

However, from the commencement of the work it became evident that there were more elements involved in deducing product costs within an industrial environment then those initially outlined, as above. A couple of the main points repeatedly raised by the practitioners throughout both phases of the research was that of challenges associated with personal interaction as well as other forms of communication. This was particularly apparent within the large companies, though was not limited to any particular one: These difficulties were observed across the majority of organisations.

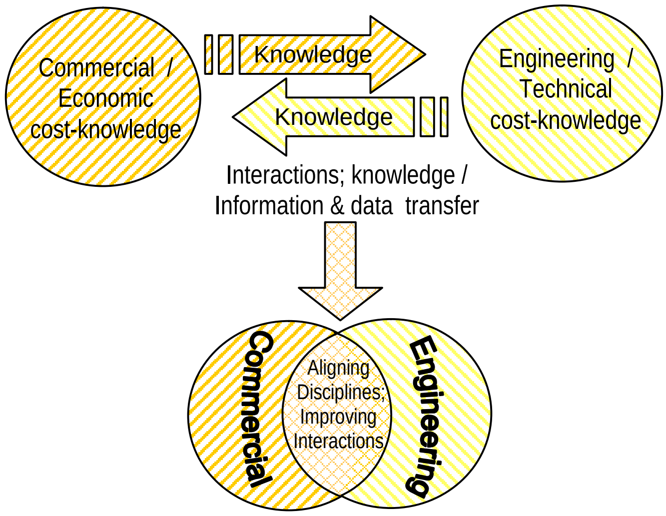



Figure 9.1: Cost-Disciplinary Contributors: Interaction created Unstructured, Confused Knowledge

[Adapted from Mishra et al, 2002a].

Contributors from the large aerospace and automotive organisations made regular references to communicational concerns, both on a personal practical basis e.g. across split working sites, holding meetings, ease and speed of decision-making. This was in addition to points linked to IT and data-relay concerns. The latter-mentioned challenges, ranged from a more commonly held viewpoint, that email promotes a lack of interpersonal communication; so when operated independently of other accompanying forms, can be an ineffective communicational technique. Resultantly its ever increasing usage throughout organisations was observed particularly by the managers and more senior cost practitioners to often result in misunderstandings. The IT / data and general communicational concerns spanned from this point, regarding the excessive use of email to issues regarding lack of compatible systems creating stifled information flow. This early observation became increasingly perceptible as the investigations continued. In fact the only noticeable exception to the aforementioned difficulties was seen within the one small-sized company (IT) examined within the exploratory study. In this case, they did not account such communicational challenges as conveyed by the large majority of other participating companies (which were medium-large) throughout the initial and extended studies. Hence the difficulties surrounding understanding, communication and data / information exchange were prevalent; these points occurred within the thematic analysis, being three of the six identified main cost-themes; see Chapter 6 for discussion.

## 9.2 Expanded Research Scope:

Therefore the findings indicate that unidentified issues with regards to the identified cost-challenges can be classified as emerging out of social and human factors, which are ubiquitously involved throughout the costing process. As the research continued it became increasingly apparent that a substantial contributor towards the challenges encountered were linked to an inattention towards such aspects such as communicational issues and cultural dynamics. See Figure 9.2 for the expansion of the research scope in response to these findings.

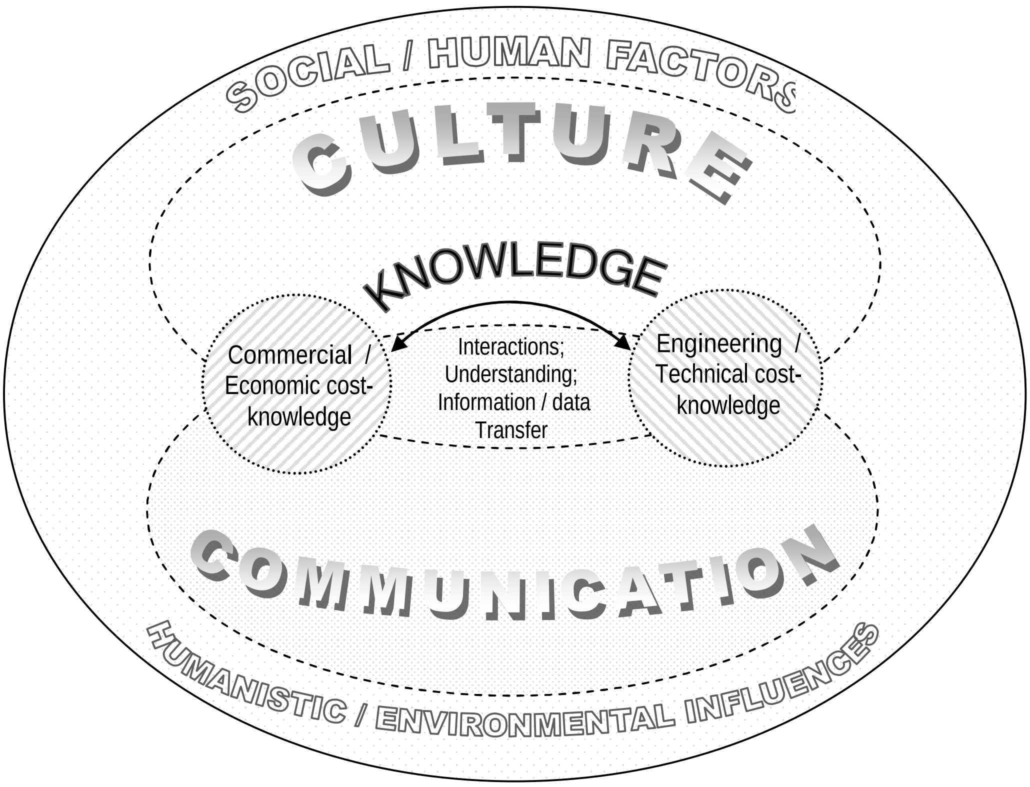



Figure 9.2: The Tangible and Intangible, Environmental Aspects of PC

Chapter 3 presents a review of cost literature. This document analysis substantiated the AS-IS, P1 research reported within Chapter 4, which relates to a lack of attention paid to tacit and environmental issues in which product-costing is performed within. A significant focus of what the large majority of practitioners indicated as contributing towards the challenges within the process, was noticeably absent throughout the related publications. The cost-related literature tended to focus on the tangible process, the costs and interacting disciplines. Issues such as the practicalities of communication, e.g. systems and procedures of personal interactions, and informational transference were not discussed within the reviewed documentation. Cultural factors between the interacting bodies both on a micro i.e. personal or departmental basis; and macro i.e. organisational and / or international level were noticeably absent within the costing-literature.

A systemic evaluation of the overall subject domain inclusive of its environmental affects in conjunction with the commonly perceived mindset of the major protagonists i.e. engineering and financial-focused disciplines, indicated that a chief cause of this inattention was due to a lack of focus towards issues considered as intangible or ‘soft’. This is because, in a primarily engineering environment little is known about such cognitive issues, which tend to be considered as unstructured, indefinable, un-measurable and therefore of lower reliability and importance. A point worth re-iteration is that the environment here means the context within which costing takes place and not just the physical and natural environments. As a direct result of the findings and observations within Phase 1, P1 of the research reported within Chapters 3 and 4, the fundamentals of organisational knowledge, communication and culture literatures were reviewed in Chapter 5. This was to provide background and preparation towards Phase 2, P2 of research which was an extended, more in-depth industrial study. P2 was designed to deepen the understanding of costing, the general practice of which was established from P1 which focused on the diversity of practices across a greater quantity of organisations; see Chapter 4 and Figure 4.1 for research structure and Chapter 6, Figure 6.2 plus company participation listing in Table 6.2. The emphasis within P2 was on the amalgamated effects of both the tangible and intangible constituents that comprise PC. This included examination of both the process itself, in juxtaposition with the environmental effects upon it.

For instance a fundamental interaction within PC is between that of the Buyer, (also referred to as ‘Purchase’ or ‘Procurement’) and the cost practitioner. If the Buyer is predominantly from a financial background, the research results conveyed that their mindset will consequently be focused on fiscal elements of the product. It was stated that if they have little experience of the technical aspects, they may overlook engineering inefficiencies discernible to a skilled viewer, within their (the Buyers) assessment of quotations, bids or cost-breakdowns from current and / or potential suppliers. Therefore if they do not involve PC for technical guidance, they could subsequently select a contractor who may be inappropriate for reasons of cost –effectiveness, reliability, and QA.

If Purchase do not understand the role of costing, they may not involve them in the supplier selection process, as explained throughout Chapter 6; see Section 9.3 for elaboration of evidence and analysis. These results included within Chapters 6, cost themes; and 7, discussing the essentially required knowledge types, which lead to the integrated cost model; emerged via examples as the interaction between Purchase and PC. In this case it was apparent that there was the need for enhanced understanding and communication of role among the other required interactions. Such enhancements would improve the overall cost outcome as well as the general dynamics of the activities. This type of scenario was commonly conveyed throughout a number of organisations, particularly the ones where the costing department was under-represented in comparison to other organisations examined, e.g. medium–large companies, with less than ten costing practitioners. This insufficient level of practitioners tended to reveal a lack of understanding, knowledge and information about the function, resulting in departmental cuts and general inadequate resource allocation; management were included in such detrimental perception i.e. having a lack of awareness in respect to PC.

The potential ongoing conflict between the main interrelated disciplines towards the cost process was in fact recognised within the initial criteria of research, see Chapter 1. Interestingly though, what was not accounted for was the significance of the intangible issues which proved to be a significant factor towards the challenges experienced. Hence subsequently needed to be encompassed within the potential solutions both theoretically (see Chapter 5), so that they then could be developed practically, refer to proposals within Chapter 8. With this said the lack of acknowledgement towards the role of HFs and social issues was not wholly unexpected due to the derivation of the research, which ultimately stemmed from the technical side of industrially identified challenges. To elaborate, though the research was finally developed among a wider community, it was instigated and subsequently supported on a core level by the dominantly technical disciplines within manufacturing–based organisations. See earlier chapters, including Section 2.6.3, Chapter 2; plus Table 4.2 (Chapter 4) for AS-IS industrial participation and Table 6.2 (Chapter 6) for overall contributors within P1 and P2 research.

A further example of such oversights towards the intangibles involved within PC was via the identification of misaligned mindsets from which transpired a range of miscommunications and culture-clashes. This included discrepancies in terminology leading to misunderstandings between the interacting parties, potentially evoking a fear culture resulting in the non-disclosure of required data and information. Generally creating a lack of co-operation between the primarily disciplines; specific examples and the research response to them are provided throughout the work, including Chapters 1, Section 1.1; 3, Section 3.1.1, 4, Section 4.4, plus see Figure 4.2 and Table 4.2. Such consequences could be derived from the different cultures surrounding these diverse but corresponding disciplines i.e. the economic and engineering functions; along with a basic lack of attention towards addressing the implicit differences of each. Though this is just one example of how challenges can occur due to communicational and cultural issues e.g. via a lack of awareness towards the fundamental cultural variances between interacting parties. Many more concerns can develop through such unrecognised, hence neglected and resultantly detrimental cause and effect relationships. They have been discussed within Chapters 4, 5, 6 and 7; whilst proposals of how they are addressed i.e. dissemination of the industrial cost-knowledge framework, ICKF developed in the research is presented within Chapter 8.

It is logical to develop the framework around the core issues that the concerns are related to. These include social and human factors in addition to the technical, explicit contributors of the initial research focus which had identified the need for enhancement of the later transfer of costing-knowledge between the main, tangible contributors, i.e. the interacting technical and financial domains. The latter includes a lack of formalised guidelines, systems and general IT issues which may hinder or even prevent effective dissemination of information for instance, to areas within a large organisation which may require them; supporting evidence given throughout Chapters 4 and 6. This can happen if coherent databases are not kept; or when there are incompatible IT systems working within the same organisation which cannot interact / transfer data between them: Examples of which were relayed by the industrial practitioners, and are discussed throughout, though principally within Chapters 4 and 6. Hence, as prior mentioned, due to these primary findings the original focus of research was expanded to include the social and cultural environments within which costing was performed. This wider, systemic approach is illustrated in Figure 9.2.

## *9.3 Methodological Approaches:*

Although the methodological approaches had been previously outlined within Chapter 2, Chapter 6 discussed the manner in which P2 was conducted, from the point of view of extended areas of research-examination. Thematic analysis of the data highlighted the main challenges identified; refer specifically to Sections 6.2.3-6.2.5 which addresses each of the 6 cost themes individually. Figure 6.3 presents a photographic depiction of the thematic derivation; Table 6.3 provides an example of the detailed analysis technique of coding and classification, which identified and established the prominence of the themes, KTs and KCs; all of which are described and discussed within the supporting text. Figure 6.4 illustrates the interrelated results in a basic manner; whilst Figure 6.5 provides an in-depth schema of the themes, being a fundamental reproduction of the photograph in Figure 6.3, summarising the principal points related to each theme whilst indicating the links across them all. This broadened research-perspective was undertaken in order to accommodate the accompanying implicit elements within costing, coupled with the explicit; discussed at the end of Chapter 4, and within chapters 5 and 6. A combined multi-method approach was adopted throughout all aspects of research, i.e. for the knowledge elicitation / data collection; framework development including validation and operalisation proposals through training implications, refer to Chapter 8. The approach consisted of case-study, interview, questionnaire, and company document-analysis, workshops and observation. All techniques utilised from the identified methodologies were designed for the specific research undertakings by the researcher, see appendices for examples of questionnaires, including practitioner responses as relevant per phase, training development, plus TNA, incorporating full DIF analysis feedback example; and industrial dissemination prototype inclusions, e.g. extracts from workbook; see Appendices 1-10.

This selection of techniques were chosen due to the degrees of flexibility required in order to gain a full view of the area; in conjunction with needing a sufficient level of structure placed around this diversity. In other words, as costing was a multi-disciplinary process i.e. it involved more then one area of knowledge such as those of the engineering functions plus the economic ones, subsequent degrees of flexibility were required to accommodate this range of domains involved. Though given the scope and therefore potential for excessive elaboration, an element of structure was also applied when eliciting the data in order to prevent unrelated tangents being included, and to scope the feedback to correlate with which had been identified as influential within the research subject-domain, i.e. the cost-process.

The flexibility and structure required could be ensured through the adaption of a multi-method approach. The semi-structured interviews which were audio-taped, were accompanied by questionnaire. These were either completed by the participant before the interview took place, which would then guide the general scope of interview: Otherwise the questionnaires were used by the researcher as a guide through the interview to ensure consistency of the subjects covered, per interview. This gave sufficient structure whilst allowing enough room for expansion to incorporate aspects which may have been relevant, but unknown to the researcher, so not initially included.

The workshops gave multiple insights which collectively proved to complete and enhance the interview findings. This resulted from the deliberately cultivated environment created by the workshop (and group interviews) which promoted diverse disciplinary interaction, evoking mental stimulus of the forthcoming views and subsequent group-discussion of them. See Chapter 2, Section 2.4 and Table 2.3; Chapter 4, Sections 4.5, 4.6 and Table 4.4., and Chapter 8, Section 8.3.5 and Table 8.6. These sessions were facilitated and directed as per research-phase objectives; whether it was ascertaining types of prominent cost-knowledge or determining ICKF dissemination via training requisites. This, accompanied by the internal document analysis, observation, one-to-one and group interviews, questionnaire-response and case study gave sufficient rounded results, for the subsequent analysis; presented and discussed in Chapters 4, 6, 7 and 8; and throughout the appendices.

## *9.4 Inclusive Considerations:*

The influence of tacit-knowledge types within such complex cost-interactions as stated above (and see Chapter 8, Table 8.6), between these communications, activities and processes are strong. If unaddressed they may not align towards the universally intended purpose of improving the accuracy and speed of producing a cost. This can therefore create challenges, such as the ones for which the research was initially embarked on to address, namely why are there inaccuracies within costing in a selection of sectors and how can they be remedied? Refer to Sections 9.8 and 9.9, aims and objectives, later in chapter for the summation of response to these points. Another major concern was related to time and how the outcome can be made more concise without incurring time penalties i.e. whilst staying within the pre-specified time frames allocated for the costing process. Such challenges will cease to be addressed fully if the less tangible influences on them are not acknowledged and tackled i.e. where the focus is directed towards the ‘hard’ identified concerns, without addressing the corresponding ‘soft’ elements.

As the costing area under investigation commenced and research interest became emergent, a commonly noted observation has been that PC is seen both as a science and an art. The scientific aspect is derived from such elements as the mathematical equations and linear regression analysis used in CERs (Cost Estimating Relationships). Plus the cost algorithms and parametric models are used to determine the estimated cost from figures including component costs (actual or approximated), quantities, dates, times and length of project. Although the final outcome is only as accurate as the inputted data, this type of cost assessment can result in high confidence levels, when there are no 'hard' or actual data, but cost-guidelines are required; see Chapter 3 for elaboration on costing techniques.

Alternately, the other aspect of producing a cost can centre around expert judgement [Rush, 2002] and the pulling together of elements, with use of common sense, experience and a degree of foresight. This is the side of product costing which has typically been perceived as a 'black art', and thus lowers confidence levels in the results. To date, much of the focus towards costing has been centred on the former scientific approach which can be substantiated with data, consistently repeated, and validated. The tacit contributions that rely on practitioner knowledge application are seen as less credible or even random, so have not been examined closely. This lack of appreciation, recognition and resultantly insight into the softer aspects of PC is the case, despite the general acceptance by practitioners themselves, that these points are major factors in deriving costs.

## *9.5 Industrial Costing Situation: Themes*

The analysis of the data is illustrated systemically in Figure 9.3: The outer layer of headings conveys the themes, initially identified with regards to the process. These highlighted the areas of challenge most commonly experienced across the costing industrial spectrum; they have been outlined and discussed in Chapter 6. During the initial industrial observations the themes emerged, often as major concerns for the practitioner. They were further validated throughout the latter stages of research. All six identified themes are inter-related, for example: The issue of Resource holds great influence across costing, as it typically would in other areas, e.g. potential lack of labour and time to produce results. However, in addition to these direct consequences which may reflect a typical experience across any under-resourced discipline, there are knock-on effects which will have more indirect, but just as severe consequences for the costing domain. For instance a lack of time will result in stifled communication and deficient data and information flow, which can impair the quality of the outcome. Additionally, insufficient labour may impact on training as the expertise is often required to prioritise on the direct outcome and results, with training generally perceived as a secondary commitment in comparison. If training is not made accessible to the practitioners either because their time / resource is too low to afford attendance of the programmes; or due to an insufficient range of courses available, then the impact is multiple ranging from having inadequate competent practitioners available, to a general lack of understanding of role internally and externally to PC. However, training emphasis and the overall importance placed on it including the amount of budget (resource) allocated, is often dependant on the culture of the organisation.

## 9.6 Cost-Knowledge Framework:

The inner octagon in Figure 9.3 symbolises the eight essential knowledge-types which collectively aid in addressing the themes; and comprises the integrated knowledge framework of product-costing, ICKF. The cost-themes relate to the environment in which the process takes place, focusing on the effects and influences on it. Whereas the knowledge-types were deduced from a more specifically process-focused internal costing perspective; they comprise the process of PC itself, and as such include the very physical tangible components of costing alongside the implicit elements. The physical knowledge types included the necessity to possess knowledge of the product itself; this includes the need to be knowledgeable about previous product or component versions, in conjunction with current proposed models. The linked knowledge's to this are identified as:

- Manufacturing process knowledge:
  - Which has associations to supplier negotiations;
  - As well as production estimates of product;
- Knowledge of material(s) used:
  - Linked to design
  - And manufacture issues;
- Plus design knowledge is heavily linked with:
  - Cost-cutting exercises e.g. potential redesign via exercises like DTC;
  - Plus more practical daily responsibilities of the practitioners cost assessments.

