CRANFIELD UNIVERSITY

OYETOLA OPEYEMI BANKOLE

DEVELOPMENT OF AN AFFORDABILITY ASSESSMENT FRAMEWORK FOR DEFENCE CONTRACTS AT THE BIDDING STAGE

SCHOOL OF APPLIED SCIENCES

THIS THESIS IS SUBMITTED AS A REQUIREMENT FOR A PHD
Academic Year: 2007 - 2011

Supervisors: PROF RAJKUMAR ROY AND DR ESSAM SHEHAB
July 2011

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ABSTRACT

Defence contracting has changed from the traditional provision of spares and repairs to contracting long-term for availability and capability. In these long-term contracts, the customer decides to outsource services (that would have been provided in-house) to contractors by consenting to an arrangement whereby payment is made only for the period that the equipment is made available to satisfy the defence need. Availability contracts may last for 40 years and more, but the main defence customer (Ministry of Defence) is constantly faced with budget constraints. Therefore, it is vitally important to assess the financial viability of the customer to invest in the contractor's offering of availability, capability and other long-term contracts.

The aim of the affordability research project is to develop an affordability assessment framework for the bidding stage of defence contracts. Thus, a close interaction with four industrial collaborators within the defence industry and the literature review revealed the need to investigate affordability from three perspectives namely, manufacturer profitability, supplier sustainability and customer affordability.

In order to conduct the research, the methodology employed included the review of literature, industrial interviews, development of the affordability framework for the three perspectives, case study application and final validation. This resulted in the development of a uniquely original affordability assessment framework that consisted of four modules and an affordability management methodology. The modules provided measurement metrics for the three perspectives of affordability and guidelines for improving affordability from the perspectives. Information availability at the bidding stage was usually low which lead to uncertainty about the project; the fourth module was focused on determining the information capability of the project team. To assess the impact of uncertainty on affordability, a methodology which involved a logic (containing two aspects) was also developed and validated within this research.

The framework developed was validated with three real-life case studies and the results obtained showed that the logic and content of the framework was appropriate. The benefit to industry is that the framework provides a platform for the manufacturer and customer to assess the affordability of defence project at the bidding stage and make decisions taking account of the impact of uncertainty.

DEDICATION

For what is a man profited, if he shall gain the whole world, and lose his own soul? Or what shall a man give in exchange for his soul? (Matthew 16:26). But as many as received him, to them gave He power to become the sons of God, even to them that believe on His name (John 1:12). According as His divine power hath given unto us all things that pertain unto life and godliness, through the knowledge of him that hath called us to glory and virtue (2 Peter 1:3). I dedicate this thesis to the God who gave me power to start, overcome and complete this journey.

ACKNOWLEDGEMENTS

Crucial to the success of a research activity is the valuable input from various sources. My utmost gratitude goes to the Holy Trinity – God the Father, My Saviour Jesus Christ and the Holy Spirit, a very present Help in time of need. Who has been my Rock and Sustenance till this stage in life. Without Whom, I would not be created, alive or able to undergo this journey.

I am very grateful to my supervisor, Prof Raj Roy for his great effort to guide me in the right path on this journey. My gratitude goes to my second supervisor, Dr Essam Shehab for his input in the research. I am always very grateful to family especially my Father (who has been a Father indeed) and my husband. Their help and support is invaluable to me. I would like to thank my friends and the PSS Cost team, and other researchers at the Decision Engineering Centre who have been of great help to me.

Thanks to my subject Advisor and chairman. Thanks to the secretaries at the Manufacturing Department for their support at every stage of my research and the academic and industrial sponsors of the PSS Cost project.

I would also like to acknowledge the significant contribution of the EPSRC and Cranfield IMRC for funding the project.

LIST OF PUBLICATIONS

Journal Papers

1. Bankole, O.O., Roy, R., Shehab, E., Cheruvu, K. and Johns, T. (2010), "Product-Service System Affordability in Defence and Aerospace Industries: State-of-the-art and Current Industrial Practice", *International Journal of Computer Integrated Manufacturing,* 1-19, Online.
2. Xu, Y., Elgh, F., Erkoyuncu, J. A., Bankole, O.O., Goh, Y., Cheung, W., Baguley, P., Wang Q., Arundachawat, P., Shehab, E, Newnes, L. and Roy, R. (2010), "Cost Engineering for Manufacturing: Current and Future Research", *International Journal of Computer Integrated Manufacturing*, p.1-15.
3. Bankole, O.O., Roy, R., Shehab, E., and Cheruvu, K. (2010), "A prediction system for assessing customer affordability of whole life cycle cost in defence industry", *Journal of Intelligent Manufacturing*, p. 1-19 (published online).
4. Bankole, O.O., Roy, R., Shehab, E., and Cheruvu, K. (2010), "Development of a Supplier Sustainability Assessment Framework for the UK Defence Industry", *International Journal of Production Economics Special Issue on 'Sustainable Development of Manufacturing and Services'*, submitted.

Conference Papers

1. Bankole, O.O., Roy, R., Shehab, E. and Wardle, P. (2009), "Affordability assessment of Industrial product service system in the aerospace defence industry", in: *CIRP IPS2 Conference 2009, on Industrial Product Service Systems,* 1-2 April 2009, Cranfield University, U.K., p. 230-238.
2. Bankole, O.O., Roy, R., Shehab, E. and Cheruvu, K. (2009), "An affordability system to assess information availability in defence projects", in: *Proceedings of DET2009 6th International Conference on Digital Enterprise Technology, Advances in Soft Computing,* Vol. 66/2010, 14-16 December 2009, Hong Kong, p.1613-1626.
3. Durugbo, C., Bankole, O., Erkoyuncu, J. A., Tiwari, A., Alcock, J. R, Roy, R., and Shehab, E. (2010), "Capturing PSS through industry sectors", in: *Proceedings of the 2nd CIRP Conference on Industrial Product Service Systems*, Sweden, April 13-15, 2010.

Industrial Publication

1. Bankole, O.O. Shehab E., and Cheruvu K, (2010), *Affordable Defence project – reality or fantasy? Project Control Professional*, The journal of the Association of Cost Engineers, Vol.48, No 6, November 2010.

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Glossary of Terms

Acronym	***Meaning***
AACE	Association for the Advancement of Cost Engineering
ABM	Agent-Based Modelling
ABP1	Approved Budget Plan at Top Level
ABP2	Approved Budget Plan at Departmental Level
ADP	Approved Defence Program
AI	Affordability Index
AOF	Acquisition Operating Framework
AS-IS	Current state
AS/EN 914XX	Aerospace Certification
ATLB	Available Top Level Budget
ATTAC	Availability Transformation Tornado Aircraft Contract fleet
B2B	Business to Business
BP1	Budget Plan at Top Level
BP2	Budget Plan at Departmental Level
BPR	Baseline Profit Rate
CADMID	The Concept, Assessment, Demonstration, Manufacture, In-service, Disposal cycle has been used by the UK MOD since 1999, when it was devised as part of the Smart Procurement initiative, since replaced by Smart Acquisition, to deliver equipment capability within agreed performance, cost and time parameters.
CADMIT	Concept, Assessment, Demonstration, Migration, In-Service, Termination cycle. Also a MoD's acquisition process for contracts involving asset management
CATS	Customer Available to Spend (a major factor in calculating the affordability index)
CER	Cost Estimation Relationships
COCOMO	COnstructive COst MOdel
CPA	Customer Profitability Analysis
CWTP	Customer Willingness To Pay
DASA	Defence Analytical Services and Advice
DEC	Directorate Equipment Capability
DEP	Directorate Equipment Programme
DES	Discrete Event Simulation
De&S	Defence Equipment and Support
DoD	US Department of Defence
DRP	Defence Resource Planning team
EFQM	European Foundation for Quality Management
EPSRC	Engineering and Physical Sciences Research Council
EVA	Economic Value Added
EVM	Earned Value Management

FACET	FAmily of Cost Estimating Tools
GAO	United States Government Accountability Office
GDP	Gross Domestic Product
HPAC	Harrier Platform Availability Contract
IMOS	Integrated Merlin Operational Support contract
IMRC	Innovative Manufacturing Research Centre
IPT	Integrated Project Teams
ISO	International Organisation for Standardization
ITT	Invitation To Tender
KPA	Key Performance Area
KPI	Key Performance Indicator
LCC	Life Cycle Costing
LCCA	Life Cycle Cost Analysis
MA	Measurable Actions
MC	Marginal Cost
MDAL	Master Data Assumptions List
MoD	UK Ministry of Defence
MR	Marginal Revenue
NAFCOM	NASA/Air Force Cost Model
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation
NoE in AE	Network of Excellence in Affordability Engineering
NPV	Net Present Value
OSCAM	Operating and Support Cost Analysis Model
P	Price
PfC	Proposal for Change
PFI	Private Finance Initiative
PI	Profitability Index
PM	Performance Measures
PSS	Product Service Systems
PV	Present Value
QFD	Quality Function Deployment
RBE1	Reduced Budget Estimate at Top level
RBE2	Reduced Budget Estimate at Departmental Level
RfA	Request for Approval for category A level projects
RfBP1	Request for Budget Plan at Top Level
RfBP2	Request for Budget Plan at Departmental Level
RfRBE1	Request for Reduced Budget Estimate at Top level
RfRBE2	Request for Reduced Budget Estimate at Departmental level
ROCE	Return On Capital Employed
ROI	Return On Investment
ROOE	Return On Owner's Equity

SC21	21st Century Supply Chain Initiative
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference model
SCRM	Supply Chain Risk Management
SD	System Dynamics
SDR	Strategic Defence Review
SEER	System Evaluation and Estimation of Resources
SP	Selling Price
SRD	System Requirements Document
TAI	Thermal Anti-Icing (TAI) exhaust plume case study
TLCC	Through Life Cycle Costing
TRL	Technology Readiness Level
UOR	Urgent Operational Requirements
URD	User Requirements Document
VFM	Value For Money
WBS/SBS	Work/Service Breakdown Structure
WLCC	Whole Life Cycle Cost refers to the holistic view of cost end-to-end across the CADMID cycle.

CHAPTER 1
INTRODUCTION

1.1 Background

The nature of contract procurement within the defence industry has witnessed a change from the traditional contracts (where contractors developed and delivered systems and equipment to meet customer requirement) and spares inclusive contracts (where the contractor provides spares and repairs for equipment) to contracting for availability and capability. Availability and capability contracts span a life cycle between 5 and 40 years or longer, hence it is important to be able to estimate the whole life cycle cost, as well as the budget available to the defence customer (Roy and Cheruvu, 2009). However, the main customer within the UK, Ministry of Defence (MoD) is faced with a constrained budget which has further reduced with the recent government cuts which affected projects such as the UK Harrier and Nimrod aircrafts (Baker, 2010). This necessitates the need to ensure that the customer has the ability to support the defence contract.

Affordability is described as the 'degree to which the whole life cycle cost of an individual project or program is in consonance with the long range investment capability and evolving customer requirement' (Ray et al., 2006).

This research focuses on the subject of assessing affordability of defence contracts at the bidding stage from three perspectives namely: customer affordability, manufacturer profitability and supplier sustainability. Therefore, it aims to develop a framework to assess and manage affordability from the three perspectives at the bidding stage. The following structure was employed in this chapter: section 1.1 provides a background of the defence sector. Section 1.2 introduces the context of defence contracting with different types of contracts while section 1.3 introduces the concept of lifecycle costing. Section 1.4 introduces the affordability concept with the three perspectives while section 1.5 presents the research motivation. Section 1.6 provides wider research activity and lastly, section 1.7 presents the structure of the thesis.

1.2 Defence Contracting

The defence environment is experiencing a transformation in its forms of contracting. Formerly, contracting was done in the traditional approach which was based on the provision of systems and equipment required by the customer. Then, spares inclusive contracts were also introduced which involved the provision for spare parts and repair services as desired by the customer. However, two major problems have been identified with the previous methods of procurement such as:

(i) slippage: due to technical difficulties, budgetary constraints leading to the postponement of expenditure, the redefinition of requirements and difficulties over collaborative programmes;

(ii) cost over-run: due to programme changes, changes in equipment specification, poor estimating and inflation of prices for defence equipment in excess of inflation in the economy as a whole.

These have triggered the advent of service and support contracts in the form of availability and capability contracts (Taylor, 2003). This is illustrated in Figure (1-1).

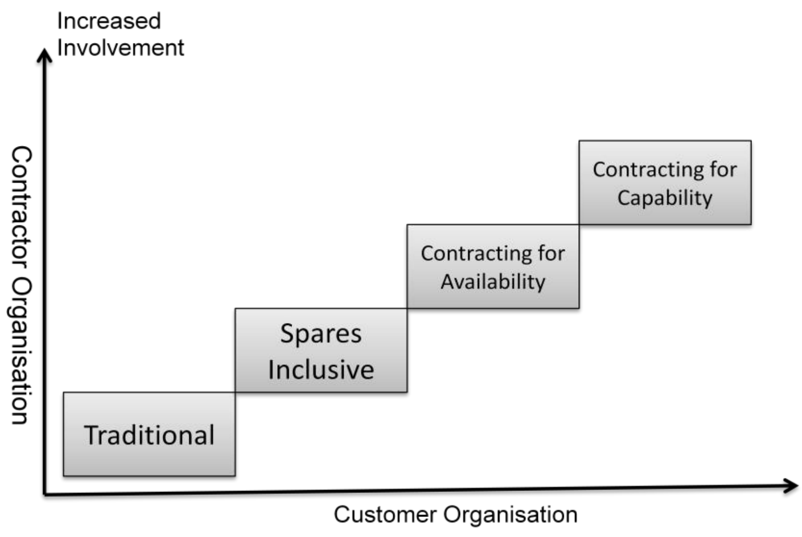


Figure 1-1: The evolution of defence contracts adapted from UK Ministry of Defence (MOD, 2005)

In order to contract defence projects, the following procedure is usually followed. The customer first identifies a need and allocates a budget to procure and support the contract.

An invitation to tender bids for the new contract is extended to contractors at the bidding stage. The contractor makes a decision to either bid or not and responds to the invitation based on that. These tenders from different contractors are then examined by the customer before the contract gets awarded to a *contractor* who then becomes the *manufacturer* within the project. The level of information the customer releases to the solution provider is determined by the lifecycle phase of the project as well as the procurement strategy employed (relationship with manufacturer). In a competitive bid, the customer normally provides an indicative funding allocation to contractors without extra financial information. Nevertheless, a spend profile could be provided when there are doubts about the affordability of the project. In a single bid situation, the customer provides data based on the willingness of both parties to share data and the knowledge of the manufacturer's offer. This procedure is further explained in Chapter 4. The lifecycle of a typical defence program is represented in the Concept, Assessment, Demonstration, Manufacture, In-service and Disposal (CADMID) cycle (Figure 1-2).

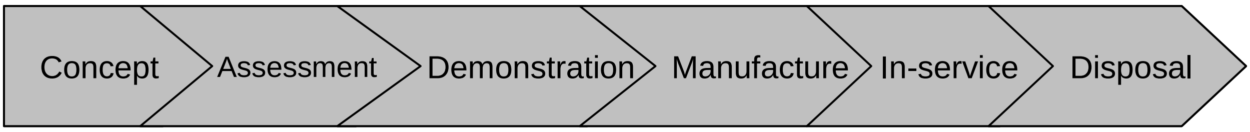


Figure 1-2: CADMID cycle of a typical defence availability contract (DASA, 2006)

1.2.1 Availability Contracting

Availability contracting is a contracting approach where the contractor is required to deliver whole platforms and equipment to meet agreed performance and standards of output which could be presented as key performance indicators, while capability contracting requires the contractor to deliver a capability to achieve the required performance standards (MoD, 2005; Cushway, 2006). The customer's desire for equipment reliability in order to reduce the movement of spares and repairs meant that the focus was to pay for availability of equipment, not repairs. Previous methods of contracting for delivery and repairs separately did not incentivise the contractor to deliver equipment for reliability. Availability contracting allows the customer to pay for the use of the equipment and contractors to generate returns continuously over a longer period while providing greater equipment availability (MoD, 2005; Roy and Cheruvu, 2009). This type of contracting is more common within the defence industry as seen in the following: Integrated Merlin Operational Support (IMOS) contract, Availability Transformation Tornado Aircraft Contract (ATTAC) fleet, Harrier Platform Availability Contract (HPAC) and the UK's Eurofighter Typhoon fleet. This contracting approach can be applied to defence contracts of any value. Within academia and other sectors, this type of contract is also referred to as Product-Service Systems (PSS). PSS is an integrated product and service offering that delivers value in use (Baines et al., 2007). Geodkoop et al. (1999) provide a comprehensive definition of a PSS being 'a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models' (Baines et al., 2007). Here, the customer pays for the use of an asset, rather than its purchase, thereby realising the advantage of restructuring risks, responsibilities, and costs normally associated with ownership in traditional business contracts. Generally, a PSS is described with the following features:

- a physical product core (e.g. aero engine) enhanced and customised by a non-physical service shell (e.g. maintenance, training, operation, disposal)
- relatively higher monetary value and importance of the physical PSS core
- business-to-business relationship between PSS solution providers and their customers (Aurich et al., 2006).

In PSS contracts, the prime contractor provides product functionality, availability or a result in quality, time and location as required by the user (Meier et al., 2010). This shows that availability contracts are an example of PSS within the defence sector.

1.2.2 Capability Contracting

Capability contracting is a contracting approach, which is concerned with the provision of a capability rather than the availability of a platform. It is the destination that the industry is heading for; hence few examples of this form of contracting exist such as e.g. air-to-air refuelling and Skynet 5 communications contract (MoD, 2005; Roy and Cheruvu, 2009). While capability could be an outcome the customer desires to achieve as a result of an operation (Acquisition Operating Framework (AOF), 2010a)), it has also formed the basis for contracting. Similar to availability contracts, there is no restricted value for a contract to be awarded under this procurement method.

In addition to the types of defence contracts described above, other contracting approached are also employed which are explained below.

1.2.3 Smart Procurement

In order to overcome some of the problems identified with some methods of procurement, smart procurement was initiated. Smart procurement is an initiative introduced under the Strategic Defence Review (SDR) to streamline defence procurement process with the aim of reducing overspends and delays in MOD equipment programmes. The purpose was to foster 'closer customer/supplier relationship and deliver equipment faster, cheaper and better' through life. The initiative was first introduced in 1998 and re-launched in 2000 (Taylor, 2003).

The SDR envisaged that the Smart measures would help achieve saving of £2 billion over ten years. Its key elements are as follows:

- Through-life systems approach substantiated by the institution of Integrated Project Teams (IPTs) to bring industry, MOD and Armed Forces together
- Comprehensive project planning at early stages of procurement with proper trade-offs between military requirements, time and costs in the bid to assuage later cost overruns and delays
- Partnering arrangements with industry, particularly in competition bid
- Procurement techniques involving incremental acquisition to allow greater flexibility to adapt to technological advancement at lower risk.

Rather than an alternative contracting approach, smart procurement is an initiative which is adopted in other procurement approaches such as partnering, availability and capability contracting.

1.2.4 Partnering

Partnering is another procurement approach aimed at improving defence contracting by using "partnering specific terms and conditions" to facilitate the successful delivery of joint objectives between the customer and the solution provider (MoD, 2008). The approach creates legal obligations and contractual commitments which are strengthened by a structured and rigorous approach to relationship management. The contracting approach provides an incentive for collaboration between the partners and a better chance of delivering the capability required within acceptable performance, time and cost parameters.

Whilst the approach encourages closer collaboration between the customer and the solution provider, it is not a replacement for competition; hence the Competition Act 1988 is still applied in this type of contract. There is need for thorough consideration before partnering as it is only suitable if the project team is able to ascertain that the investment required to partner would benefit the project, normally with a value over £5million (MoD, 2008).

The advantages to be realised through partnering include:

- Reduced whole life cycle cost of projects and performance through joint efficiency improvements and the employment of new ways of working which encourages innovation and flexibility
- Increased confidence between customer and solution provider due to greater transparency and openness on business objectives
- Ensuring that contract elements add value to the required capability as these elements would be challenged
- Faster negotiation process as each parties' respective governance and assurance processes are better understood and reduced acquisition life cycle time
- Incentivisation and joint pain/gain share arrangements enhance project efficiencies and provide avenue for increased return for the manufacturer (MoD, 2008).

However, the following challenges also apply.

- The Competition Act (competitive procurement) and European Community regulations still apply in Partnering
- Risk of delays in project approvals if there is insufficient consultation with other government departments, like Her Majesty Treasury referred to as Treasury, Business Enterprise and Regulator and the Office of Fair Trading.
- During the project life cycle, business circumstances might change to hamper the partnering arrangement.

The advantages and challenges of partnership presented above are also applicable to many defence contracts which take the through life approach such as availability and capability contracts. For this reason, it is important for both the customer and manufacturer to be open and honest while contracting and make adequate preparation for risks and other uncertainties. The partnering approach could be applied together with either a capability or availability procurement approaches due to the nature of partnering.

Additionally, in adopting any of the various procurement approaches presented above, other types of contracts can be implemented. This means, for example in contracting for availability, different pricing arrangement could be employed such as fixed-price contracts, incentive contracts, indefinite-delivery contracts and cost-reimbursement contracts (Roy and Cheruvu, 2009). The choice of a particular pricing agreement is affected by factors including price competition, price analysis, cost analysis, nature of the requirement, urgency of the requirement, period of performance, contractor's technical capability and financial responsibility, extent and nature of proposed subcontracting and acquisition history (Roy and Cheruvu, 2009).

Two important factors that affect the delivery of defence contracts are the whole life cycle cost of the project and the funding available which forms the customer budget (Nogal, 2006). The availability of these resources at the required level is crucial to the delivery of defence contracts; hence the processes leading to the allocation of these resources are introduced in the next sections.

1.3 Life cycle costing (LCC)

LCC was initially applied by the US Department of Defence based on the notion that operation and support costs for typical weapon systems accounted for as much as 75% of the total cost (Gupta, 1983) which is committed at the design stage. This motivated an approach to the costing of projects which takes account of all stages of the lifecycle (Asiedu and Gu, 1998). In order to manage the cost of products, methodologies such as *design-for-cost* and *design-to-cost* were developed. Design-for-cost involves engineering process technology to reduce life cycle cost while design-to-cost involves developing a design that complies with the functional requirements for a given cost target (Dean and Unal, 1992; Asiedu and Gu, 1998). Design-to-cost is a similar concept to *target costing* which involves profit planning and cost management to design product cost at the research and development or concept stage rather than reduce cost at the manufacturing stage. The target cost is determined by subtracting the desired profit margin from the expected selling price (Atkinson et al., 2001).

Life Cycle Cost Analysis (LCCA) is a systematic approach of applying economics in deciding the best solution for a design over the useful life of the system while affordability analysis employs the outputs of a LCCA to apply investment strategies over the life cycle of a system like reserve strategies, etc. (Chytka et al., 2006). This could be carried out by parametric, analogous (estimating by analogy) or detailed (bottom-up) costing approaches. The subject of LCC is further explored in chapter 2. The outcome of this process is the Whole Life Cycle Cost (WLCC) of the project. The other important factor in the delivery of defence contracts is the customer budget which is usually allocated by the Government through the Treasury. This is further explored in Chapter 2.

1.4 Affordability assessment

Affordability could be explained as the attribute of a product which makes it affordable to the customer. The word 'afford' or 'affordable' is commonly used by individual consumers as well as business customers. It is a concept that is associated with the ability to pay for something or the attribute of a product or service to be cheap enough that it falls within the income or budget that the customer is willing to spend or invest. Affordability is usually constrained by the customer's income or budget. This means for example, a mini would be unaffordable for a lower class earner, while it could be affordable for an upper class earner. Also a BMW model may be affordable to a middle class earner while another one may only be affordable to upper class earners. The affordability of products and services vary depending on the cost and the customer's budget. Within the Business-to-Business (B2B) context, manufacturers are moving towards providing integrated offerings to customer informed of PSS. The delivery of PSS in the defence sector usually requires the interaction between three parties namely; the customer, manufacturer and supplier. The customer is the party who identifies a requirement and provides a budget to support the delivery of the contract to meet its requirement. The manufacturer is the party who interacts with customer to provide the capability or outcome to meet the customer requirement. The supplier is the low-tier supplier who supports the manufacturer to deliver the customer requirement by providing some expertise, materials or other resources which would aid the delivery of the customer requirement. This means that each of these parties have their perspective of affordability. The customer is primarily concerned with having sufficient budget to support the defence contract. The manufacturer is concerned that it would recover its investment with profit and that it has a sustainable group of suppliers to aid the delivery of the customer requirement. This means that the manufacturer is keen to ensure that its customer can afford to pay for the defence contract, its key suppliers are sustainable throughout the duration of the contract and the manufacturer is guaranteed continuous revenue to yield a profit in delivering the defence contract. The perspectives of these parties are illustrated in Figure (1-3).

While the word affordability refers to an overarching concept, it can be viewed from three individual perspectives which are the customer affordability, manufacturer profitability and supplier sustainability. These three perspectives were identified during the review of academic literature as well as industrial interaction. The details of these are provided in Chapters 2 and 4. 'Customer affordability' refers to one of the perspectives while the term 'affordability' refers to the overall concept. Each of these perspectives is briefly explained below.

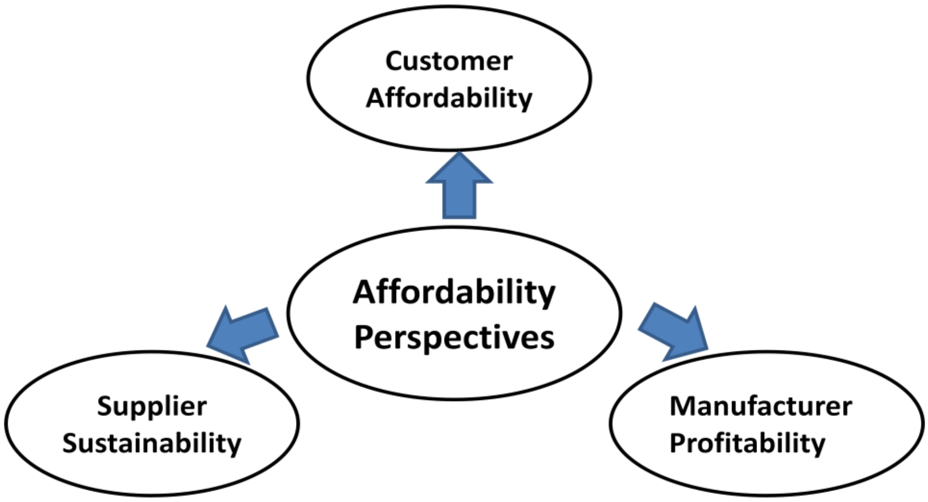


Figure 1-3: Affordability Perspectives

1.4.1 Customer affordability

Customer affordability is to the customer's ability to pay for the product or service provided by the prime contractor. Usually, this is affected by the customer's perception of value and the worth of the product offering.

1.4.2 Manufacturer profitability

Manufacturer profitability has been defined as the characteristic of the aircraft component and manufacturing systems and processes required to be procured when it is needed and supported so it remains available as needed and operated at the level of performance and quality desired within the budget allocated to systems that are being procured (Ray, 2006).

This means the manufacturer will be able to generate a profitable level of revenue by ensuring the availability of the systems or processes or PSS. The goal of every business is to make profit; hence from the manufacturer's point of view, affordability is concerned with the ability to generate continuous revenue with guaranteed profitability over the life cycle of a project.

1.4.3 Supplier sustainability

While supplier performance measurement is concerned with assessing the current performance of suppliers, supplier sustainability is concerned with the long-term performance of a supplier especially in terms of financial and operational capability. *Supplier affordability* refers to the supplier's ability to effectively utilise its resources to provide products and services (functionality) designed to offer the best-value (solutions) to the customer. It employs a strategy of aligning the supplier objective with customer requirement so the PSS remains available as needed and operated at the level of performance and quality required to meet the customer's need. Therefore, the supplier ensures that highly synthesised products can fulfil customer requirements in three ways, namely, performance, cost and effectiveness through schedule availability (Ray et al., 2006). Each of these perspectives is further expanded in subsequent chapters along with other related concepts to affordability such as uncertainty and budget setting.

1.5 Research motivation

The affordability challenge of defence contracts necessitates the need to examine the financial ability of the customer to afford to pay the cost of the contracts. Availability contracts currently exist while the sector aims to progress to contracting for capability. The objective of the affordability assessment research requires capturing existing knowledge from academic research and industry practice in order to develop a methodology to demonstrate the proposed framework for the defence sector. Another important activity would be the validation of framework by collaborating with the industrial partners to obtain case studies. The motivation for the research was generated from the problem statement.

This research aim is to develop an affordability assessment and management framework at the bidding stage for defence contracts from each of the three perspectives mentioned in section 1.4 above.

The research aim, objectives and methodology are fully explained in Chapter 3. The rigour and focus of the research lies within the defence sector and the output would be most applicable to the defence sector.

1.6 Wider Research Activity

This research sits within an overall project entitled PSS-Cost which was funded by Cranfield Innovation Manufacturing Research Centre (IMRC). The bigger project aims to improve WLCC and affordability assessment for defence contracts. It includes four PhD researchers focussing on specific areas such as the cost of design, uncertainty modelling, obsolescence modelling and affordability assessment of defence contracts. This research is undertaken with the support of nine industrial collaborators within the aerospace and defence industries namely: BAE Systems, MoD, Lockheed Martin, GE Aviation, Rolls-Royce, Galorath, Cognition, APMP and SBAC. Within the initial project plan, the first three partners are expected to provide case studies for the project while the MoD and Rolls-Royce are expected to help with the validation of the software prototype.

1.7 Structure of the Thesis

In order to report the research activities undertaken to deliver the objective of the research, a structure is developed for the thesis. The thesis structure is outlined in the steps provided in Figure (1-4).

- Chapter One: Introduction - This gave an overview of the research and introduced the main themes: defence contracting, affordability etc. It also described the affordability challenge by providing a problem statement and research motivation including the structure of the whole thesis.
- Chapter Two: Literature Review – This would review the concept of affordability from the three perspectives. It would provide a state-of-the-art review of affordability across different sectors with main focus on the defence sector. It would contain thorough review of other themes introduced in chapter one such as PSS, defence contracting,

budget setting, customer value, lifecycle costing, uncertainty etc. in order to the identify research gap.

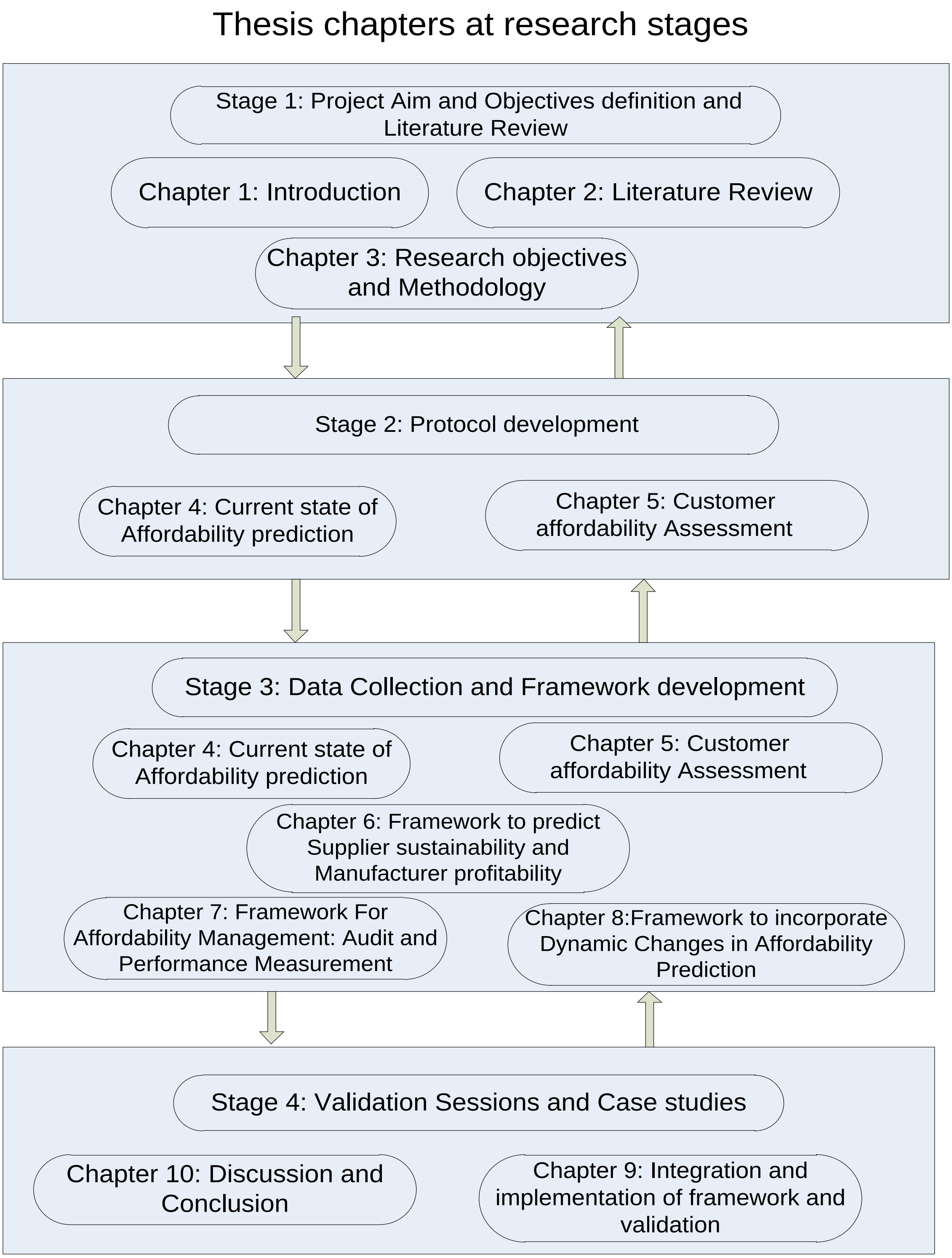


Figure 1-4: Layout of Thesis chapters

- Chapter Three: Research objectives and Methodology – This would outline the aim, objectives, methodology and scope of the research. It would also describe the process of carrying out the research and framework development in order to achieve the project aim and its objectives in addition to the case study approach adopted in the research.
- Chapter Four: Current state of Affordability prediction in industry – This would provide the findings obtained from industrial practice of affordability assessment from the three perspectives in the customer and manufacturer firms. This would enable a comparison of industrial practice and academia to identify existing gap to provide direction for the research activity.
- Chapter Five: Framework for customer affordability assessment – This would describe the first perspective of affordability which is the customer affordability. By identifying the factors affecting affordability and metrics for measurement. A customer affordability framework would be proposed which includes guidelines for improving customer affordability.
- Chapter Six: Framework and methodology for manufacturer profitability and supplier sustainability assessments - This would describe the other perspectives within the affordability framework namely, the manufacturer profitability and supplier sustainability. It would provide the qualitative and quantitative factors and dimensions involved in assessing manufacturer profitability and supplier sustainability together with the guidelines for improving supplier sustainability.
- Chapter Seven: Overall affordability audit and overall affordability management - This would explain the overall affordability audit and overall affordability management which are part of the entire affordability framework. The overall affordability audit assessment is aimed at assessing information availability for performing an affordability assessment. The overall affordability management technique would also be explored in order to derive measures for managing overall affordability of the contract.
- Chapter Eight: Development of methodology to incorporate dynamic changes in affordability assessment due to uncertainty – This would present the approaches of assessing the impact of uncertainty on affordability assessment. Both approaches would combine parameters of time and range in the assessment.

- Chapter Nine: Validation of the Framework – This would describe the integration and validation of the concepts, logic and result of the affordability model together with case study validations from industrial collaborators within the defence industry.
- Chapter Ten: Discussion and Conclusion - This would contain discussions on the validity and limitation of the research. The advantages of the proposed framework would also be presented to conclude the research and highlight future research work and suggestions.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter provides a state-of-the-art review of affordability across different sectors with main focus on the defence sector in its provision of availability and capability contracts. Affordability is reviewed from three perspectives namely, customer affordability, manufacturer profitability and supplier sustainability. The chapter includes the review of related themes to the affordability of defence contracts such as life cycle costing, defence contracting, budget allocation, customer value, uncertainty and customer willingness to pay. The following structure was employed: section 2.2 provides a brief methodology for the review. Section 2.3 reviews affordability across different sectors together with sector classifications. Section 2.4 focuses on the customer affordability assessment and measures of assessment. Section 2.5 focuses on the manufacturer profitability assessment and pricing strategies. Section 2.6 reviews supplier sustainability in relation to supplier performance measures. Section 2.7 reviews lifecycle costing approaches while section 2.8 reviews the budget allocation practice. Section 2.9 explores the theme of customer value in long term contracts while section 2.10 presents theme of customer willingness to pay. Section 2.11 reviews the uncertainty associated with long term contracts like defence contracts while section 2.12 provides the research gap identified as a result of the review. This is applied in refining the research aim and objectives in Chapter 3. Finally section 2.13 summarises the whole chapter.

2.2 Methodology

The focus of this research is to develop measurement and improvement techniques for affordability from three different perspectives such as customer affordability, manufacturer profitability and supplier sustainability. In order to do this, it was important to capture the state-of-the-art research in affordability. In carrying out the review, content analysis research methods were employed in order to capture the state of research in affordability. Content analysis involves two steps; (i) define sources and procedures for the search of articles to be analysed and (ii) define categories which are instrumental to the classification of the collected articles (Marasco, 2007). Both published and unpublished literature was involved in the review. The research methodology adopted in this review is captured in a flow chart and presented in Figure (2-1) to reflect both literature review and industrial practice. However, only findings from literature review are presented in this chapter while that from industrial practice is presented in Chapter 4.

The process began with the identification of research themes around affordability. Then extensive literature search was carried out and the results included articles from 1983 to 2010. The literature search was conducted using databases such as Compendex, Inspec, and Emerald; using key words such as 'Affordability', 'Defence contract', 'Supplier Performance', 'Supplier Management' and 'Profitability' as the keywords. The search results were analysed and narrowed down to focus on the relevant materials.

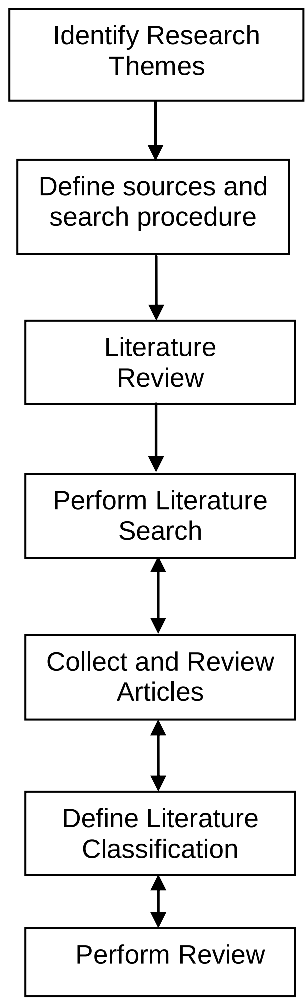


Figure 2-1: Research Methodology of State-of-the-Art Review

These materials were reviewed and classified based on their content. The findings from the literature review informed the development of the questionnaires for industrial interaction. The methodology for industrial interaction is fully described in Chapter 4.

2.3 Affordability across industries

Affordability is concerned with the ability of a customer (individual or business) to buy a product or a service (or a combination of both) at a particular time. The term may be used to indicate that something is inexpensive or reasonably priced. It is also expressed as the provision of products or services that are affordable to the customer given available income. While the word is commonly used, it is not viewed as a concept that could be a focal point. The focus of this research is affordability of defence contracts; hence affordability is treated as a concept which is to be explored in detail. In order to carefully consider the subject, first its definition is considered.