When interacting with designers, suppliers, purchase, engineers and other cost-practitioners communicational knowledge is essential. This cannot solely be conducted via IT / systems means, but has particular requirements for interpersonal communications. When such diverse disciplines are involved on an interactive basis, a comprehensive knowledge of culture is required in order to appreciate the environment and priorities of each interacting role. With all the physical and intangible knowledges' comes an element of risk. A knowledge of risk is thus imperative when working with PC. Though it may be minimised it can rarely be eliminated and needs to be accounted for as confidently as possible. The overall ability to cost a product lies in being able to effectively pull together all the components involved and compile an accurate cost to a given degree. Therefore knowledge of the costing process is fundamental to PC. Figure 9.3 illustrates the cost model developed within this research, highlighting the levels which it comprises of.

A noticeable gap reported within industrial studies which have examined areas related to cognitive recognition has been in relation to how the transformation from novice to expert occurs [Coley et al, 2007]. As discussed above the research has dissected the costing process and therefore identified the knowledge types utilised. This revelation goes some way towards bridging the gap that constitutes the unknown elements between expert and novice. With the knowledge required between them, and to a degree the various levels to which that knowledge is needed, the gap may be addressed by the implementation of systemic training where areas of relevant knowledge may be targeted and interlinked more appropriately. This will be more effective than the current primary means of knowledge-transfer, mainly on-the-job training. Though the value of SWN approaches are recognised within this research, the way in which these proposals intend PC improvements to be made is from the juxtaposition of the two techniques, i.e. on-the-job in conjunction with more formalised, structured training programmes.

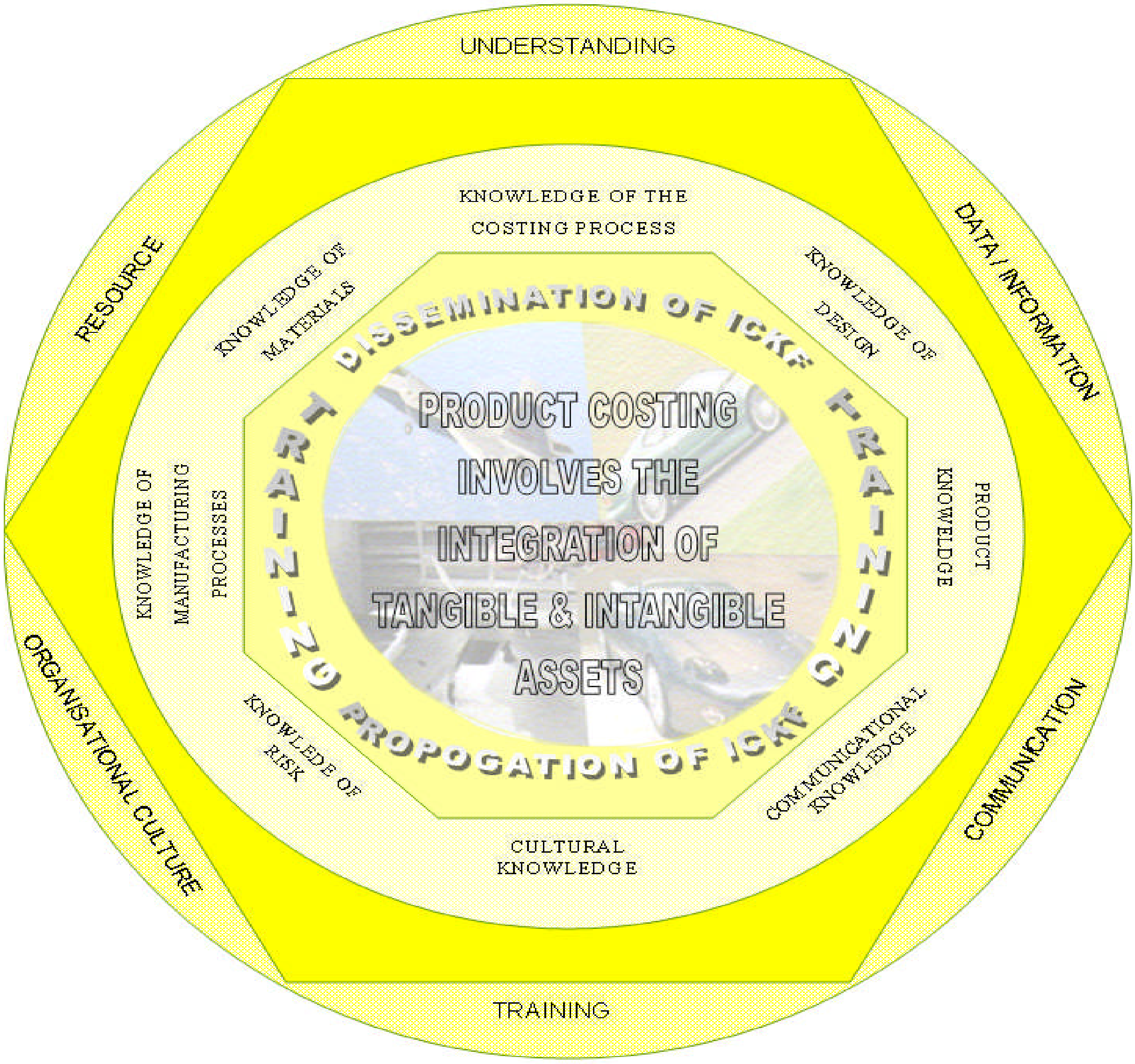



Figure 9.3: Amalgamating Layers of Themes and KTs within PC To Develop An Industrial Integrated Cost Knowledge Framework, ICKF

## 9.7 Systemic Approach to Cost-Training Implications:

Goldstein's discussion towards training context acknowledges changes and impending shifts within society as a whole. Reflecting these modifications, both gradual, subtle and the overt, towards the manner in which training design and development will need to adapt in order to cater for these predicted moves within the workforce [Goldstein, 2002]. Although these observations were of a more generalised nature adopting a holistic effect of organisational cultural, it can still be related towards the costing domain. For instance the point made towards women and other groups which are currently represented in the workplace as 'minorities', can result in the inattention to what have traditionally been perceived as feminine characteristics. In other words the negligence of soft, implicit issues within PC can equate to the markedly unbalanced gender representation evident across the board nationally, internationally and industrially of cost practitioners.

With the incorporation of the knowledge types into the training as well as addressing the cost-themes the process can be enhanced to improve performance; as the thesis has explained particularly within Chapters 4, 5, 6, 7 and 8. The research shows that skills, experience and knowledge within the areas required for costing are depleting. To elaborate, the rate at which the cost-domain is loosing expertise e.g. via retirement, personnel moves, is more rapid then the rate at which the loses are being replaced, i.e. skilled, fully trained practitioners entering the field. The need for these skills is as high as ever and arguably on the increase due to constant advances in technology, awareness towards which needs to be maintained. Therefore as the knowledge and skills stated as being essential are depleting, advancements in training is imperative if the costing domain is to avoid critically low levels of skilled practitioners.

Having dissected the process and exposed the individual constituents, training towards the reinforcement of a more systemic, inclusive process can be developed. These may now include environmental, social and other intangible elements alongside the advancement of the more practical knowledge types identified i.e. engineering and economically related. Hence the training proposals presented in Chapter 8 were designed to integrate the spectrum of elements within product-costing. This incorporated the tangible with the intangible to ultimately produce faster outputs to satisfy industrial demand rates, more accurate and generally effective degrees of costing from the practitioners.

Workshops have been incorporated into the core of the training programmes in order to promote the communicational and cultural aspects. Plus by transferring knowledge in such a direct manner, not only are the less tangible knowledge types transferred and learnt, but the explicit aspects of the costing process can be improved, disseminating best practice across the practitioners. Figure 9.3 illustrates the layers within the research, leading to the integrated cost knowledge framework, ICKF; and contributing towards the final contribution to knowledge within this area.

## *9.8 Address of Research Aim:*

The aim of the research, as stated in Chapter 1, was:

To develop an integrated knowledge framework for industrial product-costing.

The research aim has been fulfilled through examination of the current approaches to PC. This was conducted from an assessment of reviewed literature, (Chapter 3) in conjunction with an industrial exploratory study, (Chapter 4). P1 identified many of the factors that undermine PCs accuracy, and make the process more challenging, e.g. via a lack of transferred information ultimately slowing down the production of results.

A major concern was the lack of an integrated, holistic approach to the process, namely the need to address issues related to the less tangible elements involved as well as the explicit engineering and commercial ones. Identification and appraisal of the combined aspects comprising the process was undertaken through further, more focused industrial examinations, (Chapter 6) which highlighted via thematical analysis, an outline of the cost-challenges.

P2 was facilitated by an awareness of the HFs that affect PC, assessment of relevant documentation is provided in Chapter 5. Once all contributors had been established, both explicit and implicit; and the intricacies of costing had been determined, an integrated cost-knowledge framework could be comprehensively developed, when adopting a systemic approach towards classification of the knowledge requisites, detailed in Chapter 7.

## *9.9. Objectives:*

The aim was achieved through a number of research objectives, listed below:

- ✓ Critique theoretical literature and undertake an exploratory study related to current costing practice.
- ✓ Identify the themes within the costing challenges, through cross-industrial organisation examination.
- ✓ Establish a knowledge framework for costing from the juxtaposition of literature surveys plus the exploratory and an in-depth examination of costing behaviour; with use of a multi-method research approaches within a range of industrial contexts.
- ✓ Industrial implementation via the consideration of training implications for PC which arise from the knowledge framework.

The earlier section of this chapter has explained how these objectives have been met; to summarise: The literature and organisational studies identified key cost contemporary-practices. Challenges within the process were subsequently identified, with use of both cost literature concurrently with extended industrial-process research; which were documented thematically, in Chapter 6. Through communication with a range of industrial practitioners, the aspects with regards to why adequate interaction was not occurring, and how it could be improved was established.

An integrated cost-knowledge framework, ICKF was developed to address the industrial challenges identified, with use of the formally established results. This included addressing why adequate communication and interaction was not occurring, and how it could be improved. The issue of a lack of recognition towards human factors within the costing domain was also highlighted. This was in context with the more tangible need for fiscal awareness, alongside technical / engineering-focused knowledge types to identify the explicit elements of product-costing within an industrial, manufacturing environment.

The knowledge types where validated throughout the industrial studies. Operalisation of the knowledge framework was undergone via training methodology development. Techniques and processes of industrial training intervention were proposed (Chapter 8): Resulting in a generic integrative framework for costing which suggest areas for potential improvement.

## 9.10 Contribution to Knowledge:

The contribution to knowledge delivered via this research can be described as:

The development of a cost integrated knowledge-framework; and operalisation of the framework through development of a systemic, integrated approach to cost training:
Achieved via a combined multi-method approach within the costing domain.

The contribution can be classified into different types: There are theoretical, substantive, and methodological contributory areas. This research has contributed within all three areas, though primarily within the theoretical and substantive domains.

### 9.10.1 Methodological Contribution

The methodological contribution is secondary to these, and refers to the multi-method approach adopted: There is not any reported documentation to suggest that this specific, designed-for-purpose selection of research methodology has previously been implemented within the area of costing. In other words, the combination of: Case study, workshops, interviews (C.I. / semi-structured), organisational document analysis, observation, and questionnaire have not been used before this study, so were novel within this research domain.

### 9.10.2 Theoretical Contribution

The theoretical contribution is primary, as the knowledge framework for costing has not previously been developed and documented in a systematic way. The systemic approach to this occurrence is valuable to the costing community, as it serves to establish explicit guidelines regarding areas which have previously been considered implicit. As a consequence, though such a framework was required, it did not materialise as long as a non-systemic method was assumed.

### *9.10.3 Substantive Contribution*

The substantive contribution is also significant, being derived directly from the theoretical one: The proposed operalisation of the knowledge framework in the form of integrated cost training. An early observation of a limited approach with regards to this area was that training had been developed by engineers for engineers; and the cost-training was subsequently a derivative of this. Therefore there was little evidence of training that had been developed specifically for the costing process which had been targeted to suit PC needs and not simply an adaptation or fusion of existing engineering and economic material. A practical contribution of this research was in the development and delivery of training outputs, which translated the knowledge support into training procedures incorporating the previously lacking social and cultural elements in costing systemically with the physical areas.

Hence the research has produced three aspects of contribution from the same aim, though with varied weightings, i.e. the two primary and the secondary contributions to knowledge.

## *9.11 Conclusions:*

The costing domain has not been maximising its expertise due to a lack of systematic systemic approach towards the process. This approach includes intangible, humanistic as well as the explicit, physical elements involved in costing a product.  The reason behind this inattention lies with the perception of insignificance regarding these areas, as PC (in the UK) is essentially derived from, supported by and focuses around engineering functions and activities in conjunction with financial, economic disciplines. Within these unambiguous domains there superficially appears to be little call for reference towards the implicit contributors. Therefore due to the very nature of the process along with the dominant physical environment which it tends to be performed in, the collective result is that of a neglectful position towards a section of the contributory concerns.

The recognition and definite inclusion of these elements are necessary if PC is to progress to the accuracy and speed that it is industrially required to be at. An example of the need for integration can be seen within an initial challenge encountered within this research, namely terminology. Not only do the commonly utilised terms need to be standardised in a physical, manner, i.e. published documentation, widely disseminated. In order for such changes to become enforced also requires attention to the mindsets and different interacting cultures involved. This applies from the global communications to different areas working at different project phase, who will make reference appropriate to their area, often regardless or oblivious to prior and / or subsequent implications towards the same point.  This state of affairs regarding the inconsistencies in common terminology and general reference used evidently causes confusion, misunderstanding and miscommunications; as discussed throughout the thesis, refer to Chapters 3 and 4, Sections 3.1 and 4.7 respectively.

The knowledge framework has established this need for an integrated perception, not only for financial and engineering, but also with physical and non-physical elements. The training proposals solidify the framework via means of industrial dissemination of ICKF; and if adapted within industry can assist in bridging the gap between the areas that comprise the costing process. Refer to Chapter 8 for this framework pragmatic propagation principally via tailor-made training developments.

## *9.12 Research Limitations:*

A drawback of the research lay in a lack of sufficient time to examine all the identified areas of interest towards this investigation. Although the industries examined rapidly broadened from research commencement to completion, a primary focus was initially deemed to be on the military aerospace and automotive industry. A number of automotive organisations participated towards the results; however the number was not equalled by aerospace; which required expansion to incorporate various areas of defence and military bodies. This was mainly due to the high security measures around such industries which results in the requisite of a lot of time needed in order to gain security clearances. This elements of diversity in organisation was not pre-empted by the researcher, therefore although permission would most probably have been gained, it was supposed to have been granted too late to be of use, due to time limitations of the research.

Although the research was derived from a funded project, involving industrial backers as well as government funding, a drawback of the research was ultimately in lack of resource. A number of contributors commented that the French automotive manufacturers were exemplary in their costing practice. This research did not get the opportunity to visit these organisations, due to both time and financial constraints; so did not gain first hand experience about their approach to costing. Therefore the reputation conveyed as to the costing best practice, could not be validated, neither confirmed nor disproved.

Aside from the practical limitations of time and resource was the academic position of subjectivity: The ICKF was derived through analysis of the specific data in-putted into the research. Data analysis has been discussed throughout the thesis, particularly within Chapters 2, 4 and 6; and was via the thematic coding and clustering technique. Though thorough, this technique is still open to interpretation. For instance the inclusion of the knowledge type ‘Risk’ within the ICKF was debated by a couple of contributors, as they were adamant that it was not within their role as costing practitioners / cost managers. On further investigation however it became clear that risk of sorts was accounted for within their cost-process whether formally declared in their job specification or not. Hence due to the fact that a majority of participants had not questioned its inclusion, had actively referred to risk, or had overtly done so, risk was incorporated within the ICKF as one of the main 8KTs. As semi-structured, C.I. interview was part of the data collection methodology, expanded insights were often obtainable when results were either inconclusive or open to subjectivity; and resulting conclusions able to be draw with a reasonable degree of confidence as in this example. However although the tends resulting from the data were largely apparent, the researcher acknowledges that qualitative research techniques can result in the necessity of subjectivity at times; being also open to interpretation. Again Appendix 9 refers to the initial spectrum of KTs considered within the ICKF, where the original KTs numbered as 10. The appendix includes limited discussion about the reduction of that list and how it was redesigned to establish 8 as the final cost-model. This indicates that the results are not wholly inflexible; and that a degree of interpretation, such as with the allocation of levels of importance, can be challenging to solidify.

In addition, the components of research contributor add to any flexibility in result: In other words, the industry, organisation and even individual practitioners selected for investigation can impact on the output of investigation. This is because even if the same organisations were selected for a further, similar study, it would be challenging to engage the same specific contributors per company; so variation even if marginal may occur in the research conclusions. Parallel to this point are the factors of time and space. To elaborate, a new study conducted by a different researcher at a different time may result in modification of focus, due to for instance a change in the current economic environment. An organisation may have merged, expanded or experienced some other notable change which could affect the workforce, their practices and priorities. Hence the manner in which such potential inconsistencies may be addressed is to gain saturation of data in the area. In this case it would involve a number of studies, at different times within similar sectors, to establish whether changes in time and thus possible working practices did in fact affect the outcome of the research undertaken. Repetitions of investigation to this degree are clearly not possible to contain within this thesis; being effectively another three-plus research projects of similar duration to this one.

## *9.13 Future Work and Related Considerations:*

Although the diversity of industries and level of company-participation was adequate for this research, future studies may benefit from including more separate defence contributors. This will involve a degree of planning with regards to time allocation for gaining security clearance to the required levels of information.

With regards to the above point an extended line of consideration, on a pragmatic level the research needs to be embarked upon by a researcher who will be deemed appropriate for placement within a position of trust and acceptance by the entities being examined. In other words experience from within this study has exposed the impractically and lack of foresight for example in attempting to place a person of direct Russian origin within an area such as the USA military, with the view of conducting independent in-depth research into the challenges experienced, with the eventual aim of proposals to benefit their current process. In this type of situation there is a high probability that such a person would not gain the required levels of security clearances necessary to undertake the type of hands-on, field research that would benefit the examinations. Hence on purely practical levels including ease of access to information and time-saving measures, it would be sensible to consider the background of the potential researcher against the planned project of investigation prior to definite allocation of research specifics.

Linked to this point of physical background and perceived suitability is the slightly less overt issue of disciplinary and expertise domain. For instance it is usually possible to pre-select the correct experience and academic criteria to suit the investigations. However in a minority of cases it seems predetermination of specialisation is less straightforward, due to the direction which the results take the knowledge engineer. This research displayed an example of this unpredictable aspect of examination. The outcome of P1 clearly indicated that there was more to examine within the social and HFs areas in conjunction with the physical, IT and engineering ones. However the author has an engineering academic background, and technical industrial expertise; having not been prior familiarised with HF and associated domains. Therefore the HF and cultural research presented within this thesis are preliminary, reflecting the fundamentals of the softer areas in essentials related to PC, as opposed to presenting them in greater academic depth. As a result this area of research would benefit from further investigations conducted by a researcher of appropriate background, to add to the overview of the 'softer' issues, which have been introduced within this thesis; see Chapter 5.

The organisations of which directly participated towards this research were primarily based within the UK, with the minority in the USA. Although they were dominantly UK branches of international organisations, it would benefit the research particularly from a cultural–study viewpoint to actually investigated companies on-site, overseas. In accordance with the findings of this research a valuable contribution towards the costing domain would be via the examination of branches of the same company, located in different countries, e.g. the French branch of Airbus, as well as the UK and other European sites; plus the overseas i.e. Japanese branches of Nissan.  Further depth and balance would also be bestowed to this research domain if more aerospace and defence organisations were assessed against the comparatively wide spectrum of automotive contributors. As mentioned a greater degree of planning and background work would be essential in such a study.

Associated with this stance would be the examination of the French automotive companies who have been quoted as implementing industry best practice with regards to PC, discussed earlier in thesis. Comparisons of these perceived successful organisations against others would be a valuable contribution, whether confirming or not the best practice claims. Along with the validation of good practice, provided competitive advantage is not compromised, propagation of beneficial approaches across the cost community can thus be embarked upon.

Hence the repetition of research within similar fields over time, as mentioned in the previous Section, 9.12 would aid in the continual updating and modification (as relevant) to the activities around the dissemination of ICKF. In other words, in maintaining a high standard of training, keeping it current and relevant; and learning from industrial practice developed, observed, captured and reused over time. The knowledge reuse would be channelled through the continued industrial research and redesign of the results into the training programmes.

In this vein, potential study could be to visit the UK automotive branches of two or more organisations; followed by their overseas sites. The costing processes could then be compared against different industries examined, to the same degree; this would give a comprehensive view of one industry's practices, if two-plus automotive are examined globally for instance against another industry's processes. Such an approach would avoid competitive disadvantage and ensure industry participation. Hence would ultimately contribute to establishing workplace standards for product-costing internationally and across industry; which would raise the profile of PC, in turn enhancing comprehension of the process, and consequently improving corresponding disciplinary interactions.

Designers of industrial cost training programmes need to be aware of the 'softer' human issues involved in the process, what specifically is involved, how it may affect the performance of practitioners and resultantly their cost-output, and how to tackle these associated challenges. The integration of softer issues when considering PC in general, let alone when formulating targeted training is essential. This is due to the fact that the way in which a practitioner may consider technological advancements, how they collect data and information, and even the reaction they have to working under varied levels of pressure all tends to ultimately contribute to their working output. Hence awareness of the wide range of sociological and HF based issues is necessary in the pursuit of identification of industrial challenges, even seemingly technical-bias ones when determining solutions and subsequent implementation of better practice protocol.

To summarise, widely adopted standardisation of terminology, improvements in the understanding of what PC entails and produces, and adequate communication between the interacting entities; when integrated within a suitable, rounded application of cost knowledge, systemically acts to benefit the overall process. This will enable the production of faster, higher confidence level cost results.

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# APPENDIX 1: Exploratory Phase Questionnaire:

AS-IS Study
of the Interface Between Cost Estimating & Cost Engineering Processes

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The information provided will be held in the strictest of confidence, desensitised, and used for academic and research purposes ONLY.

Interview conducted by: ……………………………………………………………………………..

## Introduction

The research attempts to integrate commercial cost estimating with technical cost engineering by developing an innovative and generic approach to costing. The approach addresses two major issues: the people issue and technical issues behind the costing. The concept of integration (between the commercial and technical costing activities) is very novel, with no work being reported exactly in this area. The research will improve communication between the cost estimators and cost engineers. The outcome of the proposed research will make the cost estimation process more transparent and accurate, and thus will assist in designing a product 'right first time'.

## Definition of Cost Estimating & Cost Engineering

Manufacturing industry performs cost estimating throughout the life cycle of a product. The purpose of commercial cost estimating is to provide key business information for decision making in a top-down fashion. This costing discipline tries to evaluate, and optimise a combination of requirements (customer and business) with potential or selected solution(s), across a wide range of business processes, with cost as the common denominator. Alternatively, the Cost Engineering discipline tries to model the design to manufacturing cost in a bottom-up approach for establishing relative costs for different solutions, and methods. Similarly, the cost engineering discipline needs to have detailed knowledge about the product, the manufacturing process, and manufacturing capability of the organisation. But unlike cost estimating, cost engineering discipline focuses on design, manufacturing, and tooling activities only. They also need to be fully aware of UK & customer government legislative regulations, which govern justification and access to data used in the estimating process.

Due to this mismatch of focus, and differences in terminology and level of detail, there is a gap between the two disciplines, and this leads to inconsistencies in costing practices. There is also a lack of knowledge about each other's activities. Both cost estimating and cost engineering are essential during the conceptual product development stage for design evaluation, and thus optimisation.

Purpose of the Questionnaire

The two costing disciplines that work towards overall costing of a product are Commercial cost estimating and Technical cost engineering: It has become apparent that at present these practices are not utilising their full potential of creating an efficient estimate, right from the early stages of product development. This is due to poor internal communication –actually between the costing disciplines.
In order to improve this current state of costing affairs, Questions and Interviews are necessary to establish current practice within industry; and to also determine what type of interaction is currently occurring between the two costing disciplines.
Once these internal processes have been acquired –through the questions / interviews, ICOST can then proceed to expose any weak links present between these practices, including lack of communication and comprehension of each prospective discipline, and thus proceed to establish firm, consistent method of costing across industry.

Overall Aim: How Is An Estimate Produced?

<u>Please note</u>: Questions asking about the practices of an 'estimator' or 'estimate', should be answered according to your own profession,
i.e. Commercial cost Estimator
(those covering commercial areas -financial, etc, );
Technical cost Engineers (for those working in engineering, software, etc)

<u>Module 1 (General Issues)</u>

Q1: How long have you been employed in the company?
A1:

Q2: What is your role in the company?
A2:

Q3: How long have you held this position?
A3:

Q4: What is your experience (Academic & Industrial) prior to your current position?
A4:

Q5: How much input to an estimate is via experience / expertise of estimator?
( with respect to both commercial and technical estimates)
A5:

Q5a: How much is based on historical data?
A5a:

Q5b: How much is based on actual product data?
A5b:

Q6: From where is this product data acquired?
A6:

Q7: How is the relevant data acquired?
A7:

Q8: How is it utilised?
A8:

Module 2 ( Process)
2Q1: Could you explain the absolute fundamental development stage(s) of creating an estimate?
2A1:

2Q2: What information is required for an estimate?
2A2:

2Q3: How is this information acquired at the various stages of estimating?
2A3:

2Q4: What information is not provided that you require (if any)?
2A4:

2Q5: Which individual departments are involved in creating an estimate?
2A5:

2Q6: What is the input of these departments?
2A6:

Module 3 (Interface)
3Q1: How many stages are involved in creating a total estimate? And What are they?

3A1:

3Q2: What level of contribution towards the estimate comes from other departments?

3A2:

3Q3: Is the data / product information that is required from other departments
Q3a: Easily procured?
A3a:

Q3b: comprehensible to the recipient?
A3b:

Q3c: How is it communicated? ( meetings, reports, email / Intranet etc )
A3c:

3Q4: How is all relevant information inter-linked?
3A4:

Please use this page to add any additional information that you feel may be relevant to the description of your cost estimating / engineering practices; Attach any additional pages as required:

# **APPENDIX 2a:** Cultural Models I:

## Hofstede [2008]; Trompenaars and Hampden-Turner [1999]

Cultural Models

Cultural Dimensions
Hofstede

**PDI** -POWER DISTANCE INDEX
The level of equality between constituents within a society

**IDV** -INDIVIDUALISM
Whether a society relates to communal and social interactions or individual success

**MAS** -MASCULINITY
The extent to which a society supports the stereotypical concept of masculine work role

**UAI** -UNCERTAINTY AVOIDANCE INDEX
The degree to which a society will tolerate ambiguity / uncertainty

**LTO** - LONG TERM ORIENTATION
The extent to which a society abides by traditional philosophies.

Characteristics of Corporate Culture
Trompenaars

**FAMILY** -Person Orientated
Relationships: Bonded to whole
Status: Ascribed to parent figures
Learning/ Thinking: Intuitive, holistic, lateral & error-correcting
Reward /Motivation: Intrinsic satisfaction from love & respect; Subjective management
Change: 'Father' changes course
Criticism/Conflict resolution: Turn other cheek. Attitudes: As family

**GUIDED MISSILE** - Project Orientated Culture:
R: Specific tasks, shared obj.s
S: Contributions to targeted goals
L/T: Problem centered, practical
R/M: Pay /credit for problems solved. Management by obj.s
C: Shift aim as target moves
C.C.R: Constructive; task related
Attitudes: Specialists & Experts

**EIFFEL TOWER** -Role Orientated
R: Specific role in mechanical system of required interactions
S: Superior roles; powerful distant
L/T: Loyal, analytical, efficient
R/M: Promote 'higher'; larger role
Management by job description
Change via rules and procedures
C.C.R.: Linked with irrationality
Attitudes: Human Resources

**INCUBATOR** -Fulfillment Orientated Culture
R: Diffuse, from creative process
S: Gained via Creativity /Growth
L/T: Inspirational, ad-hoc
R/M: Participation in creativity. Management by enthusiasm
C: Improvise and attune
C.C.R. Improve not negate ideas
Attitudes: Co-creators

Dimensions of Cultural Diversity
based on Trompenaars & Hampden-Turner; Hofstede

**Specific** ●——● **Diffuse**
Direct, precise: Consistent position independent of relationships — Indirect, evasive, tactful: Situation influenced by relationship

**Neutral** ●——● **Affective**
Thinking /emotion not revealed: Monotone; little physical contact — Expressive /open thoughts & emotion: Tactile: Dramatic delivery

**Achievement** ●——● **Ascription**
Occasional title-use: Respect / progress based on competence — Extensive title-use: Respect to superior, loyalty: Selective progress

**Universalism** ●——● **Particularism**
Follow rules, codes, contract; One truth: generalisations — Focus on relationships not rules: Multiple perspectives: exceptions

**Inner direction** ●——● **Outer Direction**
Factors affecting beliefs /actions, determined from within — Beliefs /convictions derived outwardly via surroundings & relationships

**Individualism** ●——● **Communitarianism**
Use term 'I': Individual decisions /responsibility: Self-reliance — Use of term 'We': Collective decisions /responsibility: Social concern

**Sequential Orientation** ●——● **Synchronic Orientation**
Time can be measured & follows set course; punctual; inflexible — Time is series of co-ordinations; multitask; flexible approach

Attitudes To Time

| Past: Look to history; respect for/ recreate the past | Present: Live for moment Interest in current affairs | Future: Focus on future aspirations / achievements |
|---|---|---|

Attitudes To Environment

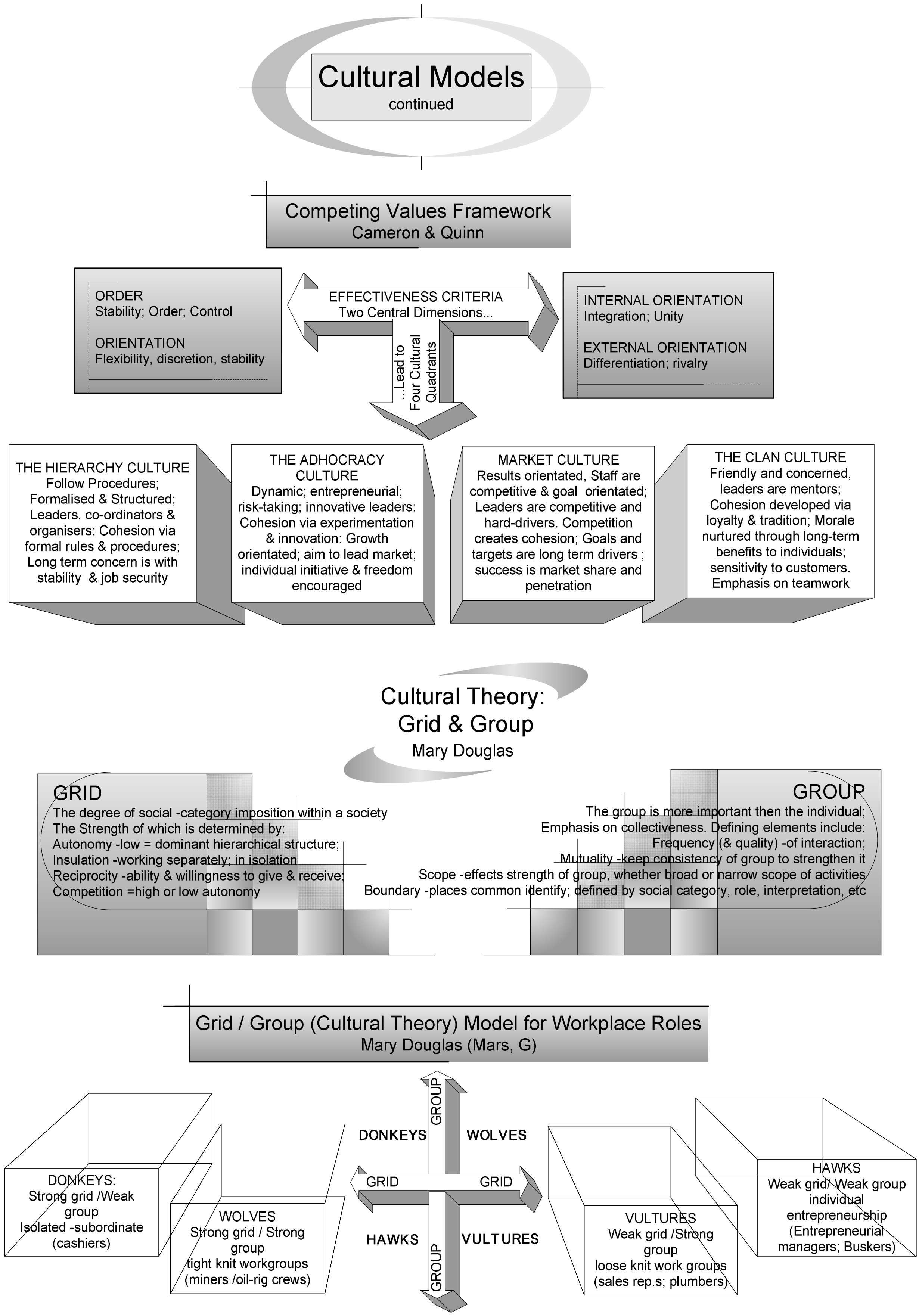
| Internal Control: Dominant approach Self-focus | Perception of nature: e.g. Fear, copy, control | External Control: Flexible approach; focus on other |
|---|---|---|

Attitudes To Risk

| High = low tolerance; High concern for rules, regulations; control | Uncertainty Avoidance Risk Aversion: focuses on degree society does or does not reinforce ambiguity | Low = high tolerance; Culture accept change / takes more risks |
|---|---|---|

## **APPENDIX 2b:** Cultural Models II:

## Douglas [1982]; Cameron and Quinn 1999]



**APPENDIX 3:** Hofstedes Cultural Ratings

Results from Hofstedes research, giving cultural dimension ranks for the primary participating areas [Hofstede, 2008]

| Hofstede Cultural Dimensions | | U.K. | USA | World Average |
|---|---|---|---|---|
| **PDI** | **Power Distance Index** | **31** | **40** | **55** |
| IDV | **Individualism** | **89** | **91** | 43 |
| MAS | **Masculinity** | **61** | **62** | 50 |
| UAI | **Uncertainty Avoidance Index** | **31** | **46** | 64 |
| LTO | **Long Term Orientation** | **20** | **29** | 45 |

## Archetypes

From the cultural studies many archetypes have been developed, from a combination of the attitudes derived from different cultural types. Appendix 2 a,b, and c have presented a small selection of these archetypes, from the works of Cameron and Quinn [1999] M. Douglas [1982], and Trompenaars and Hampden-Turner [1999]. Cameron and Quinn have developed the Competing Values framework; stemming from two central dimensions of effectiveness (continuums). One is indirectly related to the above mentioned, with regards to risk and uncertainty, as it emphasises flexibility, discretion and dynamism in organisations as Microsoft, against those who focus on order, control and stability, such as government bodies, universities, etc. The other dimension is based on internal, integrated harmonious working practice against those externally orientated, founded on rivalry and who are competitive outside their own boundaries: This can be seen as related to the ideals of 'wa' in Trompenaars work [1999], see chapter 5. These central dimensions of order and orientation have been sectioned into four cultural quadrants, (Clan, Adhocracy, Hierarchy, and Market cultures) as depicted in Appendix 2,b. Trompenaars model shows the characteristics of corporate and national culture. Attributes defined within this archetype include the relationship between employees, attitudes towards people in organisations and to authority, ways of change and motivation as well as criticism and conflict resolution, see Appendices 2 a and b for the cultural typologies. As with the work of Hofstede, countries have been defined and rated within this model, see Table in appendix 2, c.

The anthropologist, Mary Douglas derived Gird / Group cultural theory, from which is argued that non-industrial societies display two key characteristics of culture: Grid and Group. The grid dimension assesses the degree to which a culture imposes specified social categories onto its society. This determines social behaviour, how people expect to be treated and how they behave towards others. Within high grid cultures, rules limit autonomy and hierarchy separates and insulates organisational members. Low grid is where certain individuals will be willing to give more then they would receive in return, and where some have more control over others, then is exerted over themselves: Therefore levels of reciprocity and competition are unequal [Mars, 1982]. The group dimension emphasises the collectiveness of people; when this aspect is strong, the focus is on the survival of the group, as opposed to individual members, the interests of which are subordinate to the group [Mars, 1982]. Thus strong group culture is when there is high frequency of good-quality interaction; along with having contact within a mutually interconnecting framework, a fragmented one would weaken the group. As the scope of activities between a set of people becomes wider, the strength increases, as does the creation of boundaries to a common identity. The archetypes derived from the Grid Group dimension is illustrated in Appendix 2, b.

## **Appendix 4a:** Training Questionnaire: Materials Workbook Development

DEVELOPING THE COST OF MATERIALS

Karen Mishra

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Tel:+44 (0) 1234 750111 extension 2633
Email:k.mishra@cranfield.ac.uk,

Name: ……………………………………………………………………………………………………

Title: ……………………………………………………………………………………………………..

Organisation: ……………………………………………………………………………………………

Department: …………………………………………………………………………………………..

Address: …………………………………………………………………………………………………..

……………………………………………………………………………………………………

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Telephone Number: ……………………………………………………………………………………

Fax Number: ………………………………………………………………………………………………

Email: ……………………………………………………………………………………………………

The information provided will be held in the strictest of confidence, desensitised, and used for academic and research purposes ONLY.

Interview conducted by: …………………………………………………………………………………..

Introduction

The research attempts to integrate commercial cost estimating with technical cost engineering by developing an innovative and generic approach to costing. The approach addresses two major issues: the people issue and technical issues behind the costing. The concept of integration (between the commercial and technical costing activities) is very novel, with no previous reported work having been conducted within this specific area. The developments within the research aim to improve communication between the cost experts involved within the overall costing profession. The outcome of the research will make the cost estimation process more transparent and accurate, and thus will assist in creating the 'right first time' approach to costing; aiding in faster, more accurate results across the costing domain.

Purpose of the Questionnaire

The purpose of this questionnaire is to ascertain exactly what type of knowledge, information and data is required in order to develop the cost of a material, when costing a product. I.e. when creating an estimate for a product / component what does the expert specifically need to know about the material involved, in order to successful produce an estimate?

The collated results of this questionnaire will be used to help develop a training module, which the recipient will use as an aid to learn how to estimate materials within an overall cost estimate.

Expert Focus of Questionnaire:

The costing profession incorporates a multitude of skills and knowledge. As mentioned previously, the primary knowledge types involved, are commercial and engineering.
This questionnaire is aimed at experts across the costing profession.