The main concept is similar across different industries; however its definition and measures differ in academia. According to the English dictionary, the word 'afford' means to be able to do, manage, or bear without serious consequence or adverse effect or to be able to meet the expense of something (dictionary.reference.com). Milne (2004) revealed the absence of affordability from economics literature and the fact that it is often considered in terms of financial sustainability in telecoms policy and regulation debates. Engineers view affordability in terms of adopting low-cost technology. Conversely, marketing literature (which divides customers into different groups based on their incomes) uses affordability as the measure to direct advertisement based on the customer group's ability to afford the product or service. In politics, candidates usually promise the provision of affordable services to citizens if they are elected into office, however, the UK government is currently taking measures to reduce the effect of unaffordable programs by making significant cuts in public spending including defence projects. The review revealed that while the word 'affordability' or 'affordable' appear in many articles; most of them do not explore affordability as a concept. This shows the weakness of some articles as they did not provide definitions for affordability. However the researcher was able to collate available definitions of affordability across different industries and the findings are presented in Table (2-1). The definitions which are mainly from 4 industries reveal that affordability is concerned with the comparison of cost or WLCC with income or investment or customer budget. The construction and utility sectors which focus on consumer goods compare the cost of providing housing or utility services to individual customers with the household income while taking account of all basic necessities.

Table 2-1: Affordability definitions

Sector	Affordability Definition
Construction	a 'measure of whether housing can be afforded by certain groups of households' (Semple, 2007)
	'is concerned with securing some given standard of housing (or different standards) at a price or rent which does not impose, in the eyes of some third party (usually government) an unreasonable burden on household incomes' (Maclennan and Williams, 1990, cited in Hancock, 1993)
Utility	'the share of monthly household income spent on utility services such as water, heating and electricity' or the ability of particular consumer group to pay for a minimum level of a certain service' (Fakhauser and Tepic, 2007)
	'the ability of customers to pay for utility service billed to them' (Smyth, 2005)
	the amount of monthly household income that is used up by utility services, like electricity, district heating and water and the extent to which a household's income can cover the purchase price of a home and the cost of transportation (Centre for Transit-Oriented Development and Centre for Neighbourhood Technology, 2006)
Software	the ability to 'bear the cost of something' (Bever and Collofello, 2002)
Defence and Aerospace	'degree to which the WLCC of an individual project or program is in consonance with the long range investment capability and evolving customer requirement' (Network of Excellence in Affordability Engineering, Cranfield University (Ray et al, 2006))
	the ability to procure a system as the need arises, within a budget, operate at a required performance level; maintain and support it within an allocated life-cycle budget (Kroshl and Pandolfini, 2000)
	'the degree to which the life cycle cost of an acquisition programme is in consonance with the long-range investment and force structure plans of national defence administrations' (North Atlantic Treaty Organisation (NATO), 2007)

These sectors also consider customers in different groups based on their income similar to the marketing literature. The software and aerospace (defence) sectors consider affordability in terms of the WLCC of projects against the investment required which is provided through the customer budget. Definitions from these sectors which are focussed on business customers take account of all costs involved in the delivery of software, aerospace and defence projects such as cost of design, manufacture, risk, obsolescence, etc. Ray et al. (2006)'s definition of customer affordability developed by Network of Excellence in Affordability Engineering, Cranfield University, is in agreement with that of NATO, 2007 developed by the US Department of Defence since both are focussed on the defence industry. Overall, these definitions have two elements namely: the cost of investment and the customer's income or budget. All definitions take account of time, which is monthly for individual consumers and yearly for business customers. This is due to the nature of the agreement for service provision between both parties. Service provision for individual customers such as utility services, telephone etc is chargeable monthly and the life cycle of these services are generally shorter in comparison with those for business customers. On the other hand, service provision for business customers such as availability and capability contracting is usually contracted for longer duration as stated in Chapter 1. This shows the dynamic nature of affordability as it changes overtime.

Sometimes during the lifecycle of the project, a project may become unaffordable. This means the customer cannot afford to procure or sustain the project. Generally, un-affordability can be caused by a number of factors across the phases of the CADMID cycle such as performance requirement, design flaws, time, additional cost, or reduced customer budget due to government cuts. This is the reason why a project must be managed and controlled to ensure its affordability throughout the life cycle.

Within academia and industrial practice, techniques such as earned value management (EVM), value management methodology and some parametric costing techniques are utilised to assess the performance of a defence project by measuring the value created through the use of resources. Other techniques are commercially developed by vendors to manage complex programs, but insight into the development of these is usually protected to retain the know-how within the organisations such as value measurement methodology, as well as Parametric costing techniques (DeMarco, 2005; Reagan, 2004; Young and Reagan, 2004; Reagan, 2005). This technique of programme affordability management is only available commercially and available articles do not provide in-depth information about the content of the model.

In order to further understand the concept, three perspectives were also reviewed and presented below.

2.4 Customer affordability

Redman and Stratton (2001) defined *customer affordability* as the characteristic of a product or service or project that makes it possible for the consumer to:

- Procure it when it is needed
- Use it to meet their performance requirements at a level of quality that is desired
- Use it whenever it is needed over the expected life cycle of the product or service

- Procure it for a reasonable cost that falls within the customer's budget for product or service.

This definition implies that business customers are concerned about the availability of the product or service, its capability to provide the required functionality and cost effectiveness for an expected life cycle. Hence, (business and individual) customer affordability focuses on the customer's ability to pay for the product or service provided by the service provider (prime contractor). Usually, this is affected by the customer's perception of value and the worth of the product offering (see section 2.8). In literature, 'customer affordability' is often referred to as 'affordability'. This explains why most of the articles reviewed were focussed on affordability because the subject is usually explored from the customer's perspective. This means that *customer affordability is a major perspective of affordability* and all the explanation and review in section 2.2 refers to customer affordability. A comprehensive review and classification of articles was done based on the industry and the author's viewpoint expressed within the papers. These are explained in the next sections.

2.4.1 Sector classification

The results were first classified according to sectors surveyed by the authors in each of the papers. Eight sectors were identified namely: Aerospace (Defence and civil), Construction, Energy, Water, Financial, Telephone and Shipping. Figure (2-2) shows that the issue of availability is appreciated across different sectors covering both business and individual customers. However, most of the materials reviewed were within the aerospace sector (based on the availability of the literature articles). A general search using 'affordability' yielded more results within the construction sector; nevertheless, not all results are suitable for the purpose of this review. This means that many articles contain the word 'affordability', but few of them are focussed on investigating affordability as a concept. Affordability is a new research concept within the aerospace sector and is in the process of establishing measurement techniques and improvement guidelines which are approved by both industry and academia. It is also evolving within other sectors as explained below.

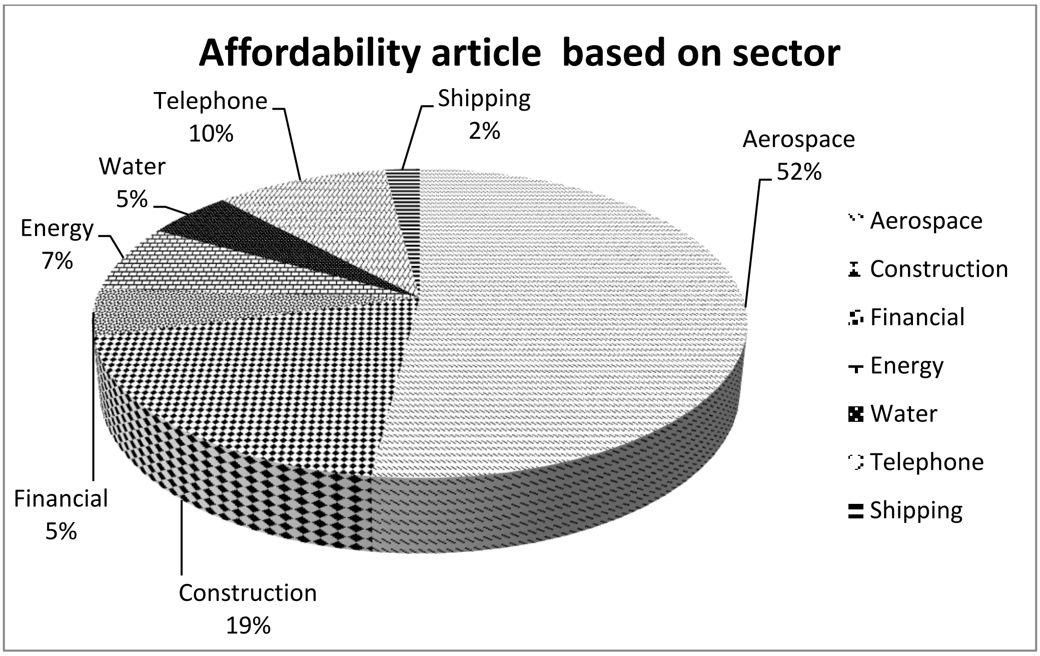


Figure 2-2: Classification of affordability articles based on sector

Aerospace Sector (Civil and Defence)

Two major factors affecting affordability within the civil and defence sectors from the three perspectives are WLCC and customer budget or Customer Available to Spend (CATS). Apart from these two major factors which are quantitative, Nogal (2006) identified other qualitative factors affecting customer affordability, as shown in Table (2-2) within the civil aerospace sector which were economic criteria, impact of regulations, technology innovation, level of performance, supplier value chain, impact of requirement change, global competition, environmental and ecological factors, potential for reuse and project management. These factors are fully explained below.

(i) WLCC – refers to cost incurred in the project from cradle to grave. It ideally offers a final statement reflecting the cost involved within project from the conceptual to disposal stage. This covers the costs of research and development, designing, manufacturing and production maintenance and service and disposal.

(ii) CATS – refers to the amount of money that the customer is willing to pay for the product or service. This is not necessarily a fixed amount of money, for example in a contract that is incentivised CATS may increase due to customer satisfaction.

(iii) Economic criteria – refers to the future value of money as well as market forces and product demand which could affect the contract. Other economic criteria could include cost of borrowing, escalation in labour and material prices.

(iv) Impact of regulations – The change of regulations may occur unexpectedly which may cause major changes in a project. There are different types of regulations namely, safety regulations, quality regulations, social regulations, etc.

(v) Technology Innovation – The acquisition of new technology and implementation throughout the life cycle of the project could affect the cost of servicing the contract e.g. spares, repairs and maintenance involving listed items.

(vi) Level of Performance – On complex projects, performance is the key measure which will affect the cost of providing the service influenced.

(vii) Supplier Value Chain – The supplier value chain depends on quality, price, time to supply, etc.

(viii) Impact of Requirement Change – The change in customer requirements usually leads to cost increase due to the effort required for the supplier in redesigning the system. However, this may be managed through contract renegotiation.

(ix) Global Competition – The rules of competition drive the cost down, hence the presence of competitors could force suppliers to reduce the cost of the service when prices go down.

(x) Environmental and Ecological Factors – The environmental and ecological factors introduce a new dimension for assessing affordability as these factors are becoming more important. National and global concerns for the environment have brought companies under a greater obligation to ensure that they adhere to environmental standards even if it means increased costs.

(xi) Potential for Reuse – Potential for reuse is the feature of a product to be configured in different versions.

(xii) Project Management – Both customer and supplier need good project management skills to achieve cost, schedule, quality and thus the benefits offered.

Each of these factors would affect customer affordability to varying degrees, hence it was important to determine the impact of each factor on customer affordability. Industrial experts and academics were consulted and the outcome of the exercise led to the weighting provided in Table (2-2).

These factors together with the weighting were employed in developing a measure for assessing customer affordability called the Affordability Index (AI).

Table 2-2: Qualitative customer affordability factors and weights (Nogal, 2006)

Acronyms	Customer Affordability Factors	Weight (%)
EC	Economic Criteria	10
IR	Impact of Regulations	6
TI	Technology innovation	11
LP	Level of Performance	11
SVC	Supplier value chain	9
IRC	Impact of Requirement Change	12
GC	Global competition	12
EEF	Environmental and Ecological Factors	8
PR	Potential for Reuse	9
PM	Project Management	12
	Total	**100**

Previous research within the defence sector (Sticker, 2002) provided an AI to measure customer affordability of aircraft systems which is provided in equation (2.1).

$$\boldsymbol{AI = \frac{Capability}{Cost}} \qquad (2.1)$$

Since the focus of the author was on defence aircrafts, affordability was measured in terms of the capability of the aircraft to meet customer requirement. However, this measure of affordability is not comprehensive as it does not take account of many other factors affecting customer affordability like those mentioned above in Table (2-2) as well as focussing on the product level, rather than project level. Nogal, (2006) improved this measure of customer affordability by considering other factors affecting affordability and weighting them based on how they impact customer affordability within the aerospace sector. The AI for the civil aerospace sector developed by Nogal, 2006 is provided in equation (2.2). This combined both qualitative and quantitative customer affordability factors mentioned earlier together with the weights and scores. However, this approach is weak because it combines both factors which have different characteristics.

$$AI = \frac{CATS}{WLCC}\left(1-\left(\sum_{i=1}^{n}\frac{(C_{i}{}_{-}S_i)}{S_i}\right)*\frac{1}{n}\right) * \frac{EC.10+IR.6+TI.11+LP.11+SVC.9+IRC.12+GC.12+EEF.8+PR.8+PM.12}{50*100} \quad (2.2)$$

Where:

i = the years where cost exceeds the expected spending ability of the customer,

Si = Expected spending ability of the customer for the ith year,

Ci = Cost incurred in the ith year,

n = total number of years the WLCC has exceeded the Total Customer Budget.

A user defined rate of 50 was selected since 50 is a half of 100 to find an average of the weights

The result of the AI is interpreted thus:

If, AI >1, project is more affordable

AI =1 is affordable

AI <1 is less affordable

The result generated would be inaccurate and cannot be interpreted within context of the qualitative factors. This means more research is required to ensure that the qualitative factors are properly employed in assessing customer affordability. This is further explored in Chapter 5. Kroshl and Pandolfini (2000) used financial metrics as the measure of effectiveness for affordability such as Net Present Value (NPV). These metrics employed in measuring customer affordability are represented thus:

$$\text{NPV} = \sum_{t=0}^{n} \text{F}_\text{t}(1+i)^{-t} \quad (2.3)$$

Where t = time period in years, n = number of years, F_t = net cash flow in year t, and i= interest rate per period.

The NPV approach is not relevant for customer affordability assessment because the current assessment with the AI is focussed on the violations between WLCC and CATS on yearly basis (impact of time); therefore, it may not be valuable to focus on the time value of money, meaning an NPV study is not required for the assessment. However, it could be applied by the manufacturer to assess the profitability of defence contracts. The Systems Analysis and Concepts Directorate at National Aeronautics and Space Administration (NASA) Langley Research Centre described a similar concept to affordability which is maintainability. It is 'an attribute of a vehicle design that is based on the ease of refurbishing, integrating, servicing and repairing a vehicle'. It is measured in terms of resources such as supplies, manpower, time and cost (Chytka et al., 2006). The authors also developed spreadsheet-based affordability models which take account of variations in time phasing of money, inflation rates, learning curves and batch buy strategies. The model provides a representation of cost against budget and its output is called the 'Sand chart'. The authors also established a link between affordability and maintainability because maintainability encourages higher development cost at the start in order to lower operation cost over the life cycle. While higher development cost at the early stage could have a negative effect on the affordability of the system at the early stage; running costs across the lifecycle would be more affordable. However, details of the measurement metric used in assessing affordability were not provided in the paper. Also the process of assessment was not described.

Emmons et al. (2010) described the affordability sand chart, which has two modes. The tool planning mode employs a process which automates budget adjustments and re-planning for multiple parallel and sequential projects, which may have coupled schedules. The evaluation mode is similar to a commercial cost-risk integration tool e.g. crystal ball. However the sand chart tool differs because it is not a mathematical simulation of statistics, rather it models the actual project cost and schedule performance, including ramp rate limits (e.g. hiring rates), limited look-ahead, and schedule analysis features (e.g. linking initial capability dates for parallel projects). Through project linkages, it realises functional correlation between projects and a fixed budget under which all content must fit. Based on historical experience from past projects, it predicts cost growth to produce total cost while providing a "reserves wedge" in order to allow the portfolio to be re-planned at different levels of confidence. When projects exceed the target cost, it applies a series of "penalties" to the projects in order to reduce their expenditures in that particular year. The tool offers a comprehensive assessment based on cost and budget, but it does not consider qualitative factors which may cause the cost over-runs. It requires robust information availability from past projects which could require more rigour and effort in obtaining detailed data. Also, the weakness of the tool is that it would not be usable without detailed data. It mainly focuses on quantitative factors of affordability without focusing on the qualitative factors.

Construction Sector

Mutchler and Krivo (1989) identified the following factors with individual consumers within the construction sector (housing).

- Reduction in Government funding
- Factors affecting household patterns such as divorce, adult children returning to parental homes, aging parents moving in with adult children.

Interestingly, while these factors affect affordability of housing, the affordability of housing also impacts the formation of new households. For example, if a young adult cannot find affordable and adequate housing, this might cause them to return to live with their parents. This means that certain factors that affect affordability can also be affected by affordability. Kim and Renaud (2009) also stated that other factors that affect affordability (positively) are lower interest rates, improved mortgage terms and increased availability of mortgage finance.

Tsolacos et al. (2005) identified other factors including the availability of space in the property and the mobility of the occupying firm among business customers (based on statistics from British Chamber of Commerce).

Sub-factors which affect the affordability of business customers include:

- Price competition (this could have a negative impact on company profitability and could impact company affordability)
- Customer willingness to pay (this could be affected by the NPV of profit)
- Profitability – this is important because 'a firm's investment is influenced by its balance sheet position. A weak balance sheet is usually linked with a weak financial position which would impact company's ability to undertake further investment.

These factors vary from the perspective of the customer. It also differs between a business customer and an individual consumer. Most authors have agreed that two key factors are common to all customers, which are customer income or company profitability and the cost or WLCC of the product or service.

The Centre for Transit-Oriented Development and Centre for Neighbourhood Technology (2006), described the limitation of the traditional definition of housing affordability as excluding the cost of transportation, which is very important in family budgets. Therefore a new housing affordability index which includes the average transportation cost was introduced. This is represented in equation (2.4).

$$\text{Housing affordability index} = \frac{\text{Housing Cost+Transportation Cost}}{\text{Income}} \quad (2.4)$$

In considering transport costs, three components are necessary namely, cost of ownership, cost of auto use and cost of transit use. They are dependent variables which are affected by nine other independent variables. The new AI was applied to households at different levels of area median income and the result was that affordability differed from one location to another and across different income levels. Milne (2000) explored the affordability of basic telephone service for both individual and business customers. The study which used a Gamma distribution to represent income levels of individual consumers resulted in an increase in the affordability of business customers and a decrease in individual consumers' affordability when rebalancing occurred (change in prices). This shows that it is essential to consider customers at lower income levels who could be vulnerable to price increase. This supports the view by Milne (2004) that affordability varies across income levels. The new housing affordability index provides an all-inclusive representation of affordability to provide better prediction model for affordability. It also clarified the importance of public investment in transportation and housing projects to support the low-middle income families. This measure of affordability is suitable for the construction sector, but would not be suitable for the defence sector.

Service Utility Sector (water, energy and telephone)

Al-Churaiz and Enshassi (2005) believed that two elements should be considered in measuring customer contributions (affordability), which are customer's ability (income) and Customer's Willingness To Pay (CWTP). This means that the CWTP plays a crucial role in the final customer affordability, not just the customer's financial ability. Customer ability is similar to Nogal (2006)'s CATS which was one of the major factors considered in measuring affordability. The idea is that the customer could be willing to pay a certain amount, but this is dependent on the customer's ability (CATS). CWTP is further explained later on in this chapter.

Within the health sector, there is an appreciation of affordability of medicines. Research conducted by Cameron et al. (2008) into the affordability and availability of medicine in 36 developing and middle-income countries revealed that affordability estimation was done mainly based on income (wages) and price.

A wider review of literature across different sectors helped to identify various affordability factors across several industries for two categories of customers (individual and business). This is represented in Figure (2-3).

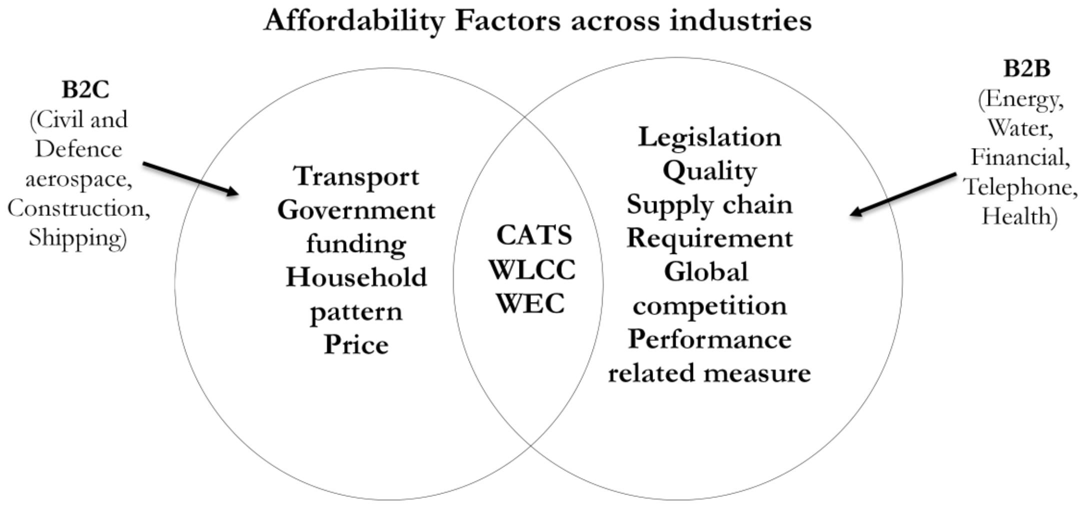


Figure 2-3: Affordability factors across different sectors for both categories of customers.

Based on the factors and measures identified above, it is clear that none of them is perfectly suitable to assess customer affordability in the defence sector. However, they provide an understanding of customer affordability assessment across different sectors and a starting point for deriving measures for the defence sector. Customer affordability is a familiar concept in industries such as construction and utility, but it is a new research area within the aerospace and defence industries. This is shown by the limited number of literature available on the topic, suggesting that little effort has been employed in overall state-of-the-art in customer affordability.

2.4.2 Authors' Viewpoint classification

The other type of classification is based on the focus of the authors. Certain authors wrote from a design perspective while others wrote purely from a financial or operational perspective. Also certain papers provided definitions of affordability while others did not. Selected papers presented the factors that were affecting affordability while others mainly provided measurement techniques for affordability. All these attributes were considered in classifying the papers. Finally, the papers were classified under five headings based on the research approach. These are: design, financial, operational, commercial and conceptual as shown in Figure (2-4). Figure (2-4) also shows that most of the papers were in the financial category, then the conceptual and design categories with the same number of papers in them, followed by commercial then operational.

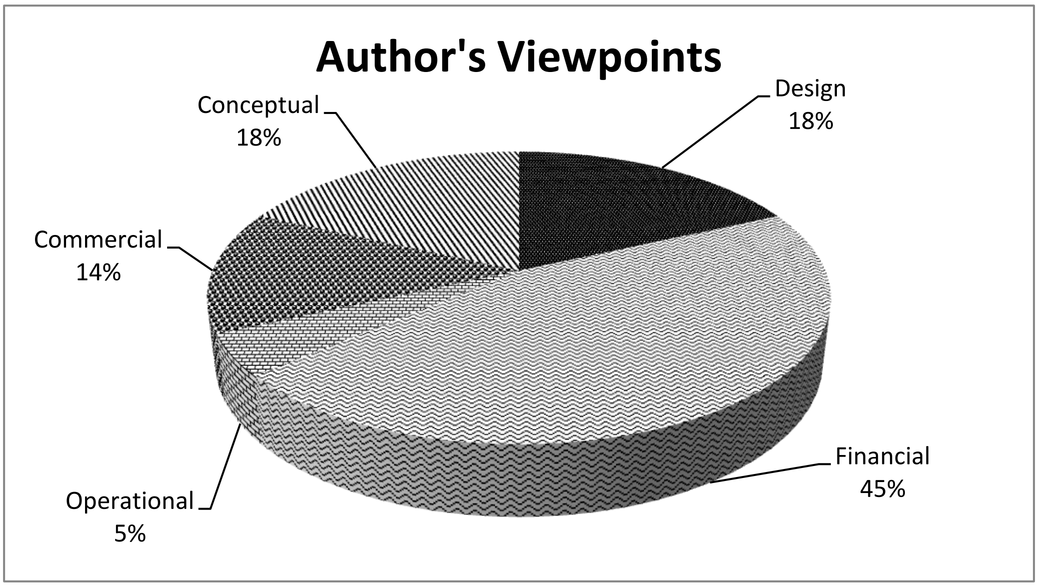


Figure 2-4: Classification of affordability articles based on Authors' viewpoints

Figure (2-5) was designed to reveal the content of the articles in each category.

a) *Design* – Papers classified in this category are written from the perspectives of designers considering affordability at the concept and design stages of product or system development. Authors stated that an integrated product and process development approach and open-system architecture are required to design affordable products/systems. The authors evaluated the effectiveness of new technologies such as robust design simulation (an experimental approach to design) as part of the roadmap to achieve affordability and stated that affordability can be achieved through the use of technology. Also authors within this category used examples to show that products can be made more affordable through the reduction of assembly cost as well as the cost of integrating and bonding different parts (Russell, 2007; Ray, 2006 and Rains, 1996). These materials made up 18% of the articles reviewed.

b) *Financial* – These papers are written from the perspectives of the financial impact of customer affordability. Authors provided definitions of affordability and identified factors affecting affordability within the industries mentioned earlier. Measurement techniques for affordability prediction were also proposed and validated using case studies. An affordability engineering framework and recommendations on how to improve affordability were also provided by authors within this category (Redman and Stratton, 2001; Kroshl and Pandolfini, 2000 and Semple, 2007). Some concepts were fully validated while others were yet to be validated. These made up 45% of the articles reviewed.

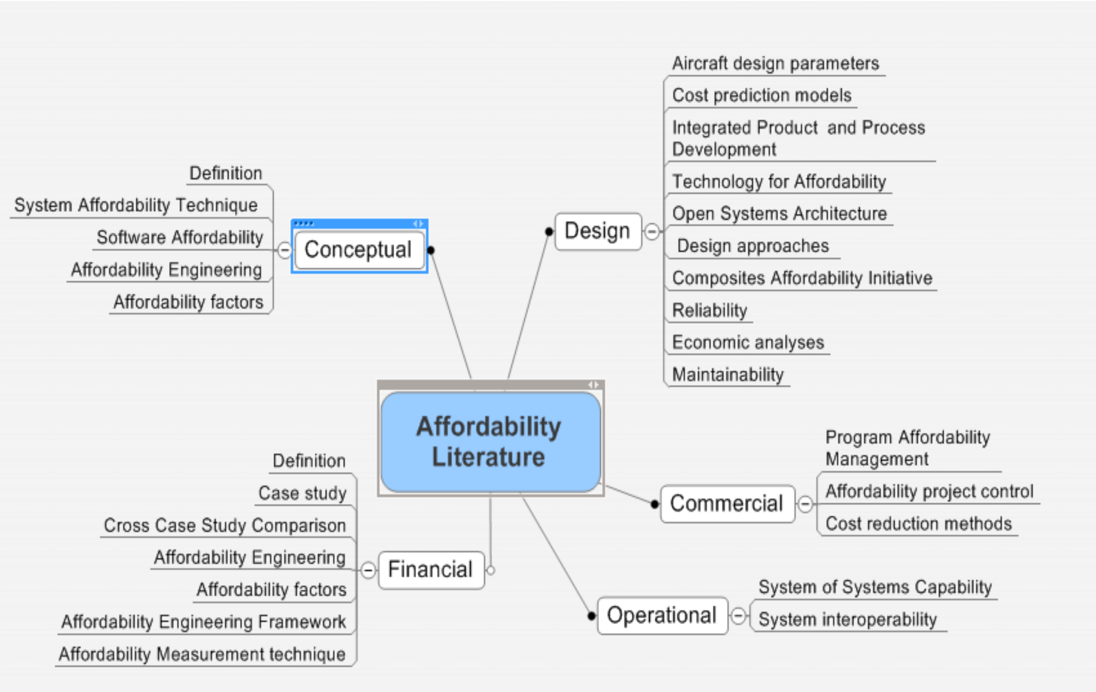


Figure 2-5: Main focus of the articles reviewed under the each classification

c) *Operational* – Papers in this category are written from an operational perspective. Authors highlight the cost issues associated with the delivery of system of systems solutions. They highlighted the importance of ensuring that different operational scenarios are taken into account in the development and delivery of systems and system of systems solutions. Guidelines for high-level analysis of system of systems costs are provided to aid decision-making in the purchase of systems which must be integrated to enable affordability through interoperability. (Minkiewicz, 2006 and Roark and Kiczuk, 1997). These articles make up 2% of the articles reviewed in this study.

d) *Commercial* – Papers under this classification are written by companies in program affordability management. Authors highlighted the affordability challenge of managing various defence programs across the life cycle and proposed metrics, tools and approaches to reduce cost at different stages of the life cycle and control long-term projects to ensure that they remain affordable (Reagan, 2005; Young and Reagan, 2004 and DeMarco, 2005). The metrics and tools were not available in public domain, rather they are owned by commercial firm who only supplied them to their customers. These articles made up 14% of the articles reviewed in this study.

e) *Conceptual* – Authors within this category proposed different concepts such as customer affordability factors and measurement metrics, without employing any case study, and they suggested measures to improve customer affordability which formed 18% of the materials reviewed for this study (Bradbery, 2005; Ray, Baguley and Roy 2006 and Baines T. et al., 2007).

The contents of the articles grouped under the conceptual and financial classifications are similar, but the difference is that the articles grouped under financial category contained case studies to validate the techniques developed. Additionally, some papers also contained cross case study comparison. A few of these articles were not available in the public domain. This is due to the novelty of the affordability research within the aerospace and defence sectors which means that some of the research had not been published prior to the time of this review. Also some articles containing sensitive information were restricted from public access. From the articles analysed and classified above, the factors affecting affordability were identified which are described in the next section.

2.5 Manufacturer profitability

2.5.1 Profitability

The second perspective of affordability is manufacturer affordability. Redman and Stratton (2001) defined manufacturer affordability as the 'characteristic of a product or service that':

- Makes it available when the customer initially needs it
- Enables it to meet customers' performance requirements at a level of quality they demand

- Makes it available whenever customers need it during its expected life cycle
- Allows customers to fit into their budget for product or service.

When a manufacturer's solution to the customer has the attributes mentioned above the customer is more willing to invest in the solution which usually guarantees continuous revenue for the manufacturer, leading to profitability. While this definition reflects that of customer affordability, the difference is that the manufacturer's focus is to fulfil customer requirement. Schrage (1999) stated that affordability 'is associated with the benefit-cost ratio' used in economic analysis when resources are constrained and relates the desired benefits to the capital investment required to produce those benefits. Manufacturer affordability focuses on the manufacturer's ability to employ its resources (skills, tools and resources) to develop an integrated solution to deliver best-value for the customer. Profitability, which is closely associated with growth, is important for a company to gain competitive advantage (Cho and Pucik, 2005). However, the nature of defence contracts often requires the expertise of more than one company to deliver the integrated offering which reveals the need for a suitable supply chain.

While profit is generally expressed as the difference between total revenue and total expenses (Wood, 1996), profitability encompasses more than just profit. Oke (2004) provided the traditional definition of profitability as:

$$\text{Profitability} = \frac{\text{Revenue}}{\text{Cost}} \tag{2.5}$$

The author argued that maintenance of products and systems yields returns to support overall profitability of the manufacturer; hence the maintenance function should be treated as a revenue activity, not just an activity which generates cost.

The definition above is similar to the *first part of the AI* explained in section 2.4.1 which shows customer affordability as a division of CATS by WLCC. This shows a similarity between the traditional measure of profitability and affordability, but profitability is concerned with revenue gained from sales based on the price which is usually cost plus profit. Customer affordability assesses the customer's ability to pay based on the budget, while the manufacturer is concerned about profitability. This means the manufacturer's affordability is about its profitability. The factors that affect manufacturer profitability are revenue or sales and price. Other measures of profitability in terms of solvency and efficiency ratios include (Wood, 1996):

$$\text{Gross Profit Margin} = \frac{\text{Gross Profit}}{\text{Sales Revenue}} * 100 \tag{2.6}$$

(Profit before indirect costs have been taken out as a percentage of sales)

$$\text{Net Profit Margin} = \frac{\text{Net Profit}}{\text{Sales Revenue}} * 100 \quad (2.7)$$

(Profit after all costs have been taken out as a percentage of sales)

$$\text{Return On Capital Employed (ROCE)} = \frac{\text{Earnings Before Interest \&} Tax}{\text{Total Assets} - \text{Current Liabilities}} \quad (2.8)$$

(Indication of the efficiency and profitability of a company's capital investments)

$$\text{Return On Investment (ROI)} = \frac{\text{Operating Income}}{\text{Investement}} \quad (2.9)$$

(Indication of the efficiency and profitability of a company's capital investments)

$$Return\ On\ Owner's\ Equity\ (ROOE) = \frac{\text{Net Income}}{\text{Owner's Equity}} \quad (2.10)$$

(Profit after taxes in relation to owner's equity)

Anderson and Mittal (2000) investigated the *satisfaction-profit chain* and stated that it contained links that are asymmetric and nonlinear which add value to the process. Smith (2006) stated that the gross profit margin is crucial in determining how a company can leverage its profit. In order to achieve this, two strategies namely, volume-based strategy (high-margin business) and price/bundling (low-margin business) strategy were applied to different markets. The result showed that the bundling strategy was successful as it was implemented using three different approaches such as platform bundling, customised bundling and convenience bundling which helped to improve a firm's profitability. Van Raaij (2005) described a valuable model to improve profitability called Customer Profitability Analysis (CPA). CPA starts with the process of discovering the active customers within a specified period of time, analyses the firm's operations to identify the cost drivers of the firm's activities, then it apportions costs (categorised into types) to each customers. This helps to determine which customers are most profitable and how to maximise profitability across all customers. The advantages of the model include the following:

- CPA provides unique 'insight into costs, revenues, risk and strategic positioning'
- It yields information about the vulnerability of future cash flows from customers
- Estimations of future revenues and future costs could be added to the CPA to help decision making about the future.

As mentioned above, manufacturer profitability is determined by the revenue generated from sales and the price charged to customers. Profitability assessment however, is carried out at the bidding stage when sales have been carried out and the first challenge is to arrive at a competitive selling price for the manufacturer. This means that the measures of profitability presented above are only suitable at the end of the business year rather than the bidding stage; hence, there is a need to look into existing methods of pricing.

2.5.2 Pricing

The Business dictionary defines pricing as a method of setting a selling price based on cost and perceived customer value given other competitive offerings (www.businessdictionary.com). Some of the pricing techniques are being employed in different companies are provided in Table (2-3).

Table 2-3: Pricing methods (Adapted from Kenessey et al., 2005).

Pricing method	Explanation
Direct use of prices of repeated services	The object of measurement is the real transaction. Mostly prices are taken from a list and are assumed to equal transaction prices. Contract pricing concerns surveying real transaction prices.
Unit value	This refers to company data that are not prices; they are figures of turnover and quantities sold. Unit value indices are used mostly to estimate a standardised model transaction or an output component (e.g. for telecommunication). Unit values of hourly charge out rates can be calculated, but these are more typically categorised as pricing based on working time.
Component pricing	Corresponds to most pricing methods that have only some output components of the underlying service as the object of measurement. In some cases, when an output component is being measured, the method is still classified as unit value or percentage fee method (company data that are not prices). This is because the meaning to the respondent of the data surveyed is in these cases more decisive for its assignment to a pricing method than the object of measurement.
Percentage fee	This refers to a peculiar kind of company data that are not prices.
Model pricing	This pertains to the object of measurement; the data used to estimate the price of a model can come in many forms.
Pricing based on working time	This is a separate, much debated, object of measurement which generally equates to the use of hourly charge-out rates for billable hours worked for a client. No matter which kind of data is used to estimate these hourly chargeout rates, they are classified in this separate category.

Kenessey et al. (2005) highlighted inadequacy of literature in the definition of pricing methods. In literature, a Service Producer Price Index which comprises a set of individual price indices that provide information on price change for a range of services provided by UK businesses was created from a statutory quarterly survey (Office for National Statistics, cited in Kenessey et al., 2005). However this may not be applicable to the defence industry. Other price indicators include the Retail Price Index and the Producer Price Index. Kenessey et al. (2005) believed that *transaction pricing* was the ideal pricing method because it is based on actual prices of individual transactions that are repeated in every survey period. The assumption about the wide application of this ideal pricing formed the basis of the development of Price index, though this is not always the case in practice. Overall transaction pricing is considered a benchmark for all pricing methods. On the other hand, pricing mechanisms involve the limiting condition in the choice of a pricing method. The differences between pricing mechanism and pricing method are clarified with examples in Table (2-4).

Table 2-4: Examples of the service nature, pricing mechanism and pricing method relationship (Adapted from Kenessey et al., 2005).

Name of Service	Nature of the service	Pricing mechanism	Pricing method
Car rental	Standard	Commercial price list, with occasional discount	Price list sample
Construction	Some product details determinable only during delivery	The exact final price is known only after product delivery	Prices of a fixed set of inputs (including profit) are combined
Legal services	Service is strictly tied to an asset	Percentage fee of the value of the asset that the service pertains to	Unit Value of hourly chare-out rates, dividing total income by worked hours
Passport	A national monopoly	Regulation: government specifies prices	Downloading documents stating obligated prices

Within the defence environment a combination of pricing mechanism and pricing method could be employed in different contracts and at different stages. Defence contracts comprise of standard services such as maintenance and support, services which are unique to assets (e.g. Defence Storage and Distribution Agency stockpile of munitions and complex weapons (MoD, 2010)) and some product details which may only be determined in the delivery phase. Pricing method would be mostly applied with a mix of commercial off-the-shelf tools; however, some costs would remain unknown until the equipment is delivered. The government regulation is applied in the profit allowed. In some contracts, the MoD could stipulate a given profit rate which the manufacturer is allowed. While the MoD may not be able to restrict the WLCC, it impacts the pricing by stipulating a profit rate. Generally, a defence project would combine a range of pricing methods, practices and mechanisms.

Within economics literature, pricing practices include the following:

1. The rule-of-thumb in mark-up pricing and profit maximisation is that marginal revenue is set at the same level as marginal cost (MR = MC) and the price must be at the same

level as marginal revenue (P=MR) in competitive markets. In markets where there is imperfect competition, price is higher than marginal revenue so profit maximisation requires marginal revenue to be same as marginal cost (MR=MC) (Hirschey, 2009).

2. The mark-up pricing is an efficient means for achieving the profit maximisation which builds up the price based on cost. Manufacturers and service providers also employ the strategy of price discrimination where they are able to segment the market and price elasticity of demand differs across submarkets. This is done at three degrees.
   - First degree: Involves charging different prices for each consumer which creates maximum profits for sellers
   - Second degree: This allows block-rates or quantity discounts
   - Third degree: This occurs when different prices are charged to different customers based on their age, income, location etc. (Hirschey, 2009).

Other pricing practices include multiple-product pricing, joint products pricing and transfer pricing.

Manufacturer profitability is usually considered after the financial year, however, the nature of long-term projects necessitates the need for profitability assessment prior to contract award in order to determine a competitive selling price. This form of assessment is closer to pricing and a range of techniques, methods and mechanisms would be employed in each case.

Within the aerospace and defence sectors, manufacturers view suppliers with whom they have long-term relationships as being less risky than those they have only dealt with in the short-term. This explains why the sustainability of suppliers is considered the third perspective of affordability.

2.6 Supplier sustainability

The delivery of a complete capability is not only down to the prime contractors, but also their supply network. The effective management of the supply chain can enable the prime contractor to gain competitive advantage and improve its profitability by aiding its success on the dimensions of cost, quality, response time, and flexibility (Presutti Jr. and Mawhinney, 2007). The authors stated that since supply chain integration and specific related measures of supply chain performance directly impacts the company's overall financial performance, overall business strategy and supply chain strategy must be aligned in order to be able to measure the impact of supply chain activities.