All costing disciplines are targeted for this research, as their combined opinion and expertise will enable the researcher to develop a fully comprehensive training package: which will be beneficial to the costing profession as a whole, as opposed to select areas within.

Therefore engineering and commercial experts within cost estimating, are requested to complete this questionnaire; from both aerospace and automotive industries.

The Structure of the Questionnaire:

The questionnaire is in four sections:
Section A discusses the knowledge, information and data you need to know about the actual material you are costing
Section B examines the interaction between experts necessary, in order to cost a product: Who is necessary for you need to speak to; for what information.
Section C explores more deeply into the costing issues related to the material; what they are and how they are obtained.
Section D investigates user requirements; i.e. what do the experts within the costing profession require from a cost-training package.

<u>Section A:</u>

A1) How do you asses what material is going to be utilised?

A2) How do you determine the quantity of material to order?

A3) What properties do you need to know, about the material?
(i.e. weight, ductility, size, heat conductivity, volume of billet, etc)

A4) Why do you need to know these properties that you have stated?

A5) How do you determine the size / format the material needs to be ordered and delivered in?
i.e. how do you determine how to specify in what size the supplier should deliver to you in, for simplicity? (to avoid excess scrap, and so forth?)

A6) What documents do you use to find relevant information about material?

Section B:

B1) How do you obtain the required material-property information? (stated in Q.A3?)
i.e. is it supplied in a Bill of Material? Or do you need speak with design engineer? Is it supplied on the component drawing? Etc
B2) How do you recruit a material supplier?
I.e. How are they vetted? Are lowest cost bid used? Or always Preferred supplier considered?

B3) How do you asses the supplier?
i.e. for reliability, deliver to specification, on time? Do they have the material required?

B4) Who do you need to speak to, when costing a material?
i.e. What range of experts do you need to interact with, in order to obtain all the knowledge, data and information you require to cost a material?

Section C: Cost Assessment:

C1) How do you obtain the cost of the material?

C2) What manufacturing processes ~or aspects of~ effect the cost of materials?
I.e. is the cooling process quick enough, or will it melt the tooling?

C3) How do you determine whether to produce the product in-house or to subcontract?

C4) How do you ascertain in-house capability? (i.e. do you consult and assets register?)

C5) How do you asses the cost of assembly?

Section D: User Requirements for Cost- Training

D1) What do you expect from a material workbook (how it could help you?)?

2) Have you done any training on materials, or is there any training in the company?

D3) What would be the best media to present the workbook?

D4) How often would you require to consult the workbook?

D5) Who else can benefit from such a workbook?

Please use this page to add any additional information that you feel may be relevant to the costing of materials; Attach any additional pages as required:

**Appendix 4b:** Costing Workshop and Training Development

The following is an example of a completed feedback form by a senior industrial cost practitioner regarding their experience of a cost workshop, developed within this PhD research, refer to chapter 8; which had been incorporated into a week-long training course, held at Cranfield university.

Cost Training

Cranfield UNIVERSITY

Your feedback will help in the continuous improvement of the training quality of this workshop. Therefore please complete this form and return to facilitator

- Number of years in your current position:
  12 years
- What was your previous position?
- Electrical Inspector on Tornado Project
- Can you briefly give your background / main area of experience:
- Time served Electrician working in the Aerospace industry
  Then developed into Cost Control for all projects in the Warton Division
- What aspects of this costing workshop did you find beneficial?
- Understanding the detailed parts of developing an estimate.
  I was very pleased with the content of the day
  which added a lot of content to all the delegates
- What costing aspects within the workshop do you think could be expanded on, (i.e. covered in more depth, more spent on, etc), if any?
- The Content was OK!
- What aspects within the workshop do you think could suffice with less time allocated (i.e. more of an overview given / less detail, etc), if any?
- As Above
- What aspects of costing do you think should be added to this workshop?
- If anything, the use of developing new
- estimates using comparative estimating
- In your opinion, Why would these additions be of benefit?
- To help people to make quicker decisions when faced
- with an estimate to consider.
- Do you feel the length of the workshop (~one day) was suitable
  i.e. do you feel it should be longer? ~Shorter? Or adequate as is?
  OK
- Please explain Why do you feel this?
- The workshop underpinned the lectures of the previous two days
-
- Do you think that there are colleagues within your organisation who would benefit from attending this workshop?
  Yes

Department of Enterprise Integration School of Industrial And Manufacturing Science, Cranfield University October2000

Cost Training

Cranfield UNIVERSITY

Please circle which answer you feel applies to you:

Q.12) Are you more confident about the process of building a cost ?

A.12) Very confident / moderately more confident / same as before / less confident / unconfident

Q.13) Are you aware of the elements that build-up a cost?

A.13) Very aware / moderately aware / same as before / less aware / unaware

Q.14) Do you know what information you require to cost a component?

A.14) Definitely know / more or less know / have a vague idea / not sure / don't know

Q.15) Do you know where to get the cost-information from, that you require to perform an estimate?

A.15) Definitely know / more or less know / have a vague idea / not sure / don't know

Thank you for your feedback!

Please add any further comments you have below:

……………………………………………………………………

…..A very worthwhile workshop -which added a lot

……to all the delegates……………………………………

…………………………Well Done! ……………………

……………………………………………………………………

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Department of Enterprise Integration, School of Industrial And Manufacturing Science, Cranfield University 04 October2000

**Appendix 5:** Advantages and Disadvantages of DIF analysis for use in TNA

## Positive Aspects of DIF Analysis:

- ✓ Industrial contributors can directly participant in the TNA derivation
- ✓ The theory of required participation is comprehensive
- ✓ It is general / flexible enough to allow different costing practitioners to participate
    - i.e. it is not an organisation or industry–specific technique.
- ✓ Whilst being general it can still be successfully applied to the costing process, and be designed to still hold relevance for each different contributor.
- ✓ The results can be analysed in an unequivocal, quantitative manner
- ✓ However there is the opportunity to present reasoning behind each choice /assumption made, via the comments section
- ✓ The outcome gives overt results to the training needs question.
- ✓ It covers the main elements in one technique
    - i.e. includes the experienced level of difficulty of an activity;
    - highlights its importance,
    - emphasizing the need for an awareness to be obtained.
    - Plus the frequency, to show the urgency of the task and how often it will be required).

The combination of the elements have resulted in a satisfactory supplement to the other more qualitative TNA techniques, described towards the end of chapter 8 including questionnaire response and interview feedback.

## Drawbacks of using this particular DIF technique:

- ✗ Can be seen as too generalistic
    - o E.g. if time frames are seen in relation to each other (each activity), or if the contributor prefers more specific parameters,
    - o E.g. more guidelines as to whether daily, weekly, or monthly is considered frequent.
- ✗ Therefore results have potential to be marginally inconsistent.

# **Appendix 6:** Extracts from the Materials Costing-Workbook:

The following are extracts taken from the materials reference book ***A Practical Guide To costing Materials*** in order to convey the type of document proposed for a permanent user-reference:

## 6. Why This Guide has been developed?

The expertise required to cost a product, comprises of both commercial and of an engineering type.
Thus two essentially different types of knowledge, skill and information are required by the expert, in order to cost a product.

The implications this has for the aspects of material-costing, is that cost-practitioners need to posses knowledge of the properties of material required; the similar materials available, in case of the need for a substitute; as well as the associated costs linked to the material.

## 6.i Direct (-Engineering) and Indirect (-Commercial) Material Costs

Costs relevant to the material consist of both direct and indirect costs.
Direct costs are more of an engineering issue, concerning immediate the product at hand: Indirect costs are more of a broader commercial nature.

The commercial material-cost aspects involve knowledge of costs not solely linked to the material itself: It also includes the broader more indirect issues of the costs, including:

- Weight / tonnage order (~10 tones of material, or 100,000 tones required?);
- Carriage, freight and general logistics (~Are there special conditions required for transportation?);
- Legislation attached to the material (~issues linked to disposal and so forth).

Engineering considerations have greater emphasis on

- Labour hours (high or low?)

- Manufacturing processes needed for the specific material. For instance, issues as below, need to be considered:
    - -intricate and complicated component being produced
        - or simplistic?
    - High or low cooling times required?
        - (low melting point or should material withstand high temperatures)?
    - Are there lower cost alternatives with regards to process times, tooling costs, etc?

- Skill levels needed to work with the material. For instance:
    - high skill, therefore more expensive,
    - Or will unskilled suffice?

- Plus functionality, and competitive advantage of material-use, requires consideration.

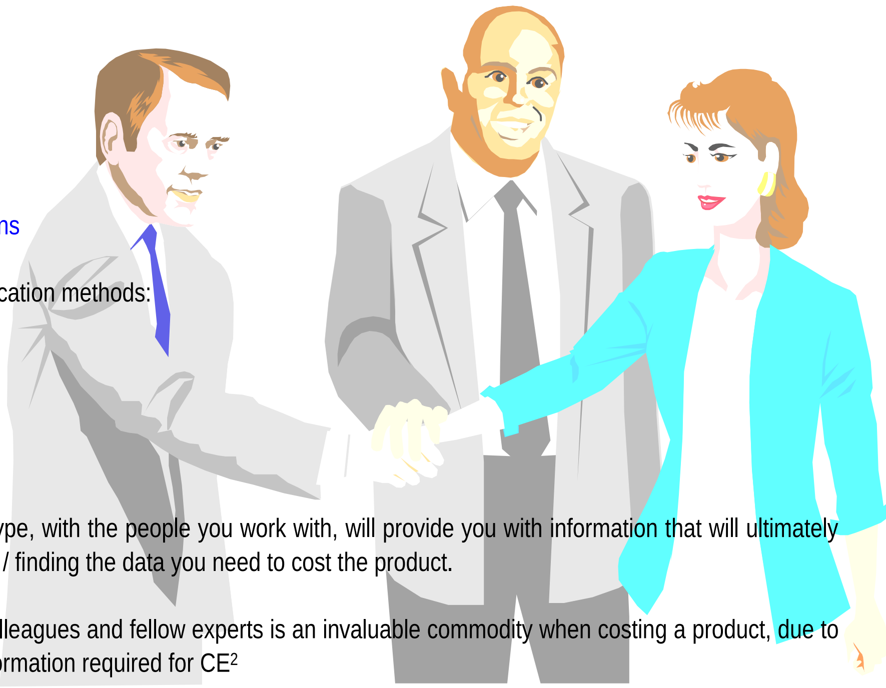
Additionally issues as the availability of material, alternate suppliers if necessary (or single source, so no alternative?); and the quality and risks involved, need to be addressed when compiling a cost estimate.

## 6.ii.e) Professional Contacts /Interaction:

The emphasis of this guide is on communication and interaction with other relevant experts across your organisation, as well as with other industries involved in your project, such as the supplier.

Traditional methods of communication:

- ✓ Telephone
- ✓ Email
- ✓ Memo
- ✓ Fax
- ✓ Meetings
- ✓ Informal conversations



Higher technological communication methods:

- ✓ Video conferencing,
- ✓ Tele-conferencing

Thus communication, of any type, with the people you work with, will provide you with information that will ultimately assist you in costing a product / finding the data you need to cost the product.

Building networks with your colleagues and fellow experts is an invaluable commodity when costing a product, due to the many different types of information required for $CE^2$

Best Practice Tip ➔ Continuously make contacts within your profession, inside and outside your organisation:
Once created, maintain these professional relationships.

## 7. But Before You Start…

**Key People Who can Help You:**

**Designers Engineers Purchasing Suppliers**

- ➢ Design Engineer

Provides knowledge and information about the product design and the materials

- ➢ Engineer specialisations

Provide knowledge and information about the manufacturing processes, the times scales and skills levels involved

- ➢ Purchase / Procurement / Buyer

Provides information about the suppliers and material quotations received

- ➢ Suppliers

Provides information about cost-breakdowns, materials and manufacturing processes utilised.

- ➢ Original Material Manufacturer

Provides an idea of raw material costs

## PART 1: A

### A. Things you need to know before you can cost estimate:

### 1.A)i. The Process

- What material to use?
- How much material you need?
- When you need it by?

Organisations have a structured form or work sheet, which will outline the overall product.
These can be referred to by a number of different names, organisational specific. I.e. Statement of work (SoW), Bill of Materials (BoM), Customer Request Form (CRF).
Such forms are the method by which companies outline the overall requirements or ‘skeleton’ of the product.
This form can act as a basis for determining the above, initial questions: What material? How much is required? When it is needed by?

### 1.A)ii. Material Choice

You can gather specific information required with regards to the material selection, from the designer.

Examination of the design specification, or more preferably, direct liaisons with the designer, can give you a detailed view of the product in question, including the particular material selected for use.

You may asses whether or not this original material specified is suitable for the product’s function.

Interaction with the engineers can clarify determine the suitability of material choice for the functionality.
A comparison of the properties of the material required, and the subsequent properties of the material selected for utilisation can be assessed.

Communication between the designer, engineer and cost expert is necessary even from these conceptual design stages.

Once the appropriate material choice has been reached, the next stage is to determine the quantities involved.

→People that can help you: Manufacturing Engineers and Designers

### 1A)iii. Quantity of Material

The original specification of product (SoW) provided by the customer or organisation will include information regarding the volume of the material required.
The number of products will dictate the amount of material needed.
Thus an understanding of this original documentation is essential.

In addition to this source of information, regular communication with the engineers involved on the project is a valuable way of gathering current data, specific and relevant to the product.
~How many parts are scheduled for production, will be information of which the engineers are familiar, and thus can be imparted knowledgeably.

Material type and volumes required for the project can be effectively determined by communication with the relevant, interacting experts.

~Information obtained from engineers and the designers, of who are also working on the overall product, will aid in the provision of preparation of a material cost estimate.

→People that can help you: Engineers

1.A)iv. Within Schedule...

The finished product delivery date will be specified on the original SoW form issued. This date is important to take into consideration, as it governs the time scales of which the entire project will be based around.

Engineers will be able to provide insight into the particular features of the product, and associated time scales related to manufacturing processes, and other product material-information.

There are a number of potential occurrences which could delay the project schedule: For instance, late delivery of material.
The possible impediments have to be accounted for in the project planning; and potential time setbacks need to be costed for, under Risks.

An additional time concern is where the completed product may be required within a tight schedule; then the subsequent processes that need to be used may have an effect on the costs
I.e. the methods necessarily employed will need to be faster / the height of technology / new equipment or expertise may be required: Therefore escalating the product costs.

Plus the issues affecting the specified material delivery may need close examination: An alternative material, or supplier could be necessary, if the time scales are to be met.

This may apply for instance,

- Where the material is rare, and / or in high demand, thus causing delays;
- And / or there is only one supplier, which means that the supplier may have high demands placed on them;
- Where there may be logistical challenges, i.e. overseas supplier. This could impose escalated costs in transportation, packaging, handling, and time frames.
- Alternately the material may need special packaging and /or machining, again adding to time and cost.

All these issues need to be determined, and catered for at the onset.

It can be seen that the reliability of supplier is key is such instances as mentioned above. The experts within the Purchase department can provide input toward reliable suppliers.

If deadlines and schedules are not kept by the suppliers, the project could run over-budget, through either trying to locate and asses an alternate, reliable source: Or through time wasted via late deliveries; bad quality product; inefficient transportation, lack of capability for -or low ability- to deliver required volumes, and so forth.

→People that can help you: Purchasers/ Buyers and engineers

## 1.A)v. Developing a Materials Estimate:

- Properties: The expert should consider the properties of the material necessary for the material to meet the functionality and specification of the part. The availability and costs need to be determined.

- Quality: The quality of the material needs to be consistent, and within the requirements, i.e. are all the delivered batches up to the same standards?

- Delivery: Can the selected source provide the material on time, within the schedule, and to a consistent, high standard; whilst keeping within the allocated project budget?

- Costs: A compilation of all the costs related to the material need to be derived, in order to determine whether the total cost is reasonable, and affordable: Or whether it proves to be escalated and above the affordability of the project.
  If over-budget, then alternatives (material and or/ supplier) may need to be considered.
  The risks associated with the material selection must also be evaluated and budgeted for in the cost compilation.

Part 1, Sections A and B examines the costing guidelines of:
Cost, Properties, Delivery and Quality.

Why they are important is outlined; as well as how they affect the costs.

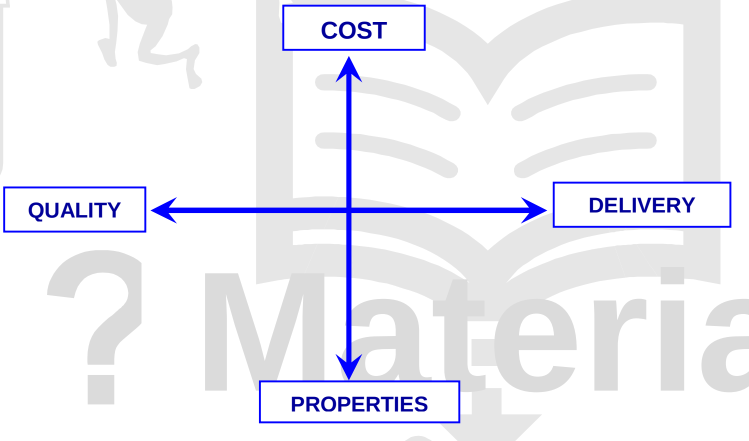



Figure 5: The issues necessary for consideration when costing a material

## 1.A)vi. Points to Prepare for:

Obtaining Raw Material Costs from Source (Original Material Manufacturer)
It has been observed across industries that an original material manufacturer may be reluctant to spend time compiling a quote for a CE$^2$ expert, of whom is not a serious (potential) buyer, but who would like simply to get an idea of the material costs.

This can be tricky for the novice estimator, as if interaction with the direct source of raw material is possible, then in theory this appears to be the best method of obtaining a cost which is less lightly to be 'top-loaded'. To expand on this point, a supplier will purchase material at one price, and charge another -higher price- to the company in question when compiling a quote, in order to cover their costs for buying from source, and to allow for a profit margin.

Although the supplier should be allowed a certain level of profit to keep the business stable, the CE$^2$ role is to ensure that this profit is not excessive.

Best Practice Tip ➔ Contact the Original Raw Material Manufacturer -to obtain a cost of material from source- if necessary / feasible.

An idea of the original material cost directly from the manufacturer is a good point to start an accurate materials estimate from.

Best Practice Tip ➔ If the original material manufacturer is reluctant to provide a quote, be persistent!
You will often be able to obtain a basic quote from them.

There will thus be many aspects to consider when compiling the cost of a material, based around a rough order of magnitude quote from manufacturer.
For instance Quantity ordered, i.e. the amount required will heavily dictate the cost: If a relatively small quantity is needed, then costs will be relatively higher, and generally decrease as the order increases.
Also, delivery specifications, i.e. will standard measurements suffice or will the material need to be cut to size?

→Key Point: Original Material Manufacturer may be reluctant to spend time compiling a quote for a non-serious buyer: Therefore be prepared to accept an approximation, which can be used to develop a more accurate estimate.

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## 2.A)iii. Industrial Variations in Costing

Due to the nature of most industries, distinct differences within the process of costing can be observed.
These discrepancies can be due to inherent differences in the end-product.

Within such different industries for example: Aerospace, Automotive, Defence, Shipbuilding, Bridge-building or Software development, the end product will enforce a certain level of cost process which will necessarily differ for different products.

For instance, military bridge –building will require a different quantity of material to software developers; and the majority of costs for these two industries will be placed in very contrasting areas. Software developers may place more costs in expertise, in order to develop software, write code, and eliminate bugs; whereas bridge-builders will need to place the greatest cost on the main bulk of material used, and the equipment required to produce the bridge.

## 2.A)iv. Reasons for Differences: Aerospace and Automotive

The material selection has been represented separately, in two individual lists, due to the differences between the two industries of aerospace and automotive.

Although there are commonalities between the two, the differences in the final product per industry, create the distinction in the materials utilised.

This difference has been used within the Guide, in order to separate the type of material, and associated processes utilised across industries, as well as highlighting the similarities.
Figures 5 and 6 illustrate the overt difference between the major products within both aerospace and automate industries.

Appendices 1 and 2 present a dogmatic view of materials currently utilised within an aerospace and an automotive organisation are listed.

The lists and Tables within these Appendices have been composed in conjunction with the experts from each participating industry.

## 2.A)v. Industrial specifics: Aerospace

All materials have an audit trail which can be traced to direct supplier, if any part should fail.

I.e. If one bracket fails: The exact component from each individual aircraft –for example a bracket from a specific euro fighter- can be traced to the supplier of that particular bracket.

Each individual Craft will be coded, and have a planning sheet per craft with a job card, for each company involved (i.e. who conducted the tests, did stresses etc).

Therefore accountability for potential manufacturing faults can be traced.

→ Subsequently all these safety measures and checks have an impact on cost.

Aerospace: Cost equation

Cost = dimensions of billet size * density * cost per measure
(i.e. cost per kg / cost per $m^3$)

Different processes have different costs:

- Fabrication: sheet/ tube material + (set up time / quantity) + manufacture time
- Machining : billet material +(set up time /quantity) + manufacture time
- Casting: non recurring costs (tooling cost / quantity) + Recurring costs (manufacture per item + X-Ray + final machining –if required)
- Composites: tools/quantity + material cost per item (i.e. material (carbon) accessories) resins bagging)
- Assembly: Fasteners + Assembly time
- Programming machine (one-of cost) etc.
- Forging

The Shape which materials are specified for delivery /usage:

- Bar
- Billet
- Sheet
- Rod
- (Extrusion)

A few examples of the types of base materials that are used widely within the aerospace industry are given in Appendix 1, B.
The shape in which the material is utilised is also listed.

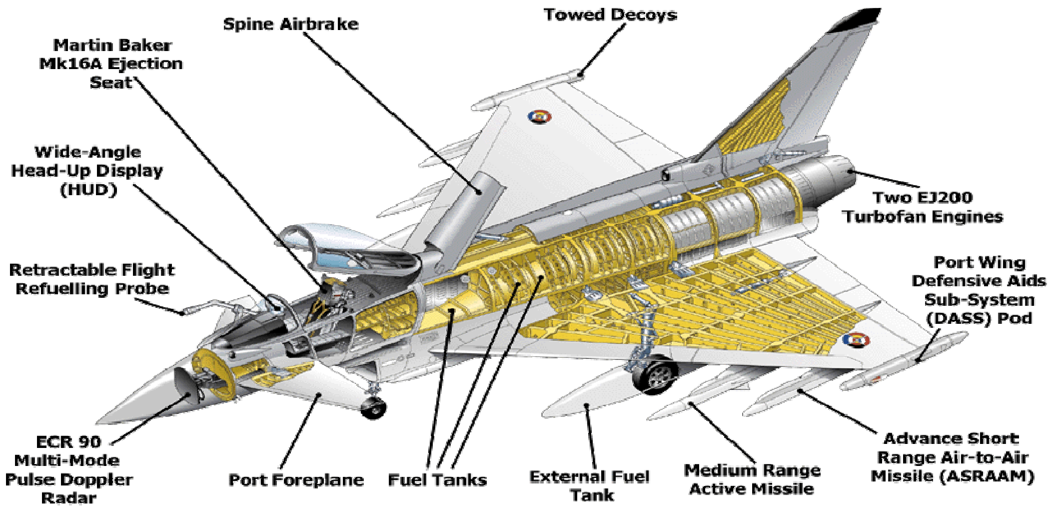
## 2.A)vi. Industrial Specifics: Automotive

The range of materials utilised within the automotive industry is vast: Consequently every individual material has not been listed within this guidebook.
However, a selection of the current materials used, are given in Appendix 1a.

Appendix 2 provides various materials in table-form, along with the typical end-product of each specified material.
The manufacturing process utilised to produce the component are listed, along with potential suppliers. This information aids in product costing, and provides the material information required to contribute to the overall estimate.

Basically, this guide presents a selection of representative materials, which are intrinsically used within automotive domain.
These materials are subsequently linked with the type of information and knowledge that a costing expert uses in order to cost each material.
Appendix 2 as stated above presents Tables 1-16.
These Tables contain materials used within both industries, and contain information of which is relevant for $CE^2$ activities.
The tables hold information of which is a starting point for an estimator be embarked on.

*Figure 5: An example of Aerospace Product:*




| AEROSPACE | | AUTOMOTIVE |
|---|---|---|
| HIGH | Cost Monitoring | VERY HIGH |
| VERY LOW | Manufacturing Volumes | VERY HIGH |
| VERY HIGH | Unit cost | LOW |
| HIGH | Manufacturing cost predictability | VERY HIGH |

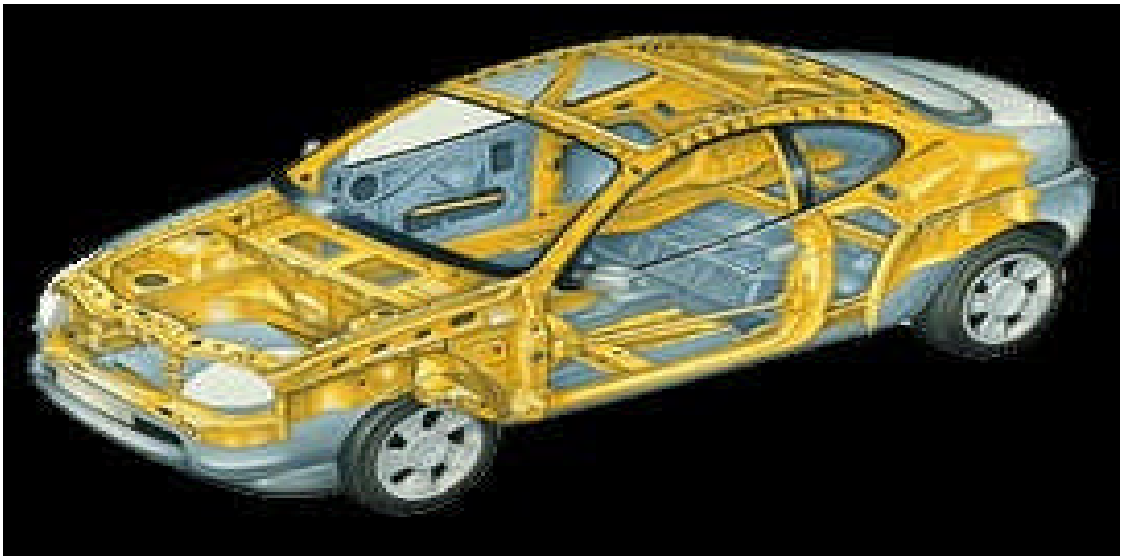


*Figure 6: An example of Automotive Product:*

Point of Interest:

ITT- Certain contractors are invited to perform a costed bid; this number will not be great, as only certain contractors will be deemed as capable of undertaking the job. It can take a lot of time –several weeks or months- to put a contract together, and will cost the contractor revenue to complete this contract proposal. This capital is generally (*) not recouped unless the contractor wins the bid.

Therefore it is not advisable to waste time and finance on unsuitable candidates.

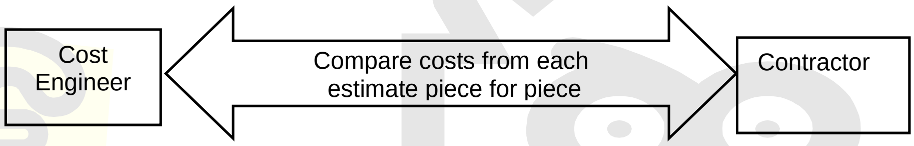
2.A)vii.b. Feasibility Stage

*-Collect Bids to do the job (occasional involvement of Cost engineer) –
→ ITT STAGE Requirement of customer are considered by team
(team consists of: Project Branch; Contracts and usually Cost engineer)

*-Asses Bids for compatibility
Decision based on factors such as: Cost, Reliability, compatibility, competence , etc. Basically assessing who can do it, at the most practically cost?.
→ ITT STAGE

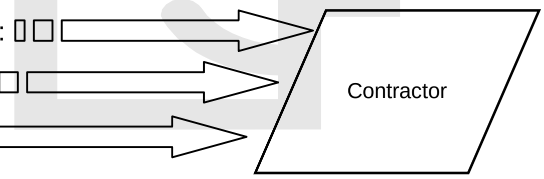
*-Contractor is selected
Decision is made as to which is the most compatible , suitable contractor for the job.
** PFG Official Involvement **
-Top Level Proposal is produced .
The selected contractor produce an initial top level proposal of the project.

Previous practice…




Current practice…

Cost engineers require contractors to:
Analysis bid content:
Prove and justify proposal costs




Previous Process:

Basic estimates were carried out on the project, by the cost engineering department. Then comparisons were made against the contractors estimate. Current practice is to take the basic bid of the contractor and conduct a technical cost audit to verify validity of bid. This change in practice is primarily due low resource.

-

PFG are tasked / requested) by Contracts and Projects Branches to EXAMINE PROPOSAL

→ Sanity check –Quick Assessment
→ Interact Directly with contractor

-Cost Engineers (PFG) arrange an initial meeting with the contractors.

This introductory meeting is primarily to allow the contractor to explain their proposal and to put basic project requirements forward.

The Cost engineer (PFG) basically compares the two sides:
What the customer wants: Ensure that the project gets only what is needs; the basics; exactly what requested –the 'Bare bones'!
What Contractors put forward: all the basic needs of the project plus add-on's and extra's – 'Gold-plating'!
**…Then the auditing process starts**

-Following the first meeting, the cost engineers request a full cost breakdown, in terms of work packages, from the bid creators (-the contractors /suppliers); For example: Into hardware and software.
Also from large sweeping figures into manageable chunks i.e. one measure of 400 labour years into smaller units

-Also requested are any data, documentation information (external or internal) that can support the bid.

Original proposal from contractor is 1 line;
Cost engineers need the costs broken down, in order to analyse the bid

-The Cost engineers concurrently discuss the project with the Project branch, to gain a greater idea of the details involved: Whilst analysing the cost breakdown

-Cost engineers arrange a series of interviews with the contractors. This is in order to validate the proposal, including data, information and documentation they may have to support it.
This also includes information / discussion about any internal and external sources related to the project i.e. both within the company and subcontractor

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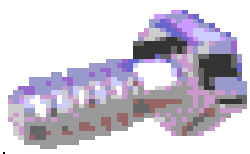
Part 2: B

## CE2 Examples and Industrial Case Studies

### 2.B) Component Examples:



### 2.B)I. Example 1. The Bolt!

A component example to high light material cost-considerations can be seen in a bolt!
Bolts are generally made from metals. An aerospace consideration would be because of the higher strength of metals and low corrosion.

Bolts are made from bar shaped metal.
This is because bar can be processed by prompt and low cost method –

Feeders can produce numerous bars used for bolts at a time.

The head of the bolt can be round or hexagonal; and may need to be machined separately, and connected to the bar.

The metal is machined with a lathe. Cost considerations are labour and machining time

The steel bolt can be coated with chrome, titanium or any of the rare metals. This is because steel will rust; but rare metals will not.

The reason why the bolts are only coated with the rare metal, and are not made by from them is due to costs. It would be too expensive to make the bolt from entirely from a rare metal.

Therefore it is more cost effective to produce the bolt from a relatively lower cost metal, as steel, and coat it with a high protector, but high cost rare metal.

**Table: The Bolt**

| | | |
|---|---|---|
| ORIGINAL SHAPE OF MATERIAL REQUIRED: | BAR | –AS THE FEEDER PROCESS IS VERY RAPID; BARS CAN BE FED THROUGH, AT A VERY HIGH RATE, PRODUCING HIGH OUTPUT. |
| Material most frequently used: | Metal | -due to high strength, high corrosion resistance |
| Type of metals: | Steel | –due to high strength: Often used in aerospace industry |
| | Brass | –has a god finish |
| | Aluminium | –due to light weight |
| Types of materials not usually used | Plastics | –due to low strength, high ductility (i.e. too soft) |
| | Copper (Cu) | – due to low strength, high ductility (i.e. too soft) |
| Processes used | Lathe / feeder | Low cost and produced high quantities of product |
| Process:<br>Attachments | Head of bolt will be secured to bar | Material can be provided in correct shape i.e. hexagonal or rounded |
| Component coated with | Chrome, titanium or any rare metal | To prevent rust (as rare metal will not rust) |

Therefore material Cost considerations:



Material used;
Quantity of material required (batch quantity)
Shape of material required;
Metallic coating;

Other cost considerations:

Labour and machining time;
Overall quantity of product required;
Overheads.

## 2.B)2. Industrial Case Studies

CONTRACTORS:

WFEL Limited (Williams Fairey Engineering Limited)

Product: Military Bridges

The following industrial case study has been related from a highly experienced member of the costing community. With over 30 years industrial experience, the Proposals Manager of WFEL Limited gave a direct account of the full costing procedure, of an actual contract between WFEL and the US government. Throughout this procedural-examination an emphasis was placed on the material aspects; particularly with respect to the associated costs, and the process and importance of material-selection.

Background:

Structural design is a very important factor in bridge building.
Weight is also a major consideration, as is high strength in low temperatures.
Therefore the material choice needs careful consideration.
Many military bridges have been and are still currently being built from steel.
This is because the materials utilised for bridge construction need to be able to withstand low temperatures; have a high strength and have low weight.

All bridges produced by WFEL Ltd, however are made with a non-commercial Aluminium alloy.
This aluminium alloy was specifically developed for (WFEL) this company: It was created for purpose by (the MOD) the defence industry, over 30 years ago.

The aluminium alloy has many virtues in relation to bridge use: These include high strength; high corrosion resistance; good fatigue and welding properties.
In addition, as the issue of weight is highly influential in determining material selection. Aluminium, being a low weight metal, is consequently a good choice.
However, not every low weight material is suitable for consideration.
For instance composites have not been examined for use, in any great depth by WFEL, due to low knowledge and previous data about composite-materials.
This lack of composite usage is due to the fact that WFEL's main strength is in welding aluminum.

WFEL have used this al alloy to build bridges for over 30 years; therefore the material behaviour is well known.
The risk of moving onto a different, less known or unknown material type such as composites, is high: This is due to the time and costs involved in testing a new material.

Current Project:

WFEL have won a contract to build bridges for the US army.
The initial contract is for 5 years, within which a total of 27 bridges will be produced by WFEL.

Knowledge of Impending Project:
The 'word was spread' with relation to this contract:
The US forces widely published information of the project on the world-wide-web, internet, and journals.

Summary of Material selection:

| Company: WFEL (-Contractor) | Product: Military Bridges |
|---|---|
| Main considerations for product | Weight and structural design |
| Material utilised: | Aluminium alloy (purpose-developed) |
| -Reasons why utilised | Low weight<br>High strength<br>High Corrosion resistance<br>Good fatigue properties<br>Good welding properties |
| Potential material choice: | Steel |
| -Reasons to use | Low cost (-comparatively)<br>High strength in low temperatures |
| -Reasons not to use | High weight (-comparatively)<br>Low corrosion resistance (?) |
| Materials not used: | Copper; Composites |
| -Reasons why not suitable | High ductility,<br>Low strength,<br>Low performance–data available<br>(therefore uncertain material performance esp. for composites)<br>Consequently high risks involved, for use i.e. High costs / time - for testing. |

Contract Competitors

Consequently on an international level, any suitable company –capable of this type of work- would have known about this large US contract.

Eventually three-four companies from around the world, bid for the project.

In order to met US specification, all bidding companies for the new US bridges worked individually: They all did what they thought was ultimately the most effective method, to produce the required specification in a method unique to each of their working practices.

Officially the customer did not reveal any information to WFEL about the competitive contractors for the project. Consequently WFEL did not know how superior or inferior their direct competitors were.

Time scale for Bid compilation:

In theory, relevant companies have known about this impending contract for several years.

However details of requirements were not known, just the fact that a large US military bridge contract was immanent. Accordingly until in receipt of the project-details, the contractors could not seriously prepare for the project.

WFEL had high-level knowledge of the impending US project for several years: However they only had the project requirements for two months; this was the time given for bid preparation by the potential customer (US army) to develop a bid.

Therefore in reality the actual time frame for contractors to develop a comprehensive, accurate bid for a major contract, from a large customer, was two months, once the project specification had been officially released from the US army.

There were four major competitors for this large contract, and three offered a bid in response to the specification, within the given two months.

Subsequently only two were selected to build the prototype.

| |
|---|
| *Bid-Cost Considerations*:<br>For this contract, the customer –which was the US army- offered:<br>*Cost plus fixed fee*.<br>This condition / term of working was specified by the customers at the Request for Proposal stage.<br>Therefore the bidding contractors, or at least, the company that won the contract, could foresee from the start, that cost was not the primary driver in this project. |

Competitors for the Contract

Military bridge building is a highly focused specialism, which caters to a niche market.

The material which the principle competitor used was steel.

This is due to the fact that the competitors' strengths are in steels, as they were primarily a shipbuilding company.

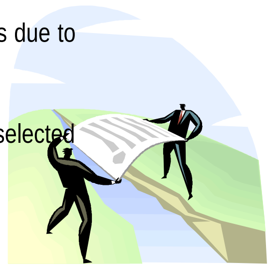
Thus they had developed high strength steels, the benefits of which they wanted to transfer to bridges.

Steel is cheaper then aluminium, therefore the competitor had lower costs associated with the project, then WFEL.

However the competitor did not win the bid, due to the provision of lower costs:

A primary detrimental factor within their proposal was the fact that the weight of system was higher. This was due to the choice of material for main use (i.e. steel, not aluminium).

Thus when the US army trailed the prototypes taking over one year to test all types of military bridging, they selected the lighter option, provided by WFEL.



Competitive advantage:

- What sells military bridges is:
- Low weight;
- Portability (therefore a good design which targets requirements is essential);
- Time factor and simplicity of system-relocation and assembly; i.e. the ability to get the bridge into place rapidly; thus, the ease of logistics.

| |
|---|
| *Primary Focus of Shipbuilding Project:*<br>= FUNCTIONALITY of product.<br>-Not cost!<br>This was very clearly set out, in the invitation to tender. |

Customer and Cost Considerations/factors:

The US government, signify a lucrative customer.
This customer specified from the start that the contractor will not pay for development out of the profits: Hence the fixed fee, for contractor, in addition to the costs for development.

From the early stage of prototype, the customer paid for both provisional contractor-developments: The cost of which was $10 million per prototype.
This was undergone even though one of the prototypes would not be developed further.
Thus the two trail-systems provided the customer with a choice; and a selection for which comparative analysis could be adequately performed i.e. both types were fully tested and compared against the other.

From a contractors viewpoint this stage was very important.
A successful prototype was essential, as if achieved, it would lead to the definite securing of contract (purchase of minimum -27 systems); and the potential purchase of 100 more systems -if the customer was satisfied with the prototype!