Supply Chain Management (SCM) has been described as the integration of Supply Chain (SC) activities through improved supply chain relationships to achieve a sustainable competitive advantage (Handfield and Nichols, 1999). The effective and efficient management of the SC is a major source of competitive advantage which enables a company to remain sustainable (Bojarski et al., 2009). For this reason, various initiatives and techniques have been developed in this area to improve SCM. Kim (2007) emphasised the need for firms to set up independent SCM departments in order to manage their supply chains more effectively while Supply Chain Risk Management (SCRM) was introduced to develop approaches for the purpose of identification, assessment, analysis and treatment of areas of vulnerability and risk in SCs. An application of SCRM is Dow Chemical Company's purchasing risk and mitigation methodology which helped to identify substitute products/suppliers to replace those suppliers with high risk (Trkman and McCormack, 2009). Also, business analytics approaches and procedures were introduced to be used in combination with other tools to gain information, analyse and predict outcomes of problem solutions. However, more effort could be expended in order to ensure the sustainability of suppliers as the diversity of industries (market forces) requires diversity of innovation to ensure sustainability since no universal solution is optimal for all firms (Trkman et al., 2010). Sustainability research generally focuses on economic, social and environmental dimensions. Environmental sustainability initiatives could lead to cost savings overall as seen in the case of Xerox's US$300m saving through reuse and remanufacturing (Hart, 1997 and Bojarski, 2009), however, financial and operational sustainability is crucial for suppliers to compete effectively in the long-term. This is underscored by some of the challenges faced by the UK defence SC which are reflected in the following quotes : "as a result of a combination of shortages of initial stockholdings and serious weaknesses in logistic systems, troops at the frontline did not receive sufficient supplies in a range of important equipment (House of Commons Public Accounts Committee)", "huge logistic effort was fundamental to the success of the operation, but improvements need to be made to ensure effective delivery of supplies to the frontline" (UK National Audit Office) (Tatham, 2005). These suggest there is need for a supply network with a degree of flexibility which enables it to be both efficient and effective to satisfy customer requirement in UK defence sector. This flexibility can only be guaranteed when suppliers are financially and operationally sustainable.

One model designed to improve economic sustainability of companies is the European Foundation for Quality Management (EFQM) excellence model. The EFQM *excellence model* is a framework for measuring the strengths and areas for improvement of an organisation based on its activities. The revised model is based on nine concepts, five of which are enablers while the other four are results. Enablers represent what an organisation is doing and how it does it while the results represent the outcome produced by the enablers. It encourages a feedback process where the feedback from the results can be used to improve the enablers (EFQM, 2010). The nine concepts are presented in Table (2-5). The explanation presented in Table (2-5) is based on the improved EFQM excellence framework. The framework was revised as a result of the feedback obtained from the members of the EFQM team which highlighted the need for the framework to recognise emerging trends in risk management, innovation and sustainability. The framework is comprehensive, focussing on various activities within an organisation. It is aimed at achieving sustainable economic excellence in organisations across various sectors.

However, as highlighted by Seuring and Muller (2008), there is a shortage of supply chain management and purchasing literature on financial and social issues affecting sustainability. The EFQM model is comprehensive, but supplier sustainability at the bidding stage requires a concise set of measures focusing on the financial and operational sustainability of defence suppliers. The manufacturer may not be able to employ the effort required by the EFQM model at the bidding stage to assess the sustainability of suppliers so it is important to focus on financial and operational sustainability measures.

Gunasekaran et al. (2001, 2004) identified three levels of hierarchy in the measurement of supplier performance namely; strategic (top-level), tactical (middle-level) and operational (low-level). These are explained in Table (2-5).

(a) Strategic Performance Metrics – this refers to measures which influence the top level management decisions and corporate objectives of suppliers. Examples include lead time against industry norm, quality level, cost safety initiatives and supplier pricing against market.

(b) Tactical Performance Metrics – This refers to measures related to resource allocation and a measure of performance against the strategic objectives. This is the middle level of decision making. Examples include the efficiency of purchase order cycle time, booking in procedures, cash flow, quality assurance methodology and capacity flexibility.

(c) Operational Performance Metrics – This refers to measure of performance of workers and supervisors of business operations in order to achieve the tactical objectives. This is the lowest level of management. Examples include day-to-day technical representation, ability to keep to schedule, ability to minimise complaints and achieve defect free deliveries (Gunasekaran et al., 2004).

Table 2-5: EFQM Criteria (Adapted from EFQM, 2010)

EFQM Criteria	Explanation
Leadership	Excellent organisations have leaders who shape the future and make it happen, acting as role models for its values and ethics and inspiring trust at all times. They are flexible, enabling the organisation to anticipate and react in a timely manner to ensure the ongoing success of the organisation.
People	Excellent organisations value their people and create a culture that allows the mutually beneficial achievement of organisational and personal goals. They develop the capabilities of their people and promote fairness and equality. They care for, communicate, reward and recognise, in a way that motivates people, builds commitment and enables them to use their skills and knowledge for the benefit of the organisation.
Strategy	Excellent organisations implement their mission and vision by developing a stakeholder focused strategy. Policies, plans, objectives and processes are developed and deployed to deliver the strategy.
Partnership and Resources	Excellent organisations plan and manage external partnerships, suppliers and internal resources in order to support strategy and policies and the effective operation of processes.
Process, products and services	Excellent organisations design, manage and improve processes to generate increasing value for customers and other stakeholders.
People results	Excellent organisations value their people and create a culture of empowerment for the balanced achievement of organisational and personal goals.
Customer results	Excellent organisations develop and agree a set of performance indicators and related outcomes to determine the successful deployment of their strategy and supporting policies, based on the needs and expectations of their customers.
Society results	Excellent organisations embed within their culture an ethical mindset, clear values and the highest standards of organisational behaviour, all of which enable them to strive for economic, social and ecological sustainability.
Key results	Excellent organisations meet their mission and progress towards their Vision through planning and achieving a balanced set of results that meet both the short and long term needs of their stakeholders and, where relevant, exceed them.

The outcome of the review resulted in the development of a framework to measure the performance of the suppliers based on literature review and the results of an empirical study of selected British companies. The metrics identified were grouped under four categories reflecting four supply chain activities or processes namely; plan, source, make/assemble and delivery. Similar measures were employed by the Supply Chain Council in assessing the performance of supply chain to develop the Supply Chain Operations Reference-model (SCOR) (SCC, 2009 and Ball and Bititci, 2006). Gunasekaran et al. (2004)

identified four supply chain activities/processes namely; plan, source, make/assemble and deliver/customer. The authors also provided metrics and measures to assess SC performance based on these activities. The activities/processes were expanded by the SC Council in the SCOR model. The model integrates the concepts of business process reengineering, benchmarking and process measurement into a cross-functional framework. SCOR spans all customer interactions, products (and services) transactions and market interactions from the supplier's supplier to the customer's customer. The model mainly contains three levels of process detail. The first level defines the scope and content of the model, the second level describes the characteristics of each process type while the third level provides detailed process element information for all the process categories (SCC, 2009).The model is presented in Figure (2-6).

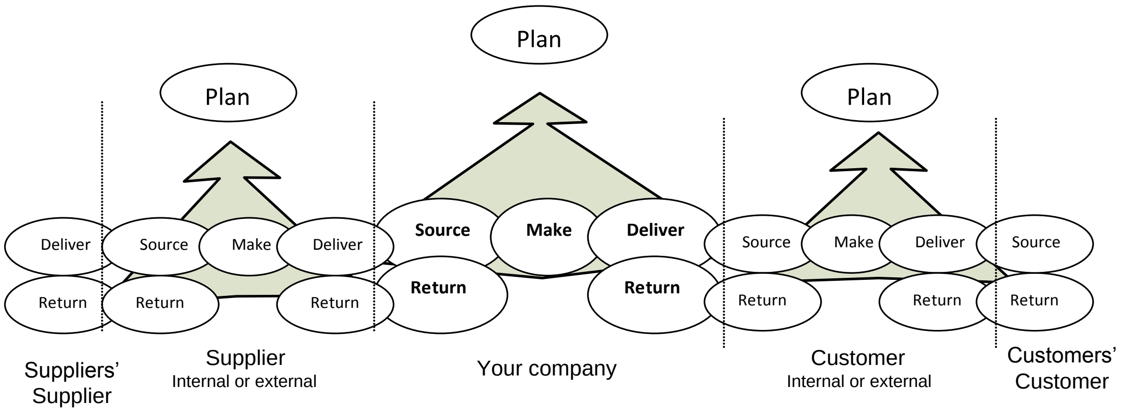


Figure 2-6: The SCOR Model (SCC, 2009)

Ball and Bititci (2006) demonstrated the effectiveness of the model in 8 small medium enterprises using the level 1 process, the SCOR Thread diagram to diagnose problems within their supply chain management. This led to the achievement of SC savings of £4m over a 12 month period. Presutti Jr. and Mawhinney (2007) stated that the limitation of the SCOR model is that it does not make the connection between supply chain management and overall financial performance. Therefore a tool incorporating Economic Value Added (EVA) and the SCOR model was proposed. EVA requires a company to provide a robust definition of its SC including the activities like purchasing, inventory management as well as product design and other upstream activities affecting EVA's revenue element. EVA has three components namely revenue, cost and assets which are related to some performance metrics within the level 1 of the SCOR model. The EVA helps to align operational goals and strategies with a measure of organisational performance that reflects the impact on shareholder value. Lee (2004) stated that in order for supply chains to provide their customers with sustainable competitive advantage, they need to be agile, adaptable and aligned. Whilst it is essential to be efficient, it is equally important to possess:

- agility – ability respond to short-term changes in demand or supply quickly and handle external disruptions smoothly
- adaptability – adjust to meet structural shifts in markets and modify supply network to strategies, products and technologies
- alignment – create incentives for better performance (Lee, 2004).

These could help to foster strategic partnership between supplier and customer which could be instrumental to supplier sustainability and performance.

A review of literature on sustainability revealed that many authors focus on environmental sustainability under three dimensions of sustainability namely social, economic and environmental (Labuschagne et al., 2003). However, within this project the focus is specifically on those dimensions of performance which would affect the supplier's ability to maintain full capability over the life cycle of the project. This creates the research gap to determine appropriate measures for assessing sustainability at the bidding stage of defence contracts. This is further explained in Chapter 6.

In summary, to deliver an availability contract, the customer must be able to afford to procure it given the budget constraint, manufacturer should be able to recover the investment through the best profit margin (Schrage and Mavris, 1994) and thirdly, the supplier should possess the capability to deliver and sustain it over the life cycle. The next sections focus on other concepts which are related to affordability.

2.7 Life cycle costing (LCC)

LCC has been introduced in Chapter 1 (section 1.3) as an approach which takes account of the costs incurred in all stages of the lifecycle of a product, service or project to develop the WLCC. This combines many costing approaches such as design-to-cost, design-for-cost and target costing etc. Another approach similar to target costing is Kaizen costing. However, cost reduction can be achieved at the manufacturing stage by employing value engineering without compromising the quality and functionality of components.

Despite the success of the methods stated above, there is a view that designers still need methodologies that directly provide cost information to them. Each stage of the product life cycle would generate costs to make up the total LCC. Whole Life Cycle Costing or Through Life Cycle Costing (TLCC) includes various costs such as design cost, manufacturing costs, obsolescence costs, maintenance costs, service costs and provision for uncertainty in long-term projects (Romero Rojo et al., 2009 and Erkoyuncu et al., 2009). It is the process of managing all costs along the value chain by providing information concerning product's design, development, manufacturing, marketing, distributing, maintenance, service and disposal stages (Atkinson et al., 2001).

Cost Engineering is defined by the Association for the Advancement of Cost Engineering (AACE) 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" (Hollmann, 2006). This means that LCC is a part of cost engineering and it is important to perform other activities such as project management, planning and control for successful delivery of the contract. EVM is another techniques applied in industry in which is 'an integrated management control system for assessing, understanding and quantifying what a contractor or field activity is achieving with program dollars' (NASA, 2010). It relates resource planning and usage to schedules and technical performance requirement (Kim et al., 2003) by assessing the performance of the project given the resources consumed. EVM is a multidimensional technique which integrates technical, cost, schedule, with risk management to aid future prediction (Kim et al., 2003 and NASA, 2010). Unlike the other costing approaches, it is carried out during the life cycle rather than the concept stage of the project to compare the performance of the project against the estimate and assess the value earned in the process, thereby providing project managers with a more accurate status of a project and areas for improvement.

Cost estimating models used in industry are mainly in three categories namely: parametric models, analogous models (estimating by analogy) and detailed models.

Parametric estimating is described as the generation and application of equations which describes relationships between cost schedules and measurable attributes of a system that must be created, sustained and retired (Dean, 1995). Parametric costing could be applied in predicting the total LCC of a product or costs at different stages including bidding stage by employing regression analysis based on historical cost and technical information.

Analogous models are applied by identifying a similar product or component and adjusting its costs to find the differences between it and the target product (Shields and Young, 1991). In order to benefit from this type of cost modelling, the products must share certain characteristics or components and the cost estimator must be able to accurately estimate the differences between the two products or equipment.

Detailed modelling is carried out in bottom-up estimating by estimating labour time and rates and material quantities and prices to estimate the direct costs of a product or activity (Shields and Young, 1991). Indirect and overhead costs are apportioned using an allocation rate. This type of modelling is the most time consuming and it requires detailed knowledge of the product and processes. It could also be the most accurate approach (Datta and Roy, 2009). All three techniques can be applied at different stages of the project lifecycle.

Other application of LCC in accounting literature are cost-plus, activity based costing and environmental costing.

Cost-plus is a method where the selling price is determined by adding an expected product cost to an agreed profit margin to arrive at the selling price (Atkinson et al., 2001).

Activity Based Costing (ABC) is a costing approach which classifies costs of various activities into a cost hierarchy: output-unit level, batch level, product sustaining and facility sustaining (Bhimani et al., 2008). It traces indirect and support costs and apportions them to products services and customers based on the level of consumption. Unlike the traditional costing method which uses cost centres in distributing costs, ABC apportions costs based on cost activities. It is currently gaining grounds on traditional cost accounting approaches as it has proved to be a better approach.

Environmental costing involves a cost management system which includes the cost of environmental impact of products and processes such as the cost of disposal of products. This would be increasingly important with the recent emphasis on climate change and the need for companies to employ environmentally friendly processes.

Given the nature of defence contracts where the customer faces budget constraints and the manufacturer or contractor profit level is usually set. Design-for-cost, design-to-cost, target costing and cost-plus methods are usually applicable with the EVM technique. Similarly, other costing approaches could also be applied where applicable. However, it is important to note that wrong estimates would lead to higher actual costs which could double the estimate. This would have a negative effect on the affordability of a product or project. Furthermore, overestimation of cost could be detrimental leading to loss of contract, given the budget of the customer. After the estimate is done, a contract can only be awarded if it is in alignment with the customer budget. Therefore, the process of budget allocation is examined in Section 2.8.

2.8 Budget Allocation

The customer budget also referred to as CATS (Section 2.4.1) is the output of a budget allocation process. Much research has been done to investigate the process of WLCC estimation and there are established tools, techniques and processes. Since the other major factor affecting affordability is CATS, it is important to also consider the process of setting or allocating the customer's budget in order to identify possible challenges and ways of improving the process to arrive at a more realistic budget.

Accounting literature defines a budget as a quantitative expression of the money inflows and outflows that predicts the consequences of current operating decisions and reveals whether a financial plan will meet organisational objectives (Atkinson et al,. 2001). It is the quantitative expression reflecting the plan and strategy of an organisation and provides feedback to managers about the impact of their strategic aims (Bhimani et al., 2008). It is also an aid to the coordination and implementation of the plan which may include both financial and non-financial elements to provide direction for the company operations (Bhimani et al., 2008).

Budget planning is done at different levels by individuals, families, departments, top management and nations. It is done in order to plan, manage and control finances in order to avoid unexpected debt or financial difficulties. The budget planning process is usually carried out by identifying a company's objectives and short-term goals, developing long-term strategy and short term plans before developing the master budget (Atkinson et al., 2001). Operating budget forecasts revenues and expenses for the next period while the financial budget identifies the expected financial consequences of the activities from the operating budget. The Budget planning process could be iterative to reflect changes in operation requirements and ensure that the budget is realistic (Atkinson et al., 2001). The budget is usually set by the top management; therefore there is a need to communicate the budget which reflects the strategic plan of the organisation to employees at other levels.

This would ensure that the tactical and operational activities are aligned to the strategic objectives.

An important aspect of budget planning is the control of the budget to ensure that the plan is actualised and to employ corrective measures if the project is slipping away from the initial plan in order to minimise the variance between the actual costs and budgeted costs. It is important that budget control is not carried out in a rigid way so that it does not have adverse effect on employees. This means if top management is unwilling to accept the fact that actual operations may cost more than budget allocated to them, this may cause managers and employees at lower levels within the organisation to take any step (including unfavourable ones) to carry out operations within the budget allocated. While this might be sustainable in the short term, it has terrible consequences in the long-term (Bhimani et al., 2008). An example of this is seen in the defence sector where the defence budget is set by the Treasury and allocated by the top management within the MoD. When the budget allocated is insufficient to cover the cost of the project, project managers may underestimate the project cost in order to get approval from top management. In the long-term the actual cost of the project increases far above the budget, requiring additional investment for the rest of the project life cycle. When many defence projects suffer from this practice, then the whole defence budget become unaffordable as presently seen in the UK defence sector. However, other factors have contributed to current state of the defence budget, which are explained in Chapter 4 of the Thesis.

Budget planning within the private sector is different from the practice in public sector and government organisations such as the MoD. Within the private sector there is a relationship between income and expenditure and the challenge is to ensure that there is regular income to offset the expenditure and in order to make a profit, overall income must exceed total expenditure. Within the public sector, there is usually no direct income as the government allocates the national budget by prioritising. The budget is then allocated to different organisations that run their operations based on the budget available to meet strategic goals and ensure there is no deficit.

One factor which can impact customer affordability is the value perceived by the customer. This is explained in the next section.

2.9 Customer Value

A major qualitative factor which influences affordability is customer value. Within the defence industry this is included in the Value For Money (VFM) affordability factor (section 5.4.1). This is important factor because the customer must perceive the value in a proposed solution particularly when reviewing tender responses from solution providers. Also given the budget constraint in public sector, VFM is a major consideration when contracting.

Value is the “worth in monetary terms that of the economic/commercial, technical, and social benefits a customer firm receives in exchange for the price it pays for a market offering” (Anderson and Narus, 2004 and Rese and Karger, 2008). This means that value contains monetary and social elements. Nevertheless, the economic environment in which companies operate causes business customers including the MoD to assess value mostly based on the monetary benefits with less focus on the social aspect. The reason for this is because customers with higher costs savings and higher profits gain more competitive advantage over others, which could put the survival of the business (customers focussed on social elements) at risk (Zintl, 2001 and Rese and Karger, 2008). These customers are usually commercial customers who receive revenue from the use of the equipment delivered. This explains why the common method of assessing value is the Net Present Value (NPV) method. In many industries, the customer would make decisions by considering the revenue that would be generated from that investment.

In long-term contracts, change is inevitable due to changes in customer requirement as well as changing environmental and structural condition; hence a crucial dimension of value is flexibility. The flexibility to adapt to changing customer preference with logical increase in cost across the project life is a true measure of value to the customer. Rese and Karger (2008) in exploring customer value and Real options stated that value should include the option to grow overtime apart from the current value of company assets. Interestingly, the solution provider could increase its own value by optimising the customer’s value. This could be achieved by providing innovative solution to the customer, which would increase the reputation of the solution provider (Rese et al., 2008). The authors presented two kinds of customer value drivers namely: corporate structure drivers and customer process drivers. These are represented in Figure (2-7).

Customer Value Drivers

(i) Corporate structure drivers

- Customers' know-how – customers with sophisticated expertise are more inclined to complex solutions. In some cases, there is a gap between the customer and supplier knowledge base (Rese et al., 2008). This means that the customer's desire for value is at a higher level in comparison to another customer with low know-how. The solution provider is faced with the challenge of increasing its expertise to the level that it would be able to deliver customer requirement and add value to customers at all levels.
- Customer resources – this includes facilities and liquid funds required in constructing or acquiring systems and equipment which are required to deliver customer requirement. It might be fundamental to involve the solution provider in customer processes in order to identify what would be valuable to the customer. Nevertheless, this could lead to costs being incurred particularly during information acquisition and negotiations in complex projects (Rese et al., 2008).
- Customer management style – the customer's style of management could be focused on developing its core competencies or executing value-based approaches. The execution of value-based approach could be assessed through financial indicators such as EVA and other financial measures (Rese et al., 2008). The focus of the customer's management would affect the customer's assessment of value whether it is based on developing core competencies or executing approaches which are seen to be

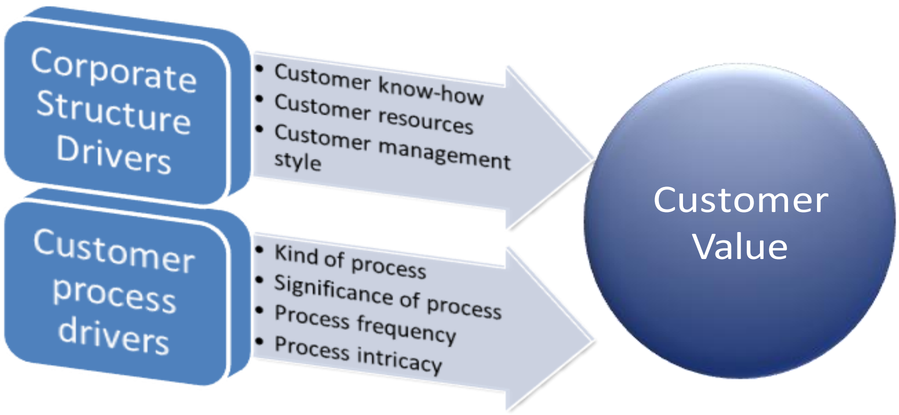


Figure 2-7: Drivers of Customer value

value-adding – for example within the defence environment where the customer is different from the end-user. The customer's perception of value differs from the end-user's, but the procurement and negotiation is done by the customer.

(ii) Customer process drivers.

- Kind of Process – this refers to the complexity, sophistication and standardisation of the process, i.e. how flexible the process should be in order to perform variations within a task (Rese et al., 2008). Complexity refers to diversities of tasks e.g. within the work breakdown structure; hence a complex process requires important information to be shared between customer and solution provider. The nature of these processes would determine the customer's perception of value.
- Significance of process – a process which is very important in the customer's operation could require extra effort and resources to ensure that the process is properly developed and delivered to meet the customer requirement. The success of such a process would affect the customer's perception of value (Rese et al., 2008).
- Process frequency – in transaction cost theory, frequency is seen as a multiplier of transaction cost i.e. the higher the frequency, the higher the cost of operation. This means that increased usage could lead to higher maintenance cost. While a high process frequency could afford the customer the exploitation of economies of scale, a high frequency would influence the customer's preference for automation within the system in order to minimise costs (e.g. cost if training employees to operate a manual process) (Rese et al., 2008).
- Process intricacy – this refers to processes with different kinds of tasks. This requires close interaction between customer and solution provider in order to capture requirement and to deliver a solution that satisfy the customer. It influences the customer's perception of value at a higher degree than simpler processes (Rese et al., 2008).

Therefore, there is a need for customers and solution providers to identify how these drivers could affect customer requirement in order to be able to deliver solution that is valuable to the customer. Accessing the value embedded in an offering, which could be intangible and intrinsic, could be a challenge as the manufacturer must demonstrate value within the solution being offered to the customer. Additionally, to draw on the flexibility within the budget and secure a higher level of budget for the project, the customer must show the decision makers at the program level that there is value in directing investment to a particular project, in the defence sector as an example. Negotiations could border around: how do we value the cost of building an aircraft carrier against a new aircraft or a military tank? Or how do we value the cost of building a new hospital against the building of a new war ship? In order to answer these questions, availability of sufficient data is required as explained under the customer know-how driver, but this is not usually available. The customer process and structure driver explained above would go to impact customer perception of value, which also influence the customer's willingness to pay. This is explained in section 2.10.

2.10 Customer Willingness To Pay (CWTP)

CWTP is closely associated with customer value as the customer wants to invest prudently in a project that delivers value. Al-Churaiz and Enshassi (2005) have described CWTP as the maximum amount that a person is prepared to pay for a service rather than not have the service. This is shown in Figure (2-8). The demand curve is based on the assumption that the lower the price of a product, the higher the CWTP for it. The area below the demand curve represents the CWTP. CWTP consists of the amount paid for a service and the "customer surplus". This is represented in the supply curve. Water systems revenue is measured by multiplying the price by the quantity.

The authors suggest that the higher the price of a service the lower the CWTP, except in cases where the service is a necessity and there are no substitutes. An example of this is shown in the CWTP to pay for improved water services in Gaza strip. The CWTP increased because the service was needed for survival and there were no substitutes (Al-Churaiz and Enshassi, 2005). CWTP is also illustrated by Ray et al. (2006) in Figure (2-9). Figure (2-9) shows that what the customer can afford is usually different from what the customer is willing to pay. This means that there could be factors influencing the CWTP apart from what the customer can afford. This suggests that CWTP is flexible and it can be influenced by the customer's perception of the value embedded in the offering. Tsolacos et al. (2005) explained that the customer requirement and the space supplied by the service provider can result in the different levels of rent or rental growth depending on the how much the business customer is willing to pay.

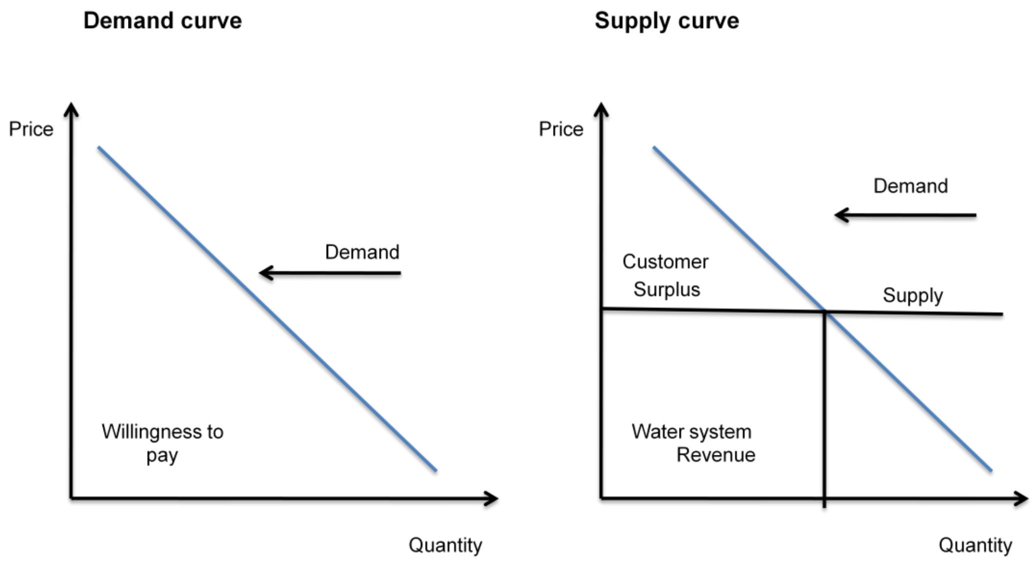


Figure 2-8: Demand curve and the supply curve relating to CWTP and customer surplus (Al-Churaiz and Enshassi, 2005)

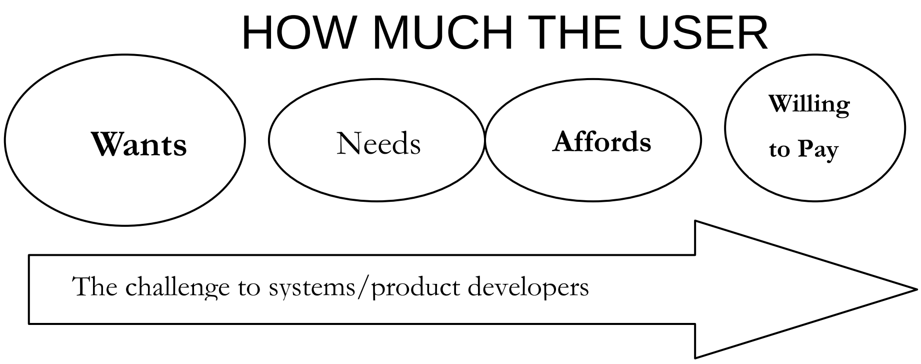


Figure 2-9: Customer Willingness to pay (Ray et al., 2006)

This means the CWTP is dependent not only on business customer's profitability but also the value perceived in the space supplied; hence customer value could be effective in engineering affordability. Within literature, approaches such as conjoint measurement, auctions, NPV and direct measures were employed to increase CWTP.

2.11 Uncertainty

LCC is largely based on prediction which has some uncertainty associated with it. There is uncertainty about future events which could have serious impact of the delivery of the whole project. Uncertainty has been defined as a potential deficiency in any phase or activity of the modelling process that is due to lack of knowledge (Oberkampf et al., 2000). It causes a variation which could have either a negative or positive effect on a process which could have a minimal or significant impact on overall performance. For defence contracts, it could affect the schedule, delivery, cost and affordability of the project. This is due to insufficient data to inform contracting at the bidding stage since the customer may only be certain about the budget for next two years; a stochastic representation is more suitable for assessment. When uncertainty has a negative impact on the delivery of the project, it becomes a risk. Risk is a very common type of uncertainty which could cause significant cost increase and drive a project towards unaffordability. Some negative types of uncertainty (risks) which should be considered during affordability analysis include: uncertain customer requirement, infeasible design, technology complexity or unavailability, uncertain or inadequate supplier capability, inadequate human resources and expertise and other disruptions to continuity of operations (Koury, 2010).

A review by Erkoyuncu et al. (2010) identified uncertainties in the defence sector and grouped them into the following categories.

- Commercial uncertainty – this refers to uncertainty which impacts the contractual agreement. This could be driven by dynamic customer requirements, yet the manufacturer has the responsibility of absorbing the requirement and employing their capability and resources to satisfy the requirement. This is affected by uncertainties in cost dimension (cost estimation), labour availability, supply chain and environmental responsibility.
- Affordability uncertainty – this refers to uncertainty surrounding the customer's budget which decides the level of funding available to the customer to support the contract over the life cycle. This is affected by uncertainty in budget allocation as well as cost growth over the life cycle.
- Performance uncertainty – this refers to uncertainty surrounding the ability of the manufacturer to be able to deliver the contract based on the KPIs specified by the customer for the given project. This requires a multi-dimensional approach to encapsulate the many sources of uncertainty covered in affordability, commercial, training, operations and engineering.
- Training uncertainty – this refers to uncertainty concerning the manufacturer's delivery of training needs required by the customer. This is affected by uncertainty in trainee

skill level, number of trainees to attend courses, ability to screen candidates (e.g. trainee examination skill level) and availability of training facilities etc.

- Operational uncertainty - this refers to uncertainty concerning the manufacturer's ability to deliver the project at the required level of service and support. It focuses on activities or services associated with equipment delivery and maintenance. This is affected by uncertainty in equipment utilisation, rate of reparability, operating parameters and maintenance policy etc.
- Engineering uncertainty - this refers to uncertainty concerning the manufacturer's ability to manage strategic decisions regarding the future service and support requirements (i.e. offshore, obsolescence management) of the defence project. This is affected by uncertainty in interpretation of data, rate of capability upgrades, licensing and certification failure rate for software, technology refresh, severity of obsolescence, and rate of fault investigation (Erkoyuncu et al., 2010).

Generally the two types of uncertainty are aleatory uncertainty (variability) and epistemic uncertainty. According to Erkoyuncu et al. (2010) aleatory uncertainty has the following characteristics such as stochastic, irreducibility and randomness while epistemic uncertainty is due to lack of knowledge, and both subjective and reducible.

Uncertainty is also inherent in the customer budget in defence contracting as mentioned above (affordability uncertainty); hence this research seeks to address the dynamic nature of uncertainty and its impact on the customer affordability. This is considered in Chapter 8. For the purpose of clarity and within the focus of this research, risk is considered as a special case of uncertainty where the outcomes of a specific event or a number of events have a significant negative effect on the overall performance of a project. This means that risk is a very common type of uncertainty which has a negative effect on a project, especially by causing significant cost increase. This is the reason why uncertainty assessment of WLCC in industry is usually done by employing risk assessment software.

2.12 Research gap analysis

- In academia, the concept of affordability is in its infancy even though the words "afford", "affordable" or "affordability" are commonly used. Many articles related to affordability do not investigate affordability as an independent concept.

- Also the definition of affordability varies across different industries and they usually depict two common elements namely: customer income and cost or CATS and WLCC. While affordability research in the construction sector is well developed, it is just developing in other sectors. However this current research is being done in the defence and aerospace sectors to identify three perspectives of affordability with two quantitative and ten qualitative factors which affect customer affordability as presented in Section 2.4.1.
- Various measures for customer affordability assessment exist across different sectors, however the Affordability Index (AI) in the defence and aerospace sectors only performs a quantitative assessment (section 2.4.1). Existing factors must be reviewed to ensure they are applicable within this research.
- The current AI combines both qualitative and quantitative measures, which would not yield an accurate result. Since qualitative factors would affect customer affordability at varying degrees within different contracts, they should be assessed separately from quantitative factors. Therefore there is a need for metrics to perform qualitative assessment of customer affordability which includes a system of capturing and representing the importance of each factor. This means a refined AI is needed to give a quantitative assessment of customer affordability.
- Few definitions of manufacturer profitability existed within literature; hence there is a need to develop a definition for manufacturer profitability as a perspective of affordability in the context of this research.
- Manufacturer profitability is usually calculated using accounting ratios provided in section 2.5.1; however, all the measures are only applicable at the end of the financial year. Manufacturer profitability of a defence contract is considered before the contracts starts, hence there is a need to assess the profitability at the start of the project based on the cost estimates, the customer budget and the agreed profit rates. This type of profitability assessment would help the manufacturer determine a competitive selling price taking account of risk. Further research is required to investigate this area.
- Most of the research in the area of supply chain management or supplier performance management does not focus on the long-term sustainability of suppliers. Sustainability literature usually focuses on environmental, economic and social dimensions, but there is little effort in considering financial and operational dimensions (section 2.6). There

is a need to develop a definition of supplier sustainability in the context of this research.

- While measures of supplier performance exist in literature, there is a need to identify performance measures that are related to the financial and operational sustainability of suppliers in the delivery of defence contracts.
- Though defence contracts combine both products and service, most measures of performance are focused on products and processes rather than services. The intangible nature of services creates a challenge in measuring the delivery of services. The closest effort to provide a method of assessing economic sustainability by the European Foundation for Quality Management initiative provided a generic framework as it is designed to apply to all sectors. This means that there is a need for measures that assess the ability of suppliers to sustain service delivery over the life cycle of the project within the defence sector.
- Finally, there is a need to investigate the factors affecting affordability from each perspective to know how they could change over the duration of the project. One these factors are uncertainty, which is mature research area. The most suitable approach must be adopted to represent the impact of risk (uncertainty) on the affordability factors.

2.13 Summary

The chapter provided a review of affordability across different industries. First a general explanation of the concept affordability was provided, and then the definitions of affordability across different industries were explored to identify common elements (section 2.3). The standard definition adopted within the research was the NoE definition which states that "affordability is the degree to which the WLCC of an individual project or program is in consonance with the long range investment capability and evolving customer requirement". Three perspectives of affordability were identified in the B2B environment such as customer affordability, manufacturer profitability and supplier sustainability (section 2.4, 2.5 and 2.6).

Customer affordability is the most popular of the three perspectives, hence most studies on affordability within literature usually refer to customer affordability rather than the other two perspectives. It is usually referred to as affordability rather than customer affordability.

A total of 12 factors were identified which affect affordability which were WLCC, CATS, economic criteria, impact of regulations, technology innovation, level of performance, supplier value chain, impact of requirement change, global competition, environmental and ecological factors, potential for reuse and project management. An AI is used to measure customer affordability which combines both quantitative factors and qualitative measures.

While manufacturer profitability is a mature subject in accounting literature, the perspective adopted within the affordability research provided a definition of manufacturer profitability as the "ability of a manufacturer to generate a substantial level of revenue in the delivery of project or program which offsets the cost incurred over the WLCC of the contract". The main factors that affect manufacturer profitability are revenue or sales and price. It is measured through existing accounting ratios such as gross profit, net profit, return on capital employed, return on investment and return on owner's equity calculations.

Within the supply chain literature, supplier performance measures already exist, but this research focuses on the financial and operational sustainability of suppliers. Therefore, within the affordability research, supplier sustainability was defined as the capability of a supplier to maintain products and services in a dependable manner. In order to ensure their availability and operability over the project life cycle with flexibility to adapt to changing customer requirement in a cost effective and ethical way.

The approach of estimating through life cost of products and projects was also reviewed including the categories of LCC in industry (parametric, analogous and detailed) and accounting literature (ABC, cost-plus, target costing) (section 2.7). The concept of budget allocation for company operations was explored since the customer's budget allocation would affect the investment for the defence contracts (section 2.8).

Customer affordability is also affected by the perception of value embedded within the offering which could influence the customer's willingness to afford the project. Therefore, drivers of customer value were explained which are corporate structure together with customer processes (section 2.9). A close concept to customer value is CWTP, which was explained in section 2.10.

Also uncertainty was reviewed since LCC and customer budget are affected by the impact of uncertainty which may be negative (risk) or positive (section 2.11). The sources of uncertainty within the defence sector were revealed and affordability uncertainty would be further investigated. Finally, section 2.12 provides the research gap identified as a result of the review of all the concepts which form a basis for the research aim and objectives in Chapter 3.

CHAPTER 3
RESEARCH AIM, OBJECTIVES AND METHODOLOGY

3.1 Introduction

A detailed description of the literature review has been provided in the previous chapter, which lead to the refining of the project aim. A set of objectives is further outlined in order to achieve this aim. This chapter provides a description of the research scope, aim and objectives as well as the methodology adopted for the research. The methodology contains a four-stage rigorous process that involved literature review, interview protocol development, data collection and analysis, framework development, system implementation and validation. The case study approach adopted in the research employed the use of standard research techniques such as content and Meta analysis, field research, sector survey and interview questionnaires. The generic approach employed in the final stage of the validation process with case sessions is also provided.

3.2 Research Scope

The research is designed to help the customer and the manufacturer to assess defence contracts at the bidding stage from the three perspectives (customer affordability, manufacturer profitability and supplier sustainability) described in Chapter 2. In order to define the focus of the research, the scope of the research is described below.

- *Context* - The issues, themes and solutions identified and proposed within this research are focused primarily on contracts within the defence sector, especially availability contracts. This is done in the context of a peace situation rather than war, because in a war situation funds are spent to respond quickly to perceived threats as seen in the recent conflicts in Libya. The framework development and tool implementation within the research were designed and applied to defence contracts at the project level rather than program or system level. These could also be applicable to contracts within the civil aerospace domain or other long-term contracts.
- *Affordability* - As explained in the previous chapter, affordability of defence contracts is investigated from three perspectives namely customer affordability, manufacturer profitability and supplier sustainability. Therefore, **affordability**

refers to **three perspectives**, while **customer affordability** refers to **one** of the perspectives.

- *Literature review* – The review of literature focused primarily on academic and sector-related articles relating to the subject of affordability within the defence sector; however, the subjects of customer affordability and supplier sustainability were reviewed across different industries as seen in the literature review chapter.
- *Validation* – The affordability framework that was implemented as a system was validated with experts within the defence sector and through four case studies within the defence and civil aerospace industries.

3.3 Research Aim

The aim of this research is to develop an affordability assessment and management framework at the bidding stage for defence contracts, focusing on three perspectives, namely customer affordability, manufacturer profitability and supplier sustainability.

3.4 Research Objectives

In order to achieve the research aim, suitable objectives were carefully defined in alignment with the research gaps identified from the literature review and sector challenges. These are to:

1. Investigate the industrial context of this research in order to capture the current practice (AS-IS) of customer affordability, supplier sustainability and manufacturer profitability within the defence sector.
2. Investigate the qualitative and quantitative factors affecting customer affordability and how to generate the customer Affordability Index (AI) to measure customer affordability.
3. Investigate the factors affecting manufacturer profitability and how to generate the manufacturer Profitability Index (PI) to measure manufacturer profitability.
4. Investigate the dimensions of supplier sustainability and measures for assessment.
5. Develop a methodology to assess information capability for affordability assessment at the bidding stages.
6. Develop a methodology to manage and control affordability during a project life cycle.
7. Investigate the impact of uncertainty on affordability assessment over the project life cycle.

8. Validate the developed framework through industrial case studies.

3.5 Research Methodology

After the aim and objectives of the project were defined a rigorous methodology consisting of four main stages was adopted, as shown in Figure (3-1). A case study approach was employed in the research to capture the subject of affordability from academic literature and sector practice. In order to achieve this, qualitative and quantitative research techniques were adopted throughout the stages of the research. This section explains the research techniques and stages.

3.5.1 Research Techniques

A case study approach was employed in conducting the research, which involved a triangulation of both qualitative and quantitative approaches by combining field research and industrial interviews to capture industrial practice, and employing content analysis and meta-analysis in the review of literature. A case study is "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009). This definition shows that case study research is not just a data collection tactic but it encompasses the logic of design, data collection techniques and specific approach to data analysis (Yin, 2009 and Creswell, 2007). In order to achieve the aim of this research as stated in section 3.3, reconstructed logic (organised formal procedures) and logic in practice (adaptive approach based on individual cases) was employed through the case study approach. This approach was employed in order to properly capture a broad view of affordability assessment from different organisations within the defence sector. The findings from this approach can be applicable to the major defence organisations including both customers and manufacturers. Also, this would make it easier to validate the developed framework with any defence company. The research methodology is presented in Figure (3-1).

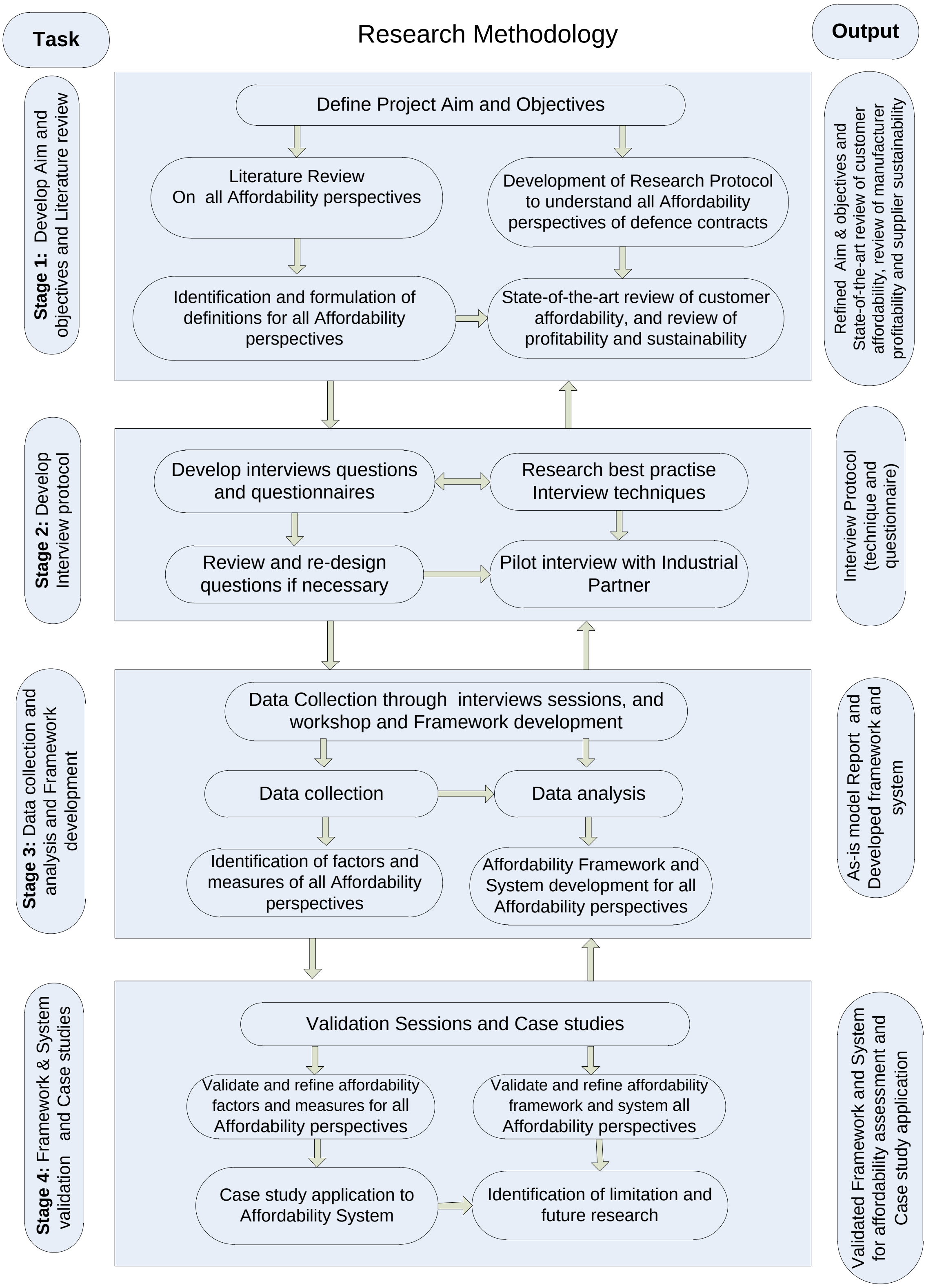


Figure 3-1: Research Methodology

3.5.2 Stage 1- Aim and objectives development and Literature review.

This stage is focused on the process of refining the research aim and objectives based on findings from literature review. It also explains the comprehensive approach in conducting the literature review. The research aim and objectives have been described in section 3.3 and 3.4; next, the literature review approach is described below.

Literature Review

i. Content analysis is a technique for examining the content or information and symbols contained in written documents or other forms of communication.
ii. Meta-analysis is a technique used to create a methodological review so the researcher organises the results from many sources to identify similarities or differences (Neuman, 2006).

These two types of research were employed in conducting the literature review of affordability, which is a concept related to defence contracts. In order to have a good foundation on affordability as a subject, it was essential to review literature.

A comprehensive report of the findings was provided in the Literature review in chapter (2). The steps followed in the review of literature include; (i) define sources and procedures for the search of articles to be analysed and (ii) define categories that are instrumental to the classification of the collected articles. This was done in order to gain an understanding of the subject and explore customer affordability in particular, as this was the major perspective of affordability. To investigate the concept of affordability, various journals and articles related to these topics were consulted. The subject of customer affordability is new particularly within defence literature; hence, industrial visits were also conducted to further understand the subject in addition to the other two perspectives. Due to the relative newness of the affordability research area, a broad range of materials were included in the review, namely masters theses, textbooks, conference papers, a doctoral thesis, sector reports, and published and unpublished working papers. The literature search was conducted using databases such as Compendex, Inspec, and Emerald; using 'affordability' as the main keyword, because customer affordability is often referred to as affordability in literature since customer affordability is the major perspective of affordability. Other keywords include defence contracts, affordability assessment and availability contracts. The results from each search were edited and reviewed to select the most suitable articles for the subjects. Then the articles relating to customer affordability were classified based on certain characteristics and areas of research. While all the themes were reviewed, the review was done in the subject of customer affordability. An in-depth review of customer affordability is presented in the literature review chapter, which was accepted for publication as a journal paper in the International Journal Computer Integrated Manufacturing.

3.5.3 Stage 2 - Interview protocol development

The interview protocol was informed by the literature review, which helped to identify themes related to affordability such as LCC, defence sector, defence contracts and budget setting. The companies to be involved with the study were selected based on their industries (aerospace and defence) and their willingness to participate in the study (two manufacturers and one customer). As mentioned in section 1.7 of the introduction, the affordability research is a part of a bigger research project in product-service system-cost, this meant that a group of four researchers were involved in the initial interview protocol development. This helped to develop familiarisation questionnaires (Appendix A) to get a general understanding of the defence industry. Familiarisation interviews were held with the companies for the group of researchers to gain fundamental understanding of their operations and help the industrial experts understand the context of the study in order to commence initial data collection and to identify potential case studies for the study.

After the initial familiarisation sessions, the affordability researcher identified specific industrial experts in the area of costing and affordability assessment in order to draw on their knowledge in this area. Therefore the next set of interviews was focused on the affordability research. In preparation for the interviews, questionnaires were developed around the themes identified and structured under various headings. The questionnaires were reviewed and refined to make them more suitable for the study (Appendix B). A semi-structured interview method was adopted among best practise research techniques, as it was best suited to capture the industrial practice in affordability assessment from the three perspectives and guide the industrial interviews. Semi-structured interview sessions also allowed the flexibility required for the researcher to gain additional information from respondents. A pilot of the interview protocol was conducted with an industrial partner, after which introductory interviews were conducted with other industrial partners. The outcome of these interviews informed the development of the next set of questionnaires to commence data collection.

3.5.4 Stage 3 - Data collection and analysis and framework development.

This stage is focused on the data collection. The data collection was done to establish the current practice and begin the framework development and system implementation. Sector survey and field research techniques were the main methods employed at this stage and they are explained below.

Sector Survey – a survey is a procedure aimed at collecting information in a systematic way (questionnaires) about a set of cases selected from a defined population in order to construct a data set from which estimates can be made and conclusions reached about the population (Greenfield, 1996).

Field research – involves conducting studies on a small group of people for a length of time, which begins with a loosely formulated idea or topic. In this approach, the researcher observes and interacts with people in the chosen field for a few months or years in order to gain a detailed understanding of their activities and processes through formal or informal interviews (Neuman, 2006). This approach was employed while conducting the affordability research through industry interviews as various individuals were identified within defence companies for data collection such as the project managers, business development managers and cost assurance team leaders, etc.

The respondents were chosen because of their knowledge and experience in the area of cost estimating, bid assessment and affordability assessment. The industrial interviews were conducted at different times during the research using the Delphi method in order to discover the opinions of sector experts due to the newness of affordability within academia. This was useful in capturing industry practice in the area of affordability across different companies within the defence industry, with regards to the bidding stage and challenges facing defence contracts such as affordability. When required, telephone conversations were also held for the purpose of clarifying information or having an interview session during the industrial interviews.

The initial interview sessions were held with industrial experts across the selected organisations in sessions of 60, 120, or 150 minutes, making a total of more than 30 hours, and responses were captured via audio recording and hand-written notes. Interview results were analysed using the MindManager software, which helped to produce Mind maps based on various themes identified. These results enabled the researcher to understand the current practice of defence contracting, and whole life cost estimation and affordability. The analysis of results led to further literature review of recommended materials and other useful materials. The results also helped to identify the three affordability perspectives namely customer affordability, manufacturer profitability and supplier sustainability, including another activity which has a major influence on customer affordability known as Budget setting. Following the introductory sessions was the data collection period. In conducting the data collection a semi-structured interview approach was adopted with industrial experts. Another set of questionnaires was also developed for the next stage of data collection to focus on budget setting and each perspective of affordability (Appendices B, C, D and E). Details of the data collection and analysis are presented in relevant chapters.

Interviews were conducted with functional experts and project managers within the manufacturer firms and the customer firm whose profiles are presented in Table (3-1).

Additional methods of data collection were employed by searching and obtaining publicly available information from the Internet, sector-specific databases, available company information on previous bids and press reports. These served to investigate data obtained from interviews. The results of the interviews were recorded on audio (where appropriate) and in hand written notes, and were carefully analysed in order to gain a better understanding of each affordability perspective. The results helped to identify factors and measures for each perspective of affordability and a new set of questionnaires were designed to focus on these factors and measures and gain deeper insight into them. These sessions helped to develop initial ideas about the affordability framework. A schematic of this was designed to be built using Microsoft Excel as recommended by the industrial partners due to its functionality and accessibility to industrial experts and the researcher. Findings from the sessions informed the initial development of the affordability framework which was implemented within an affordability system. These include the qualitative and quantitative affordability factors and measures and profitability elements as well as affordability improvement actions. In addition to the three perspectives, there was the need to determine the level of information availability in order to perform the assessment for affordability. The methodology designed to assess information availability was fully described in Chapter 7. Therefore the affordability system consisted of 4 modules namely the three affordability perspectives and an additional module for the audit assessment of information capability. A detailed description of the whole affordability framework and system is provided in Chapters 5, 6 and 7. The next stage of the methodology was the final framework development and system validation as well as the application of case studies.

Table 3-1: Sample interviewee profile

Job role	Responsibilities
Project manager	Responsible for ensuring contract delivery to customers on time, on schedule and within budget. Also responsible for managing resources effectively and delivering on budget.
Engineering manager	Responsible for day-to-day (technical) problem solving as well as the delivery of contracts to meet customer requirement within budget.
Business Development Leader	Responsible to the UK MoD working to understand their current and future training needs and to develop the company strategy and tactics for maximizing market place opportunities.
Strategic Forecasting Team Leader	Responsible for supplier management and strategic forecasting. Involved mainly with software, aircrafts, space aircrafts and skills and competence documentation.
Set Assurance Team Leader	Involved in examining Business Cases and cost estimations. A key member of the Integrated Project Team who is also involved in thorough life analysis of Business cases.
Strategic Forecasting Team Leader II	Responsible for supplier management and strategic forecasting. Mainly focussed on land and sea systems as well as ensuring a realistic budget with the performance of historic trend analysis.
Integrated Logistics Support	Takes a whole life cycle view rather than focusing on the in-service phase in cost modelling. Experienced in contracts involving the DoD, MoD and Lockheed Martin.
Director of Global Marketing, Systems and Customer Services	Currently also part of the marketing team, which involves working out the right set of services for the customers. Engages in tasks relating to both civil and military domains.
Proposal Director in Military Customer Management Systems	Experienced in Field support engineering on military projects. Currently a programme manager on availability contracts (since 1996).
Business development manager II	Involved in pricing civil and commercial projects (non-military projects). Also leads a team that is responsible for enhancing services rather than solely providing spare parts.

3.5.5 Stage 4 – Framework and system validation and case studies

This stage is concerned with the final framework development and validation process. After the initial framework development and system implementation, validation sessions were held in order to improve and refine the system, after which real-life case studies were applied to the system. These are explained below.

Validation

The system consisted of four modules, which are the audit module and modules for each of the affordability perspectives. After the framework was developed and implemented as a system, validation sessions were held with four companies including the customer and prime contractors. Three case studies were identified from one company and one of the other companies provided the other. First, validation sessions were held for individual modules within the system for over 14 hours and the results are presented in Chapter 9. These sessions helped to clarify the major factors and dimensions affecting affordability as well as the measures for each. Also, the suggested actions for improving affordability were clarified. The process of validation helped to refine and improve the system in terms of logic, usability, clarity and content. The questionnaires employed in this process are provided in Appendices F, G, H and I. The case study sessions were carried out with two prime contractors within the defence sector, which lasted over 24 hours apart from further analysis of results. Details of each case study are provided in Chapter 9. The process of conducting the case studies is provided below.

Case Study Process

The case study session were held mostly in the company with two or more project managers by applying real-life data to the system. Initially, the researcher delivered a presentation to explain the aim of the research and describe the affordability system features and all four modules (three perspectives and the audit). After this the project managers would provide an introduction or background to the case study to help the researcher gain an understanding of the case study. The affordability model was then populated by the researcher who would go through the modules with the project managers and enter the input provided into the model. Case study sessions held at the development stage of the affordability system were re-validated with the improved system via a less rigorous process of liaising with managers via telephone calls and e-mails. This is the generic process applied during the case study sessions.

3.6 Summary

This chapter has outlined the scope of the research, which focuses on the affordability of defence contracts at the project level. A careful attempt was made to refine the research aim based on findings from literature and sector practice. The research objectives were also defined to ensure that they are aligned to address research gaps identified in the literature review and sector challenges.

The rigorous four-stage methodology employed in conducting the research was also explained in this chapter. This methodology was characterised by:

- A detailed literature review of affordability and all its perspectives, and the use of standard research methods to review existing affordability research. This was useful in refining and establishing the research aim and objectives (Chapters 1, 2, 3)
- Collaboration with industrial experts to acquire knowledge and present the current practice in affordability (Chapters 4, 5)
- Triangulation of qualitative and quantitative research techniques to develop (initial and final) the affordability framework, which is implemented as a system (Chapters 6, 7, 8)
- Collaboration with industrial experts to validate the content, logic and result of the affordability system (Chapters 9, 10)
- Collaboration with industrial experts to apply real-life case studies to the affordability system (Chapters 9, 10).

The next chapter provides details of the findings from the current industrial practice of affordability from all three perspectives.

CHAPTER 4
CURRENT STATE OF AFFORDABILITY ASSESSMENT IN INDUSTRY

4.1 Introduction

The first three chapters have provided an introduction to the research and findings from the literature review which have helped to design the aims and objectives of the research activity. This chapter provides findings from industry practice that helped to identify various themes related to the concept of affordability from all three perspectives. This has helped to confirm some of the research gaps from literature which informed the design of the research aim and objectives. In order to address the research aim and objectives, it is important to investigate industry practice and capture knowledge from the experience of industrial experts. The methodology employed in the survey included semi-structured questionnaires, face-to-face meetings and telephone discussions as stated in Chapter 3.
Semi-structured questionnaires were designed to be used during the face-to-face interviews to guide the interviews and ensure relevant points are covered. Face-to-face interviews were held to provide a good environment to establish a relationship with the respondent and communicate clearly in order to obtain the right responses. Telephone discussions were employed along with electronic mail to obtain clarification or further explanation about issues raised during the face-to-face meetings. These methods are fully discussed in this chapter. The findings from the interaction provided the researcher with background information about the bidding stage, affordability assessment process, budget allocation process, profitability assessment process and supplier sustainability practice. The following structure was employed: section 4.2 fully describes the methodology employed. Section 4.3 fully describes and analyses current state of the defence environment in terms of the bidding process, budget allocation process, cost estimating practice, overall affordability assessment process as well as customer affordability, manufacturer profitability and supplier sustainability practice. The section also highlights current challenges and proposed resolution strategies. Section 4.4 focuses on the gaps between industry and academia. Then section 4.5 summarises the whole chapter.

4.2 Methodology

4.2.1 Industrial Interviews

As identified through the literature review, while affordability is commonly expressed as a feature of a product or a service, the investigation of affordability as a concept was originally done within the construction sector. However, the focus of this research sits within the defence sector, hence it was important to capture the current state of affordability assessment within the defence industry. This was done by conducting industrial interviews with the customer and three manufacturer organisations.

4.2.2 Rationale for Industrial Interviews

The rationale behind the industrial interviews is described in the points provided below:

- To capture understanding of customer affordability, manufacturer profitability and supplier sustainability from customer and (prime contractor) manufacturer organisations
- To identify qualitative and quantitative factors affecting affordability from the three perspectives
- To capture the process of affordability assessment from the three perspectives
- To understand the challenges of affordability in defence contracting from the three perspectives.

4.2.3 Choice of companies and respondents

The respondents were chosen from four companies within the defence industry. The respondents were chosen because of their knowledge and experience in the area of cost estimating, bid assessment and affordability assessment. The companies chosen had been involved in research activities with Cranfield University and had shown interest in the research area of cost estimation and affordability assessment, prior to the start of the project. For this reason, they were the first set of companies to be contacted for initial data collection. These companies were BAE Systems Insyte, Ministry of Defence (MoD), Lockheed Martin and G.E. Aviation. At the other stages of the research such as validation of initial framework and case study analysis, other companies such as Rolls Royce, General Dynamics and C.I. consultants were also involved in these aspects of the research. Also, the choice was based on the availability of employees within certain functions such as project management, cost assessment, business development and engineering to provide useful responses to the questionnaire. The profiles of the respondents from each company are provided in Tables (4-1 to 4-5). Due to confidentiality, the company names are no longer specified in the rest of the thesis.

Table 4-1: Company A Interviewee profile

Job role	**Responsibilities**
Project manager(s)	Responsible to ensure contract delivery to customers on time, on schedule; within the budget. Also to manage resources effectively and deliver on budget.
Engineering manager	Responsible for the day-to-day (technical) problem solving as well as the delivery of contracts to meet customer requirement within the budget.
Business Development Leader	Responsible to the UK MoD working to understand their current and future training needs and to develop the company strategy and tactics for maximizing the opportunity in the market place.
Integrated Logistics Support	Takes a whole life cycle view rather than focusing on the in-service phase in cost modelling Experienced in contracts involving the US DoD and UK MoD.
Director of the Global Marketing, Systems Customer Service	Currently also part of the marketing team, which involves working out the right set of services for the customers. Tasks relate to both civil and military domains.
Proposal Director in Military Customer Management Systems	Experienced in Field support engineering on military projects. Currently a programme manager on availability contracts (since 1996).
Finance Team member	Involved in financial assessment military projects (non-military projects).
Head of procurement and Sub contract manager	10 years experience in aircraft equipment design and accreditation. 10 years experience in international sales and marketing with business development. 10 years in procurement of mission electronics and systems engineering.
Principal Reliability Specialist	Experience in cost modelling especially uncertainty

Table 4-2: Company B Interviewee profile

Job role	Responsibilities
Strategic Forecasting Team Leader I	Responsible for supplier management and strategic forecasting. Involved mainly in the software, aircrafts, space aircrafts and skills and competence documentations.
Set Assurance Team Leader	Involved in examining Business Cases and cost estimations. A key member of the Integrated Project Team who is also involved in Through life analysis of Business cases.
Strategic Forecasting Team Leader II	Responsible for supplier management and strategic forecasting. Mainly focussed on land and sea systems as well as ensuring a realistic budget with the performance of historic trend analysis.
Assistant Head for Defence Resources Planning	Involved accepting overall budget allocation from the Treasury with much experience in Finance and policy assessment.
Head of Defence acquisition Program	Deputy Head of Secretariat Equipment Capability for 2 years. This was concerned with affordability considerations and requirement scrutiny. Also Head of Maritime team on the Aircraft carrier program.
Asst Head Equipment Plan	Part of Capability Sponsor team with responsibility towards equipment plan, procurement and support for new equipment.

Table 4-3: Company C Interviewee profile

Job role	Responsibilities
Statistics and Modelling LCC Analysis Lead	Responsible for life cycle costing analysis with focus on risk and uncertainty assessment of defence contracts

Table 4-4: Company D Interviewee profile

Job role	Responsibilities
Reliability Engineer	Responsible for whole life cycle costing and various studies of designing aircrafts for reliability. Also involved in simulation and logistics support
Project Manager	15years experience in cost estimates and project management to provide be-spoke offering to customer requirement

Table 4-5: Company E Interviewee profile

Job role	Responsibilities
Field Support Engineer	Responsible for military project support including the management of the proposal. Also the programme manager for availability contracts
Business development manager	Involved in pricing civil and commercial projects (non-military projects). His team aims to enhance service offerings rather than solely providing spare parts.
Programme Manager	Involved in contract and logistics support and currently programme manager for Performance-Baled Logistics in the UK e.g. Tornado support contract

4.2.4 Design of questionnaires

The design of the questionnaires was guided by findings from initial literature review as well as the research objectives provided in Chapter 3 (section 3.4). Initially the questionnaires were designed together with three other researchers who were within the same project with the affordability researcher, but each of them focused on different research area such as uncertainty, obsolescence costing and design re-work. The results of the initial sessions were analysed by individual researchers based on their research focus The focus of the questionnaires at the initial stage was to gain a background understanding of the defence environment and the issues considered in contracting at the bidding stage. A pilot session was run with one of the companies to gain background information of industrial practice. Later on, the questionnaires were also refined and piloted with two other defence companies.

Following these, the next set of questionnaires was designed by the affordability researcher to capture the understanding and practice of affordability in defence contracting from the three perspectives. Both open-ended and closed questions were included in the questionnaires, in order to obtain a comprehensive set of responses from the respondents. The respondents were employees who were usually very busy and had limited time to spare for the interview sessions, hence in order to ease the process, the researchers provided two copies for the questionnaires. The respondent'(s) copies of the questionnaire only contained a list of questions, but the researcher's copies included enough space to record all the responses to each question. Where applicable, the respondent(s) would provide addition information inform of documents or provide further details by writing on a piece of paper, a white board or a flip chart. The responses were usually analysed and used in designing the next set of questionnaires. A sample of the questionnaires used for introductory interviews and initial data collection are provided in Appendix A.

4.2.5 Approach to respondents

The researcher made efforts to establish contact with employees from the organisations mentioned above in order to start initial correspondence and arrange face-to-face meetings. An initial meeting was held with an industrial expert who had been involved with a previous research activity at the Network of Excellence in Affordability Engineering at Cranfield University (NoE in AE). Through him, the contact details of other industrial experts were obtained. Contacts from the other companies were obtained through the principal investigator who had interacted with defence companies in previous projects and the researcher making contacts with companies within the defence sector through industrial events. The contacts from the companies mentioned above were then approached to arrange face-to-face meetings. A few meetings were conducted prior to the project launch event where the researchers was able to personally meet the other industrial partners and obtain their contact details to be able to arrange interview sessions with them. Prior to each visit, a brief description of the agenda and the length of time required were sent to the respondents to help them prepare the required information for the interview sessions. Sometimes, the questionnaires were also sent ahead of the meeting. Some of the questions asked are presented below:

1) What is the customer's view of affordability?
2) How do you define/what is your understanding of affordability?
3) What factors drive/ affect your Affordability?
4) How would do you carry out the budget setting activity ?
5) What are the factors/elements that are considered in /factors that affect budget setting?
6) When is the budget setting activity carried out?
7) Which employees are involved in the activity?
8) How would you assess the profitability in a defence projects at the bidding stage? How does the mismatch between offer price and customer budget affect profit?
9) What type of information would you require to perform the assessment?
10) Are there non financial elements which affect profitability?
11) What level of data would be available to the manufacturer for the assessment e.g. customer budget?
12) How can you make a bid/contract more affordable?
13) What factors are taken into consideration in the selection process?
14) What tools are used in predicting/ measuring the supplier?
15) At what stage is supplier selection done?

4.2.6 Process of conducting face-to-face interviews

Over 22 hours of introductory meetings were held with four of the companies mentioned earlier. The interview sessions were usually conducted at the company site, in sessions of 60, 120 or 150 minutes. The respondents interviewed include project managers, engineering managers, business development manager, strategic forecasting team leader and integrated logistics support manager. The details of their job roles were provided in section 4.2.3. The sessions started with the researchers introducing themselves, the aim and scope of the whole project on cost estimation and each research area such as affordability, uncertainty, obsolescence costing and design re-work. They also explained the information required in response to the questionnaire and to help each researcher gain the background understanding of the defence environment and some of the challenges faced at the bidding stage of defence contracting. After this the respondents also introduced themselves and explained their job roles before the questionnaires are administered. One of the researchers would pose questions to the respondent(s) while the other researchers would take down the responses in the form of hand written notes. Where possible, audio recordings of the interview sessions were also done and these were consulted in clarifying and analysing the responses from the meeting. The researchers could be provided with documents which are useful in improving their understanding or referred to websites where useful materials could be obtained. These sessions helped the researchers to identify the best people to contact for future interviews focussing on individual research areas. After the initial face-to-face meeting held jointly by all four researcher; the next set of semi-structured interviews were solely conducted by the researcher in affordability to collect data about affordability practice in industry. The findings are presented in section 4.3.

4.2.7 Telephone Discussions

The telephone discussions were employed to clarify and analyse the information obtained from the face-to-face interviews. They were also used to arrange interviews session with the contacts obtained from the face-to-face sessions or other meetings. At other times, interview sessions were held with industrial contacts who found it difficult to provide face-to-face interviews due to constraints with time or venue. Telephone interviews were carried out in a similar fashion to the face-to-face sessions, but usually done by the researcher. The details of the findings from these interview sessions are presented in the sections below.

4.3 Industrial interviews findings

4.3.1 Defence Environment

As mentioned in Chapter 2, the defence environment is changing its forms of contracting from the tradition approach to service and support contracts in the form of performance-based contracts such as availability and capability contracts. To assess the affordability of defence contracts, two major factors are taken into account namely, the WLCC of the project and CATS. These two factors are the output of two different processes which are the cost estimation process and the budget setting process as illustrated in Figure (4-1). The WLCC is provided by the defence contractor while the CATS is provided by the customer. Sufficient research has been done in the practice of cost estimation and many cost estimating tools are available in academia and industrial practice, but there is need to capture the process of budget allocation as well as the actual affordability assessment exercise.

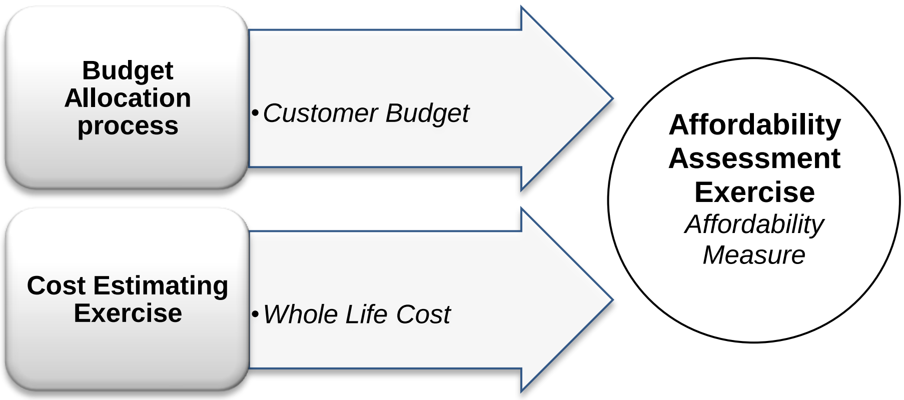


Figure 4-1: Link between the three processes

4.3.2 Budget Allocation Practice

The budget setting takes place during the customer's planning round. This planning round has been revised to include the various stages of negotiation before the final budget is allocated at the departmental level and presented in Figure (4-2).

The process is broadly broken down into three stages as shown in Figure (4-2). The whole process is better known as *Budget allocation* and *management* because the Treasury sets the budget based on the Spending review which is carried out every 3 years.

Stage 1: The Treasury releases Available Top Level Budget for defence to the Financial Planning team (ATLB). The financial planning team then requests the Top Level Budget (TLB) holders to submit the cost of Budget Plan (RfBP1). This could take about 3 months. The TLB holders and Capability Sponsor then request individual departments to submit Budget Plan at departmental level (RfBP2). The TLB holders and Capability Sponsor are regarded as the unified MoD customer. The departments include Defence Equipment and Support (De&s), Estates, Research etc. These departments provide a 10-year Budget Plan (BP2) to the TLB holders and Capability Sponsor who provides a 10-year Top Level Budget plan to the Financial Planning team (BP1).

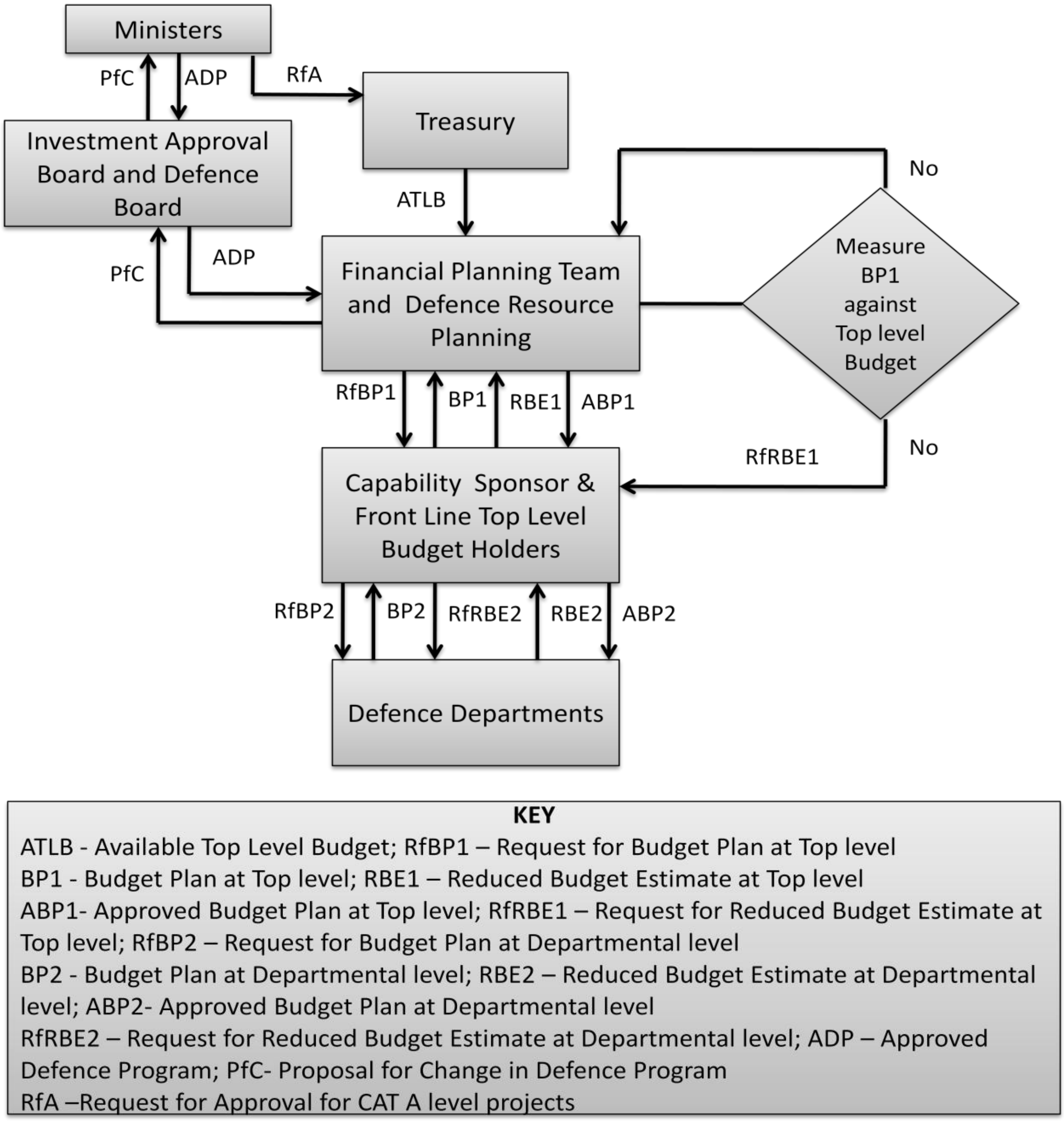


Figure 4-2: Budget Allocation process within the defence customer organisation (Bankole et al., 2010a)

Stage 2: The Budget plan is usually higher than available budget overall so the Financial Planning Team (FPT) requests a reduced Budget estimate at the Top Level (RfRBE1) by seeking new efficiencies and making savings where possible in order to get back to Available Budget. The TLB holders also request a reduced plan at departmental level (RfRBE2). The departments work to reduce the Budget Estimates (RBE2) and send this to the TLB holders who in turn send a Top level Reduced Budget Estimates (RBE1) to the FPT. This could last about 4 months.

Stage 3: Where the Reduced Budget Estimate is still higher than available Budget, the Defence Resource Planning team (DRP) sees how to make more significant cuts and see how to prioritise and eliminate the gap. (It could involve laying off staff; taking equipment out of service or trimming down the civil service). If the gap between available Budget and Reduced Budget Estimate still persists, DRP then arrives at Proposal for Change (PfC) in the Defence Program and make recommendations to the Investment Appraisal Board (IAB). The IAB scrutinises the investment to identify best value for money solution by taking account of service support such as mid-life upgrade and obsolescence. The IAB does this assessment at 10%, 50% and 90% confidence level and usually sets the budget at 50% confidence level. Then the proposal is also sent to the Ministers to be approved by the Secretary of State after which DRP decide the Approved Budget Plan at Top level (ABP1) and apportion this to each department (ABP2). For Category A level projects which requires a capital cost over £400m, Ministers need to seek approval from the Treasury (RfA). Then an In-Year financial team is responsible for tracking and monitoring how the Budget Plans are being spent. This could last about 4 months.

Generally the factors that affect the Budget are changes in defence priority and the strategic Reviews, internally. While external factors include the recession, fuel cost, foreign exchange rates and estates. It is important to note that all these factors are dynamic. Budget allocation is also affected by the viability and affordability of the program, not just the affordability. Viability is concerned with the operational and technical capability of the project to deliver VFM while affordability is concerned with the financial capability to procure and support the project (Bankole et al., 2010a).

4.3.3 The Defence Budget

The defence budget, which is the outcome of the planning round, forms the basis for defence contracting. While defence needs abound, the contracts awarded to meet these needs are constrained by the available budget set by the Treasury. The defence budget is faced with major challenges such as the procurement delay and overspends due to poor financial management. A report by the parliament shows that there has been a decline in government spending on defence which is currently 2.7% of Gross domestic product (GDP) compared to 5% in mid-1980s. The maintenance of long-term military operations in addition to new acquisition to maintain defence capability has slowed down the MoD operations with grave consequences on the defence budget. Also, the impact of the reduction of civilian and army personnel means that the UK's ability to sustain its in-service capabilities is at risk (The UK Parliament, 2010). The Strategic Defence and Security Review in 2010 which was meant to assess the proposed cuts by the new government was put off due to disagreement over the aircraft carriers and Trident's replacement. Tradeoffs are being suggested to sell off some amphibious assault ships in order to keep the carrier and Trident programmes going, however these have served important missions including war and humanitarian operations. Another proposal was to reduce service personnel by nearly 40,000 since it easier to reduce employees than to stop defence contracts (The First Post, 2010).

The figures in Table (4-6) from the MoD suggests an annual increase in defence spending from 2007 to 2010, however, the practical reality as expressed by many defence manufacturers, reveals that many defence projects are suffering as a result of inadequate provision of funding. There are two possible reasons for this:

Table 4-6: The Defence Budget - Adapted from MoD, (2010)

Description/Year	**2007/08**	**2008/09**	**2009/10**	**2010/11**
Resource Budget (£million)	32,618	33,602	35,165	36,702
Capital Budget (£million)	7,404	7,871	8,187	8,871
Total Departmental Expenditure Limit (DEL) (£million)	32,579	34,057	35,365	36,890
Of which near cash (£million)	29,411	30,763	31,921	33,628

(i) Customer requirement is not increasing at the same rate as the customer budget

(ii) The increased in budget was with operational expenditure while budget for defence equipment and support did not witness any increase.

i. Increased Customer requirement

The defence requirement has experienced significant transformation involving the procurement of new major platforms including platforms with very long life cycle in service (including the future aircraft carriers, Type 45 Destroyers, new medium-weight armoured fighting vehicles, and the A400M, Typhoon and Joint Combat Aircraft). Hence future contracts would be focussing on upgrade and support of these platforms and technology insertion to counter perceived threats, fulfil new requirement and respond to innovative opportunities. In addition to this, industrial rationalisation continues in order to encourage competition to meet domestic requirements (MoD, 2005).

This reveals the complex nature of customer requirement which is dynamic in the development of new platforms and greatly affected by a high level of uncertainty. The nature of the new platforms would require substantial funding in order to successfully deliver the customer requirement. Therefore the question is - does the increase in defence spending (Table 4-6) satisfy the substantial increase in the dynamic customer requirement? (Bankole et al., 2010a).

ii. Operational expenditure vs. Equipment support

The cost of operations is highly dynamic as seen in the impact of the war in Iraq and Afghanistan defence spending. This was as "bad news" for the industry because the massive amount of money and resources it requires has created squeezes elsewhere (The Independent, 2008). In order to satisfy the speed and flexibility required in particular operational environments and emerging threats Urgent Operational Requirements (UOR) funding is employed. This requires additional funding from the Treasury which came to over £3.6 billion for operations in Iraq and Afghanistan (MoD, 2010). The Treasury also provides funding for all additional costs associated with operations, including equipment support. While funding for operational activities has significantly increased, equipment support contracts may not have witnessed an increase in budget allocation. Therefore the increase shown in Table (4-5) is more applicable to operational rather than equipment support funding.