Process leading to Contractor Selection:

- Information about project is widely published by customer
- Suitable Contractors gather requirements from customer
- Contractors formulate bid (~in this case, bidding contractors were given 2 months to compile the bid from specified customer requirements).
- Customer request for potential suppliers to build a full prototype, based on initial bid: Only 2 contractors were selected at this stage (~given 2 years to produce)
- The customer paid for the prototypes and the designs (~at a cost of ~$10 million each)
- Customer analyse each companies prototype (~the bridges were trailed for over one year by US military forces)
- Customer interviews the two candidates further; including discussion / negotiation of terms and conditions of work, prior to official notification of successful candidate
- Contractor is selected; project mass-production begins

Customer–Contractor relationship: Contractual Benefits

The customer required a product which completely met their specification: They were interested in a product which was unsurpassed in the military field.

To aid in the delivery of this pursuit they specified a cost plus fixed fee contract, as they were willing and able to fully pay for the high cost of such an enterprising development.

The customers were aware that if the contract was not a cost plus fixed fee type, but instead a fixed cost / price arrangement, that when any difficulties arose in the design /development stage, in respect to meeting specification, that contractors would be reluctant to increase development expenditure.

This is due to the fact that further costs spent on product development, when working under the latter type of contract, would decrease company revenue.

Thus, the customer recognised that in order to create a state-of-the-art product, the developers may not achieve this on the first attempt.

A number of modifications may be required prior to delivery.

Therefore if the costs for the total development of product are covered, the contractors will utilise their maximum expertise, to product the most exceptional product that they are capable of, regardless of cost.

Contract Competitors:

- All contending contractors were requested to produce a proposal (RFP): For a 5-year contract; for design and production of 27 bridges
- After the bidding stage, the contenders were narrowed to two: Of whom were requested to produce and design a prototype system.
- WEFL were still unaware of the competitor technical capability.
- Therefore they were still conscious of being commercially more competitive i.e. were not informed that they had won the contract until all aspects of their approach to the project had been examined by the customer.

This will result in the delivery of a system in which quality is not compromised; and the only real consideration of the contractor will be in an awareness of customer time-constraints.

Working with Specified Time frames:

The time scale for initial bid was two months.
Thus the contractor was aware that if the requirements for the systems had taken the development into a new league of materials (other then the materials of which WFEL were familiar with); Then it was highly unlikely that a successful new product would not have been achievable, within the limited time frame.

The time scale to make the prototype was two years.
This project had three main international tenders.
Thus, three bids were submitted to customer. From these, WFEL were one of the two companies which were selected to build a full prototype of their products.

The company-costs for the prototypes and their design were covered by the customer.

Following production of the prototypes, the customer took in excess of one year to thoroughly test all aspects of each system.
As the bridges needed to be capable of rapid construction with relative ease; whilst having total capability, they were tested for all foreseeable situations and usage.

Factors Effecting Material Selection

The contractor formulated the bid in general, with the use of historic data/ information and knowledge; and therefore known materials and processes.

This was because the experts examined the requirements and felt that they could achieve the desired product-specification via their established methods, i.e. the load required, the length and life span of the bridge, could be achieved with the familiar materials.

Therefore due to a basic lack of time, previously unused, new materials, whose results were unknown / unpredictable, were not considered for this project.

The contractors tended towards materials and processes that they had previous success with; and in results which they were confident in.

Design of Prototype System:
However one of the most apparent differences between this new product and their other types of systems was in the use of plate.

A natural feature of the latest design was the incorporation of plate use.
This was due to previous bridges having been essentially built by hand, as there were less of them.
This product though is a mechanised bridge; therefore has fewer, of much greater sized pieces.

General Point:

The majority of industries operate in the above stated manner i.e. will consistently use tested, established methods where feasible; in preference to embarking upon new, un-established techniques and untested materials.

Exceptions to this working practice are within the 'cutting-edge-type' industries such as motor sport development, and potentially within aerospace research. In such industries, new, sophisticated, state-of-the-art materials (and manufacturing processes) will be sought, in an effort to constantly improve product performance.

If such projects are working with costs of two-three million pounds, i.e. relatively low quantities, then a balance can be struck between use of new materials, and use of known ones and established techniques.

Contractor-Designers

Experienced bridge designers make the decisions about the latest project i.e. new US military bridges.
It is generally accepted that there will not be time to consider the employment of new materials (previously unused by WFEL) i.e. such as composites or other commercial alloys.
The designers for this project determined that the desired specification could be achieved with use of familiar materials, i.e. the required load, length and life of bridge: Therefore the developed-for purpose al alloy was continued use for this new system.

SubContractors of Material forms:

<u>Plate metal</u>, use of which is designed into the product, is only supplied by one company in Switzerland.
Single source supply means that this subcontractor has to be used!

<u>Extruded aluminium</u> is available from three companies:
Corrus in Germany; a British aluminium company in Worthington; and Alussuisse, in Switzerland.
Thus extruded material is competitive.
Out of the three potential subcontractor-competitors, only one offered clear advantageous terms of supply, as far as the customer –WFEL- was concerned.
The preferential offer was in the form of fixed prices for five years (which is the duration of the project). Consequently WFEL opted for use of this subcontractor.
This fixed-price aspect of material supply greatly assists the estimation of project costs.

Forgings are supplied by subcontractor in form of a forged billet.

| |
|---|
| Cost-Realisation / benefit: Historic Replacement for forging<br><br>In a previous era, where such costs (as material-form) were not strictly observed, and consequently the high expense of forgings were not particularly comprehended by producers, forgings have been used.<br><br>Nowadays, have changed to use thick plate in preference to forgings, as is lower cost.<br>For instance, one type of bridge was built consistently for over 20 years.<br>This bridge was designed by MOD Christchurch, and was built for their own use, in royal ordinance; therefore cost was not tightly restricted.<br><br>Following commercialisation of the domain, the same design continued to be used; as it was deemed to be an effective, stable and generally successful design.<br>The producers did not want to change the design of something good.<br>Plus, testing novel types of bridges is expensive and highly time consuming.<br><br>As a consequent of the same successful design being continued with; the expensive processes used to implement it, needed to be changed.<br>Therefore an alternative to forging was sought; and found in thick plate -a process cheaper then forgings.<br><br>The materials used for this bridge were not totally interchangeable with the newer bridge (with use of the specially developed Al alloy); due to slight differences in technical properties.<br><br>Hence when it came to the making of the new bridge, where technical properties allowed, the contractor selected ‘plate’ rather then forging.<br><br>Eventually, the use of aluminium forging was completely eliminated for the newer bridge design.<br><br>However Stainless steel forgings are used, as in the context in which they are utilised, they are considered to be economical.<br>For instance it is economical to have dyes made, as the amount of machining required for production is reduced. |

Within the design of the latest project, use of forgings was avoided, due to high cost i.e. £9-11 per kg.

Cost of Prototype System:
WFEL contractors needed to gain an awareness of the costs involved in the project. This was achieved essentially by a systematic break-down of the design and system requirements.

The contractors had an approximate idea of the ideal weight of the system.
This was ascertained via examination of the customer-specification; in where it was stated that the bridge is required to be carried in a certain number of vehicles / aeroplanes, etc.
This requirement largely dictated the system weight

The average price per kg of aluminium alloy was known; therefore the cost of material for the bridge was able to be determined.
The launching system, which is what the bridging system is built on, requires a high level of steel, hydraulics and electronics.

Thus, the main cost of the alloy, is known; as is the amount required (through the specified weight of the overall system); and the cost per kg can be determined via historical price levels.
The launching system, which is the next major cost, can be negotiated and established, with companies with specialist knowledge in the areas of hydraulics and electronics.

Therefore the approximated design costs in addition to the known costs, (which are informed from material suppliers and subcontractors, as above stated) are then put together to produce the total costs required.

System Production:

The prototype was produced by hand-forgings billets, (i.e. slabs of metals).
However when the production in quantity was started, dye forgings were used; with the view that a minimum of 27 bridges will be produced; and up to, in excess of, 100. The total number that may be requested from the customer is undetermined as of yet.

Thus the current contract will conclude in five years, after 27 bridges are produced. However it is anticipated that the demand will be greater, beyond the five years.

SubContractors:

The best situation for WFEL with regards to material supplier is to have as many companies competing for their business as possible.
It is recognized that if a subcontractor is never used for aluminium supply, they will not continue to bid for work, perceiving that it is not worth the time and effort involved in compiling the bid.
However, if possible, it is better to keep them (and all suitable contenders) in the competition.

Subcontractor: Selection

WFEL select their suppliers via both the consideration of previous suppliers: And by examining the general market, and assessing and selecting from suitable candidates available, internationally.

The launching system requires a vehicle mounting crane. Therefore in a very systematic manner, WFEL contacted all companies who produce cranes and requested a cost quotation.
Globally, there are approximately four reputable companies who make cranes.

The criteria for selection, as far a WFEL were concerned, rested in the technical expertise. Next to this interest, price was secondary.
This was because cost was not a major driver of the customer, so the contractors did not need to subcontract the project, in accordance with the best price comparison.

International Working Practice: Differences:

US Defence working practice:
Pay for prototype and design, so the contractor does not bear the costs. The primary driver for this customer is functionality and quality; not costs

This is in contrast to UK Defence working practice:
The profit is prior agreed; and is deemed as fair and reasonable profit; therefore the contractors cannot exceed this agreed specified amount. T
Thus this customer is more financially driven, in general.

Confidentiality of Design:

The design of this novel and state-of –the-art system is protected by the British government.
Therefore export licenses will be controlled by the UK government.
This indicates that any undesirable future customer's i.e. potential threats to the immediate customer, will not be sold to.
This understanding is implicit; it is not stated-outright or directly, anywhere throughout the process or interaction between customer and contractor.

Cost Estimator Role:

The contractors profit is a constant, which is expressed as a percentage; as a margin –cost plus fixed fee.
Therefore as the profit is a fixed percentage of the costs, the US customer checked the costs to ensure the profit-percentage, required by the contractor, was valid.

The customer subcontracted the above auditing procedure to the UK MOD.
The MOD examined all aspects of the contractors working practice associated with the US project, both directly and indirectly.
Open book inspections were undergone; this was as agreed at the contract stage.

This securitisation included the labour rate; overhead rate; time bookings; purchase orders.
The WFEL are in total compliance with the open book method, stating that all their figures are transparent, and open for MOD /US military customer inspection.
Production Investment and Costs:

Main Project Cost Summary:

- ✓ Materials
- ✓ Crane main hydraulic systems; plus electronics that control it.
- ✓ Additional Hydraulic and mechanical subsystems, from other companies (from company suppliers).

When in production, investments are made into equipment, part-funded by customer and part by company.
The contractor jointly contributes to this cost, as the new, required equipment; though is especially for the new product, is also for long term, future use by the contractor.

The project has provided the contractor with another product, and thus another business to exploit.
Therefore the contractor accepts a level of the costs for this aspect of their business development; as they will also reap the benefits.

The system-prototype was build by hand, by skilled workers.
For full development conditions, the system-production is required to be undergone in approximately half the number of hours, in which the prototype was produced.
Therefore the mass system-production becomes automated.
Accordingly a requirement emerges, for the investment of larger machines, and the most modern technology.
Tools are principally funded by the company.

Risks:

The contractor has now partly invested in new tooling, equipment, and machinery. If consequently there is not a market for the new product, beyond this contract, the investment will not be returned.
This loss can potentially be avoided if the contractor markets their new, additional product effectively.

**Tables of Material with Properties:**

*Table 4*

| MATERIAL: POLYpropylene (POLYOLEFIN) | |
|---|---|
| Common or Trade NAMES: | Profax, Oleflo, Marlex, Novolen, Carlona |
| Symbol: | PP |
| | |
| MANUFACTURING PROCESSES: | Weld or Uni-weld<br>Polypropylene Black rod |
| END PRODUCT:<br>(Output /component produced) | Bumper covers,<br>Deflector panels<br>Interior mouldings<br>Radiator shrouds<br>Inner fenders |
| | |
| SUPPLIERS: | -Urethane Supply Company<br>-Himont U.S. Inc.<br>-A Visun<br>-Philips Chemical Co.<br>-BASF Corp. |

# **Appendix 7:** Details of Training Implications:

## **Appendix 7a:** Training Course Attendee Assessments:

The training will incorporate as wide a level of delivery as possible including CBT, workbook and interactive workshop. These sessions will incorporate all the main techniques of training; and use a wide range of medium to relay the knowledge and information.
This means the knowledge transfer module will include:
<u>Instruction/ lectures</u> (~telling trainee what to do)
The lecture material will be developed by relevant experts / consultants and academic researchers, in order to include as many industry-relevant subjects as possible. During development and subsequently for validation, they will be implemented within industry (at least aerospace and automotive): Modifications will be made as dictated.
<u>Demonstration</u> (~showing trainee what to do)
This includes guiding the trainees, in a step-by-step manner through practical examples; with the 'why's, how's, 'what's', where's' and 'who's (to communicate with) of product-costing being answered. Experts will also take trainees through industrial case studies.
<u>Direction</u> (~allowing trainee to perform task under supervision)
This includes 'Costing Table' activities, where a physical part is provided, allowing trainee to go through the process of estimating, using only the parts /prototypes/ drawings and information that an industrial costing expert would be provided with.
Examination of techniques selected, thought-processes behind actions, and result will be assessed, which the most suitable options being relayed; question and answer sessions and 'lessons learned' reviews, as per costing exercise.
<u>Cross-discipline-Expert and novice Interaction</u> (-workshops)
This will be to promote economic /commercial and engineering /technical communication, and the lateral knowledge transfer: Differences in working cultures will be exposed. The Cost centre experts will heavily facilitate and guide through these sessions, though ultimately the participants will learn from each other; and from practice / trial and error. These sessions will take place both:
In a structured form =workshops (up to 1 day);
In a less structured form =mini group projects /discussion and assignments (1/2 day).
See throughout this appendix for elaboration.
The varied approach to transferring knowledge to the cross-discipline experts and the novices is in order to access mental stimulus of the training recipients at all levels i.e. people learn at different rates, and via different methods. Therefore if as broad a spectrum of training techniques is employed throughout the module, all aspects of participant-learning will be catered for. Nonaka's [1995] SECI model discusses knowledge conversion, tacit / explicit: Between the expert-lecturers / facilitators and the designed trainee-interaction, the type of Knowledge conversion described may be applied to the proposed costing-courses, (see chapter 5, and illustrated in Figure 5.2). This is in conjunction with aligning 'the audience' (in this case the cost-trainees) with the message (e.g. the course context, as deemed appropriate by the module –developers).
The Lateral Transfer of Costing Knowledge will be promoted:

⇨ Between the different levels of novice. I.e. the trainees new to industry, with the more experienced industrially individuals, of whom are still novices within the cost-domain (see table 8.6). The interaction will broaden the formers general industrial knowledge.

⇨ Between different backgrounds and experiences of costing participants i.e. practitioner who is prior experienced in avionics, can learn from materials; polypropylene learning from austenitic stainless steel, and so forth. This interactive group learning approach creates a forum in where there is an opportunity to expand knowledge, with all the relevant aspects of costing to be learnt per specialisation.

Novice training: Type of Novice -New to industry or Industrially experienced:
It is recognised that there are currently different levels of novice within this profession, (see training participant section) and this will reflect in the course-content:

- For the <u>new-to-industry novice</u>, the training will incorporate not only a high-level view of the estimating process, before leading-in to more depth in this domain. It will also include modules which will develop basic, required manufacturing knowledge, with the aim of bring up-to-speed, those novices with little or no industrial (workshop) experience.

- Economic /Commercial background: The novice emerging from such experience will also benefit from these engineering modules, as above stated. Engineering current practice, both high-level and in greater depth, will aid in their understanding of engineering concerns with regard to costing issues. Thus the content of these pre-costing sessions include: product-functionality, -performance, –manufacturing processes, material and design selection.

- The more Industrially Aware Cost novice will be given the option of attending the above-mentioned modules. However other sessions will be available and recommended to them (once their needs have been established –see Pre-course Assessments, below). This will include sessions on the commercial aspects of costing, both at beginners' level or intermediate. Course content includes: Company-cost breakdown; overhead breakdown and variations on the content of 'overhead'; current legislation changes; international currency trends, supplier management and risk analysis.
- The above pre-costing modules will be beneficial to Engineering background practitioners, who require a fuller view of all aspects of the business, in order to cost from a wider viewpoint, then from sole engineering concerns. They can learn to cost from a wider organisational view with considerations as market –trends, etc.

## **Appendix 7b** Pre-Course Attendee Assessments:

In order to establish which modules will most benefit which course-participant, an evaluation form can be sent out (hard or soft copy; physically or made available on-line) prior to attendance, to each individual. These forms (completion of which will be mandatory for attendance) will involve an overview of module content, in order to aid in self-assessment level of participant. However they will primarily act as an assessment for the facilitators to determine more specifically at what level/ aspect of the course each trainee falls into (i.e. which aspects lecturer should tailor the main body of lectures to experienced or inexperienced novice?); and from what background they are. The background check will aid in determining firstly whether the individual requires the pre-costing modules, and secondly, which sessions would most benefit them i.e. the engineering or commercial-orientated.
NOTE: This is important as not all companies make these costing practice distinctions.

This pre-course form will also include a section which will be designed to protract specific requirements of the attendees, which can be addressed if feasible. I.e. such questions as: State why attending the course? What hope to get out of this week /4 days? What would you/ the company like to see covered?
Thus these forms will ensure course content accuracy meets the main body of attendee-needs; whilst concurrently improving the quality of course and adding to its repertoire of content (as dictated by current industrial trends).

## **Appendix 7c: Training Techniques:**

Lectures:
Lecture material will form the basis of this training; therefore lectures designed for use within the cost-centre programmes will be all encompassing. There will be lectures on every aspect of costing, from fundamental levels through to expert modules. (Topics included in List 1 xx).
Thus the beginner modules (engineering and commercial), and the intermediate modules (eng and com) will have core lecture content (see Expert-lecture section).

Other Training Techniques:
As stated previously the lectures will be supported by a host of other medium.
The consultants lecturing these modules will be able to provide up-to-date information as to industrial practice, best-practice and industry-challenges and advances. This will include demonstrations (going through procedures or even estimating components –with reliable and less accurate processes) and with use of case-studies.
Videos of processes will be on display throughout the centre.
Audio recordings of costing processes and evolvement of process will also be run alternately with the visual displays.
The lectures will also incorporate videos' primarily for the engineering processes-sessions.
Course lecture notes will be summarized and incorporated into the module handbooks for the session (beginner/ intermediate).

Manufacturing Process CBT and Material Guide book will be on sight, and available for use throughout. However main use of these training tools will be specified as an aid during group / individual costing sessions.

Interactive Workshops: Where possible this will include experts and novices (it is foreseen that both the Beginner and intermediate modules will contain a range of abilities / background/ experiences within each catchment). Thus the range of experience within the Beginner modules will allow a diverse level to participate with these interactive workshops (due to the range of cost-novices catered for). Thus bringing out costing processes, information and knowledge.
In the mixed-industrial sessions (where one company has not sent a full course of people; but instead a number of organisations have sent from one, upwards, of attendees) then these workshops will divulge a basic diverse spectrum of costing practice. However, the workshops will help establish the core fundamentals of costing i.e. cost aspects common, regardless of industry.
It must be noted that in such cases, where a mixture of attendees are present, the course content must adapt to cater for potential confidentiality issues, and potential competitive codes of practice. This is especially relevant for the participant discussion / workshop sessions, and the guided practice exercises. Activities should be selected which will bestow the generally principles of costing relevant to all bodies, whilst being compromising via excess specifics, to none.

To summarise these workshops will allow:

- Beginners will learn from other levels (higher) of experience.
- It will present the opportunity for commercial experts to interact with engineering purchase, with technical, financial and so forth; subsequently all contributory disciplines of the cost will have the opportunity to learn from each other.
- Industrial practice will be exchanged, establishing permanent commonalities across the profession, plus differences; and why these both occur. This will aid in overall process comprehension, best-practice, and standardisation within the process.