There is sufficient evidence to conclude that the budget allocation for defence activities overall is insufficient to meet defence needs. At the macro level the key challenge to Budget allocation is to align requirement against resources this is why the agreement between the government and the MoD is to deliver the requirement within the budget.

Challenges of the Budget allocation process are presented below:

a) Initial estimates been under estimated

b) Financial Risk

c) Uncertainty in costs without any benchmark

d) Over optimism due to: technological complexity and institutional behaviour causing employees to bid low for approval in program then manage higher through life costs later (Bankole et al., 2010a).

As stated by Gray 2009, the competition for scarce funding by the Armed Forces, means that each department would seek the largest share of resources for their own by underestimating the likely cost of equipment. Also the current system of defence cost estimation lacks the capability to determine the real cost of defence equipment early on and to do effective prioritisation. The defence customer usually doesn't cancel equipment order; hence the practice of over-ordering and under-costing is encouraged.

Against the existing practice, the new coalition government has cut costs as seen in recent cuts in education and health care and it excluded the replacement of the current Trident fleet from the strategic defence review against the advice of the former defence secretary, Des Browne. This Trident nuclear deterrent would cost £20bn which is more than half of the MoD's annual budget (BBC, 2010). The MoD is also considering 10% to 20% cuts in its budget which creates major challenges for the defence budget because existing defence programs would be funded with reduced Budget even if the programs require additional funding. Also this would give no allowance for new projects which would affect the affordability of defence programs overall (Bankole et al., 2010a).

Recommendations

Some recommendations that are provided to improve defence budget allocation process as provided by Gray, 2009 and supported by the Defence Board Sub-Committee for Equipment include:

i. Advance forecast of 10 year defence budget

ii. Strategic Defence review

iii. More clarity within the customer organisation

iv. Ensure Defence plans take account of all possible additional costs

v. An Executive Committee of Defence Board should be accountable for an affordable Equipment Programme

vi. Revise the Approval process to improve decision making *vii.* Improving De&s' capability to deliver efficiently on new equipment and support

viii. Efforts should be extended to reductions in-service support costs and Through Life capability management should be re-visited.

Having explored the budget setting practice and challenges in this section, the next section is focussed on the affordability assessment process.

4.3.4 Bidding process

The bidding process takes place prior to contract award and it is during the bidding process that affordability consideration is made. Bidding is only done after the UK MoD has decided to procure new equipment or materials or support existing equipment. The UK MoD's acquisition process could also be evolutionary or incremental, but it is mostly sequential with two variants of a CADMIT lifecycle (Concept, Assessment, Demonstration, Migration, In-Service, Termination) or CADMID (Concept, Assessment, Demonstration, Manufacture, In-Service, Disposal) cycle. The CADMIT cycle applies more to contracts involving asset management; hence the 'T' refers to termination/closure of the estate while 'M' refers to migration to new service or handover of services or assets to the user or customer.

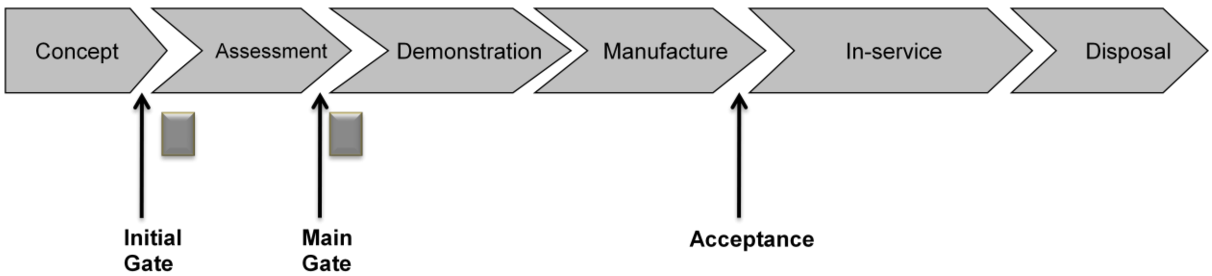


Figure 4-3: CADMID Lifecycle (AOF, 2010b).

In each phase the plan previously agreed must be executed and the outcome reviewed to planning for the remaining phases.

The basic activities of each phase are summarised below:

Concept – this involves the formulation of the User Requirements Document (URD) which states the outputs required by the user from the system. Also the delivery team is formed and the contractors from industry are involved. This leads to the identification of technology and procurement options for meeting the requirement. At this phase, funding is obtained and an assessment plan is agreed to assess the performance, cost and time boundaries. A Through Life management plan is initiated and continuous monitoring of concept maturity. An Initial Gate Business Case can be constructed and submitted when appropriate to seek approval for the Assessment Stage within time, cost and performance boundaries.

Assessment – At this phase, a System Requirements Document (SRD) is produced to define the systems capability required to meet user needs. A link between user and system requirements is maintained while identifying the most cost-effective technological and procurement solution. Risk is assessed and reduced to a level consistent with delivering an acceptable level of system performance within time and cost boundaries. The Through Life management plan could be refined with detailed plans for the Demonstration phase while continuous monitoring of project maturity is carried out. A Main Gate business case could be submitted when appropriate to seek approval for the project within performance, time and cost boundaries.

Demonstration – at this phase, development risk is gradually removed and performance targets for the next phase are fixed. The SRD and URD must be consistent the final selected solution which must be produce integrated capability.

Manufacture – at this phase the solution is delivered to the military requirement within the time and cost limits and System Acceptance is conducted to confirm that the system satisfies the SRD and the URD, as agreed at Main Gate. The lead customer function is handed over to the equipment user.

In-Service – at this stage, the Defence capability provided by the system must be available for operational use as defined at the Main Gate. Effective support must be provided to the front line to maintain levels of performance within agreed parameters, whilst driving down the annual cost of ownership. This could include upgrades or improvements, refits or acquisition increments.

Disposal – Finally, there may be need to execute an efficient, effective and safe disposal of the equipment (AOF, 2010b).

This cycle may vary with individual contracts as each phase of the cycle may not be applicable in every case. The affordability assessment, which is done during the assessment phase, is described in the next section.

4.3.5 Current Practice in Cost Estimation

The nature of defence contracts such as availability contracting requires a holistic approach of WLC which includes the cumulative cost of a capability or service over the life cycle of the contract. This could include non-recurring costs delivery, unit production cost of manufacture or instantiation, the ongoing maintenance cost, operating cost e.g. staff training, or disposal cost. Availability and capability contracts also involve new types of risk and uncertainty like obsolescence which are new to the manufacturer. These constitute challenges for the manufacturer to be able to negotiate a profitable contract at the bidding stage. Also, the customer is faced with uncertain customer budget due to extra financial commitment involved in this transfer of risk. The bidding stage is characterised with limited information which creates a challenge in estimating WLCC for contracts spanning 5 to 20 years or more though the contract may not cover the whole CADMID cycle.

Most projects do not cover the whole CADMID cycle; consequently, a whole life cycle approach is not taken. It is important to acknowledge the fact that the adoption of a whole life cycle approach, to varying degrees, transfers risks to the manufacturer over the life cycle. In order to prepare accurate estimates, some inputs, techniques, processes as well as tools need to be employed.

Inputs

- Work/Service Breakdown Structure (WBS/SBS)

A well designed WBS/SBS would contain a breakdown of the tasks and activities involved in the contract to inform costs such as management costs, support costs, repairs costs, manufacturing costs, post design costs etc. These costs including overheads are classified under different activities and tasks while each class carries different weights of cost. Each organisation has its own generic WBS/SBS which could be adapted to specific contracts or projects.

- Master Data Assumptions List (MDAL)

The MDAL is a document which contains the details of assumptions and data made concerning a contract must be available to support the cost model. This document which is the main supporting document for the cost model describes the origin of each input and the adjustments made to them. It is usually updated as the contract progresses and amendments are made with the agreement of both customer and manufacturer and could be made visible to the customer in a close working relationship. At other times, the manufacturer overhead rates could be agreed with the customer without allowing the customer full disclosure of cost estimates. The original document is called the MDAL is normally the document that contains the WLC assumptions. On the other hand, an Electronic MDAL called, dynamic object oriented report, is a requirements management tool which is progressively matured through early project phases so that it can be used as the specification against which equipment is contracted for.

- Customer requirement

The customer requirement which is sent to the manufacturer is contained in a document called the URD. This requirement goes through a process in which it is transformed into a system requirement by the supplier. This system requirement is contained in a document called the SRD which is a solution offered by the designer to the customer. While the URD, takes the customer/user perspective, the manufacturer needs to provide evidence that what they have built meets the SRD and that satisfying the SRD achieves the URD.

- Customer Budget

All projects are part of a program for which a budget is set by the customer. The budget affects customer affordability because the cost of a manufacturer's solution is usually weighted against the customer budget to decide whether or not to invest in the solution. The delivery of customer requirement in fixed price projects could be affected by changes in the cost of resources e.g. labour rates, fuel price, cost of raw materials as well as factors affecting the supply chain. Fixed price contracts could also exceed budgets, though any change in contracts will require re-negotiation between the supplier and customer.

- Historical data and Expert judgment

The accuracy of cost estimates could be improved with the availability of historic data from previous projects as this can be reviewed in order to forecast future costs. On some projects the customer holds historical data; therefore it would be beneficial to share this data with the manufacturer to enable the delivery of a better solution. Additionally, it is important to ensure that historical data is stored in a way that can be easily retrieved and in a form that other employees can understand of the cost and the context of the data without the need to consult employees previously involved in projects. Furthermore, the availability of historic data helps the customer set a more realistic budget because there is transparency of customers cost data. While expert judgment is useful in cost estimation, a higher degree of accuracy can be achieved when this judgment is enhanced by the provision of historic data.

Techniques

- Expert Judgement

Expert judgment is mainly used across participating organisations in situations where time, information or any other resources are insufficient to use another cost estimation technique. Commonly, the expert judgement technique is used in order to get a rough estimate early in the initial stage, in order to assess whether it would be worthwhile bidding for a project. The subjectivity associated with this method makes it very delicate and controversial. However, this technique is unavoidable because the use of judgment cannot be substituted by a computerised-cost model. Moreover, the cost estimates produced from both algorithmic and non-algorithmic cost models can be inaccurate; and require use of judgment in order to produce a meaningful result.

- Analogy-Based Costing

The method is based on the assumption that similar products share similar characteristics which would lead to them having similar costs. Therefore, it employs information about past estimates to form the basis for the new estimates which have similar characteristics. The methodology is mostly utilised for estimating at the initial stage, since it does not require full details of the project and it generates timely and reliable estimates. However this technique could also become subjective if a lot of adjustments are made to it, meaning that the technique may be combined with expert judgment.

- Parametric Costing

This was explained in detail in Chapter 2 (section 2.7). It uses mathematical equations including regression analysis that relate cost to the physical or performance variables associated with the item being estimated. This technique develops estimates based on Cost Estimation Relationships (CER) which are created by analysing historical data. In many projects top-down estimates are used where there is not enough data available, usually this occurs at the early stages of the project. Parametric models must be based on a significant number of historic programs in order to establish strong parametric relationships. Parametric models are good at explaining historical data rather than latest trends. Also, it is dangerous to use these models to drive requirements because the model might not be robust enough to generate accurate costs when some variables have changed.

The advantages of using Parametric Cost Estimating are:

a) Rapidity of execution
b) No subjectivity
c) Easily replicated
d) Less information required than in analytical methods

However it has some disadvantages which are presented below.

a) It is very difficult to justify the results and understand the reasoning as it works as a 'Black box'
b) It is useful only in combination with other methods
c) Sometimes CERs are too simplistic to predict costs
d) Sometimes some specifications needed for application of this method are not available
e) Uncertainty in the estimate is derived from it.

- Bottom-Up Costing

The Bottom-up Costing method is based on the WBS of the project. As explained in Chapter 2 (section 2.7), though, regarded as a slow method, it is used in all the phases on the CADMID cycle as it ensures higher accuracy It allows the independent estimation of each of the subsections in which the WBS is divided to produce the WLCC. It is generally combined with expert judgement at the early stages of the CADMID cycle due to the unavailability of most of the specific data required. This is applicable where data availability is high, perhaps at latter stages of the project life cycle. A downside to bottom-up is that it could fail to recognise synergies across subsections and thus lead to a higher cost estimate. It is important to select the right costing technique depending on the stage of the contract, information availability and a desire for accuracy. Double counting could occur when each department concentrates on a different subsection and apply their preferred technique for cost estimation. This must be avoided.

The bidding process has been presented in Figure (4-3), but Figure (4-4) presents the stages of the bidding process with the relevant costing techniques.

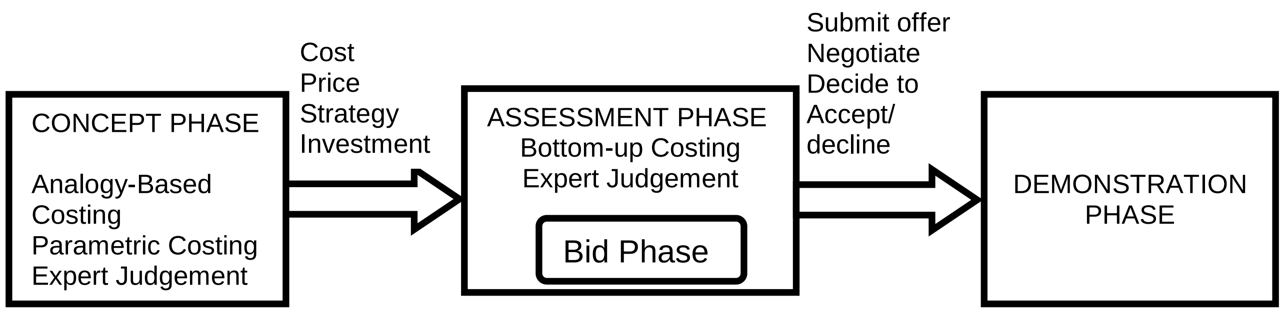


Figure 4-4: Costing techniques at the bidding stage

Tools

Some of the tools employed by the industrial partners are either developed in-house or bought off-the-shelf from commercial providers. Examples of commercial tools are presented in Table (4-7).

Table 4-7: Commercial tools

Commercial tools	**Application**
NASA/Air Force Cost Model (NAFCOM)	estimate development and production cost of space hardware
FAmily of Cost Estimating Tools (FACET)	estimate WLCC of military systems
Operating and Support Cost Analysis Model (OSCAM)	estimate operations costs of high cost capital assets
ProPricer	proposal pricing software, cost analysis and source selection;
COnstructive COst MOdel (COCOMO)	estimating effort, cost, and schedule for software projects
PRICE	estimate and analyse the effort, schedule and cost of projects
System Evaluation and Estimation of Resources (SEER) including SEER-H	estimate hardware cost and schedule including risk analysis.

Examples of in-house tools are: rule-of-thumb and CER are in common.

- A rule-of-thumb is a principle which is an easily learned and easily applied procedure for approximately calculating or recalling some value, or for making some determination using Microsoft Excel and Microsoft Project.
- CERs are applied in mathematical equations where cost is expressed as a dependent variable of one or more independent cost driving variables, or as a function of one or more technical parameters using Microsoft Excel or any other suitable application

The inputs, techniques and tools described above are employed in cost estimating practice for defence contracts. The cost estimating process helps to determine the WLCC of the project and the budget allocation process helps to determine the customer budget. In order to determine the affordability of the project, an affordability process is followed which is described below.

4.3.6 Affordability Assessment Process

Findings from interactions with one customer and three contractors within the defence industry revealed there was no uniform definition of affordability from both parties (customer and contractors), but both parties agreed that affordability related to a comparison between the customer budget and the WLCC of the project. The definition developed by NOE in AE at Cranfield University was proposed and adopted as the standard definition of affordability. The current practice of affordability assessment was captured from the customer and presented in the flow chart in Figure (4-5). Affordability assessment must be done at the bidding stage to inform the negotiations on the scope and price of a contract such that the customer knows if it has the financial strength to bear the burden of the contract, given the value the supplier is able to provide.

The process starts with a cost model (activity❶) being built by the customer which includes provisions made for risks. The estimate could be refined (activity❷) before being fed back to the Directorate Equipment Programme (DEP) who is responsible to the MoD Finance Director for the equipment plan. The Directorate Equipment Capability (DEC) is the equipment customer, also part of the DEP. DEP pull together the plan while the DEC manage the priorities and programme (activity❸). The refined estimates are then measured against top level budget (activity❹). Upon approval, solution providers from industry are invited to tender for the contract, otherwise the estimate needs to be refined (activity❺). At this stage the contract specification could be adjusted based on functionality, performance or availability (activity❿). The financial controller is involved in the process of refining and adjusting the estimates. The customer seeks to build flexibility into the contract. Tenders proposed by industry are examined by the commercial team together with the cost estimate, cost implications of risk and the supply chain sustainability, and then an evaluation is made with the MDAL. After this, through life VFM is assessed through investment appraisal and through life support till the disposal phase.

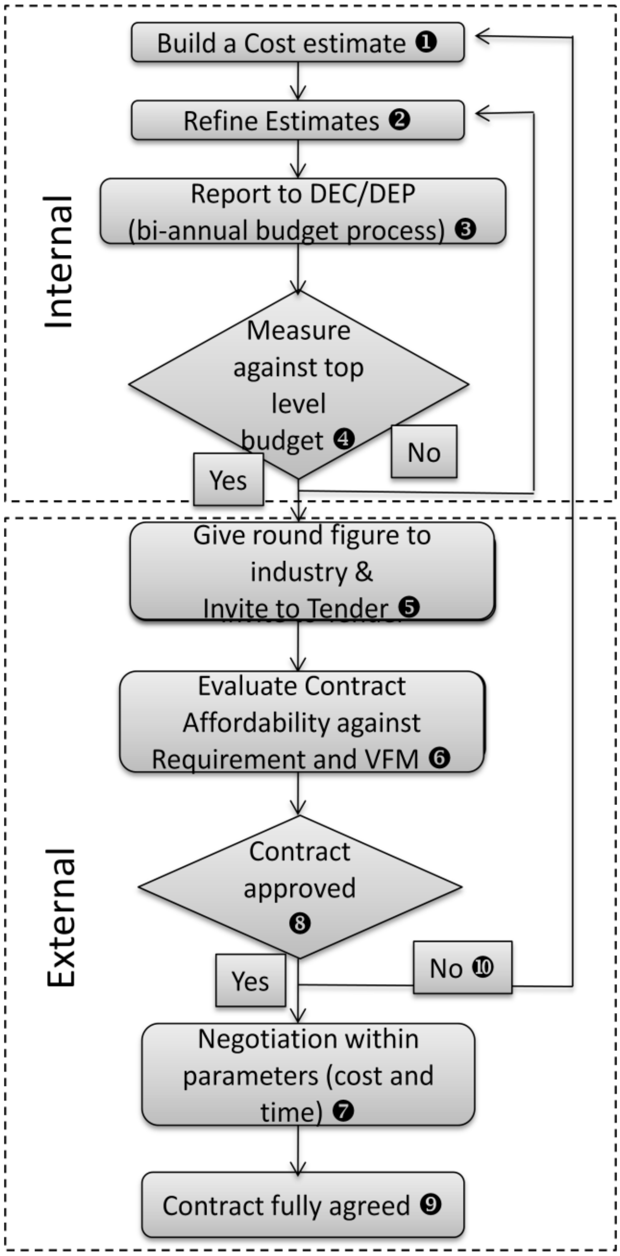


Figure 4-5: The affordability Assessment Process (Bankole et al., 2009a)

These are also compared to in-house capability and the traditional types of contracts in order to make a good prediction of affordability (activity❻). In a single bid, the customer would investigate the solution provider's finances and require a level of detail during the evaluation process, while contractors' responses are compared in competitive bid. If the tender is suitable, the contract would be approved with negotiations within parameters (activity❼). When negotiating the contract with the solution provider, bottom up estimates are done to be able to reduce technical risk and reduce overall cost. The process is iterative in order to get the best solution for the customer. For example reduce availability from 99.9% to 99.5% to achieve cost saving. This negotiation would be taken back to the DEP for approval (activity❽). This leads to a full contract award, otherwise the whole process starts again (activity❾).

The affordability process presented in Figure (4-5) is iterative in order to achieve the best customer solution which could involve settling for a reduced level of availability to save cost e.g. from 99.9% to 99.5%. The earlier stages of process are done internally before an invitation is sent to contractors in industry. This flow chart is more reflective of an individual project. It is useful to note that supplying financial information to the customer to support this process normally requires a significant level of company effort and appropriate management approval/review (Bankole et al., 2009a).

The factors affecting the affordability of defence contracts are CATS, WLCC, Requirement, Value For Money, Environment, Supply Chain, Quality, Legislation, Risk, World Economic Climate, Global Competition, Performance-Related measure, Political Climate and any Other factor which is peculiar to the project. Affordability is usually considered in terms of the major factors such as CATS and WLCC since the other factors are qualitative and cannot be represented in terms of financial values.

4.3.7 Un-affordability

Un-affordability refers to a situation where the customer cannot afford to procure or sustain a product, a service or a PSS. It could occur where the customer's affordability position is getting worse as the WLCC is exceeding the customer's budget. Generally, un-affordability can be caused by a number of factors across the phases of the CADMID cycle as shown in Figure (4-6).

- Performance requirement – If a project cannot be delivered to meet user requirement because equipment is under performing or the customer overestimated the functionality that would be obtained from new technology, it could be considered unaffordable. As soon as this is discovered at the earlier stages of the project life cycle, steps are taken to help correct the failure which could have a cost impact.
- Design flaws – if there are technical flaws in the design of a system or equipment and the manufacturer is not able to correct them, the contract could be brought to an end as the final equipment would not meet customer requirement. This could be discovered and addressed at the early stages of the project life cycle.

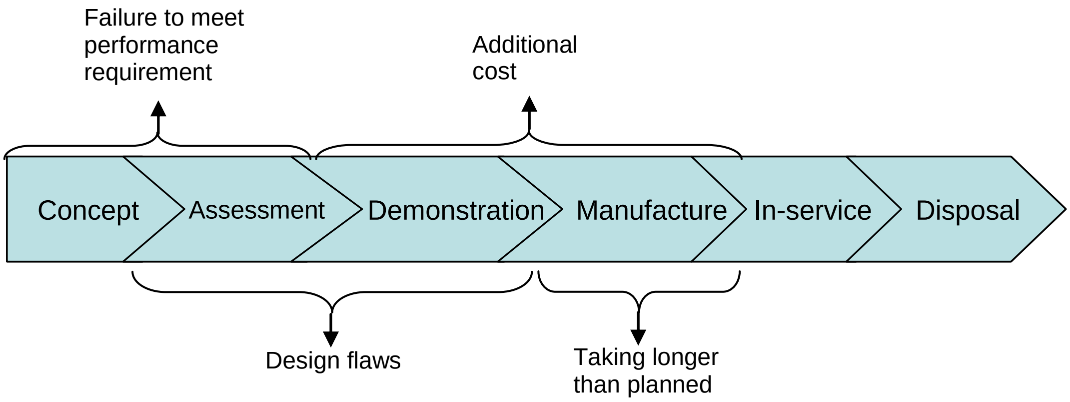


Figure 4-6: Causes of unaffordability across the CADMID Cycle (Bankole et al., 2010b)

- Time – it is very important that the manufacturer can deliver the project within the required time frame as the longer a project takes, the higher the cost of project delivery. This could lead to a project becoming unaffordable. This may not be discovered until later stages of the project life cycle.
- Additional cost – this could occur due to number of reasons especially at the demonstration phase of the CADMID cycle. If the system involved within the project is common, its components could be produced at a lower cost, while a be-spoke system could lead to significant cost increase e.g. the NIMROD aircrafts. This may not be realised until later stages of the project life cycle (Bankole et al., 2010b).

When a project becomes unaffordable, the steps taken to make a project affordable include:

- Capability evaluation – the customer and contractor re-assess the capability requirement to see where they could make trade-offs and take out the luxury requirement while focusing on the basic capability the customer needs.
- Quantity – the customer could choose to reduce the number of equipment or systems in order to reduce the total cost of the project and accept a lower quantity.
- Time – the customer could choose to spread the delivery of the requirement over time in other to reduce immediate expenditure and possibly with the aim of securing more budget allocation along the life of the project (Bankole et al., 2010b).

Affordability Challenges identified from industrial interactions

Apart from the challenge of not having a uniform definition, key challenges identified within industry are as follows:

- The main defence customer has budget constraints which has a major effect on customer affordability of defence contracts alongside the WLCC.
- The customer affordability could be affected by the project team underestimating the cost of the project in order to gain approval at the top-level to secure the contract.
- Projects can become unaffordable due to underestimation of costs, design flaws and inability to meet performance targets at different stages of the life cycle.
- Uncertainty is inherent within cost estimates and also the customer budget which may result in a risk leading to unaffordability during the project life cycle.
- The major determinant of affordability is the customer budget which is determined by the Treasury.
- There was no standard way of predicting or measuring affordability which takes account of the qualitative factors affecting affordability.
- The procurement arm of the MoD sources and secures contracts to deliver defence, is controlled by the Treasury's financial allocation which may not always prioritise the end-user (service men)'s interest.
- The end-user had no view or opinion on affordability, but it can assess customer value in terms of performance. The end-user does not influence the budget allocation on each contract; hence it has no view of affordability.
- The customer's view of VFM is influenced by financial constraint while the end-user's view of value is based on operational need and functionality
- A major challenge identified within the industry is the lack of a standard method or metric of predicting or measuring affordability unlike cost estimation where many tools and measuring techniques exist. Also within literature, no suitable method or technique was available which could be applied to assess the affordability of long-term contracts such as the defence contracts.

4.3.8 Manufacturer profitability

From accounting literature, profitability is usually calculated at the end of the business year in order to assess the financial activities of a firm through the difference between revenue and expenses as well as the financial position of the company in terms of return on investment, efficiency and solvency ratios (Dun and Bradstreet, 2003). However, profitability assessment at the bidding stage when contracting for defence projects is focussed on generating a competitive offer or selling price. In non-competitive government contracts, the UK MoD stipulates the Baseline Profit Rate (BPR) for the manufacturer after giving allowance for the fixed capital servicing and working capital servicing (MoD, 2007; 2009). While the MoD has its own methodology to calculate the contract price, the focus within this research is the contractor manufacturer's profitability assessment.

Within the affordability framework, the profitability module is focussed on the manufacturer generating a competitive price to offer to the customer. This includes consideration for risk, uncertainty and contingency. Different manufacturers employ different approaches in assessing profitability depending on the nature of the project. The profitability assessment in a competitive bid could differ from that of a single bid situation. Also variance would occur depending on the duration of the project and the customer. Within the UK defence environment, the MoD sometimes determines the profit rate for the contractor. The average BPR was 9.74% between 2005 and 2006; 10.14% between 2006 and 2008 which has reduced to 9.74% in 2009 for non-competitive government contracts. In other contracts the MoD has stipulated profit rates of 7% or 4% depending on the nature of the contract (MoD, 2007; 2009). A crucial element in profitability assessment is risk. Risk allocation varies as some contracts carry higher risks than others. For contracts in excess of £5m, the MoD stipulates risk allocation of -10% BPR or +10% BPR, standard BPR depending on the level of risk. However, there is a Contract Baseline Profit Allowance which is allowed for risk provision for firm, fixed-price and target cost contracts (MoD, 2007; 2009). When contractors are trading between each other the profit rate would vary based on the agreement between both parties.

Findings from industry practice reveal that there are a number of drivers affecting the profitability of defence manufacturers. These are: WLCC, CATS (which forms the basis of revenue), Uncertainty (risk), Perceived customer value, Project life cycle, Market trends and Contract life cycle or time.

Some of these have been explained in Chapter 2, they are summarised below.

- WLCC and CATS have been explained in previous chapters as they are major factors of affordability from customer and manufacturer perspectives. The CATS determines the revenue that would be generated in the contract.

- Customer value perceived would influence their WTP for the offering, as explained in Chapter 2.
- Market trends or characteristics such as perfect or imperfect competition as explained in Chapter 2 would affect manufacturer profitability.
- Uncertainty as discussed in Chapters 2 and 5 would impact WLCC and CATS in turn affect manufacturer profitability.
- Life cycle or time refers to the duration of the PSS offering right from conception or contracting to the end of life (disposal or recycling). The long duration of availability and capability contracts has motivated defence manufacturers due to assurance of steady revenue. In addition to the life cycle is the trading plan which shows the stages at which payment would be made during the project delivery. This has a major impact on the cash flow management of the project.

All these factors are taken into account when assessing manufacturer profitability; however different approaches are taken by different manufacturers. Also the choice of method and mechanism to employ is dependent on the nature of the contract and the stages of the life cycle.

In addition to the factors provided above, some minor qualitative drivers that affect profitability include:

- Nature of business – if the market and/or product are new, the contractor may be willing to sacrifice some profit to be able to enter and build market share in the new market.
- Strategic advantage – in order to keep competition out of the market, the contractor might need to position itself in a particular market, perhaps to improve its reputation and maintain a strong presence.
- Off-set requirement – An illustration of this is seen in an example where the Indian government might require a UK manufacturer to buy raw materials from India or employ Indian subcontractors. This may help reduce the cost of import (increase profit), but reduce the quality of the solution delivered.
- Political interest – The national interest of countries must be protected. For example, the UK government could prohibit some UK contractors from having business dealings with certain countries that are regarded as enemy countries.
- Intellectual Property protection – This could occur in situation where a UK contractor owns the intellectual property to a technology in a foreign country where it is operating.

Other companies within the same country could decide to copy the technology without paying royalties and succeed because there is no legislation prohibiting the practice. This would have a negative impact on the business relationship and could have financial consequences on the UK contractor's profitability and their willingness to continue with the business.

These drivers may not affect every defence project; however it is useful to recognise them. Profitability is generally measured as Revenue less WLCC. Another method of assessing the financial value of a project is the net present value approach

Net Present Value (NPV) Calculation

This has been explained in Chapter 2 (section 2.4.1). Additionally, as part of investment appraisal, manufacturers apply different techniques to ensure that they would achieve return on their investment in defence contracts. Management accounting methods which are applied include Accounting rate of return, Payback period, Internal rate of return and NPV (Atrill and Mclaney, 2007). A common method across defence manufacturer firms involved in this study was NPV. This method is used to evaluate investment decision by taking account of cash inflows and outflows over a period of time to ascertain if the manufacturer would recover its investment along the project life cycle. The NPV of an investment is affected by risk, inflation and interest loss (Atrill and Mclaney, 2007). It is measured by the formula below.

$$\text{PV of the cash flow of year n} = \frac{\text{Actual cash flow of the year n}}{(1+r)^n} \tag{4.1}$$

Where PV = Present Value for each year; n = the year of the cash flow

r = the rate of investment

The NPV is generated by adding together the sum of the PV of all the years. The cumulative PV also helps to determine the payback period for the investment. Within defence contracts there are milestone payments agreed between both parties based on the manufacturer's delivery of customer requirement. This method is also included in the profitability module within the affordability framework.

Earned Value Management (EVM)

This has been explained in Chapter 2 (section 2.7). It is an integrated management control system for assessing, understanding and quantifying the value a manufacturer would achieve by investing in a project (NASA, 2009). The technique is used to establish and manage goals and risks within a defence project by monitoring progress in the project in terms of cost, time and tangible attainment against the schedule. The advantages of EVM are presented below:

- Integrates technical, cost, schedule, with risk management
- Allows objective assessment and quantification of current project performance
- Helps predict future performance based on trends (NASA, 2009).

This technique would not be used when estimating the offer price of contracts; rather it would be used when the contract has started to compare actual cost against the target and the payment received from the customer. This explains why it has not been included in the profitability assessment module of the affordability framework.

In industry practice, profitability assessment at the bidding stage is aimed at calculating a competitive selling price as the profit rate is given in many cases. However, the current practice does not reflect possible changes over the life of the project due to uncertainty. Though contingency and escalation have been included in the calculating the WLCC, this has been done as a round figure. The uncertainty in the CATS could have a major impact on profitability, hence the need for a method of assessment which reflects the periodic changes during the life cycle of the project.

Industrial interviews findings on manufacturer profitability

A member of the finance department joins the bidding team during the bid process together with the project manager, and project accountant to assess profitability. After initial estimates, assumptions are made concerning the margin; but, unforeseen problems or delays could later affect this margin. To make the prediction, it is important to have up-to-date costing of work packages, monthly costs incurred, Estimate to completion and selling price to customer or order value. After estimates are done, the margin is incorporated to the selling price offered to the customer. Standard accounting profit and loss assessment is done at the end of the year end while the profitability margin is measured at the project level which eventually leads to total organisational profitability.

Challenges

Challenges in predicting long-term profitability include:

- Fluctuating exchange rate
- Fuel price increase
- The risk registers – e.g. areas of risk within the project which would be difficult to implement sometimes
- Supplier bankruptcy - If a supplier goes out of business, the contractor would be solely responsible for project delivery. This could lead to delay over a period of time for which the contractor would incur additional costs
- Difficulty of understanding cost at the component level.

Management contingencies are usually built into rectify these escalations and rise in WLCC.

Resolution strategies

By interfacing with prime contractor, some of these problems could be rectified, but the company may have to bear some costs in order to maintain a good reputation and relationship as it delivers to meet the customer requirement. For example, equipment which is owned by the contractor, but run at the customer's site could cause to a delay in the final delivery of the contract if the customer does not return the equipment on time. However, the contractor still has to maintain its own workforce and pay them, though they are not able to work on the equipment for a space of time.

WLCC could also affect profitability based on the warranty period specified to the customer. There is a need to understand the life cycle of the product in order to provide the right warranty. It is also important to ensure that both contractor and customer have the same understanding and ensure smooth communication channel between both parties. This is because sometimes the customer does not understand its own need so it is best to communicate the need to the contractor and the contractor transforms this into a requirement that would form the basis of the product or system design.

Monitoring

Once the project commences, profitability is monitored by the senior project accountant who checks different cost packages through a monthly assessment through cost evaluation and schedule modules. Each month contract status report is produced at each review to assess profitability based on work done so far and cost to completion changes over time.

The UK MoD restricts the level of margin the contractor can get in a Private Finance Initiative (PFI) contract which is between 8 and 10%. However, there is no restriction with other customers. The findings from supplier sustainability are presented below.

4.3.9 Supplier sustainability

Supplier sustainability here focuses on the supplier's ability to remain financial and operationally sustainable over the life cycle of the project. In the defence industry, like other industries, strategic decisions have to be made by different parties at the stages leading to the contract award. As earlier explained, the customer identifies a defence need and invites different contractors to tender and bid for the contract before awarding the contract. The contractor who wins the contract becomes the prime contractor and works along with first and second-tier suppliers to deliver the contract (competitive bid). At other times, the customer decides to negotiate with one contractor to deliver the project (single bid) along with low-tier suppliers. In a competitive bid situation, prime contractors could win a bid on the basis of capability (technology expertise) or on the basis of cost-leadership. In some contracts, the customer could be involved in the selection of sub-contractors (suppliers) to work with the prime contractor, but in many cases the prime contractor chooses the sub-contractors to involve within the project. After contracting, the life cycle of defence contracts is represented in the CADMID cycle for which the customer could contract for some phases of the CADMID or all phases.

One attribute that affects defence bids is the relationship between the customer and the prime contractor (Graham and Hardaker, 1998). This could affect the decision on the procurement method which could be either single source or competitive bid. The MoD would only award the contract to a contractor through a single source arrangement as a result of a good relationship, based on past performance. Also in a competitive bid, a good relationship based on past performance could have an impact on a contractor's ability to win a contract. This explains the motive behind Smart acquisition initiate to encourage through life consideration and effective delivery in terms of cost, performance and time (MoD, 2005). The PFI and the public private partnerships were designed to encourage a closer working relationship with key suppliers and provide better value capability and profit returns to both parties (MoD, 2005). The MoD's defence industrial strategy states that partnership relationships are designed for mutual benefits to share risks and reward performance. This is in alignment with (Mohr and Spekman, 1994)'s definition of partnerships as being "purposive strategic relationships between independent firms who share compatible goals, strive for mutual benefit, and acknowledge a high level of mutual interdependence". The sustainability of supplier and contractors is indispensable to realise the benefits of partnership. Some of the forces that influence these relationships are poor infrastructure, failure to meet customer requirement and inventory management.

These challenges would vary depending on peace time or war situation. This means that the defence supplier is required to capable of handling these challenges and still meet customer demand, while maintaining competitive advantage. Long-term financial and operational sustainability is inevitable to be able to achieve this. From the perspective of a prime contractor, the sustainability of a low-tier supplier is important because of:

i. Counterfeit products – There are much counterfeit equipment worldwide which resemble the original; hence it is important to ensure that the suppliers providing equipment are trustworthy and their products are original.
ii. Quality Standards - There are quality standards for many components including wood. Suppliers could mislead contractors to think that such components are meeting quality standards by processing old component to look like new. For this reason, it is important to ensure suppliers comply with the quality standards and new legislation on quality continually.
iii. Financial sustainability – Good cash flow management is important because cash flow problems could lead to bankruptcy as seen in the case of Chrysler's supplier, Plastech, which caused the automotive manufacturer to temporarily close down four plants in 2008, thereby losing $millions (Trkman and McCormack, 2009).

It is better to know the state of the supplier sooner during contract negotiation rather than later as this could become major source of risk and uncertainty; having a negative financial impact. Prime contractors adopt different measures to assess suppliers before contracting with them, but the industry has developed an initiative to assess supplier's ability and performance. The Supply Chain21 (SC21) initiative developed by companies within civil and defence aerospace industries in 2006 embraced the EFQM framework and developed other metrics to measure performance improvement in organisations under four elements namely; sustainable improvement, performance metrics, improvement framework and recognition (SC21, 2009). The EFQM excellence model is a robust technique for assessing overall organisational performance from the strategic level (including leadership) down to the operational level. The SC21 initiative 'is a change programme designed to accelerate the competitiveness' of the civil and defence aerospace industries by raising the performance of its supply chains (SC21, 2009). The implementation of the initiative focuses on three streams.

- Certification and quality improvement – common standards such as AS/EN 91XX and Nadcap are adopted across industry as the quality standards. AS/EN 91XX is the standard for quality management systems while Nadcap is a standard for assessing the manufacturing processes such as chemical processing, coatings, composites, surface enhancement etc.
- Development and performance – This process has four elements: sustainable improvement, performance metrics, improvement framework and recognition. For sustainable improvement, an Act-Plan-Do-Review Model is employed which is linked to key performance indicators. Performance metrics based on delivery and quality are also developed to measure the performance of suppliers within the supply chain. Two of these measures are represented below.

$$\text{Delivery} = \frac{Number\ of\ 'Ontime'\ deliveries}{Number\ of\ scheduled\ deliveries} \quad (4.2)$$

$$\text{Quality} = 1 - \frac{Number\ of\ rejects}{Number\ of\ deliveries} * 100 \quad (4.3)$$

Number of 'On Time' deliveries refers to number of products e.g. steel delivered on-time at the agreed date

Number of Scheduled deliveries refers to number of products planned for delivery at an agreed date

Number of rejects refers to number of products rejected after delivery

Number of deliveries refers to number of products delivered at an agreed date

In addition to this, the EFQM excellence framework is adapted to measure performance and achieve excellence together with Lean manufacturing principles. Recognition is done through an award system which gives gold, silver or bronze awards based on the three elements explained above.

- Relationships - The programme adopts a view that the manner of interaction and communication between suppliers would impact the industry's performance. In order to assess supplier relationship, a code of practice was developed. This comprises five elements, namely: communications, through life capability management, continuous improvements, commercial agreements and ethics (SC21, 2009).

Companies within these industries adopt different measures in assessing their supplier performance. While most of the metrics SC21 initiative are focused on the measurement of products and processes (SC21, 2009), little or no measures have been developed for the measurement of services.

The link between the three perspectives of affordability represented in the three modules within the affordability framework is shown in Figure (4-7). The result of the sustainability assessment would inform the supply chain cost within the manufacturer's cost estimate which would be used to assess manufacturer profitability. The result of WLCC estimate which combines profit and cost to provide the offer price would be used by the customer in assessing the affordability of the contract.

Industrial interviews findings on supplier sustainability

The interview session revealed that a supplier sustainability assessment as identified by the researcher was not being done in a singular and focused manner. The current practice was focused on supplier engagement, supplier management and supplier performance measurement. Sustainability assessment is linked to performance measurement, but the main difference is that the focus of the measurement is on financial and operational performance which is being measured by monitoring trends in performance over time.

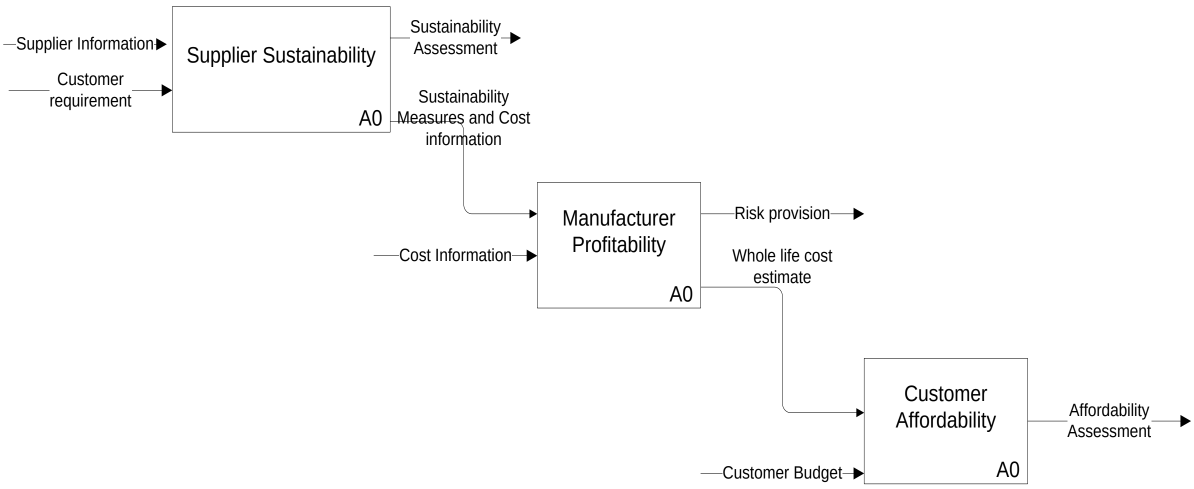


Figure 4-7: Link between customer affordability, manufacturer profitability and supplier sustainability

The current practice shows that supplier engagement is done at the bidding stage when the Invitation to Tender (ITT) has been sent to the manufacturer. Part of the WLCC estimation during the bidding process includes the supply chain costs which comprise material and sub contractor costs. In order to provide these costs, potential suppliers are selected from the approved suppliers list to be involved in the project. Then capability assessment is done to ascertain that the supplier can help to deliver the customer requirement. At other times, the UK MoD may specify that the manufacturer engages with certain suppliers for economic or other reasons. The supplier engagement could also be guided by the customer requirement. Where the requirement is unique, there may only be one or two suppliers with the capability to meet the requirement. The financial viability of such supplier is crucial to the success of the project. Generally the manufacturer would try to provide enough information for the supplier as soon as this is available. Each manufacturer has its own measures used to assess its suppliers before contracting with them. Some manufacturers design a questionnaire which the supplier must fill out after which a financial check might be done. This is to check the supplier's commercial viability as well as their track record. Once the supplier is approved, then, they are involved in the delivery of the project. Some strategic suppliers are involved as early as possible while suppliers of commercial off-the-shelf items may only be involved at the latter stages of the bidding process. In the selection process price, risk, financial stability, commercial facility and company history are considered by the procurement team, bid manager, engineering manager and the project manager. Knowledge about supplier capability at the may be available at the corporate level within the manufacturer organisation, but there is a need for each project team to assess the suppliers before contracting with them. This could include paying visits to assess supplier facilities and watch their performance in other projects.

Tools

Tools such as EVM could be used to measures supplier performance during the project life cycle which requires cost and schedule performance indicators, though some suppliers are reluctant to embrace the EVM application. Also relationship management tools are used to assess supplier's relationship with their customers. Additionally, suppliers are also assessed using a scoring mechanism which is measured against a given criteria. Agility and responsiveness are crucial to supplier performance. The role of suppliers in maintaining capability over time is important because a major supplier might be the only one who possesses the capability to build equipment. This means it would be the main source of maintenance and support services.

Challenges

There are challenges involved in predicting long-term sustainability because it is important to provide the support needed for a supplier to be able to take risks. Also risks must be bounded to ensure that the supplier can handle the risk and still deliver the requirement. Supplier sustainability can be maintained by the manufacturer providing steady demand to keep suppliers in profitable operations.

Generally, suppliers are affected by market demand, dynamic requirement, financial stability, competition and take-over. Also smaller suppliers could be negatively affected by uncertainties, while the bigger companies are more stable. The manufacturer could choose to change a supplier if it goes bankrupt or sometimes if a cheaper supplier is identified who delivers the value desired.

In order to manage its suppliers, a manufacturer could choose to use open systems with common components so that it is easy to procure components from different suppliers. The application of the findings in developing measures for assessing manufacturer profitability and supplier sustainability is presented in the next sections.

4.4 Gaps between academia and industry

From the review of literature and industrial interaction, a comparison was made between industrial practice and academic research. These reflect the need for further research in the three affordability perspectives particularly in the formulation of metrics for assessment and control in industry and academia.

4.4.1 Customer affordability

- Definition
    - In academia, the concept of affordability is in its infancy even though the words "afford", "affordable" or "affordability" are commonly used. The standard definition formulated by Cranfield University's NoE in AE has been adopted.

    - Within industry, customer affordability is usually seen as a factor which affects the delivery of defence solutions. For this reasons, there is no formal definition of customer affordability in industry.
- Method of Assessment
    - In academia, some methods were developed to assess customer affordability including the AI. This assessment method was refined by the researcher to make it more suitable for the defence industry. This is further explained in Chapter 5.
    - Within industry, not much work has been done to develop methods of assessing customer affordability for the aerospace and defence industries; rather a comparison is made between the WLCC and CATS.

4.4.2 Manufacturer Profitability

- Definition – profitability is usually defined as revenue less cost. The focus here is to on the calculation and measurement.
- Method of Assessment
    - In academia, profitability assessment is well established, but the focus is usually on profitability at the end of the financial year.
    - Within industry, there are methods employed is assessing manufacturer profitability both at the bidding stage and the end of the financial year to arrive at a competitive selling price. A generic process was presented in this Chapter which could vary from one manufacturer to another.
    - The major challenge is to assess profitability by taking account of time and the impact of changes in the customer budget over the life cycle of the project. This is not being done both in industry and academia.

4.4.3 Supplier sustainability

- Definition
    - In academia, there is no definition for supplier sustainability, however a definition has been developed by the researcher.
    - Within industry, there is also no definition for supplier sustainability as the concept is emerging from academia.
- Method of Assessment

- In academia, there are methods employed in assessing supplier performance and continuous improvement, but they are not necessarily focussed on financial and operational sustainability.
- The SC21 initiative is the result of the effort of the defence industry to develop a method of assessing the sustainability of suppliers. However, only a few performance measures are provided. Most of the measures are focussed on measuring current performance rather than long-term sustainability. Also most of the metrics in the SC21 initiative are focused on the measurement of products and processes and little or no measures have been developed for the measurement of services.

The gap identified above from the three perspectives of affordability formed the focus of the research activity as shown in the next few chapters.

4.5 Summary

This chapter presented the industrial interviews employed in capturing the current state of affordability in the defence sector. This helped to capture the current state of the defence environment, budget allocation process, the defence budget, cost estimating practice, overall affordability assessment process as well as customer affordability, manufacturer profitability and supplier sustainability practice in four defence companies. The industry practice was captured through the design of questionnaires administered through face-to-face interviews which was clarified and analysed through telephone discussions (where necessary). The various measures, drivers and factors employed in assessing customer affordability, manufacturer profitability and supplier sustainability were described alongside the challenges and possible resolution strategies. The chapter also identified the gap between industry practice and literature. The gap highlighted the need for measures for assessing affordability which take account of both qualitative and quantitative factors. Also there is a need for a profitability assessment that takes account of time and changes in customer budget which would affect manufacturer profitability. Finally there is a need to develop metrics which can assess the financial and operational sustainability of suppliers in the provision of products and services in the long-term. The needs identified through the gap are addressed in Chapters 5 and 6 which presents the research contribution to cover the research gap. This Chapter has helped to achieve the objectives of capturing the current industrial practice as well as identifying the gap between academia and industrial practice as stated in Chapter 3.

CHAPTER 5
CUSTOMER AFFORDABILITY ASSESSMENT AND MANAGEMENT

5.1 Introduction

The previous chapter contained findings from the industrial practice of affordability assessment from the three perspectives namely customer, manufacturer and supplier, and identified the gap between literature and industrial practice. This gap provided direction for the research activity. Therefore, this chapter outlines the researcher's further investigation into each of the qualitative and quantitative factors affecting customer affordability that were highlighted in Chapter 4; and furthermore presents the development of a customer affordability assessment framework for defence contracts.

5.2 Customer affordability assessment

As explained in Chapters 2 (section 2.3) and 4 (section 4.3.6), customer affordability is defined as the degree to which the WLCC of an individual project or program is in consonance with the long range investment capability and evolving customer requirement (Ray et al., 2006). As presented in Chapters 2 and 3, the existing affordability assessment both in industry and academia is focused on the quantitative factors. In order to reflect the impact of qualitative factors, the researcher proposed a customer affordability framework that is implemented as a customer affordability system, including both qualitative and quantitative factors, and provides recommendations for improving customer affordability. The proposed framework generates the qualitative and quantitative assessments separately. These are fully explained in this Chapter together with the approach adopted in the framework development and system implementation.

5.3 Methodology employed in framework development

As mentioned earlier in Chapter 2 (sections 2.7 and 2.8), the interview protocol was informed by the literature review which helped to identify themes related to affordability, such as whole cost estimation and budget setting. The companies (two manufacturers and one customer) to be involved in the study were selected based on their sector (defence) and their willingness to participate in the study. Familiarisation interviews were held with the companies for the researcher to gain fundamental understanding of their operations and help the industrial experts understand the context of the study in order to commence initial data collection and to identify potential case studies for the study. In preparation for the interviews, questionnaires were developed around the themes identified and structured under various headings. The questionnaires were reviewed and refined to make them more suitable for the study and a semi-structured interview method was adopted in adherence to best practise research techniques. A pilot of the interview protocol was conducted with one industrial partner, after which introductory interviews were conducted with other industrial partners. The outcome of these interviews informed the development of the next set of questionnaires to commence data collection.

5.3.1 Design of questionnaires

The design of the questionnaires was guided by findings from the initial literature review as well as the research objectives provided in Chapter 3 (section 3.4). The focus of the questionnaires at the initial stage was to gain a background understanding of the defence environment and issues relating to contracting at the bidding stage. A pilot session was conducted with an industrial collaborator before being conducted with other companies.

Some of the questions asked at the first interview are presented below:

1. What is your understanding/definition of affordability?
2. What factors drive/affect your Affordability (qualitative and quantitative)?
3. What additional risks arose, in terms affordability, when you got to availability contracts – what financial burdens did they put on you as the customer?
4. How does Affordability change from sale of product to a contract?
5. How is Affordability predicted at the bidding stage (Flow chart description)?
6. Is there a difference between what you can afford and what you are willing to pay, or are they both the same thing?
7. How do you define Customer Value? – Customer 1 and Customer 2.
8. How do you measure Customer Value? – Customer 1 and Customer 2.

After this, another set of questionnaires was designed to capture the understanding and practice of affordability in defence contracting. Some examples of the questions posed at the second interviews are presented below:

1. What level of information is available at the bidding stage for each factor?
2. How does each factor impact on different stages of the CADMID cycle?
3. How does each factor weigh at the bidding stage? Is there a difference in a single source situation/competitive bid?
4. What could be Key Performance Indicators (KPIs) generally?
5. From your experience, could you give an example where a project became unaffordable during its lifecycle? Could please explain why?
6. What additional risks come in terms affordability when you got to availability contracts?
7. What are the sources of uncertainties involved in affordability assessment at the bidding stage?

Both open-ended and closed questions were included in the semi-structured interviews.
As explained in Chapter 4 (section 4.2.4), the researcher prepared two copies of questionnaires, the respondent's copy containing the questions and the researcher's copy, which included both questions and space to record the responses to each question. Where applicable, the respondent(s) would provide addition information in form of documents. The responses were analysed in terms of similarities and differences. This informed the design of the next set of questionnaires. At the validation stage of the research, questionnaires were designed which respondents filled based on their understanding of the affordability framework. This is discussed further in Chapter 9. The main questions are provided below and the process followed for conducting the interviews is further explained below.

5.3.2 Industrial interviews

In carrying out the data collection to establish the current practice and begin the framework development, industrial interviews were employed. This approach was employed in order to obtain the opinions of various individuals identified within the companies such as the project managers, business development managers, cost assurance team leaders etc. As mentioned in Chapter 4 (section 4.2.5), the companies were selected based on their interest in the research area and ability to give time and provide data for the research. The respondents were chosen from three companies among the industrial collaborators within the defence industry. At the other stages of the research such as the validation of the initial framework and case study analysis, these companies in addition to other companies among the industrial collaborators were also involved at this stage of the research as described in Chapter 9. The profiles of the industrial experts in cost estimation and affordability assessment from each company were provided in Chapter 4 in Tables (4-1), (4-2) and (4-4).
As explained in Chapter 4 (4.2.6), the initial interview sessions were held with 10 industrial experts in groups within the selected organisations and the responses were captured by hand-written notes and audio recording. These were analysed using the mind manager tool to identify various trends. The results enabled the researcher to understand the current practice of defence contracting, life cost estimation and affordability. The analysis of results led to a further literature review of recommended materials and other useful documents. The results also helped to identify the need to investigate the budget setting practice since the result of the process has a major impact on customer affordability. Following the introductory sessions was the data collection period. A semi-structured interview approach was adopted during the data collection with industrial experts. The next set of questionnaires developed for the next stage of data

collection are provided in Appendices B and E. These questionnaires focus on customer affordability and the approach to budget setting.

Additional methods of data collection were employed including searching publicly available information on the Internet or specific industry databases, obtaining available company information on previous bids and reading press reports to investigate data obtained from the interviews. The results helped to identify factors and measures for each perspective of affordability and a new set of questionnaires were designed to focus and gain deeper insight into these factors and measures and the budget setting process. Findings from the sessions informed the initial development of the affordability module of the overall framework. These include the qualitative and quantitative customer affordability factors and measures as well as guidelines for improving customer affordability. Telephone discussions were also employed in data collection as described below.

5.3.3 Telephone discussions

The telephone discussions were generally employed to clarify and analyse the information obtained from the face-to-face interviews with the experts. They were also used to arrange interviews session with two experts who could not provide face-to-face interviews due to time and venue constraints. Telephone interviews were carried out in a similar fashion to the face-to-face sessions, but usually conducted with one expert at a time. The findings from these interview sessions are presented in the sections below.

5.3.4 Industry interview findings

The findings are summarised below.

- The defence environment is moving from spares and repairs contracts towards service and performance-based contracts like availability and capability contracts.
- The main defence customer has budget constraints, which has a major effect on customer affordability of defence contracts alongside the WLCC.
- Customer affordability can be affected by the project team underestimating the cost of the project in order to gain approval at the top-level to secure the contract.
- Projects can become unaffordable due to underestimation of costs, design flaws and inability to meet performance targets at different stages of the life cycle.
- Uncertainty is inherent within cost estimates and the customer budget.
- In order to achieve cost savings, the customer does not always disclose the amount of budget available to the manufacturer in a competitive bid.

- Upon contract award, the manufacturer engages closely with the customer to agree on the terms of the contract.

There is no systematic approach to assess customer affordability in industry. The AI designed by Nogal (2006) for the civil and defence aerospace sector can be refined for specific application to the defence sector. The main challenge lies in employing the qualitative factors in the assessment of customer affordability, as this would require a process of quantifying the factors and determining their respective impact on customer affordability. In order to address some of these challenges the customer affordability module, which is a part of the overall affordability framework, was developed and embraces both qualitative and quantitative factors. The customer affordability module within the affordability framework addresses the qualitative and quantitative factors separately to provide an accurate assessment.

5.4 Customer Affordability Module

A framework is defined as 'a hypothetical description of a complex entity or process; a set of assumptions, concepts, values, and practices that constitutes a way of viewing reality' (free dictionary, 2010), while a system is defined as 'an assemblage or combination of things or parts forming a complex or unitary whole.' The affordability framework provides a hypothetical description of a complex entity encompassing assumptions and concepts, etc. Since the whole concept of affordability encompasses three other subject matters, namely customer affordability, manufacturer profitability and supplier sustainability including an audit and management process (Figure 7-1), it is best presented in the form of a framework. Each of the main subject areas may be presented as a system or a module because they combine different elements within them that require input to generate an output. Within this research a framework has been designed to address the gap identified from the literature review and industry practice from the three affordability perspectives. Within this chapter, the focus of the customer affordability assessment module within the framework is to fulfil the research objective of investigating qualitative and quantitative factors affecting customer affordability and generating the customer Affordability Index (AI) to measure customer affordability.

The defence customer is keen to see that its requirements are delivered within budget while the prime contractor is concerned about meeting customer expectations, maintaining the desired level of profitability and finding suppliers that will be financially sustainable over the lifecycle of the contract.

The framework was designed to be implemented using Microsoft Excel software, as recommended by the industrial partners due to its functionality and accessibility to customer and manufacturer organisations, and academic researchers. Each module within the framework was validated with the industrial partners and this is discussed further in Chapter 9. Findings from the initial interview sessions as well as the literature review provided data for the overall affordability framework development.

Customer Affordability Factors

Findings from industry practice and literature revealed there are two major quantitative factors (whole life cycle cost and customer budget) and twelve qualitative factors (all other factors presented in Figure 5-1) affecting customer affordability; and uncertainty was identified as a factor which is common to them all. These factors are explained in Table (5-1).

The most important factors out of all fourteen are the two quantitative factors, and the five qualitative factors that are presented in bold in Figure (5-1). These five factors were chosen because the respondents identified them as the major factors affecting affordability during the industrial interviews. In capturing customer affordability, there was a closer interaction with the customer organisation (MoD), and this aided the identification of the most important affordability factors. These were the factors that the customer believed were crucial to their operations. The other factors, such as political climate, legislation, world economic climate, and global competition, are also important to the delivery of defence projects but they are greatly affected by external forces that defence customers and manufacturers may not be able to control. Uncertainty, which has an element of risk, is considered in detail in Chapter 8.

Performance related measures can also be presented as a way of measuring value for money; hence it will not be assessed as a separate factor. All qualitative and quantitative affordability factors are further grouped into pillars, drivers and capabilities within the customer affordability model (Figure 5-2). The pillars are the two quantitative factors, WLCC and CATS, which are the most important factors. The capabilities (major qualitative factors) required in assuring customer affordability include customer requirement, VFM, quality, supply chain and environment.

Figure 5-1: Affordability Factors (qualitative and quantitative)

The drivers are those qualitative factors that are outside the control of the manufacturer, yet they drive customer affordability. These include uncertainty, performance related measures, political climate, legislation, world economic climate and global competition. The other qualitative factor that was not included in the model is 'other'. Other refers to any other factors that arise from the project. This could be a driver or a capability, hence the reason why it wasn't included in the model. The output of the model is customer affordability that is sustainable over the lifecycle of the defence project. This explains why the top five qualitative factors (capabilities) have been selected to form the basis of assessment in the customer affordability model, which is implemented as a module within the overall framework.

5.5 Quantitative Assessment

As stated earlier, the quantitative assessment is based on both quantitative factors. As shown in Chapter 2 (section 2.4.1), the AI is the mathematical equation employed to generate a score that is an indication of how affordable a project is. The AI was originally generated by Nogal (2006) for the aerospace sector and revised by Bankole et al. (2010b) to improve accuracy with conditions under which the AI should be employed. Nogal (2006) identified two quantitative factors and ten qualitative factors within the civil aerospace domain, which formed the basis of an AI, combining both qualitative and quantitative factors.

Table 5-1: Description of Affordability factors

No	Affordability Factors	Description
1	**Customer Budget (CATS) (quantitative)**	This refers to the financial ability of the customer to procure a contract based on the budget allocation. It is also represented as Customer Available To Spend (CATS).
2	**Whole Life Cycle Cost (WLCC) (quantitative)**	This refers to the cost of a contract across the life cycle from the concept stage to disposal.
3	**Requirement (R)**	Customer requirement forms the basis of the contract and a change of requirement could increase the WLCC of the project where extra effort is required in redesigning the system, especially with be-spoke systems and services.
4	**Value For Money (VFM)**	The customer assesses tender responses from suppliers against VFM; this may be done by employing three techniques, namely economy, efficiency and effectiveness.
5	**Environment (E)**	This refers to a company's responsibility to ensure that its operations and activities are environmentally friendly. This ensures sustainability.
6	**Supply Chain (SC)**	Lower tier suppliers are crucial to the delivery of both products and services for the duration of the availability or capability contract life. The challenge is to ensure continuity in the supply chain over the contract life.
7	**Quality (Q)**	Customer focuses on a specific project and the financial commitment involved in that project to ascertain that the solution is delivered at high quality. Therefore, customer's affordability is influenced by perception and interpretation of quality.
8	Legislation	Changes in UK, EU and International law, regulations, and protocols concerning the environment, safety and social issues can affect affordability. This impacts both the WLCC at the outset of the project and the affordability of extant projects.
9	Uncertainty	Uncertainty represents any variation from the initial target, whether positive or negative (risk). Risk is the combination of the probability of an event occurring and its consequences on the contract. This should be assessed and adequate provision should be made while contracting in order to ensure the affordability of the contract. This is an important factor, hence it is common to all the other factors
10	World Economic Climate	The economic climate is influenced by inflation, interest rates and share prices. Exchange rate fluctuation between two currencies dictates how much one currency is worth in terms of the other. This can have a negative or positive effect on affordability.
11	Global Competition	Competition reduces cost. If competitors are offering lower prices, a supplier could be forced to reduce the cost of their service. Suppliers/contractors from other countries could provide attractive offers in order to expand their customer base.
12	Performance-Related measures	In some contracts, full payment is made upon contract delivery; hence the level of customer satisfaction with the delivery and performance of capability could impact the CWTP, based on system or equipment performance. This is linked directly to performance management.
13	Political Climate	The defence industry's operations are typically affected by the nation's political climate. Perceived threats from other nations can affect the government's willingness to invest in defence projects.
14	Other	This applies to any other factors that arise as a result of the nature of the project.

However, Bankole et al. (2010b) identified two quantitative factors, as did Nogal (2006) and twelve qualitative factors from the defence sector, some of which were similar to Nogal's (2006). The initial AI was not accurate because it combined variables, which had different characteristics into one equation; therefore, Bankole et al. (2010b) retained the quantitative variables within the AI and suggested a suitable method for assessing the qualitative factors, which reflects the importance and impact of each variable in a defence project. In addition, when the existing AI from the civil aerospace sector (Nogal, 2006) was applied to case studies within the defence sector it generated some inaccurate results; hence, the need to provide conditions under which the quantitative part of the AI may be applied in the defence sector. The new AI is presented below with conditions.

The AI is presented in equation (5.1).

$$AI = \frac{CATS}{WLCC}\left(1 - \left(\sum_{i=1}^{n} \frac{(C_i - S_i)}{S_i}\right) * \frac{1}{n}\right) \tag{5.1}$$

Where:

i = The years where cost exceeds the expected spending ability of the customer

Si = Expected spending ability of the customer for the ith year

Ci = Cost incurred in the ith year,

n = total number of years the WLCC has exceeded the Total Customer Budget.

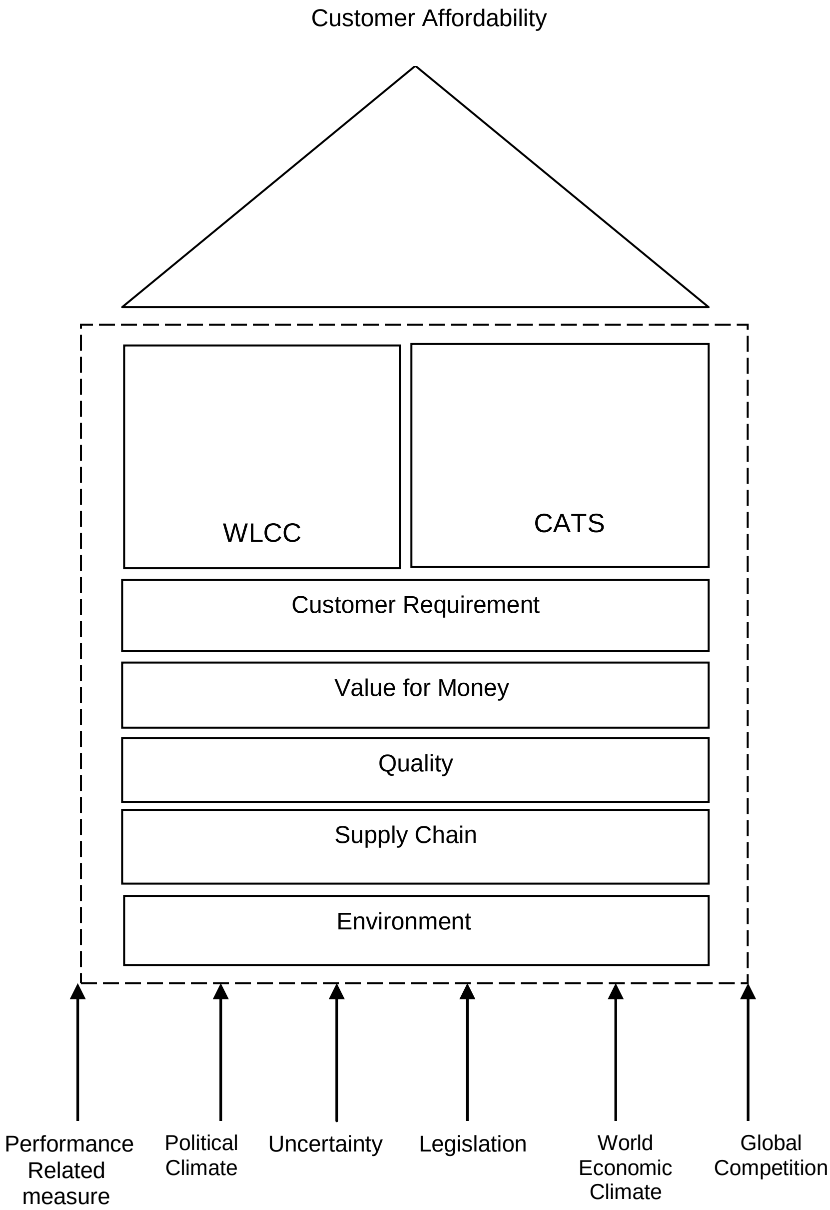


Figure 5-2: Customer Affordability Model

The conditions to apply this AI are:

(i) If sum of CATS > 0, then apply full AI

(ii) If sum of WLCC < CATS or WLCC = CATS, then only apply CATS/WLCC

(iii) If sum of WLCC > CATS, then apply full AI. This means there is a violation in the profile

(iv) Apply full AI if there are any violations in the spend profile.

The result of the AI is interpreted thus:

If, AI >1, project is more affordable

AI =1, project is just affordable

AI <1, project is less affordable

5.6 Customer Affordability Assessment Module Development

The choice of Microsoft Excel software to implement the various modules within the affordability framework was guided by findings from the industrial interviews. The software provided the functionality required to develop a system that allows mathematical calculations, graphical representation, storage and the use of macros, or programming where required. This software was also accessible to the industrial stakeholders and the researcher who were expecting to receive the complete module as a deliverable unlike the Microsoft Access software.

5.6.1 Customer Affordability Module Benefits

The customer affordability assessment module has three main benefits:

- It enables the customer to evaluate a bid proposal submitted by industry to assess whether the solution would be affordable over the project life based on the qualitative and quantitative factors. It could also highlight potential risk involved in the proposed solution.
- It enables the manufacturer to understand the customer's view of affordability, and consider how to make the project more affordable as well as how to increase the customer's willingness to pay at the bidding stage.
- It provides recommendations in order to improve affordability based on each affordability factor (Bankole et al., 2010a).

The module users will be both customer and manufacturer organisations. This means that the customer can use the module to assess how affordable their project is, in order to provide sufficient funds in the budget. The manufacturer can use the module to assess the affordability of its customer in order to know how to negotiate with the customer where there are concerns. The module would enable both parties to model possible changes during the life cycle of the project and develop possible mitigation strategies in the form of risk provision or contractual agreements of periodic project reviews. The module may be used jointly or separately and the results shared between both parties. Potentially, it could be used by project managers or anyone working on a project primarily at the bidding stage, but also at different stages of the project life cycle.

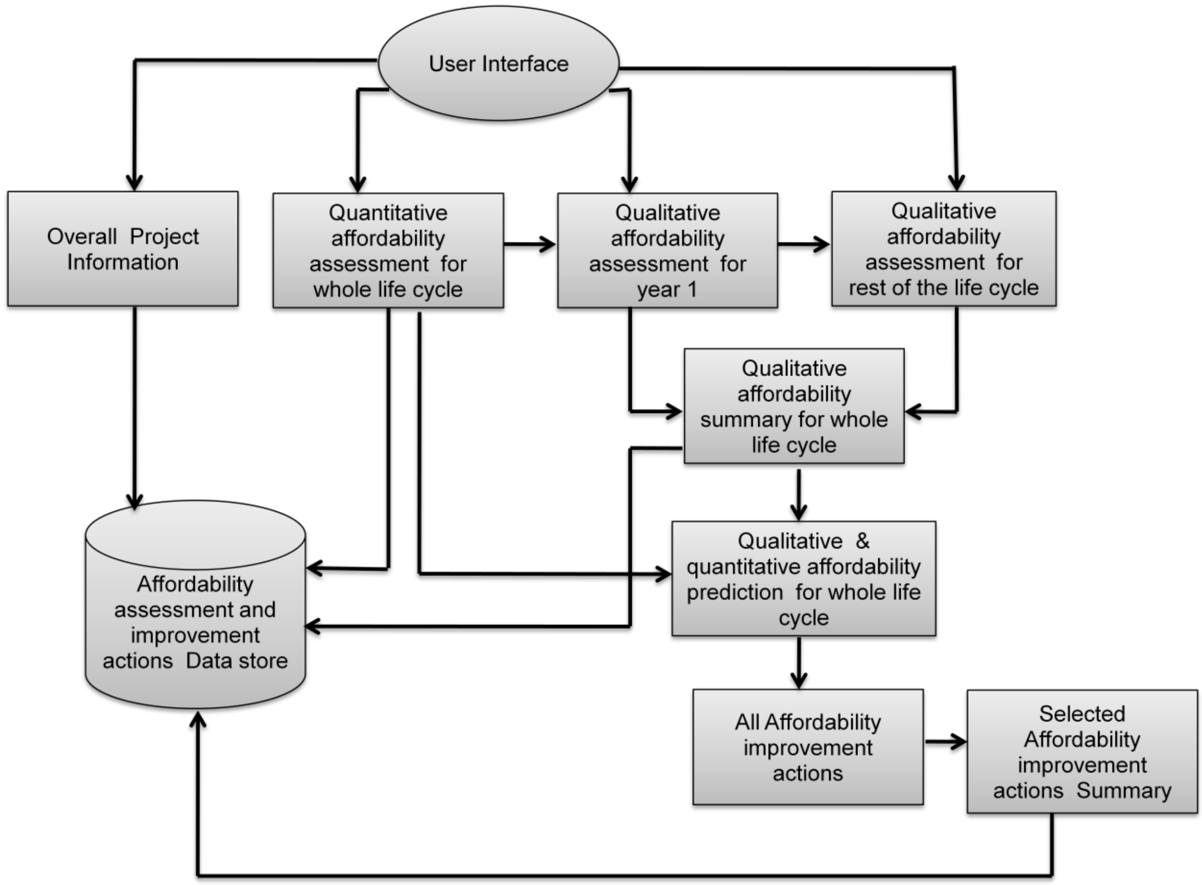


Figure 5-3: Customer Affordability Module Architecture (Bankole et al., 2010a)

In order to employ the module, the user must have Windows Microsoft Excel 2003 or a newer version. A basic knowledge of how to use the package is also required. The higher the proficiency of the user in the software, the more effectively they would be able to use the module. A user guide is provided within the module and user and technical manuals were developed and delivered to the industrial partners.

The components of the customer affordability module are derived from the pillars and capabilities of customer affordability presented in Figure (5-2). The module architecture presented in Figure (5-3) describes the customer affordability assessment module. This representation was adopted because it provides a simple description of the main activities and results of the module. The architecture shows that there are four key activities: providing overall project information, quantitative information for the whole project life cycle, qualitative assessment for year 1 first, then qualitative assessment for the rest of the project life cycle. In addition, there is a set of guidelines for improvement that may be done in order to improve customer affordability.

5.6.2 Customer Affordability Module input

The input required to perform the assessment is provided below.

- Overall project information - project name, description, platform type, contract life cycle, procurement method, lifecycle phases and type of contract.
- Quantitative affordability assessment - yearly amount for CATS and WLCC figures. This is used to calculate the AI.
- Qualitative affordability assessment - scores and weights for each affordability factor based on the factor elements first for year 1 then for the remaining years of the project life cycle.
- Customer affordability improvement guideline selection.

The qualitative assessment is done for one year initially, for better presentation and clarity of information. Example of the module input within Microsoft Excel is shown in Figure (5-4).

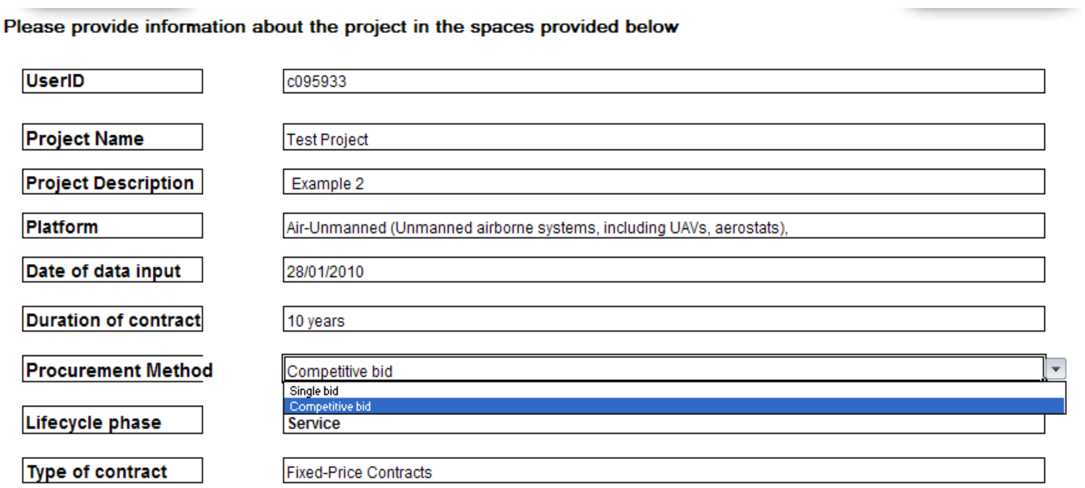


Figure 5-4: Customer affordability module input screenshot

5.6.3 Customer Affordability Module output

As a result of these activities, the module outputs are qualitative and quantitative results and are generated to be interpreted based on the project information. These are the AI, weighted scores which are presented in amber, red or green colours and line graphs. These present the quantitative factors and other graphical representation of qualitative factors as shown in Section 5.8 during case study application. Upon generating the results, the module also contains recommendations for improvement from which the user can select suitable guidelines to improve the affordability of the solution. The process and content of performing the assessment is described below.

5.6.4 Method of Assessment

Within the customer affordability assessment module, two methods of assessment are adopted which are qualitative and quantitative. The quantitative method is based on the two major quantitative factors while the qualitative method is based on the five top qualitative factors discussed in section 5.4.1. Both assessments are done based on actual amounts (for quantitative factors), scores, weights and open or closed questions. These are aimed at assessing the capability of the proposed solution. The factors provide a comprehensive list of elements that could affect any defence contract. This means that some factors may be less important in some defence projects and this could be presented while performing the assessment. The main inputs involved in the process are described below.

Actual Amount – this is the financial value of CATS or WLCC in each individual year of the project life cycle.

Scores – these provide an indication of the capability of the manufacturer to deliver an affordable solution that meets the customer requirement based on the elements within each factor. These are assessed in three levels of high, medium and low represented as 1, 3 and 5. This means that the lower the score the higher the capability. These numbers were chosen because they provide a logical hierarchy of difference that suits the three levels of scoring for qualitative assessment.

Weights – these reflects the importance of the element within each affordability factor to deliver an affordable solution that meets the customer requirement. These are assessed from the unimportant to most important as presented below.

5 – Most important

4 – More important

3 – Some important

2 – Little important

1 – Unimportant

This means that the higher the score, the higher the importance. The scores and weights are multiplied to provide the weighted scores. The weights and scores have been inversely assigned in order to ensure accuracy of the results. This is because allocating the same values for the three levels for scores and weights would generate results that could be potentially erroneous. This is illustrated below without the inverse arrangement, meaning a high score or weight signifies high capability or importance.

		Weights				
		1	2	3	4	5
	1	1	2	3	4	5
Scores	3	3	6	9	12	15
	5	5	10	15	20	25

A weighted score (result) of 3 or 15 could be an indication of high capability or low one. This means weighted score of 3 could mean high capability with low importance, or low capability with high importance. The same way, a weighted score of 15 could mean medium capability with high importance, or high capability with medium importance. To avoid this confusion, the scores are applied in an inverse fashion so that lower scores signify high capability.

With the inverse application, a weighted score of 3 means low importance with medium capability, or medium importance with high capability. Both of these results can be interpreted similarly as being favourable to the affordability of a project. In addition, a weighted score of 15 means high importance with medium capability, or medium importance with low capability. Both of these results can be interpreted as the solution having a medium to low capability to deliver an affordable project.

Therefore, results from the inverse application are interpreted thus:

Weighted scores between 1 and 15 signify highest to medium (capability), while weighted scores between 16 and 25 signify medium to lowest (capability).

In addition, an attribute or quality that is crucial to the delivery of a project would be assessed as being highly desirable (high importance score). Then the question is whether the proposed solution has that important feature (capability). If the scores and weights had the same allocation, then higher importance/capability would attract a higher score and lower importance/capability would attract a lower score. So an attribute that is not important and not present in the proposed solution would generate a low weighted score, which would be deemed a negative result. However, this is not the case. For this reason, the inverse allocation of values for scores and weights was adopted in order to correct this and generate accurate results.

Open-ended or closed questions – these are aimed at allowing the user to provide other important information, which may not be represented in the form of a weight or score e.g. type of contractor, which would be either single source or competition,; relationship with contractor which, could be long-term or short term, etc. This helps to assess the potential level of risk involved within the project, either low or high.

5.7 Customer Affordability Assessment Process

The assessment process would be undertaken as part of the bidding process that was explained in Chapter 4 (section 4.3.6). The process is presented in the form of a flowchart in Figure (5-5). This presentation was chosen due to its wide recognition and familiarity across research and industry to represent business processes. The notations used in the flowchart are as follows:

- The two round boxes represent the beginning and the end of the process
- The rectangular boxes represent tasks
- The connecting arrows represent the flow of information in performing the tasks
- The diamond box represents a decision point

The flowchart is a means of explaining and visualising the steps involved within the process, and the flow of information to show how inputs are turned into outputs. The mathematical parameters adopted to accomplish each task are provided in Appendix J. Examples are the 'IF FUNCTION' in excel, and the 'Data Validation functionality, etc.