These workshops will start with a brief lecture in order to bring everyone to the same level of understanding; then primarily consist of open questions, to promote discussion (transfer knowledge), bring forward viewpoints (establish differences in practice), and determine best practice (create solutions to costing challenges).

Workshop techniques will include participant brain-storming, grouping and categorisation of ideas, visible note-taking -on wall chart or similar (proceeding initial ice-breaker activity) and so forth.

## **Appendix 7d:** Other Interactive learning: Estimating Table with physical components.

The trainee can work through an estimate of an actual component. The physical part will be laid out in the studio. Wall charts giving the overall process of estimating will be above the estimating table.

Estimating Table:
This will be an area (table) where all information required to produce a basic estimate will be provided, and more. From the selection of information given the trainee will need to apply what they have learnt in order to produce an estimate. They will subsequently have to go through this estimate (with other trainees and facilitators) and be able to fully explain all their assumptions and choices made; and will also need to justify their costs.

The Table will have:

- A physical part –to represent a component from the industries present in the training course (i.e. from automotive –a tensioner; for aerospace and more generically -a bolt; and also something all encompassing -a plug).
- The designers' actual drawing of that part, to work from

- Price indices –for labour and material –i.e. DASA
- Statement of work
- Bill of materials
- Journals: as recommended by industrial experts
- Organisational information i.e. NASA, US Defence (DoD), MOD –codes of practice
- Supplier information (i.e. full cost breakdown, or single-line quote); information which will provide location of suppler – (but not directly).
- Organisational budget constraints.
- Other project specifications i.e. time scales.

The trainee will be required to determine (or establish that they need batch size, material specification; form of delivery; etc). Also to identify cost breakdowns i.e. recognize that 100's of hours of labour need to be broken into perhaps individual components; tooling against machinery costs; depreciation breakdowns; overtime costs. Additionally what is relevant from organisational code of practice i.e. what to look for in supplier quote –'fair and reasonable profit' and so forth.

This area will have an array of costing information at hand i.e. visual aids such as Estimating-process Wall chart for generic guidance, (of the step by step process required); this exercise will be designed to encourage trainee to apply this process to a real situation; apply knowledge known to identify knowledge unknown. This may also involve group interaction and post-costing discussion.

### **Appendix 7e:** Commercial software:

All popular commercial software will be up and running on-sight with the costing studio. These will include Cognition, Galoreth, Price, (Cocomo) (and CAPE for Ford users). Actual group training sessions will be run as part of every course. Additionally the software will be open for use for individual user requirements.

One-to-one instruction will be available if requested /pre-arranged. However, this facility will also be available for those course participants who feel any aspect of the course is not relevant /suitable for them.

To summarise, individual can use, as and when required: plus official sessions to run through each software type will be scheduled into the training.

### **Appendix 7f:** Expert Module:

As these modules are predicted to be highly specialised, and more industry or even organisational-specific, they will be developed on an As-requested basis.
The original research will enable the creation of a few core, popular modules, to get these sessions started. Proceeding this stage they will be added to as and when. This is to ensure time is not wasted via a time consuming development process, to produce an expert module which requires in-depth knowledge, from both trainers and already known (to a certain level) by trainee; but then to avoid low use of module which had high-resource development.
The costing studio repertoire of such modules will be developed gradually, and updated regularly. The content of courses will be industrially dictated, to ensure
That the courses developed are ones wanted; and are up-to-date and of value to the recipients.

List 1: Topics to be Developed for Lecture Modules:
Fundamentals of costing: (Basic techniques)
Type Of estimates: (Parametric, Comparative, Single line, Detailed)
Estimating Techniques: (Time Appreciation, Sampling, Learner, Risk)
Estimating Allowances: (Scrap, Relaxation, Rectification, Rework)
The Price Build: (Direct and Indirect costs Overheads, Profit)
Negotiation skills: (report Writing, Interviewing, man Management)
See Table 8.6 for subjects to include within the core training modules

## Knowledge Transfer Training Sessions:

Joint disciplines = commercial and eng in together
Targeted = separate –i.e. lectures /workshop aimed at novices and practitioners from the same backgrounds i.e. commercial; and separate, aimed at eng.

The week course covers the aspects involved with costing profession, that are in need of training, as identified within the research.
It also outlines the latest methods of interactive training, as identified throughout the study.

The training course can incorporate participants with a range of backgrounds, experiences and thus, needs. The interactive training can assist them to learn from each other; addressing communicational and cultural issues whilst transferring knowledge and best practice.

Within this training week there is: the lateral transfer of costing knowledge: –through interactive workshops and expert-facilitation.
including the identification of where the transfer is needed by the participants.
The identification of the need for a transfer of the knowledge
The outline of how the practitioners will subsequently continue to do this within their organisation, as the training will recommend.

By the group discussions (which with the aid of ice-breakers, all present will contribute to), the identification of a misunderstanding of each others roles will be shown (commercial /finance towards engineering /technical and vice versa).
The particular discipline / role in question will be represented, in order to say what this misinterpretation is, and clarify the actual role (thus laterally transfer that aspect of cost-knowledge).
The challenges that each one is having –what info they need, why –and the fact that it isn't always available can come out via these workshop-type discussions what commercial info is needed by eng; what eng info is needed by com –each other discipline can explain why this isn't always available, whilst concurrently learning as to why it is so important, for use by the other.
Eventually throughout the week –with the participants having time to think about the lateral knowledge transfer from within industry; -following all this the participants w ill have the opportunity to give their views (prompted constantly by the facilitators /course experts) as to how they could tackle this lack of communication within their working environment.

This is important, as it will seem that they have identified the challenges present; and the causes; and subsequently the solutions.
If this is theory own suggestion, they will ideally suggested realistic opinions, which they would've already brought into.
(As opposed to unrealistic options, suggested by outside (unknown) sources, which they do not believe would work)

The facilitators play a major role in throwing in ideas and possible solutions to the identified challenges –as each opinion gets exhausted, identified as being possible /not possible –until the best way of improving overall working practice is arrived at. When this is done collectively, the participants will have, in arriving at this point, identified any potential flaws, and moved on until a solutions in which all agree is the best way forward –either as a company –or for individual working practices (the course sessions can be modified as required, as confidentiality may be an issue, when looking at separate working practices and areas in need of improvement; and potential solutions / new methods of working in order to make the costing more accurate, more quickly).

The lectures will be the targeted instruction on the areas in need of focused training. They will include

- lectures, -to present expert information;
- demonstrations –to visually show the information;
- Tutorials –to allow interactive questions, in where the individual participants can specially learn how to adapt the given (more generic) information to their own situation in industry.

The targeted workshops will allow the users to implement the information gained from the lectures, into use, coupled with their own current knowledge; with the addition of the knowledge transferred from the group discussion sessions.

The group's w/shop-discussions transfer knowledge, laterally along with industry best practice.

## **Appendix 7g:** An Example Timetable of Training Week Course

| TRAINING WEEK: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monday | Tuesday | | Wednesday | | Thursday | | Friday |
| 9:00-<br>10:30 | Introduction (including ice breakers) | Targeted LECTURES: | | Targeted LECTURES: | | Targeted LECTURES: | | Interactive workshop /Group discussion: Feedback /review of expert opinion |
| | | ECONOMIC<br>Material cost considerations | ENGINEERING:<br>Bid compilation | ECONOMIC<br>Detailed cost Estimating Versus tools | ENGINEER-ING<br>Contact management | COMMERCIAL<br>Estimating physical components -prototype | ENGINEER -ING<br>-Annual Cost breakdown Analysis | |
| 15 min.s | Break | Break | | Break | | Break | | Break |
| 10:45-<br>12:00 | Interactive group discussion / workshop on 'Lateral transfer of costing knowledge & expertise' | Manufac -ture Process Issues | Annual cost breakdown / supplier cost breakdown | Customer Req.s change; budget cuts; And other change-manage -ment to product | Customer analysis needs Management analysis | Continued: Include Manufactur Process | Analysis of:<br>-Supplier cost break- down;<br>-Bid compilation | 'Industrial costing' discussion -Continued |
| 12:0-<br>1:0 | Lunch | Lunch | | Lunch | | Lunch | | Lunch |
| 1:00 -<br>2:30 | Joint lectures:<br><br>Interactive costing working practice | Cost oversights: Supplier Cost break-downs | Overheads: Main components Plus Secondary Additions | Group discussion<br><br>'Roles, Interaction and Information' | | Continued:<br><br>Material issues | Bid formations: Identification of info. required & compilation | Discussion 'Importance of lateral transfer of knowledge' |
| 2:3-<br>2:45 | Break | Break | | Break | | Break | | Break |
| 2:45-<br>4:00 | Joint lectures:<br><br>Components of product costing | Aspects of Estimate from<br>-Physical part<br>-Designers drawing | Overheads /burden Cont. | Continued<br>'Cost Perception Versus Reality'<br>(Additions to Group discussion –day1) | | Continued<br>-Estimate derivation from Designers Drawing | Development of Bid cont. | Change – identification<br>-implementation |
| 4:0-<br>4:15 | Break | Break | | Break | | Break | | Break |
| 4:15-<br>5:30 | Joint lectures:<br>Current Industrial Issues<br>(i.e. legislations changes)<br>(Negotiations) | Product development/ performance: R&D; QA Recalls; Disposal; in-life Service Support | Supplier management; Logistics and Risk analysis for non-commercial experts | Continued:<br><br>Best Practice:<br>Challenges, Causes and ideal Solutions | | Continued:<br>Location of information;<br>Time scales;<br>Skill-level<br>Project-phases estimate | Development of annual cost b/down | Continued and summarised<br><br>→Action points<br>Questions<br>User feedback<br>Week Summary |

## Training Week Plan:

### Day 1:

- Introduction –(Joint disciplines: com/eng)

-what's on course, what will know when leave etc.

-Then why course is needed, -research into industrial costing and results therefore why required etc..

- Ice Breaking session (joint disciplines)
- 'Leading Questions..' session -MIXED SESSION (joint disciplines)

→Discussion of interpretations of each others roles

➔Designed in order to bring forth the major mis-interpretations, and hence a forum for discussion, and start-of correction for misunderstanding /lack of comprehension of what each other does.
Open Questions will be put-out for general group discussion; designed to provoke:
'what is involved in the commercial activities?'
'What does a cost estimator do all day?"
This will highlight the lack of knowledge –i.e. if experts present cannot answer
–and also bring forth the stereo-types of each participants role –the other side will have the opportunity to say the (correct or incorrect) version of their opinion of the role; then the actual role-expert will have opportunity to respond.
-Facilitators will constantly bring refer to generic industrially roles –with the aim of highlighting bias in the present expert i.e. and how their opinion is not absolute; but certainly relevant to their role.

Joint Lectures:
Negotiations: costs from source (i.e. for in-house manufacturing, material costs from original supplier); manufacturing costs etc
Negotiations with supplier
Negotiations with customer –over bids

Any latest issues within the field:
I.e. teaching while group about new legislation: i.e. for environmental issues as gas emissions:
Why brought into enforcement by government; what effects on industry; penalties if not followed; potential modifications that can now be considered by industry; international viewpoint of this issue –whether same internationally or not.
Expert-lecturers will keep up with current issues, and be able to teach on them

## Day 2:

Specialist targeted Lectures
Commercial (financial disciplines)
Engineering (engineering functions)
Up to 5 topics per day

## Day 3:

Targeted lectures -morning
Group discussion –afternoon
As above going back to the first days discussion -and by then the understanding of each others roles should be more accurate
-with the initial group, open discussion about roles (lateral transfer); followed by the specific training for each discipline (see novice type, Table 8.5; plus participant-dependent).

## Day 4:

Targeted workshops
Engineering
Morning: Engineering go through an actual annual cost breakdown
Then a supplier cost breakdown
Then a bid compilation

Afternoon: Create own bid; annual cost breakdown; and own cost estimate focusing on the 'other costs' (other then material and Manufacturing processes) i.e. the overhead breakdown
This is either done for their company
Or in mixed group, experts will create generic situations, where all taught skills will be utilised.
Issues such as sudden (or not sudden, but expensive) change required in Manufacturing Process /material used due to government legislation –i.e. environmental issue association. How does this impact on the overall project –including the company revenue?
Where will extra money be taken from budget to cover changes?
→This emphases how every product issue effects each other

➔Thus importance of working together, to have a constant flow of what's going on; what issues effect what; essential cuts to be made; why and where? Etc.

Commercial:
Day spent going though engineering aspects of cost estimating.
This will include: actual physical part estimation

-from a prototype and
-from a designers drawing.

Also: determining best manu. Process (time, cost, machine and tolling costs, depreciation, skill level, number of shifts, breaks, holiday, sick, new /potential new techno, etc);
estimating the cost of change of design (i.e. is a different process now required? Higher skill level then previous design? What's time increase and therefore cost increased with this time increase?)
Material costs: What affects this? Batch size, shape delivered in, environmental / legislation issues (i.e. gas emissions, etc)
Logistics, suppliers, (issues as oil/gas prices?)
Testing, R&D; QA; recalls; disposal; recyclable issues; in-life service and support; etc.

### Day 5:

Interactive workshop and group discussion: Feedback from lecturers on other group discussions –and reminders of main points.
Review –asking participants if would like to change anything stated earlier
-will be more knowledgeable, the lateral transfer of knowledge will be clear.
Discussion on importance of lateral transfer of knowledge, and how they propose to implement this within their working domain; and incorporate into the day-to-day working activity.

### Potential Titles for such a training and development Centre:

COST: Centre Of Specialised Training
CREDIT: Costing Centre of Research, Expert-Development & Interactive Training
CREATE: Costing Research, Expert Activity (Advances) and Training Excellence
TACIT: Training Advances for Cost Innovation (Interaction) and Technology

See Figure 8.12, chapter 8 for visual floor plan of proposed type of cost-focused training centre.

## **Appendix 8:** Knowledge Definitions

*"Knowledge is an assured belief or that which is known"*

[Chambers dictionary, 2006]

Polanyi believed that:

*"Knowledge, or the process of knowing, is personal and related to the individual. It can be viewed as a type of "intellectual capital" that has the ability to change how individuals and organisations view and create the world around them"*

[Polanyi, 1998]

Unlike physical assets, which are tangible, knowledge is intangible, and therefore often difficult to formulate in an explicit, 'solid' manner. A fairly widely used model of knowledge is where it is linked it to data and information: Where data is represented in the form of numbers, unrelated, unspecified facts and /or figures described by Saint-Onge as arriving: "in ours lives and on our desks as dispersed elements" [Saint-Onge 1996], and is said to exist "in finite volume and variety" [Sahota and Lemon 1999]. Information is the structuring of this raw data, into something meaningful and useable; but neither data nor information is knowledge. Knowledge is the ability to / being able to utilise this information in order to make decisions.

An example of this paradigm is to perceive raw data as random figures. These figures are transformed into information when they are structured into a weather chart for a particular region. Knowledge is employed when the information provided within the weather trends is used to assist in a decision as to whether or not to build a plant in the region. For instance a study of the weather trends will reveal potential time losses if the weather is seen to be unsuitable for a plant which involves a high level of outdoor activity, which could be held up if the prior 'rainy weather trends' are an accurate prediction of the future climate, and so forth.

Throughout the research a number of industrial definitions of knowledge have been procured, (see chapter 7); this seems to be because knowledge is seen as an intangible, implicit construct, therefore explicit, consciously derived definitions have proved to be inconsistent. Hence a literary derived explanation of knowledge, primarily stemming from Nonaka's musings is as follows: "Knowledge is dynamic as it is created in social interactions among individuals and organisations. Knowledge is context specific, because it depends on a particular time and space.."

[ von Hayek, 1945] [Nonaka, 2001, p14]

Therefore without which, it is just information. It has further been defined as:

"Knowledge is also humanistic ..essentially related to human action ...has the active and subjective nature ..deeply rooted in individuals' value systems. Information becomes knowledge when it is interpreted by individuals"

[Schoenhoff, 1993] [Nonaka, 2001, p15]

This observation about the essence of knowledge can be seen to expand on, if not slightly contradict Polanyi's definition, which is stated above. The latter focuses on the individual contribution, however does make reference to an entity wider then an individual, when stating the organisational influence.

The areas of knowledge defined in the work of Collison and Parcell [2008] link closely to that discussed throughout the thesis, the 5W's and H, which define the knowledge categories utilised to structure PC knowledge around. The former refers to know-how, know-why, know-what, know-who, know-where, know when; each area depicts an aspect of knowledge, all of which directly relate to industrial product costing. Refer to chapters 3, 5, 6 and 7 for further discussion.

## **Appendix 9:** Refinement of the Essential cost Knowledge Types.

This appendix has been included to address the derivation then subsequent updating of the essential knowledge-types. The clarification of why slight amendments have been made to the original selection are highlighted, going through each knowledge-type and discussing why it either stayed within the requisite classification, or whether it would be represented within the other areas sufficiently enough, to allow these amalgamations to address the omitted knowledge-type adequately. Section 7.2.4, chapter 7 subsequently discusses the final eight knowledge types, KT, in detail.

Table A9.1: The final eight knowledge types, deemed essential for product costing, listed against the original identified areas.

COSTING PROCESS ESSENTIAL KNOWLEDGE TYPES

| **Original 10 Knowledge types** **(with Traditional disciplinary Categorisation)** | **Revised Knowledge Types Incorporating Human Factors and Culture** |
|---|---|
| *Knowledge about the COSTING PROCESS (Commercial) | Costing Process Knowledge |
| *MANUFACTURING PROCESS Knowledge (Engineering) | Manufacturing Process Knowledge |
| MATERIAL Knowledge (Engineering) | Knowledge of Materials |
| DESIGN Knowledge (Engineering) | Knowledge of Design |
| Knowledge of PRODUCT (Engineering) | Product Knowledge |
| *Knowledge of RISK (Commercial) | Knowledge of Risk |
| *CONTACT Knowledge (Engineering / Commercial) | Communicational Knowledge |
| Knowledge of COMPANY STRATEGY (Commercial) | Knowledge of Organisational Culture |
| MARKET TREND Knowledge (Commercial) | |
| *SUPPLIER Knowledge (Commercial) | |

## 9.1 Knowledge of the Supplier

Knowledge of the supplier is crucial within product-costing: This involves a high understanding of an organisation of which close interaction is required, in order to establish whether the necessary products can be delivered to the required specification and costs. Although specifics of this knowledge can vary from supplier to supplier, the fundamentals of it are present within each of the cost-knowledge types, as shown in Table 7.2 in chapter 7 which highlights how the need for awareness of issues related to the supplier impacts on all knowledge-types. As an understanding of supplier-functions is integral throughout the process because many aspects of cost are directly linked to supplier activities, and it is apparent within the finalised eight knowledge-types, it was subsequently deemed unnecessary to isolate supplier–knowledge as an individual knowledge-type in itself, whilst it was so prominently present within all the other knowledge-types.

Another key aspect of supplier knowledge is linked with the nature of why a supplier is needed, i.e. to provide a service or component for the user organisation. The clear elements involved with the subsequent interactions are communication, and an understanding between the companies about the way in which each other works. This includes having an awareness of the organisational culture, the details of the required result, and any potential adaptations needed therein. Thus the Phase 2, P2 focus of research was significant in addressing the prominence of communicational knowledge and the numerous ways in which it is essential in this area. For example communication is needed:

- ✓ In order to ensure adequate understanding of what is needed by both companies,
    - ✓ But particularly the customer;
- ✓ When the item is required by;
- ✓ How it will be produced
    - ✓ Being aware of supplier limitations / capabilities,

  - ✓ And allowing for them;
- ✓ To suitability negotiate the terms, conditions, and of course costs.