5.8 Qualitative Assessment

As mentioned in section 5.4.1, the five major affordability factors (which are within the control of the manufacturers and customer) to be included in the assessment are explained below including the individual weighting and scoring for each element under each factor. These elements, measures and weightings were developed from findings from literature review and industrial interaction. The methodology adopted in generating these elements under the factors is the same as the one described in section 5.3. After the development of the elements and the measures, they were validated with industrial partners. The validation methodology is also presented in Chapter 9.

(i) **Requirement** - The requirement is based on the customer need, which is dynamic in nature. A contract that could last for 15 years or more would certainly change over time. There is a need to manage the impact of this change on WLCC of the project as well as schedule in order to ensure the delivery of an affordable solution to the customer, which secures manufacturer profitability. Measures of assessing customer affordability based on each element under the requirement factor are presented in Table (5-2) (Bankole et al., 2010a) :

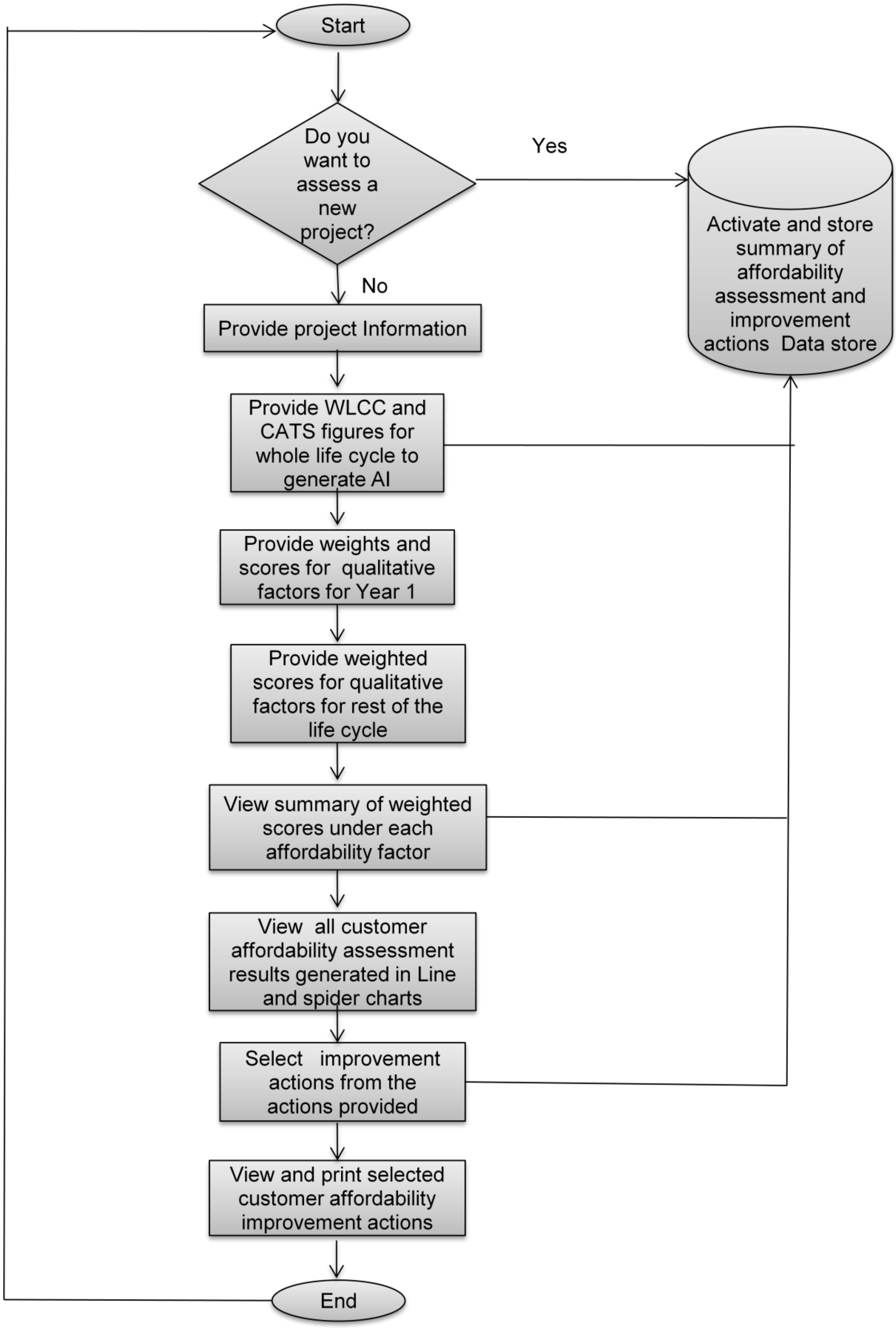


Figure 5-5: Customer affordability assessment process

(a) *Customer Requirement* - To what level does the proposed solution fulfil customer requirement?

(b) *Integration of systems and equipment* - To what level is the proposed solution able to achieve interoperability between different systems and equipment?

(c) *Liability allocation* - What is the level of clarity in the definition of responsibility (for the activities and operations) within the project?

(d) *Schedule* - What is the level of planning in the schedule (resources) to ensure the contract requirement can be delivered to satisfy customer requirement?

(e) *Performance and cost targets* - What is the likelihood that the project requirement will be delivered within the budget and according to contract requirement?

(f) *Flexibility* - What is the degree of flexibility within the system to adapt to change in requirement?

(g) *Technology Readiness Level (TRL)* - What is the scale of technological maturity within the proposed solution? (See AOF, 2008 for definitions of TRL Scales).

(ii) **Environment** – This refers to the responsibility of a firm towards the environment to ensure that activities and operations are environmentally friendly. There is need for an on-going plan for environmental sustainability, which must include the production and consumption processes, climate change and energy, natural resource protection and environmental enhancement. The scores are represented in Table (5-3).

(a) *Plan for disposal* - What is the level of long-term planning for the end of the life of the equipment?

(b) *Environmental Impact* - What is the level of effort that has gone into developing initiatives or schemes to ensure environmentally friendly processes e.g. emissions reduction, energy reduction, water reduction, green supply chain, green information technology and green data centres?

(c) *Change in Legislation* – How responsive is the contractor to new legislation and regulations?

Table 5-2: Requirement factor scores

Customer Requirement	
Score	*Definition*
1	>95% fulfilment
3	>85% fulfilment
5	=<70% fulfilment
Integration of systems and equipment	
Score	*Definition*
1	Interoperability is achieved without any issues relating to integration and interoperability at a high level
3	Interoperability is achieved but there are some issues relating to integration
5	There are serious issues with interoperability
Liability Allocation	
Score	*Definition*
1	All responsibility is fully allocated and accepted
3	Some responsibility has been allocated
5	No responsibility has been allocated
Schedule	
Score	*Definition*
1	Critical plan is known and scheduled with risk and uncertainty
3	Schedule is planned
5	Schedule is not planned
Performance and cost targets	
Cost	
Score	*Definition*
1	Fulfil customer requirement under budget allocation
3	Fulfil customer requirement within budget allocation
5	Fulfil customer requirement over budget allocation
Performance	
Score	*Definition*
1	Fulfil all customer requirement
3	Fulfil some customer requirement
5	Fulfil little or no customer requirement
Flexibility	
Score	*Definition*
1	Flexibility within solution at reasonable cost
3	Flexibility within solution at extra cost
5	No flexibility within solution
Technology Readiness Level (TRL)	
Score	*Definition*
1	TRL Scales 7, 8 and 9
3	TRL Scales 4, 5 and 6
5	TRL Scales 1, 2 and 3

Table 5-3: Environment factor scores

Plan for disposal	
Score	*Definition*
1	Supplier has long-term plan for disposal
3	Supplier has short-term plan for disposal
5	Supplier has no plan for disposal
Environmental Impact	
Score	*Definition*
1	High level of planning for environmentally friendly initiatives
3	Medium level of planning for environmentally friendly initiatives
5	Low level of planning for environmentally friendly initiatives
Changes in Legislation	
Score	*Definition*
1	Contractor is very quick to comply with new legislation
3	Contractor gradually complies with new legislation
5	Contractor is very slow to comply with new legislation

(iii) **Value For Money (VFM)** – VFM has been described as a judgement of the "quality of provision, processes or outcomes against the monetary cost of making the provision, undertaking the process or achieving the outcomes" (Harvey, 2009). The customer assesses tender responses from supplier firms against VFM. This can be done by employing the measures described below with the score allocation in Table (5-4).

a) Efficiency - To what degree will the proposed solution maximise resource usage throughout the contract duration?

b) Effectiveness - To what degree will the solution fulfil customer requirement effectively throughout the contract duration in terms of capability and competence?

c) Economy - To what degree will the proposed solution be delivered with savings in cost, time or effort throughout the contract duration? (Erlendsson, 2002)

d) Performance-Related measure - To what degree would the proposed solution satisfy the key performance indicators for the contract?

e) Availability - What is the degree of availability the proposed solution is able to sustain overtime?

f) Technology innovation - What level of technological development is the supplier firm able to provide in the proposed solution?

(iv) **Supply chain** – Every contract requires the activities of lower tier suppliers in order to deliver a fully integrated solution to the customer over the life of the availability or capability contract. Due to the lengthy duration of the contracts, manufacturers face the challenge of ensuring continuity in the supply chain. This can be assessed by the following measures with the scores in Table (5-5).

a) *Type of contractor* - Is the contract to be awarded to a prime contractor or individual suppliers? The benefit is that day-to-day management of the contract would become the responsibility of the prime contractor not the customer if the contract were awarded to a prime contractor.
b) *Supplier certification status* - To what level are the certification status and the maturity of the contractor's quality management system satisfactory?
c) *Contractor relationship* - Does the customer have a long or short-term relationship with the contractor? (A short-term relationship may not result in a higher level of risk, but no relationship at all could mean the level of risk is higher).
d) *Scope of the supply chain* - What percentage of major contractors are domestic or foreign? (Foreign suppliers may not pose a higher level of risk in some cases, but if there are more foreign contractors compared to the domestic ones this may pose a higher level of risk to the contract delivery. This is why it is also important to ascertain if the foreign company is an established trading partner. The presence of a foreign contractor means there is need for smooth collaboration among the supply chain partners to deliver an affordable solution to the customer).
e) *Financial capability* - To what level is the contractor's financial capability satisfactory?
f) *Price* - To what level is the contractor's price satisfactory?
g) *Number of Nations* - How many nations are involved in the supply chain? This gives an indication about the length of the supply chain. The presence of foreign suppliers could affect lead time, cost (due to exchange rates) and other aspects of the project.
   - Also what is the nature of the working relationship between the nations?
h) *Number of Vendors* - How many vendors are involved in the supply chain?
   - How long have the vendors been working together?
i) *Number of Unique Interfaces* - How many unique interfaces are involved in the project delivery?

Table 5-4: VFM factor scores

Efficiency	
Score	Definition
1	Fulfil customer requirement with reduced resource usage
3	Fulfil customer requirement without reduced resource usage
5	Fulfil customer requirement with increased resource usage
Effectiveness	
Score	Definition
1	Fulfil customer requirement with maximum capability and competence
3	Fulfil customer requirement with minimum capability and competence
5	Lacks capability and competence to fulfil customer requirement
Economy	
Score	Definition
1	Fulfil customer requirement with savings in cost, time & effort
3	Fulfil customer requirement without savings in cost or time or effort
5	Unable to fulfil customer requirement
Performance-related measure	
Score	Definition
1	>95% satisfaction
3	>90% satisfaction
5	<80% satisfaction
Availability	
Score	Definition
1	High level of availability sustainment
3	Medium level of availability sustainment
5	Low level of availability sustainment
Technology Innovation	
Score	Definition
1	Actual technology system qualified through successful mission operations
3	Technology system/subsystem model is demonstrated in a relevant environment
5	Analytical and experimental critical function and/or characteristics of proposed system is provided as proof-of-concept

Table 5-5: Supply chain factor scores

Type of contractor	
Type	*Select one*
Prime contractor	
Individual suppliers	
Supplier certification status	
Score	*Definition*
1	Fully approved supplier
3	Non-approved but has international accreditation e.g. AS9100, ISO 9001
5	Non-approved supplier
Contractor relationship	
Relationship	*Please select one*
Long term	
Short term	
Scope of supply chain (a)	
Contractor	*Percentage (Please provide)*
Domestic	
Foreign	
Scope of supply chain (b)	
Foreign Contractor	*Please select one*
Established trading partner	
New trading partner	
Financial capability	
Contractor capability	*Please select one*
High	
Low	
Price	
Score	*Definition*
1	Competitive price with extra value e.g. economies of scale
3	Competitive price without extra value
5	High price without value
Number of unique interface	
Unique Interfaces	*Number (Please provide)*
Number of nations	
Nations	*Number (Please provide)*
Nature of nations' working relationship	
Score	*Definition*
1	Excellent working relationship based on historical relationship
3	Good working relationship based on historical relationship
5	No previous working relationship
Number of vendors	
Vendors	*Number (Please provide)*
Length of vendor working relationship	
Score	*Definition*
1	High relative to industry average
3	Medium relative to industry average
5	Low relative to industry average

Table 5-6: Quality factor scores

Innovation		
Score	*Definition*	
1	Highly innovative with high value	
3	Highly innovative with low value	
5	Non-innovative solution	
Regulations and Standards		
Solution meets quality regulations		*Please select one*
Yes		
No		
Requirement Delivery		
Score	*Definition*	
1	Achieving customer satisfaction the first time	
3	Achieving customer satisfaction after iteration	
1	Failure to achieve satisfaction	

(v) **Quality** – This has been described as the 'totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied need.' It could also include 'degree of excellence' and fitness for use (ISO8402) (Harvey and Green, 1993). The assessment of quality varies depending on the customer's perception. It can be assessed by the following measures with the scores in Table (5-6).

(a) *Innovation* - What is the degree of innovation in the proposed solution?

(b) *Regulations and Standards* - Does the proposed solution satisfy the relevant UK/European or International regulations and agreements on quality (e.g. AS9100- Supply Chain 21 standards or ISO9100)?

(c) *Requirement delivery* - At what level of satisfaction would the proposed solution deliver the customer requirement (fitness for purpose and getting it right the first time)?

The scores and weights described in Section 5.6.4 would be allocated to the element under each affordability factor. Then an average of all the scores and weights under each customer affordability factor is allocated for the factor as shown in the case study (section 5.10). The allocation may be done jointly by the bidding team from both customer and manufacturer organisations or separately. The assessment would be performed based on available information about the customer's need and the manufacturer's capability. After the allocating of scores and weights based on the elements of each qualitative factor to generate the weighted score, the results are presented in a traffic light system as described in Table (5-7). The table also shows the interpretation of the result in terms of the level of risk in the proposed solution.

Table 5-7: Result of qualitative assessment

Weighted Score				
Colour	***Formatting***	***Capability Level***	***Weighted score***	***Level of risk***
	GREEN	High	<12	Low risk
	AMBER	Medium	>=12, <16	Medium risk
	RED	Low	>16	High risk

5.9 Customer Affordability Improvement Guidelines

After assessing the affordability of a defence project at the bidding stage, it is important to ensure that the project is managed properly so that it remains affordable over the life cycle. Also, if the assessment result shows that a solution is unaffordable, there is need to take appropriate action to correct the unaffordability and make the project affordable. A variety of actions may be proposed to make a project affordable and to manage a project to ensure it remains affordable over the life cycle. Therefore, based on each affordability factor and factor elements, both quantitative and qualitative, a set of improvement guidelines were designed to improve affordability. These improvement guidelines were developed from literature review and industrial interaction following the same methodology described in section 5.3. After development they were validated with industrial partners as described in Chapter 9. The improvement guidelines are provided below.

1. Requirement (1.1 Customer requirement, 1.2 Integration of systems and equipment, 1.3 Liability allocation, 1.4 TRL, 1.5 Schedule, 1.6 Performance and cost targets, 1.7 Flexibility).

Table 5-8: Improvement guidelines - Requirement

1.1a Ensure that customer requirement is clearly communicated to prime contractor
1.1b Work closely with customer to draw up the requirement
1.1c Design schedule to meet customer requirement on time and at right quality
1.2a Investigate equipment and system hardware and software to identify ways of improving integration
1.2b Consult the project team and/or customer to identify ways of improving integration between equipment and systems
1.3a Put communication plan in place and disseminate responsibility among partners
1.3b Consult contracting partners to allocate and agree liability so each partner knows the risks they'll bear
1.4a Perform detailed inspection and testing of system and subsystem technology in an operational environment to certify that system is qualified to meet mission needs
1.4b Allocate sufficient funding for technology development
1.4c Consult the project team to develop an effective a method of technology improvement within the system
1.5a Design a schedule (resources) with sufficient level of detail to provide a plan to deliver the customer requirement
1.5b Consult the project team to develop a feasible and effective schedule to deliver customer requirement
1.6a Consider uncertainty and build in adequate contingency
1.6b Have a good understanding of customer requirement in order to achieve performance targets
1.6c Investigate cost effective options in requirement delivery
1.7a Ensure the proposed solution is flexible enough to accommodate requirement change
1.7b Consult customer to discuss the impact of changes in requirement on project delivery

2. Environment (2.1 Plan for disposal, 2.2 Environmental Impact, 2.3 Change in Legislation).

Table 5-9: Improvement guidelines – Environment

2.1a Have a plan for the disposal of equipment at the early stages of planning and developing the proposed solution where applicable
2.1b Consult customer to consider plan for the disposal of equipment
2.2a Assess current processes and identify areas for improvement to ensure the project meets environmental quality standards
2.2b Consult the project team and/or customer to identify ways of operating to meet environmental quality standards
2.2c Consult customer and stakeholders to determine the cost and resources involved in disposal planning of project
2.3a Set up a process to provide team with updates on environmental quality standards
2.3b Invest the effort and funds required to implement new quality standards based on new legislation

3. VFM (3.1 Efficiency, 3.2 Effectiveness, 3.3 Economy, 3.4 Performance-related measure, 3.5 Availability, 3.6 Technology Innovation).

Table 5-10: Improvement guidelines – VFM

3.1a Develop a feasible plan to achieve efficiency by using less resources in fulfilling the customer requirement
3.1b Consult project team and/or customer to develop ways of reducing resource usage while maintaining performance (Value Analysis/Value Engineering)
3.1c Employ quality management and performance measurement techniques such as Six Sigma, Taguchi, EFQM etc, to improve processes and achieve savings
3.2a Develop quality training to improve employee skills and competence
3.2b Invest in research and development to develop capabilities
3.2c Employ quality management and performance measurement techniques such as Six Sigma, Taguchi, EFQM etc, to improve processes and achieve savings
3.3a Consult stakeholders (suppliers) to identify options to achieve savings in cost, time and effort (Trade Studies)
3.3b Review organisation processes to identify ways to achieve savings in cost, time and effort
3.3c Employ quality management and performance measurement techniques such as Six Sigma, Taguchi, EFQM etc to improve processes and achieve savings
3.4a Consult project team to develop options to achieve performance indicators
3.4b Monitor schedule to ensure consistency and address slippage in schedule
3.5a Consult project team to ensure the solution achieves the maximum level of availability possible
3.5b Monitor schedule to ensure consistency and address slippage in schedule
3.6a Invest in research and development to keep abreast of technology evolution
3.6b Engage in partnership with companies who are innovation leaders in technology

Table 5-11: Improvement guidelines – Supply chain

4.1 Ensure that the best contractor arrangement (prime contractor or individual supplier) is secured for the project based on project requirement
4.2 Ensure the contractor's certification status and quality management system meets the legal standards
4.3a Consult stakeholders to identify ways of improving relationships among partners in a competitive way
4.3b Incentivize sub- contractors to foster long-term relationships e.g. pain-gain sharing
4.4 Ensure that the scope of the supply chain can be properly managed by the prime contractor
4.5 Consult contractor to identify ways of improving major sub-contractor's financial capability e.g. by maintaining demand over a period of time
4.6 Incentivise the sub-contractor to offer a competitive price by providing benefits where possible
4.7a Understand and exploit working cultures in different nations
4.7b Find ways of incentivising and ensuring smooth working relationships between nations
4.8a Understand and exploit the strengths of different vendors
4.8b Find ways of incentivising and ensuring smooth working relationships among vendors
4.8c Employ the use of lower cost economies such as China, India, Mexico, Eastern Europe, etc. by identification and proportion of total cost of supply chain
4.9 Consult the project team and/or customer to identify ways of improving integrated interfaces among equipment and systems

4. Supply chain (4.1 Type of contractor, 4.2 Supplier certification status, 4.3 Contractor relationship, 4.4 Scope of supply chain, 4.5 Financial capability, 4.6 Price, 4.7 Number of nations, 4.8 Nature of nations' working relationship, 4.9 Number of unique interfaces).

No improvement guidelines were provided for the number of nations and the length of vendor working relationship because these may not cause a project to be unaffordable.

5. Quality (5.1 Innovation, 5.2 Regulations and Standards, 5.3 Requirement Delivery).

Table 5-12: Improvement guidelines – Quality

5.1a Invest in research and development to encourage innovation
5.1b Encourage sub-contractor to invest in innovation
5.2 Ensure that the proposed solution meets the UK/European or International regulations and agreements on quality (e.g. AS9100).
5.3a Consult project team and/or customer to develop ideas in order to ensure customer requirement is delivered right the first time.
5.3b Review schedule against customer requirement

6. Whole life cycle cost - Improve cost estimating process to reduce the gap between actual and estimate.

7. Customer budget

- Ensure the budget is realistic and adequately takes account of real costs of projects through closer engagement with the sub-contractor.
- Ensure the budget is realistic and adequately takes account of real costs of projects by referring to data from past projects (especially those that are similar in nature).

Overall

- Develop methods for robust data collection through closer engagement with the sub-contractor.
- Develop methods for robust data collection by storing data from past projects (especially those which are similar in nature).

The next section provides a case study application of the module.

5.10 Initial Case Study Application

Description

The initial case study is based on a non-competitive price contract between a prime contractor and a major defence customer initially contracted for five years. The contract is aimed at delivering a next generation user control device communications system. The existing user control communications system had obsolescence issues, which could cause degradation or failure in system performance. Though this would be inherited by the new contract, there is an opportunity within the new contract to minimise this through technology insertion, however the risks need to be carefully considered. The contract covers the Assessment, Demonstration, Manufacture and In-Service (ADMI) phases of the CADMID cycle for five years. There is potential for a disposal phase to start immediately after the five years. The predicted WLCC over the 5 years was £11,079,028 while predicted CATS was £10,000,000. The case study's obsolescence challenges are significant as these costs could account for more than half of the WLCC. Currently the project is awarded on a single source basis; however, the customer wants to run a small competition to further assess VFM in the project. This contract was first awarded to a different prime contractor, but the prime contractor was running the program at a loss. The customer then decided to re-award the contract to the current prime contractor. However, the previous sub-contractors/suppliers were retained and moved to work with the current prime contractor. A major supplier in this contract is another division of the current prime contractor, which is based overseas. This is the supplier whose sustainability is assessed in the case study in Chapter 6. In terms of supplier sustainability, this supplier's position would change over time; hence the initial assessment could only be done for the first 2 years.

The bidding team included: Programme Lead, Programme Management, Capture Management, Lead Engineer, Support Programme Manager, Lead Support Engineer, Project Coordination, Finance, Commercial, Contracts and Bid Manager. Data from this case study was applied to the overall affordability framework after the project had been contracted and begun.

Customer Affordability Assessment

The customer affordability assessment was carried out using both qualitative and quantitative assessments. These are presented below with the results of the assessment.

(i) Quantitative assessment

Table 5-13: Case study 1 CATS and WLCC values - Predicted

Year	**1**	**2**	**3**	**4**	**5**	**Total**
Currency	**£**	**£**	**£**	**£**	**£**	**£**
WLCC	2,215,805.60	2,215,805.60	2,215,805.60	2,215,805.60	2,215,805.60	11,079,028.00
CATS	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	10,000,000

Table (5-13), which is the predicted information, reflects violation of the 5-year life cycle. This means that the project would be unaffordable since the sum of WLCC is greater than CATS, suggesting that the customer's budget could not cover the cost involved in the project life cycle. As a result, further negotiation between the contractor and the customer led to the CATS and WLCC values in Table (5-14). The initial proposed solution was unaffordable and the capability required by the customer was evaluated to improve the solution by spreading the cost of the project over a longer duration of 10 years.

Table 5-14: Case study 1 CATS and WLCC values - Actual

Year	1	2	3	4	5	6	7	8	9	10	Total
Currency	£	£	£	£	£	£	£	£	£	£	£
WLCC	890,160.00	890,160.00	1,000,000.00	1,000,000.00	1,114,000.00	1,114,000.00	1,118,000.00	1,120,000.00	1,500,000.00	1,600,000.00	11,346,320.00
CATS	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	12,699,935.98

$$AI = \frac{CATS}{WLCC}\left(1 - \left(\sum_{i=1}^{n} \frac{(C_{i} - S_{i})}{S_{i}}\right) * \frac{1}{n}\right) \quad \text{(ii)}$$

Affordability Index (AI) = 0.87

The re-negotiated figures were the amount actually contracted. Applying the AI equation generated an AI of 0.87 which shows that the project is less affordable, since it is less than 1, but nearer affordable rather than unaffordable as it is nearer to 1 than 0. The total CATS is higher than total WLCC, but there are violations in years 9 and 10 as shown in Figure (5-6).

The profile in Figure (5-6) shows that the CATS is a steady straight line as the budget is evenly spread across the 10 years. The WLCC line increases in years 3, 5 and 9. The value in year 10 is almost double the value in year 1, meaning that a significant cost increase is expected over the life cycle. However, the sum of WLCC is still below the sum of CATS, which makes the project less affordable by only 0.13.

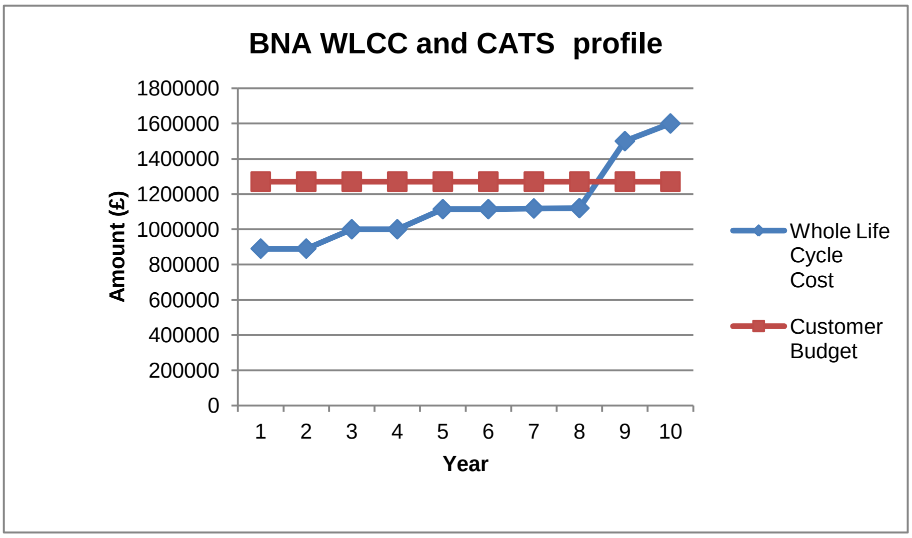


Figure 5-6: Case Study 1 CATS and WLCC profile

(ii) Qualitative assessment

The scores and weights have been allocated to each customer affordability factor element and the average has been generated under each customer affordability factor. As explained previously, the scores for the customer affordability assessment is analysed as a lower score signifying higher capability. Table (5-15) shows the predicted project affordability based on qualitative factors while Table (5-16) shows the actual project affordability using the traffic light system.

Table 5-15: Case study 1 Qualitative customer affordability weighted scores-Predicted

Affordability Factors	Year 1	Year 2	Year 3	Year 4	Year 5
Requirement	6	6	6	6	6
Environment	1	1	1	1	1
VFM	12	12	12	12	12
Supply chain	4	4	4	4	4
Quality	1	5	5	5	5

Table 5-16: Case study 1 Qualitative customer affordability weighted scores – Actual

Affordability Factors	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Requirement	5	9	9	8	8	9	9	9	8	6
Environment	4	5	5	5	7	7	9	7	5	5
VFM	12	18	18	20	21	18	18	17	13	11
Supply chain	4	8	9	11	10	9	10	9	8	8
Quality	1	9	15	18	23	20	15	15	18	12

Table (5-15) was based on assumptions that the solution would be able to fulfil the customer requirement and deliver the required quality, however, the commencement of the project revealed the actual qualitative assessment in Table (5-16).

The affordability (customer affordability, manufacturer profitability and supplier sustainability assessment) changed from the predicted to the actual as a result of the following:

- Increase in WLCC due to Obsolescence issues;
- Increase in WLCC due to exchange rate fluctuations in the cost of the dollar to the sterling;
- Increased customer requirements;
- Increased utilisation and usage rates of equipment in Afghanistan;
- Higher attrition and failure rates due to the above;
- Extended range of use due to new emerging customer requirements;
- Closure of repair facility in Hastings resulting in increased sales of spares;
- Single source of component supply from a foreign major resulting in monopoly of spares and repair capability resulting in higher support costs than originally planned;
- Near neighbour project was taken out of service thus limited opportunities for economies of scale for new orders and spares purchases.

The impact of these assumptions on qualitative affordability factors are described below:

1. Requirement

- Customer requirement – enhanced customer requirement means the capability of the solution to deliver customer requirement may be high in year one, but this would reduce to medium in subsequent years as customer requirement would be highly unpredictable. Towards the end of the project life, the requirement could stabilise meaning that the capability of the solution improves to a high level.

- Integration - enhanced customer requirement and higher attrition and failure rates means the capability of the solution to achieve interoperability may be high in year one, drop to medium in the next few years and vary between medium and high for the rest of the lifecycle, as the solution provider would invest more effort to achieve the desired level of integration.
- Technological Readiness level (TRL) - enhanced customer requirement and higher attrition and failure rates means that TRL of the proposed solution would not be at the highest level, at the same time, technology maturity within the proposed solution must be at a medium level in order to be approved and fulfil customer requirement.
- Liability allocation – within the project, liability allocation is well defined and while solution provider takes responsibility in terms of operational activities, the customer may be required to provide additional financial investment to deliver the requirement, especially with enhanced customer requirement.
- Schedule – Enhanced customer requirement and higher attrition and failure rates means that the schedule planning within this project could be at a medium level, but this would vary between low and medium throughout the project lifecycle.
- Performance & Cost - Enhanced customer requirement and higher attrition and failure rates mean that the cost of project delivery would be higher than planned (low capability) and the performance of the solution may not be as high as desired (medium to low capability). Overall the performance and cost measures of the project would be between medium and low.
- Flexibility - Enhanced customer requirement and higher attrition and failure rates means that the solution would be flexible, but this would come at extra cost. The solution's capability to be flexible may be high in the first year, but this would reduce to medium and vary between medium and low across the life cycle. It could increase to high towards the end of the project.

2. Environment

- Plan for disposal - Extended range of use due to new emerging customer requirements would make it difficult to have a plan for disposal; also the current project had no disposal phase. The disposal phase was to start as another project after the current one, so while the score for disposal plan is low the weight (importance) within this project was also low, and hence the weighted score was low across the lifecycle. The low weighted score is because the project is affected by disposal plans.

- Environmental Impact – Initially, the level of effort to employ environmentally friendly processes may be just enough for the requirement of the project at first, however, this could change along the life cycle. Extended range of use due to new emerging customer requirements could increase the importance of environmental impact of the project over the lifecycle. The weighted score is lower for the first few years, which increases towards the middle of the lifecycle and drops again towards the end of the project life.
- Change in Legislation – the project may not be required to be highly responsive to change in legislation especially at the earlier stages. Hence the weighted score is low throughout the year.

3. VFM

- Efficiency - the project may be able to maximise resource usage by employing some resources from the previous project, but enhanced customer requirement coupled with increased utilisation and usage rates of equipment would reduce the manufacturer's capability to be efficient. The weighted score is high for most of the life cycle and it reduces towards the end of the life cycle.
- Effectiveness - the project would face challenges in delivering customer requirement due to enhanced requirement coupled with increased utilisation and usage rates of equipment. The weighted score is high for most of the life cycle and it reduces towards the end of the life cycle.
- Economy - the project would face challenges in achieving savings in cost, time or effort due to enhanced requirement coupled with increased utilisation and usage rates of equipment. Also the closure of a supplier's site, which led to increased buying of spares would hinder savings with a near neighbour's project being taken out of service. The weighted score is high for most of the life cycle and it reduces towards the end of the life cycle.
- Performance Related measure - the project would face challenges in satisfying the key performance indicators due to enhanced requirements coupled with increased utilisation and usage rates of equipment. Also challenges with the supply chain and economic factors might lead to lower capability, i.e. higher weighed scores generally.
- Availability - the project would face challenges in sustaining the required degree of availability due to the reasons stated above. This means the weighed scores are high and medium for the most part of the lifecycle, but low at the start and at the end.

- Technology innovation - the project would face challenges in providing the right technology innovation due to the reasons provided below, hence weighted scores are between high and medium for most parts of the lifecycle.

4. Supply chain

- Type of contractor - the project was awarded on single source basis to the contractor in order to reduce the risk for the customer.
- Supplier certification status – the main contractor (supplier) in this case is well certified and has experience in communications systems, hence the weighted scores are lower.
- Contractor relationship – there is a long-term relationship between the customer and main contractor, therefore there is lower level of risk from the contractor.
- Scope of supply chain – the supply chain includes 16% foreign and 84% domestic; hence there is lower level of risk.
- Financial capability – the contractor is financially sustainable, therefore level of risk is low.
- Price – the contractor's price was satisfactory to the customer and profitable for the contractor.
- Numbers of Nations – there are three nations involved in the project, but this poses low risk as one of the suppliers is the Canadian subsidiary of the main contractor in the UK. As a result, the weighted scores are low.
- Number of Vendors – there are twenty-six vendors involved in the project, but this poses a low risk as there is a high level (7 years) of interaction between the suppliers. As a result, the weighted scores are low.
- Number of Unique interfaces – there were four unique interfaces initially, but with the enhanced customer requirement this will increase. The contractor would require more effort to ensure a smooth integration between the interfaces. As a result, the weighted scores are between high and medium for most of the lifecycle.

5. Quality

- Innovation - Initially a low degree of innovation was required to deliver the project, however with the changes in the customer requirement and equipment usage, more innovation would be required and the contractor's capability could vary from low to high. As a result, the weighted scores are between high and medium for most of the lifecycle.

- Regulation and standards - The proposed solution within the project does certify the relevant national and international quality standards, hence the level of risk is low.
- Requirement Delivery - Initially the customer was satisfied with the proposed solution, however this would vary along with the dynamic nature of the customer requirement.

  As a result, the weighted scores are between high and medium for most of the lifecycle.

All of these assumptions informed the allocation of weights and scores which shows the actual results rather than the initial prediction. This is presented in Table (5-16) and Figure (5-7).

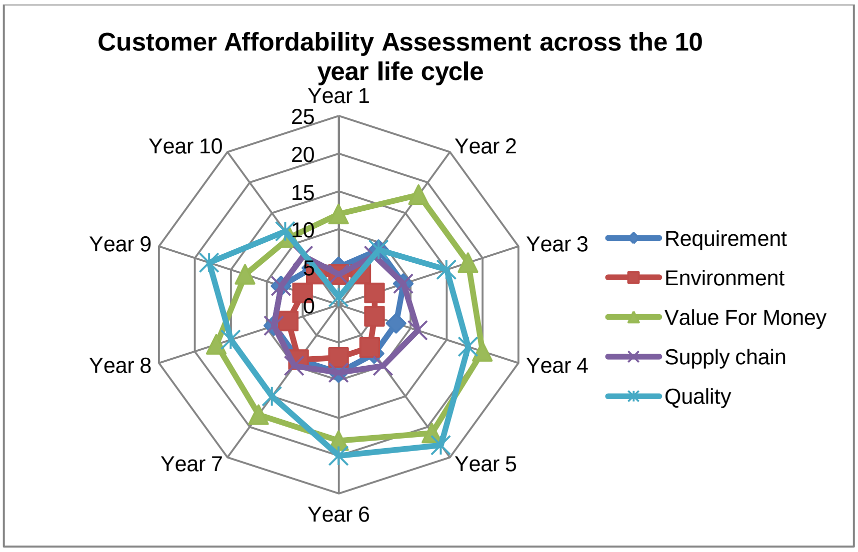


Figure 5-7: Case study 1 Qualitative customer affordability actual results

The result in Figure (5-6) shows that the project is affordable based on most affordability factors in terms of the environment and requirement, just affordable based on supply chain, but less affordable based on VFM and quality. This means the manufacturer is able to deliver the customer requirement, but at higher costs (low VFM capability) and lower quality.

Based on this result, improvement options are suggested to improve VFM, supply chain and quality as shown in Tables (5-10, 5-11 and 5-12). The manufacturer can select those options that are most relevant and feasible among those provided.

At the bidding stage, the result of this assessment would highlight potential risk within the project in terms of the quality of the manufacturer's solution and the ability to deliver VFM due to major cost increases caused by the supply chain. This means the project team would encourage the manufacturer to put more effort into reducing supply chain cost without compromising the quality, and the customer to put more effort into secure funding to provide adequate investment in order to achieve the desired quality which may come at additional cost.

5.11 SUMMARY

This chapter focused on the customer affordability module by providing detailed explanation of the affordability factors while identifying the major qualitative and quantitative factors. These factors were employed in developing the customer affordability model. The elements under each factor were explained and the descriptions for scoring were provided for each individual factor elements. It provided the content of the customer affordability module using Microsoft Excel, the parameters and the process of conducting the assessment. The quantitative assessment involves the financial assessment based on actual amounts of WLCC and CATS while the qualitative assessment is carried out by assigning scores and weights to each affordability factor. The module also provides guidelines to improve the affordability position of a project based on the major factors. A case study was also provided to illustrate the application of the customer affordability module and detailed explanation for the assessment results were provided including the suggested guidelines for improving the customer affordability of the project. The next chapter focuses on the manufacturer profitability assessment and supplier sustainability modules within the overall affordability framework.

CHAPTER 6

MANUFACTURER PROFITABILITY AND SUPPLIER SUSTAINABILITY ASSESSMENT

6.1 Introduction

The previous chapter presented the customer affordability, which is the first perspective within the overall affordability framework. This chapter is focused on the other two perspectives within the affordability framework, namely the manufacturer profitability and supplier sustainability perspectives. It will provide the qualitative and quantitative factors and dimensions involved in assessing manufacturer profitability and supplier sustainability together with the guidelines on the improvement of supplier sustainability.

In order to fulfil the aim of the research the manufacturer profitability assessment is designed to do a quantitative assessment of the profitability of defence manufacturers by taking account of the changes during the project life cycle. It is usually assessed within accounting literature at the end of the business year as a division of revenue over cost. However, at the bidding stage the profitability assessment is carried out to calculate a selling price which guarantees profitability. For this reason, a new definition for manufacturer profitability in defence contracts is developed within this chapter. Based on literature review and industrial interaction, this chapter focuses on developing a measure of manufacturer profitability which helps to generate a competitive selling price by taking into account the impact of time on long-term defence contracts.

The supplier sustainability perspective is also aimed at assessing supplier sustainability based on qualitative and quantitative measures that reflect financial and operational sustainability in the long-term. Five dimensions of sustainability were identified from literature review and a systematic methodology was followed to generate performance measures within each dimension. These measures are both qualitative and quantitative and they indicate sustainability by monitoring the trend in supplier performance over time. These measures are applicable both for project control after the project commences as well as for early assessment. Since the focus of this research is on the bidding stage, the measures would be applied for early assessment within this research. The supplier sustainability module within the overall affordability framework is presented in this chapter, which combines the dimensions, process and measures together with the module implementation.

6.2 Methodology employed in Module development

The interview protocol to investigate manufacturer profitability and supplier sustainability was informed by the literature review, which helped to identify these affordability perspectives. The same companies involved in investigating the customer affordability were involved in conducting the research into manufacturer profitability and supplier sustainability since initial contact had been made with them and they were willing to participate in the study. Similar to customer affordability, after the initial interviews had been held with the companies, further interview sessions were held to focus on these two perspectives of affordability and to identify potential case studies for the study.