Another major aspect brought into the research by P2 and linked to the communicational issues, was that of organisational-cultural knowledge; which is essential when working with an organisation external to the 'main entity'. This is due to the fact that many practices, beliefs and priorities may differ creating challenges if such issues are unknown, and close interaction / integrated working practices between the two are required. Given this, supplier knowledge, which was initially singled-out individually as one of the essential knowledge types, was absorbed into the final knowledge requisites, having been established as an important aspect within each of them, see chapter 7, section 7.3.

## 9.2 Direct, Product-Related Knowledge Types

There are technical /engineering knowledge types which are directly related to the product, namely knowledge of: Design; Manufacturing Process; Material and Product. These all remained in the classification of essential knowledge types in their own right, to highlight their importance; as a thorough and broad level of technical /engineering knowledge was continually referred to by the participating practitioners,. This even applied within the USA, where there was a noticeable difference in practice, from the viewpoint of costing practitioners backgrounds. This manifested in the fact that occasionally a practitioner was recruited with an economic /financial background; whereas an overwhelming majority of the UK practitioners had technical backgrounds. However, with the cases of non-engineering recruits, it was commonly specified that a lack of knowledge of the product and specific engineering aspects related to it gave a noticeable disadvantage to the practitioner. For instance an experienced practitioner commented that a relative novice from a financial-background should ideally gain access to the product, e.g. a military ship, in order to gain a 'feel' or sense of the item being assessed. A cost-practitioner even a novice from an engineering or technical background would generally have already gained this experience. Therefore all of the above mentioned knowledge-types, related directly to the product remained as originally classified.

## 9.3 Costing -Process Knowledge Requisites

A comprehensive knowledge of the Costing Process was a clear requisite throughout the research and across the range of contributors and research elements. This knowledge needs to be stated, as though its need is evident, it is necessary to highlight the importance, of having a combination of economic /financial, engineering, communicational and organisational-cultural knowledge, in order to cost a product successfully. This combination of identifiable disciplines and intangible elements of human factors is not common, or automatically acquired throughout the experience in what would be perceived as a typical career path. This combination of variants would not even be found commonly within most training packages, as the typical perception will be that there is little need to train an impending financial practitioner in engineering minutiae, and vice versa: So is often not achieved without design, or amalgamated by chance. The disciplines and knowledge-types which comprise the costing-process are both distinct, and broad within themselves, and include a comprehensive knowledge of the organisation in question and how it operates. Therefore having an overall knowledge of how the process is performed, what it consists of i.e. what information comprises it is essential, and does need to be highlighted as such.

## 9.4 Essential Knowledge of Risk

Risk was not always perceived to be within the role of costing, as expressed by a minority of the participating organisations; refer to chapter 4 where the product-cost roles have been described. Occasionally the broad description of risk assessment lay within other departments. However, in reality it seems that whether on a subtle level, or overtly written into the process, risk in one form or another is always a consideration of the practitioner assessing costs, e.g. when attempting to predict the potential risks in projects, in order to include the cost of them within the overall cost-assessments. There may be a number of different risk types that differ in nature but will affect costs, from IT developments to supplier selection; see chapter 7, section on supplier 7.3.1.7, and risk knowledge 7.3.6. Even the refreshing of vehicles will have an element of risk involved despite marketing information, such as with new product launches. Additionally, within the organisations that acknowledged risk as being a part of the process, it rapidly became evident that risk management was vital within product-costing, primarily due to the consequences, potentially costly if it was mismanaged. All these factors contributed towards Risk being affirmed as an important enough aspect to be left as one of the main eight knowledge types; see section 7.3.6 in chapter 7 for a more detail analysis of risk.

## 9.5 Other Knowledge Types: Organisational Strategy and Market Trends

When it came to re-evaluating the knowledge required of both Organisational strategy and Market trends, it was deemed that though they are utilised within PC, the level of usage was comparatively lower than for the other eight knowledge types, refer to table A9.1. Therefore, although knowledge of market trend and organisational strategy do have an effect on the costing-process and a degree of these knowledge-types is required, they are not as prominent in their own right as the ones that have been isolated as essential. Additionally, they are dealt with through the other areas. Often the emphasis on these two knowledge-types lies within other departments such as finance, marketing, and other disciplines that were more economically focused, as opposed to product-costing which has the mix of engineering, and monetary aspects.

Subsequently, the aforementioned knowledge-types could be seen as being amalgamated within the other essential knowledge's, particularly the Costing-process knowledge itself, in where economic knowledge, and the need to acquire a general monetary sense is imperative. Risk also incorporates various market trends and predicted tendencies of the customer in order to consider the affects changes in the market have on the costs and profits.

The finalised knowledge-types in question are prominent within communicational knowledge; and particularly that of organisational knowledge, in order to understand where costs can be cut and expenditures should be made: For the former (communication) the costing-practitioner will need to liaise between a number of different disciplines. This includes not only management and other similar 'overseeing' areas, but also the more specialised domain's, in where the decisions made will actually take effect. Market trends will need to be communicated, and interaction between knowledgeable parties, both internal and external to the organisation is essential; thus drawing in the organisational-cultural knowledge to allow the successful procurement of knowledge between different industrial bodies.

An element of risk is involved in both stated knowledge-types as the strategy adopted of the company will rely to a degree on risk assessment, and marketing feedback: Such measures, though reliable guidelines, are assessments, rather then actual data and information; therefore are subject to risk, changes in market, unexpected events, such as 9/11. The latter mentioned refers to a terrorist attack in New York, USA which occurred on 11th September, 2001; and proved to be a major international incident, impacting global markets.

This trail of thought can also apply to market-strategy knowledge and therefore the resultant decisions based upon it. Knowledge of the product and its design will often be dictated by the general trend in which the market appears to be adopting. For instance if 'greener', environmental issues are at the forefront of consumer concerns due to raised awareness, an automotive manufacturer will need to take this into account and modify its products according to the predicted demand. Both directions, either towards such an estimated trend, or a decline or reluctance to change towards it, pose risks.

Thus although the knowledge-types in question, namely 'organisational-strategy' and 'market-trend' knowledge, have not been singled out in the list of essential knowledge-types within the final assessment, they can be found within a number of the ones that have. This includes costing-process knowledge; risks, communicational, cultural and knowledge of product. Due to their presence within many of the other knowledge-types; and their individual use being a subtle one, they are not listed as specific, essential knowledge requirements individually, but can often be detected as present within parts of the whole.

## 9.6 TNA and DIF Analysis of the Original KT List:

From this 'pilot' list, three KTs were subsequently omitted from the initial selection: As prior mentioned, see above sections; these were Supplier knowledge, Company Strategy- and Market trend –knowledge types. A thorough review of these three KTs which had been classified within 'informalised training requirements', exposed that they had either been classified as Over-train or No-train by the majority of respondents; see chapter 8, section 8.2 for TNA and DIF analysis. Therefore the industrial outcome further enforces the academic view taken towards these three knowledge types, which was that they were ultimately not independently essential for the costing process.

The subsequent omission of these three knowledge-types from the final list of essential KTs was due to their lack of individual prominence, which was partly deduced by either a lack of required formal training resulting from DIF, as directly specified by the industrial contributors. Alternately the 'Overtrain' outcome tended to indicate a low frequency of use of the knowledge, despite its possible high importance and / or difficulty ratings.

With this said the knowledge types ultimately deemed most essential for the costing process, tended to be used frequently. This is not to say that the high difficulty and importance rating did not hold equal strength in determining which where placed under the essential KT list; but is to emphasise that a number of knowledge-types were recognised as being utilised within costing, at some point or other. However the value of the eight essential knowledge-types, is that it lists the knowledge that needs to be employed for a large majority of the costing process; with the others, particularly these three being incorporated within these eight, as described in chapter 7. Refer to Figure 7.7 for the direct and influential, but indirect knowledge within industrial product-costing. Although other KTs (not singled out in the final costing list) would ideally be at hand for the cost-practitioner, as are required for occasional use, the process would fundamentally still be able to be conducted without them, provided the essential eight were basically able to be utilised.

Of the complete range of knowledge's identified as essential, all have been classified as requiring formal training; such developments would assist in the continuation towards a comprehensive and improved system with regards to the costing processes. The specifics of the types of training proposed as a direct result of the knowledge-type TNA, are discussed throughout chapter 8.

# **Appendix 10:** A Full Example of DIF Analysis Industrial Response

The following is an example of an actual practitioner response to the TNA, specific DIF analysis method, including the response to all eight knowledge types, and incorporated exactly in the format which the industrial - response request was submitted in:

*TRAINING NEEDS ANALYSIS: DIF Technique*

This research has explored the components involved in the costing of products (cost estimating and cost engineering). Over twenty organisations have contributed to the research the aim which is to provide insights leading to improvements across the costing-process.

The final phase of this project would greatly benefit from the insights of industrial experts.

Please read the following description and complete Tables 1 – 8 accordingly.

## *DIF Analysis:*

The research has identified eight essential Knowledge types which are utilised within product costing functions; these are labelled 1-8 in the tables. The purpose of the following activity is to determine which of the identified knowledge areas, and sub-areas, need to develop formalised training, and which would suffice with informal. The technique for establishing this is *DIF Analysis*, and is outlined below.

***The function of DIF analysis for Training Selection criteria:***

| | | | |
|---|---|---|---|
| *D* | ***Difficulty*** | ***Difficulty in learning / performing task.*** | ***E.g. The difficulty for costing, may also lie in the location /procurement of data/ information*** |
| I | Importance | Level of criticality of task to job performance; or consequences of error | **E.g. Cost implications (Added expense) if errors are made; or cost estimates are inaccurate or delayed.** |
| F | **Frequency** | **How often task has to be performed** | **E.g. Is it only performed at the beginning of project; or required throughout?** |

The level of Difficulty (D), Importance (I) and Frequency (F) requires expert-assessment for each activity; with the judgment, simply requiring classification as 'Low' or 'High' (or non applicable). Please add exploratory comments to your rating where you feel this would be appropriate.

Two examples have been give in the Example Table, where the first two rows have been filled out: Example 1 presents a practitioners judgment for the activity of determining the *Direct costs* involved in projects. Example 2 describes a response for the *Indirect Costs:* Both of which are aspects of the Costing-Process Knowledge.

***Example Table:*** Taken from Table 1, Knowledge of the Costing Process:

| *ACTIVITIES / Functions* | *Difficulty* *Difficulty in learning / performing task.* | *Importance* *Level of criticality of task to job performance; or consequences of error* | *Frequency* *How often task has to be performed* |
|---|---|---|---|
| | **HIGH or LOW** | **HIGH or LOW** | **HIGH or LOW** |
| EXAMPLE 1 | **LOW** | **HIGH** | **HIGH** |
| **Direct Costs** | **Comments:** -Usually provided within BoM, (industry dependent) so can be established early. | -High effect on cost | -Required for every phase of product / project |
| EXAMPLE 2 | **HIGH** | **HIGH** | **LOW** |
| **Indirect Costs** | **Comments:** -Can be different per project | -Big effect on the overall project | -Only needed for overall project cost (not done per component i.e. for material costs, not needed, etc.) |

**1. Knowledge of the Costing Process:**

| *ACTIVITIES / Functions* | *Difficulty* *Difficulty in learning / performing task.* | *Importance* *Level of criticality of task to job performance; or consequences of error* | *Frequency* *How often task has to be performed* |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty **HIGH or LOW** | Importance **HIGH or LOW** | Frequency **HIGH or LOW** |
| Direct Costs | L | H | H TRAIN |
| Indirect Costs | L | H | H TRAIN |
| Supplier cost breakdown | L | H | L TRAIN |
| Overhead Allocation | L | H | L TRAIN |
| Logistics (-overseas or not?) Difference in costs | L | H | H TRAIN |

| | | | |
|---|---|---|---|
| Legislative Effects | L | H | H TRAIN |
| Annual cost breakdown | L | H | H TRAIN |
| Depreciation | L | H | H TRAIN |
| Competitive pricing | L | H | H TRAIN |
| Product profits -future trends of market | L | H | H TRAIN |
| Market trend knowledge and info. | L | H | H TRAIN |
| Outsourcing Vs In-house development (-cost of developing long term, or short term gains by paying outside companies) | L | H | h TRAIN |

**2. Knowledge of the Product**

| *ACTIVITIES / Functions* | *Difficulty* *Difficulty in learning / performing task.* | *Importance* *Level of criticality of task to job performance; or consequences of error* | *Frequency* *How often task has to be performed* |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty HIGH or LOW | Importance HIGH or LOW | Frequency HIGH or LOW |
| Overall product Information | L | H | H TRAIN |
| Functionality | L | H | H TRAIN |
| Performance | L | H | H TRAIN |
| Competition | L | H | L TRAIN |
| Basic models | L | H | H TRAIN |
| Upgrade models | L | H | H TRAIN |
| Time scales | L | H | H TRAIN |
| Costs | L | H | H TRAIN |
| Historical Data (Previous projects) | L | H | L TRAIN |
| Company Objective -quality or quantity? | L | H | H TRAIN |
| Accessing information from each component /element | L | H | H TRAIN |

**3. Knowledge of Manufacturing-Process**

| *ACTIVITIES / Functions* | *Difficulty* *Difficulty in learning / performing task.* | *Importance* *Level of criticality of task to job performance; or* | *Frequency* *How often task has to be performed* |
|---|---|---|---|

| | | *consequences of error* | |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty HIGH or LOW | Importance HIGH or LOW | Frequency HIGH or LOW |
| Labour hours | L | H | H TRAIN |
| Machinery / Equipment | I | H | H TRAIN |
| Skill Level -level of expertise | I | H | H TRAIN |
| Alternative processes | I | H | H TRAIN |
| Times | L | H | H TRAIN |
| Tooling investment -supplier, owns tooling -strategic investment / relationship | L | H | H TRAIN |
| Innovation /new processes -identification -associated risks -ease of bringing into the organisation | I | H | H TRAIN |

**4. Knowledge of Materials**

| *ACTIVITIES / Functions* | *Difficulty* *Difficulty in learning / performing task.* | *Importance* *Level of criticality of task to job performance; or consequences of error* | *Frequency* *How often task has to be performed* |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty HIGH or LOW | Importance HIGH or LOW | Frequency HIGH or LOW |
| Price | I | H | H TRAIN |
| Source | I | H | H TRAIN |
| Material composition (properties) | L | H | H TRAIN |
| New compositions | I | H | H TRAIN |
| Alternatives -selection | I | H | H TRAIN |
| Batch size | I | H | L TRAIN |
| Delivery form | | H | H TRAIN |

| | | | |
|---|---|---|---|
| -delivered to spec.<br>-or milled in-house?<br>Logistics | l<br><br>l | H | H TRAIN |

**5. Knowledge of Design**

| *ACTIVITIES / Functions* | *Difficulty*<br>*Difficulty in learning / performing task.* | *Importance*<br>*Level of criticality of task to job performance; or consequences of error* | *Frequency*<br>*How often task has to be performed* |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty<br>HIGH or LOW | Importance<br>HIGH or LOW | Frequency<br>HIGH or LOW |
| General in-put /understanding | L | H | H TRAIN |
| Alternatives (suggestions) | L | H | H TRAIN |
| Drawing knowledge (in case need to est. cost from drawing) | L | H | H TRAIN |
| Change - Management | L | H | H TRAIN |

**6. Knowledge of Risk**

| *ACTIVITIES / Functions* | *Difficulty*<br>*Difficulty in learning / performing task.* | *Importance*<br>*Level of criticality of task to job performance; or consequences of error* | *Frequency*<br>*How often task has to be performed* |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty<br>HIGH or LOW | Importance<br>HIGH or LOW | Frequency<br>HIGH or LOW |
| Product knowledge /historical data –to determine associated risks | L | H | H TRAIN |
| Supplier<br>-background knowledge<br>-stability i.e. overseas source, etc. | L | H | H TRAIN |
| Weather affects | L | H | L TRAIN |
| New product / processes /IT | l | h | H TRAIN |

**7. Communicational Knowledge**

| *ACTIVITIES / Functions* | *Difficulty*<br>*Difficulty in learning / performing task.* | *Importance*<br>*Level of criticality of task to job performance; or* | *Frequency*<br>*How often task has to be performed* |
|---|---|---|---|

| | *consequences of error* | | |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty HIGH or LOW | Importance HIGH or LOW | Frequency HIGH or LOW |
| In-put of information from other departments INTERNAL: | | | |
| -purchase / buyer | l | H | H TRAIN |
| -engineering | l | H | H TRAIN |
| -design | l | H | H TRAIN |
| -finance | l | H | H TRAIN |
| -marketing | l | H | H TRAIN |
| -management | l | H | H TRAIN |
| EXTERNAL: | | | |
| -supplier interactions | l | H | H TRAIN |
| -customers in-put | l | H | H TRAIN |
| Negotiations | | | |
| -internal | l | H | H TRAIN |
| -external | l | H | H TRAIN |
| Establishing general practice &/or ‘Tricks’ of supplier | L | H | H TRAIN |
| Market-trend knowledge | l | H | H TRAIN |
| IT system usage (for general information flow). | L | H | H TRAIN |
| Personal meetings /interactions | l | H | H TRAIN |
| Best –practice sharing | L | H | H TRAIN |

**8. Knowledge of Organisational Culture**

| *ACTIVITIES / Functions* | *Difficulty* *Difficulty in learning / performing task.* | *Importance* *Level of criticality of task to job performance; or consequences of error* | *Frequency* *How often task has to be performed* |
|---|---|---|---|
| ACTIVITIES / Functions | Difficulty HIGH or LOW | Importance HIGH or LOW | Frequency HIGH or LOW |
| Access to supplier information /general interactions<br><br>E.g.<br>Reliability<br>Stability<br>General Environment | L | H | H<br><br>TRAIN |

| | | | |
|---|---|---|---|
| Single or multiple sources? -many options) or not any choice? | L | H | H TRAIN |
| Establishment of Networks | | | |
| -Within the function | L | H | H TRAIN |
| -Between functions | L | H | H TRAIN |
| -External to organisation | L | H | H TRAIN |
| Tolerance for Risk-taking | L | H | H TRAIN |
| Establishing appropriate negotiation techniques | L | H | H TRAIN |
| Awareness of Organisational strategy | | | |
| -short-term | L | H | H TRAIN |
| -long term | L | H | H TRAIN |
| Strategic suppliers | L | H | H TRAIN |
| New market | L | H | H TRAIN |
| New Market risks | L | H | H TRAIN |
| Integrated working procedures | L | H | H TRAIN |
| Open, direct communication | L | H | H TRAIN |

***Do you have any general or particular comments about these activities, with regards to training:***

In general terms the techniques used in the function of Cost Engineering as not complex and are not difficult to teach or understand. All the items listed here are easily within the understanding of the average engineer.

The problem is the breadth of understanding that a cost engineer needs. They must be a “Jack of all trades” to estimate efficiently. Cost engineers depend on their communications skills and interpersonal skills to elicit information from others, which they need to, perform their cost estimates, risk analysis and pricing activities. They need to be sufficiently rounded in their knowledge, engineering understanding and skills that they are able to know when they are being miss lead or experiencing duplications and omissions in the costs estimate.

The frequency depends on the task, activity and job that the cost engineer is actually performing. And if you consider the frequency, daily, weekly, monthly or yearly whether the answer is low or high?

Would you like a copy of the final thesis for which this section of work will be included within, and explained fully: YES NO

*Yes please!*

Thank-you for your help; your contributions are valued!

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