6.2.1 Design of questionnaires

The questionnaires (Appendices C and D) were used in interview sessions which were in sessions of 60, 90 and 120 minutes. The researcher recorded the responses using both an audio recorder and hand-written notes. The responses were analysed and used in designing the second set of questionnaires. Details of validation are discussed further in Chapter 9.

6.2.2 Industrial interviews

Similar to the approach for the customer affordability, the industrial interviews was carried out to capture the current practice of manufacturer profitability and supplier sustainability as explained in Chapter 4 (section 4.2). This systematic approach was carried out to collect data to understand the current practice of manufacturer profitability and supplier sustainability assessment and to provide data for the overall framework development. The purpose for the selection of the companies has been mentioned in Chapter 4(section 4.2); hence many of the respondents involved in the customer affordability study were also involved in studying the other two perspectives. This is because they were experts in cost estimating, profitability and supplier engagement assessment.

The respondents were chosen from the industrial collaborators including two additional companies within the aerospace and defence sectors. At the validation stages of the initial module, two of these companies were involved in these aspects of the research which is described in Chapter 9. The industrial experts' profiles are provided in the Tables (6-1 to 6-3).

Table 6-1: Company A Interviewee profile

Job role	Responsibilities
Strategic Forecasting Team Leader I	Responsible for supplier management and strategic forecasting. Involved mainly with the software, aircrafts, space aircrafts and skills and competence documentations.
Set Assurance Team Leader	Involved in examining Business Cases and cost estimations. A key member of the Integrated Project Team who is also involved in Through life analysis of Business cases.
Strategic Forecasting Team Leader II	Responsible for supplier management and strategic forecasting. Mainly focussed on land and sea systems as well as ensuring a realistic budget with the performance of historic trend analysis.

Table 6-2: Company B Interviewee profile

Job role	Responsibilities
Programme manager	Responsibility covers Design Services, Tasking & Subcontractor Management on Bowman and ComBAT and Information and Platform (CIP) Long Term System Support Contract.
Supplier Engagement	Responsible for the long-term support of defence contracts with a core role in supplier engagement and international Logistics support.
Capture Manager	Involved in the Bowman Network Architecture - Tactical C41 Radio System as the capture manager. Responsible for Business development and long-term affordability support

Table 6-3: Company C Interviewee profile

Job role	Responsibilities
Project manager(s)	Responsible for ensuring contract delivery to customers on time, on schedule; within the budget, and also for managing resources effectively and delivering on budget.
Engineering manager	Responsible for day-to-day (technical) problem solving as well as the delivery of contracts to meet customer requirement within the budget.
Business Development Leader	Responsible to the UK MoD working to understand their current and future training needs and to develop the company strategy and tactics for maximising the opportunity in the market place.
Integrated Logistics Support	Takes a whole life cycle view rather than focusing on the in-service phase in cost modelling. Experienced in contracts involving the DoD, MoD, and Lockheed Martin.
Director of the Global Marketing, Systems Customer Service	Currently also part of the marketing team, which involves working out the right set of services for the customers. Tasks relate to both civil and military domains.
Finance Team member	Involved in financial assessment military projects (non-military projects).

The industrial interviews were conducted with respondents at different times at the manufacturer's sites. The Delphi method (Boehm, 1998) was adapted to conduct the structural survey and capture intuitive information from industrial experts. This helped to collect both qualitative and quantitative results, dimensions and measures for assessing manufacturer profitability and supplier sustainability. The interviews were carried out with individuals and groups of experts based on their availability for the same duration at those stated earlier. The survey results were captured and analysed in a similar way to the one described in Chapter 5. Useful articles were reviewed to gain better understanding and observe different approaches employed to study the subjects.

6.2.3 Telephone Discussions

As stated in Chapter 5, telephone discussions were also employed to clarify the information obtained from the survey and analyse it. One telephone interview was conducted with an industrial expert who could not hold a face-to-face interview session due to time constraints. The respondent was an expert in the Finance department of a manufacturer. The expert whose profile is provided in Table (6-1) was involved in the first round of industrial interviews to investigate the current practice of profitability assessment. The same questionnaires referred to in section 6.2.1 were used and the responses were captured through hand-written notes in a similar fashion to the face-to-face sessions. The results of the findings have been presented in Chapter 4 (section 4.3.8).

6.3 Manufacturer profitability assessment

The profitability assessment is carried out by the manufacturer when deciding whether to tender a bid. The assessment here is focussed on calculating a competitive selling price while preparing a tender. Similar to the quantitative assessment of the customer affordability, a Profitability Index (PI) is provided to generate a score of the manufacturer's profitability as well the NPV calculation.

6.3.1 Manufacturer profitability Factors

In order to properly represent the research focus in investigating manufacturer profitability and to ensure uniformity with the other affordability perspectives, the researcher defined *manufacturer profitability* as the ability of a manufacturer to generate a substantial level of revenue in the delivery of a project or program which offsets the cost incurred over the life cycle of the contract. This means manufacturer profitability cannot just be measured at the start or the end of a defence contract; rather it is an ongoing assessment throughout the life cycle. The factors and methods applied in the manufacturer profitability assessment were obtained from both the first and second rounds of industry interaction. Some drivers affecting the profitability of defence contracts are provided in Figure (6-1). These factors are basic cost, contingency (risk) and escalation, basic profit rate, selling price, other non-recurring expenses (where applicable) and final selling price (minimum and maximum selling price). Further explanation is provided below.

Figure 6-1: Profitability drivers

- *Basic Cost* – this comprises of the variable and fixed costs that are fundamental for the delivery of customer requirement. These include labour, overheads, raw materials and supply chain. Supply chain cost is an estimate of sub-contractors and other costs associated from suppliers. Here the assessment of supplier sustainability would inform the contractor in providing a better estimate for the supply chain.
- *Contingency estimate* includes the cost of *risk and uncertainty.* Contingency is put in place to provide for increasing cost, for example a higher demand for labour, overhead and materials. These are decided based on expert judgement and/ or 3-point estimates. Management Contingency is later added on at the discretion of the management.
- *Escalation* is similar to contingency but it addresses increase in cost due to price increase or exchange rate fluctuations. These are decided based on expert judgement and/or 3-point estimates and applied to the basic cost items. Other contractors may only add on risk and contingency at various rates after generating the basic selling price.
- *Works cost* is a sum of total basic cost, contingency and escalation. The addition of management contingency to the total works cost generates gross *works. (Total works cost = total*

basic cost + total contingency + total escalation) (Gross works cost = total works cost + management contingency).

▪ *Basic Selling Price* is generated after basic profit has been added onto the subtotal of costs. *(Basic selling price =basic profit rate + gross works cost).*

▪ *On-Costs* are generated as a result of other costs, which would vary from one contract to another such as warranty, penalty, royalty and commission. The costs are affected by the nature of the contract, e.g. imports from other countries, penalties imposed by the customer or duties to be paid to the government.

▪ *Negotiation Margin* is the level of margin that the manufacturer charges on the minimum selling price to arrive at the final offer price.

▪ *Minimum Selling Price* is generated after total on-costs and profit have been added to basic selling price.

▪ *Offer Price* is the selling price revealed to the customer after adding a negotiation margin at the discretion of the commercial team within the organisation. The offer price is the starting point for negotiation with the customer.

▪ *Basic Profit Rate* is the profit rate that is added on to the *gross works* cost to generate the *basic selling price.*

The major costs in profitability calculation are presented in Figure (6-2). These costs provide the total cost upon which contingency, basic profit rate, and any additional profit are added to generate the basic selling price, minimum selling price, negotiating margin and the offer price. The profitability assessment is usually presented in a spreadsheet that is reviewed at different times during the project life cycle. In order to reduce the offer price, the customer may be willing to reduce some requirement specification or quantity of deliverables. Also the contractor may be willing to reach a compromise on its negotiation margin or escalation or contingency provision in order to win a bid. Profit and loss calculation would be used to assess actual profitability after the contract has started. Manufacturer profitability assessment is highly developed and well established in industry as shown in Chapter 4 (section 4.3.8); hence the main contribution to this research is in reflecting the nature/changes in the level of manufacturer profitability over the life cycle time. This helps to generate a profit or loss profile for the project life cycle. The next section focuses on the manufacturer profitability assessment, which reflects the impact of changes in profit profile during the life cycle.

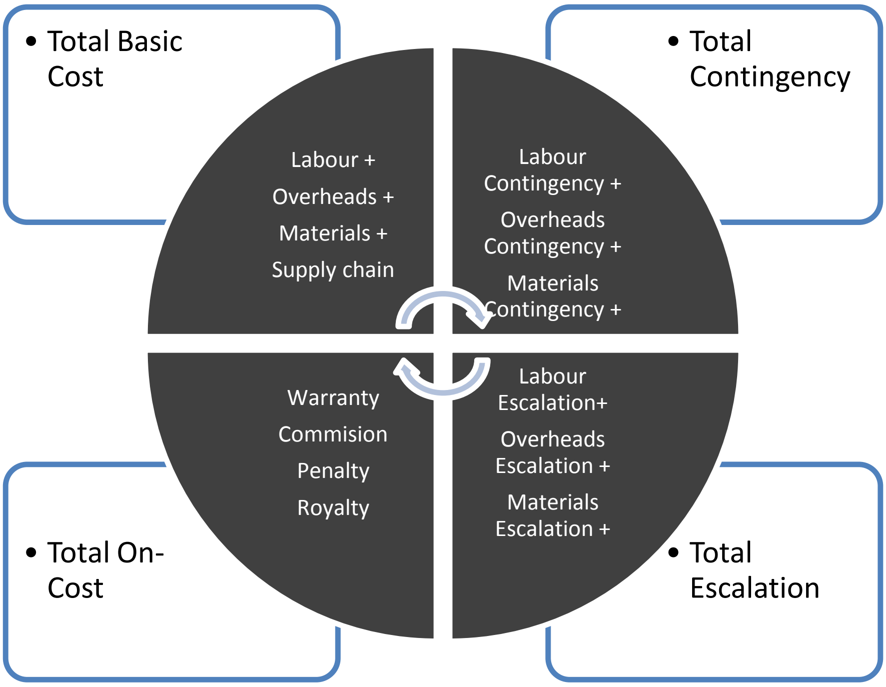


Figure 6-2: Costs in Profitability Calculation

6.3.2 Method of Assessment

Profitability Index (PI)

The assessment focuses mainly on the quantitative factors (WLCC and CATS) that are employed in generating the other factors such as price and profit. The main method of assessment is based on the actual values of WLCC and CATS, and the profit rate.

As stated in Chapter 2, profit is usually expressed as the difference between total revenue and total expenses. Literature also revealed the traditional measure of profitability as:

$$\text{Profitability} = \frac{\text{Revenue}}{\text{Cost}} \qquad (6.1)$$

This measure is similar to the first part of the AI, which is used to measure customer affordability

$$\text{AI} = \frac{\text{CATS}}{\text{WLCC}} \qquad (6.2)$$

This shows a similarity between the traditional measure of profitability and affordability but profitability is concerned with revenue gained from sales based on the price, which is usually cost plus profit. In order to represent a time dimension in the profitability assessment, the researcher proposed a Profitability Index (PI) similar to the AI. The PI is presented in equation (6.3).

$$PI = \frac{CATS}{SP}\left(1 - \left(\sum_{i=1}^{n} \frac{(P_i - S_i)}{S_i}\right) * \frac{1}{n}\right) \tag{6.3}$$

Where

i = the years where price exceeds the expected spending ability of the customer in that year

Si = Expected spending ability of the customer for the ith year

Pi =Price offered in the ith year

n = total number of years the price has exceeded the spending

CATS = customer budget

SP = Selling Price

While affordability is assessed based on WLCC, profitability is assessed based on the SP. The PI takes into account the violation between CATS and SP over the life cycle, by comparing the two factors. The visual comparison of WLCC, Total profit, SP and CATS could also be done to see the impact of one factor on the other e.g. a steady total profit curve means that the CATS is greater than SP.

The conditions for applying the PI are as follows:

(i) Total CATS > 0

(ii) Where yearly CATS is 0, replace with 1

(iii) If Sum of SP < CATS or SP = CATS and there is no violation, only apply CATS/SP

(iv) Apply full PI if there are any violations in the spend profile

The result of the PI is interpreted thus:

If PI < 1, project is less profitable

PI = 1, project is profitable

PI > 1, project is more profitable

A project can be profitable overall based on CATS and WLCC, but secure losses at some stages during the life cycle. This is not a desirable situation as the impact of these losses on the actual project may be detrimental to the cash flow and success of the project (Figure 6-3). The ideal situation is one in which the manufacturer profitability is sustained throughout the project life cycle. The PI helps to emphasise this idea by reflecting the impact of losses or lower profitability at each stage of the project life cycle.

Another assessment was based on the Target Cost Incentive arrangement. This means there is an agreement with the customer that if actual WLCC rises above the target WLCC that was used in pricing the customer would share the increase in WLCC with the manufacturer, which means increasing CATS.

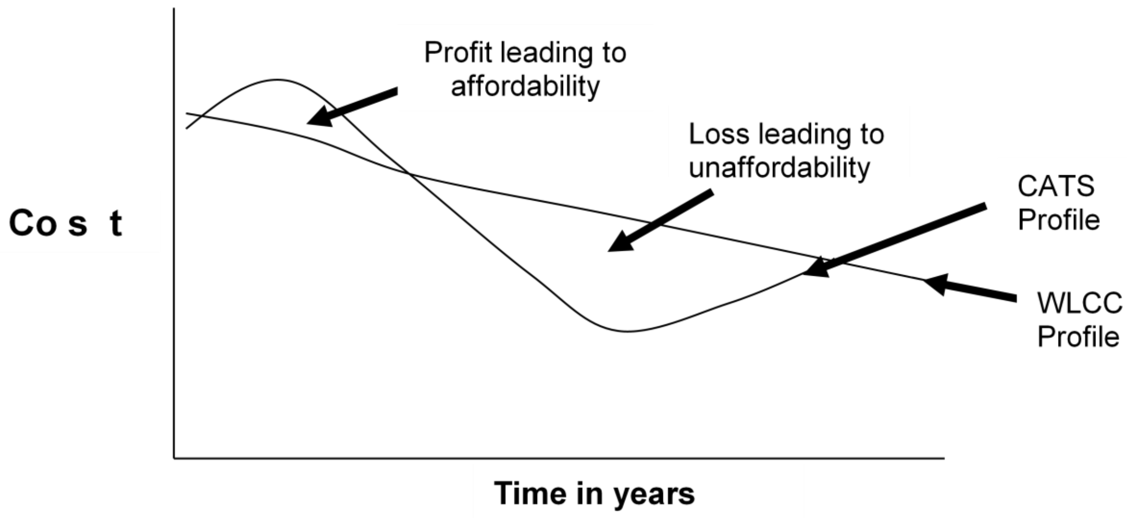


Figure 6-3: Illustration of affordability

It could also mean that when the contractor is able to achieve lower actual WLCC compared to the target WLCC it would share this gain with the customer and thereby reduce CATS. This helps to keep the contract profitable in the long-term. However this might be an incentive for the manufacturer to relax in its effort to control the WLCC. This would only apply to projects that would really require extra investment along the lifecycle.

Net Present Value

Net Present Value (NPV) assessment is a good practice technique identified from literature reviewed and industrial interaction in profitability assessment (Chapters 2 – section 2.4.1 and 4 – section 4.3.8); hence it has been included in the manufacturer profitability module within the overall affordability framework. However, the technique is not always employed in every contract.

$$NPV = \sum \left(\frac{PV\ pf\ cash\ flow}{(1+r)^t} \right) \tag{6.4}$$

Where, r = rate of return

t = the time of the cash flow

PV = Present Value

The standard rate stipulated by the MoD is 3.5% as revealed by the industry interaction. Milestone payments are agreed and delivered based on progress in the contract delivery, e.g. first prototype, safety case, demonstration of performance project acceptance, start of warranty period, etc.

The NPV method is useful in visualising a profile of the customer's payment based on CATS. Beyond this, it includes the time value of both CATS and WLCC. This enables the manufacturer to assess the actual profitability not just based on what the customer has budgeted to pay, but based on other economic factors, which determine the actual value of money at each point in time. The advantage of NPV is illustrated in Figure (6-4).

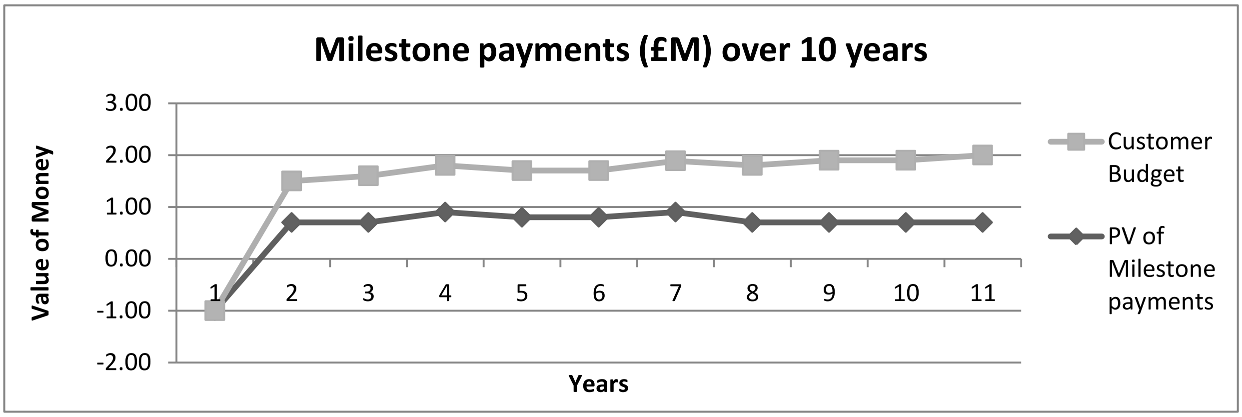


Figure 6-4: The impact of NPV analysis

Figure (6-4) shows that there is a difference between the Customer Budget (predicted CATS) and Milestone payments (actual CATS paid) due to economic factors. The economic factors cause the PV of the milestones to differ from the predicted customer budget. While PI assessment highlights the impact of possible violations during the project lifecycle, NPV goes further to define the actual value of the CATS and WLCC, which determines actual profitability. The manufacturer profitability assessment is also a module within the overall affordability framework. This is expounded upon in Chapter 7. Similar to the quantitative customer affordability assessment, some mathematical parameters were devised in order to implement the manufacturer profitability calculation within the overall affordability framework, which was also implemented as a system.

Like the quantitative customer affordability assessment (Section 5.8), parameters were designed for the implementation of the system in order to perform functions such as addition, multiplication, subtraction and division. Also, to display results and ensure accuracy, functions such as conditional formatting, IF function and automated NPV calculation were used. These are demonstrated in the case study application. The next section focuses on the supplier sustainability perspective.

6.4 Supplier sustainability Assessment

The supplier sustainability assessment represents the view of the manufacturer about the ability of its supplier to remain financially and operationally sustainable during the project life cycle. In order to directly explain the researcher's concept of supplier sustainability, a definition was provided. Supplier sustainability is defined as the *capability of a supplier to maintain products and services in a dependable manner*. This is in order *to ensure their availability and operability over the project life cycle with flexibility to adapt to changing customer requirement in a cost effective and ethical way*. This definition has been reviewed and validated with industrial experts and the details are provided in Chapter 9. The dimensions, measures and process of sustainability assessment, which form the basis of the sustainability module, are described below.

6.4.1 Supplier sustainability dimensions

Sustainability is a concept that many people interpret differently, but this research addresses sustainability in terms of the ability of the defence supplier to stay in business and deliver customer requirements at the right quality and price. As stated in Chapter 2 (section 2.12), generally there is a shortage of supply chain management and purchasing literature on financial and operational issues affecting sustainability. However, Gunasekaran et al., (2001, 2004) designed a framework to measure supplier performance at strategic, tactical and operational levels. This framework provided several measures to assess supplier performance at the three levels. This also includes an environmental dimension since concern for the environment is becoming increasingly important to compete in the current economic climate.

Figure 6-5: Dimensions of supplier sustainability

Based on literature review and industry interaction, five dimensions of supplier sustainability are proposed in this research as shown in Figure (6-5). These dimensions are explained below; however, they are not presented in order of importance.

- Cost – The ability to manage cost in supply chains is vital in order to gain and maintain competitive advantage (Whicker et al., 2009). This dimension is important in order to assess the supplier's ability to manage its cost in order to offer competitive price.
- Management (People & Resources) – this dimension examines the ability of the supplier to manage it resources. Resources can be assets, tools and also the skills and expertise of the supplier's workforce. This is important because the effective management of resources (human and material) will have significant impact on supplier performance (operational) and financial sustainability (SC21, 2009).
- Delivery & Quality – As explained in chapter 5 (section 5.8), this refers to the totality of features and characteristics of a product or service that bear on its ability to satisfy customer need which make it fit for purpose. This dimension is important because the supplier's capability to deliver products and services of good quality on time and in full is crucial to sustaining the satisfaction of customer requirement and maintenance of competitive advantage in the long term (SC21, 2009, Whicker et al., 2009).
- Stakeholders – this dimension is important because the stakeholders in the company especially customers are keen to ensure that the supplier is flexible and can respond to changes in demand and maintain competitive advantage in the market. This enables its sustainability over time.
- Environment – this dimension is becoming increasingly important with growing concern for environmentally friendly processes and initiatives for companies and nations in the 21st

century. This was seen in the last United Nations Conference on Climate Change held at Copenhagen in December, 2009 (Hennessy et al., 2009). Environmental sustainability is a mandatory requirement for companies to be sustainable.

The measures generated under each dimension are both qualitative and quantitative. While most of them are supplier Performance Measures (PM), they have been carefully selected because they give an indication about long-term sustainability of a supplier; this is the major contribution from this module. The indication of sustainability can be derived from monitoring the variation in the performance of a supplier based on these important measures over a given period. This would provide visibility of the trend in current supplier performance to suggest future performance.

6.4.2 Supplier sustainability measures

A systematic methodology based on Del Rey Chamoro et al. (2003) was followed to derive the measures.

1) Understanding the Sustainability Dimension
2) The conceptual description of the Measurable Actions (MA) under each dimension
3) Prioritisation and selection of the major MA based on the feasibility and importance scores
4) Sustainability Measure generation

Step 1: Understanding the Sustainability Dimension – this first step is to identify and define the sustainability dimension in order to generate a MA. The sustainability dimensions are similar to top level strategy aims within an organisation which forms the viewpoint from which the sustainability of suppliers would be assessed. This has been identified in section 6.4.1. While an explanation of each of the parameters is provided in Appendix K, a worked example is presented in the template provided in Tables (6-4) to (6-6).

Table 6-4: Sustainability Dimension model

<table>
<tr><th colspan="2">Supplier Sustainability model</th><th>Opportunities for the measurement solution</th></tr>
<tr><td colspan="2">Sustainability Dimension</td><td>Deliver project within the specified period</td></tr>
<tr><td rowspan="3">Impact on the Project Delivery</td><td>Competitive Indicator</td><td>Time</td></tr>
<tr><td>Department</td><td>De&s</td></tr>
<tr><td>How? Attribute</td><td>Inability to meet project deadlines resulting in failure to deliver project to schedule.</td></tr>
<tr><td colspan="2">MA</td><td>Strategic project plan and schedule with supplier to ensure projects are delivered within the time scale specified.</td></tr>
</table>

Step 2: MA conceptual description – the MA is described in terms of the activity, input and output required to fully understand and carry out the action. Several MAs can be generated as a result from each sustainability dimension; hence it is important to determine the major ones. For this reason, the MA was defined in terms of feasibility and importance scores that indicate the practicability and significance of each MA. The original feasibility and importance scores have been refined to make them clearer and more appropriate. The meanings of each score are provided below in Table (6-5).

Table 6-5: Explanation of score allocation

Explanation	Weighted score
Very low	*1*
Low	*2*
Medium	*3*
High	*4*
Very High	*5*

The benchmark for deriving performance measures (step 4) is defined as a score of 3. This means an MA must have an importance score of at least 3 (medium importance) for PMs to be generated based on the MA. This means MAs with medium importance score or higher must be measured and steps must be taken to ensure that the feasibility scores are improved. The worked example of an MA is provided in the template presented in Table (6-6).

Table 6-6: Measurable Actions mapping

Measurable Action (MA) model	Measurement Action analysis
Measurable Action	Strategic project plan and schedule with supplier to ensure projects are delivered within the time scale specified.
Competitive Dimension	Time
Activity description	Measurement of project output at different stages to ensure that the project plan is suitable in helping to achieve the planned output within the time scale
Inputs	1. Breakdown of the project into tasks 2. Allocate time required to deliver each project task 3. Prepare a final plan for project delivery and confirm with the customer
Agents available	De&s: project management team and solution provider: project management team.
Outputs	To measure the duration of the project delivery
Overlapping	NO
Feasibility score	5
Importance score	5

Step 3: Selection of the MA - This is done based on the MA Matrix which is presented in Figure (6-6). These feasibility scores and importance scores would be provided by the project team. For further analysis, the Boston matrix was applied to the MA matrix to define the MAs based on four categories as shown in Figure (6-7). The Boston Matrix is a business tool developed by the Boston Consulting Group in the early 1970s to help organisations make investment decisions by grouping their business activities or products into categories and deciding the best areas to invest or divest (www.mindtools.com). The four categories used in the matrix are explained in Appendix K.

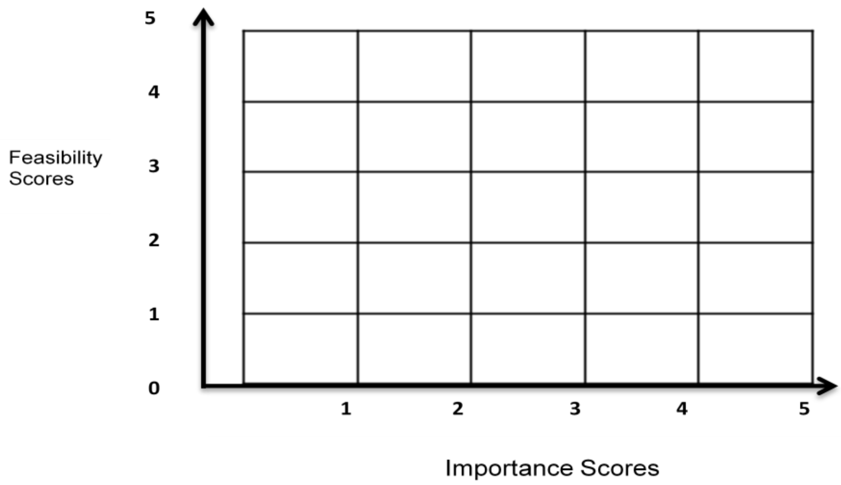


Figure 6-6: Generic MA matrix

The MAs with the highest feasibility and importance scores within the categories of stars and cash cows are then selected to be measured in order to derive PM to assess sustainability.

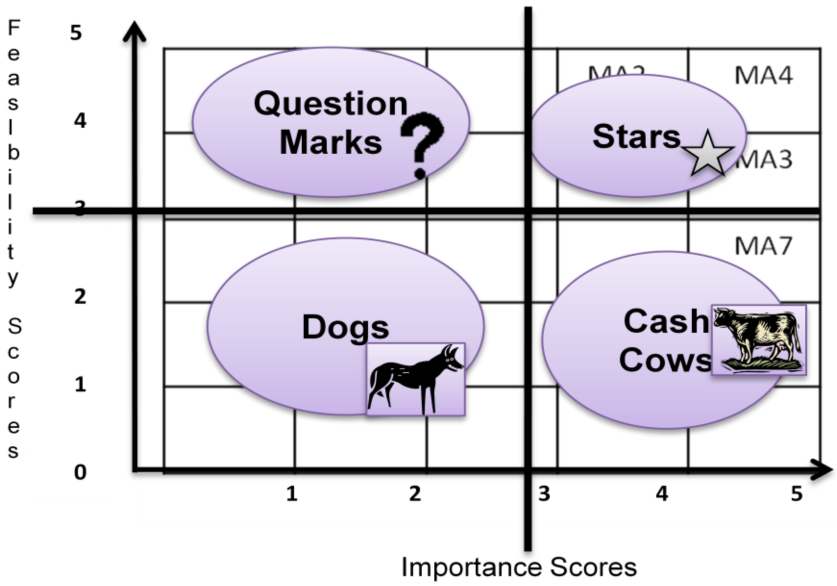


Figure 6-7: Boston Matrix imposed on MA matrix

An example is presented in Figure (6-7) and the major MAs to be selected would be MA4, MA2, MA3 and MA7.

Step 4: PM generation – Table (6-4) provides the PM model that is applied to generate the PM for each sustainability dimension. This is done based on some of the attributes described above. This process involves working back-to-front in order to identify the PM. All the other attributes such as MA, competitive indicator, activity description, etc, have been defined in step 2 above; hence they are able to provide the context of the PM. Finally, an appropriate PM from those already identified within literature and industrial practice is selected based on these attributes. The sustainability measures are generated for each dimension based on the approach described above and the dimensions presented in Figure (6-7) and incorporated into a supplier sustainability module. This module was implemented in a system using Microsoft Excel. This software has been chosen for the same reasons expressed in Chapter 5.

Table 6-7: Performance Measure Model

PM model	**PM description**
PM	Percentage (%) Late delivery $= \frac{No\ of\ late\ delivery}{Total\ number\ of\ order} \times 100$
MA	Strategic project plan and schedule with supplier to ensure projects are delivered within the time scale specified.
Competitive Dimension	Time
Inputs	1. Break the project down into tasks 2. Allocate time required to deliver each project task 3. Prepare a final plan for project delivery and confirm with the customer
Activity description	Measurement of project output at different stages to ensure that the project plan is suitable in helping to achieve the planned output within the specified time scale
Agents available	De&s: project management team and solution provider: project management team.
Outputs	To measure the duration of project delivery

The methodology presented above is logical as it provides an order for the process of generating PMs for the sustainability of suppliers. The methodology helps to prioritise and select the major MAs in order to generate the major PMs by employing feasibility and importance scores in the third step. The ranking of the measures in the order of importance is presented in Figure (6-8) however; most measures under the quality and delivery dimension are of equal importance.

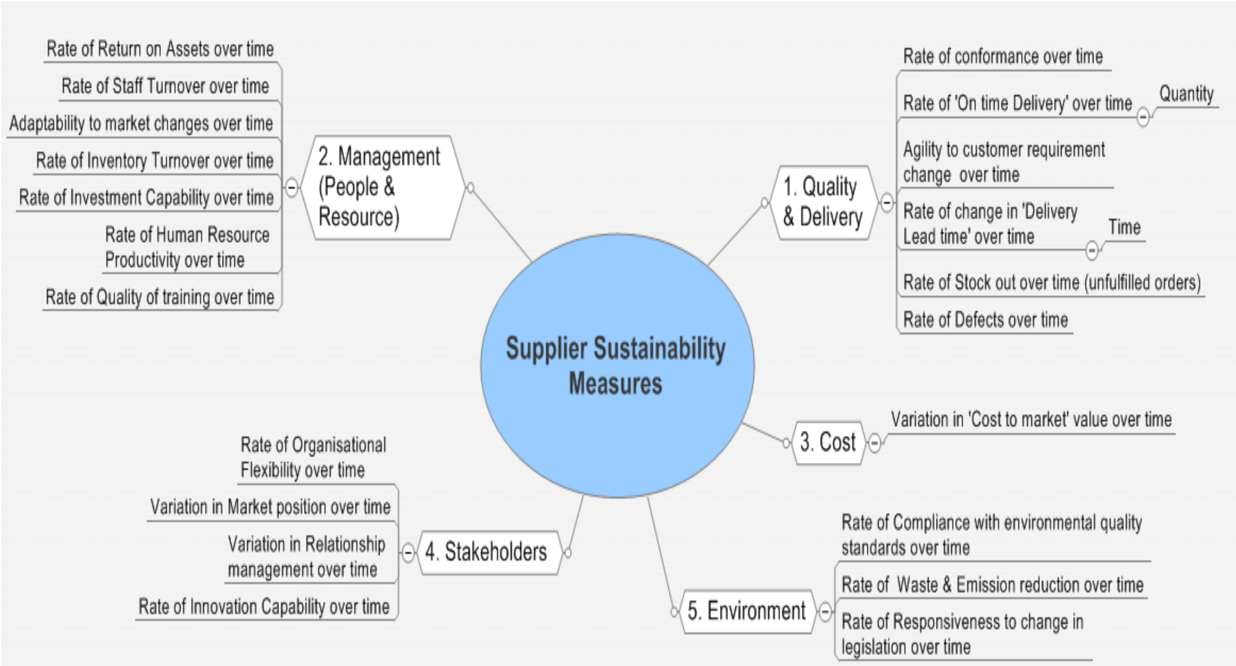


Figure 6-8: Sustainability dimensions and measures

The PMs, which are the output of this methodology, would be applied by defence manufacturers when selecting suppliers for a defence contract based on their performance in terms of the PMs. However, this decision would be made based on trends rather than the score for a PM at one time. This means there is a need for the manufacturer to have some historical information about the supplier in order to assess their financial and operational sustainability. For existing suppliers, it would be easier to obtain this information based on current and past performance measurement data, but for new suppliers it may be more difficult to obtain this information. However, the manufacturer can contact the supplier directly to obtain information from them, or contact their current customers as well as external agencies such as Dun and Bradstreet Corporation who may hold some information relating to the desired supplier. The sustainability assessment based on trends is illustrated in Figure (6-9).

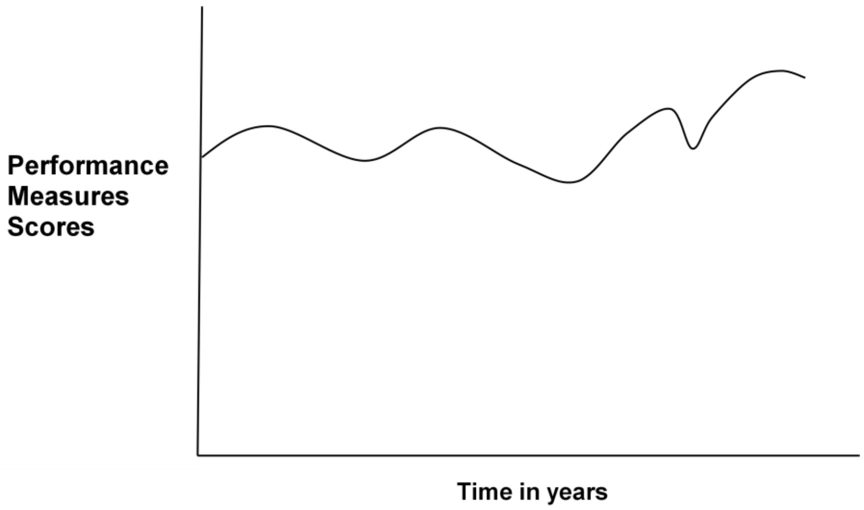


Figure 6-9: Sustainability assessment based on trends in performance

The PM generated from the methodology is the basis for deriving PM scores over a period of time in order to monitor the trend of performance and compare this to the industry average in order to assess supplier operational and financial sustainability. The sustainability assessment involves three main stages as shown in Figure (6-10).

The first two stages have been explained and they are the major steps. The third stage of comparing the PM result against industry average is conditional upon the availability of data about the industry average. An organisation may only focus on ensuring that the trend is improving without comparing the trend against industry average, depending on the size of the organisation and its strategic objectives.

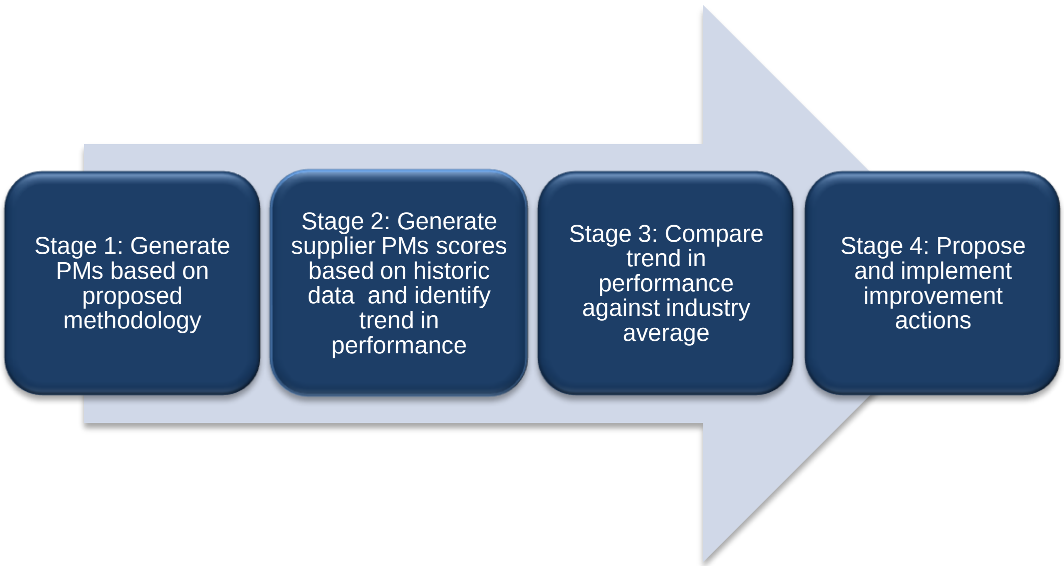


Figure 6-10: Stages in supplier sustainability assessment

However in order to become market leaders, an organisation would compare the trend against industry average. The fourth stage could be carried out based on the result at the second or third stage. The suggested guidelines for improvement are provided in Section 6.4. The next section explains the module development.

6.4.3 Supplier sustainability module development

In implementing the sustainability module, the EFQM Excellence model approach was adopted. The EFQM Excellence model was identified within literature and industrial practice as a framework which provides an assessment of an organisation's performance to maintain sustainable economic growth. This was fully explained in Chapter 2 (section 2.6) and the review showed that the EFQM model was a performance assessment framework which was applicable to any organisation either a supplier, manufacturer or customer. However, the EFQM model is designed to be generic to organisations across different industries and of different sizes across private and public sectors.

Also from Chapter 2 (section 2.6), Gunasekaran et al. (2001, 2004) identified three levels of hierarchy in the measurement of supplier performance namely; strategic (top-level), tactical (middle-level) and operational (low-level). The authors also provided metrics and measures to assess supply chain performance based on these activities. Also, it is important for suppliers to maintain competitive advantage through agility, adaptability and alignment as well as efficiency (Lee, 2004). The supplier sustainability module contains dimensions, drivers and measurable outcomes relating to supplier sustainability.

The dimensions have been explained above in section 6.3.1 while the 4-stage process of obtaining the measures was described in section 6.3.2. The factors that can drive the supplier's ability to remain sustainable based on the dimensions and measures are explained below.

- Customer requirement – this refers to the need that the customer desires to meet. This shapes the customer's demand and it can be dynamic in nature due to various reasons such as perceived threat, change in political climate, etc. A change of requirement could increase the whole life cost of the project where extra effort is required in redesigning the system especially with be-spoke systems and services.
- Cost and uncertainty – this entails a difference between anticipated outcome and an actual outcome, which could impact the delivery of the offering especially in relation to cost.
- Economic climate – this is affected by the inflation, interest rate and share prices. Exchange rate fluctuation between two currencies determines how much one currency is

worth in terms of the other. This could have a negative or positive effect on supplier sustainability.

- Global competition – the rules of competition drive cost down. If competitors are offering lower prices, the supplier could be forced to reduce the cost of their service. Suppliers/contractors from other countries could provide attractive offers in order to expand their customer base.
- Regulation – This refers to the current and future standards and regulations that could impact the supplier's ability to deliver a project over the lifecycle.

While all these drivers have been identified as factors affecting customer affordability in Chapter 5 (section 5.4.1), most of them are external factors, which are outside the control of the manufacturers. They also drive the sustainability of suppliers. These have been presented in the supplier sustainability module in Figure (6-11).

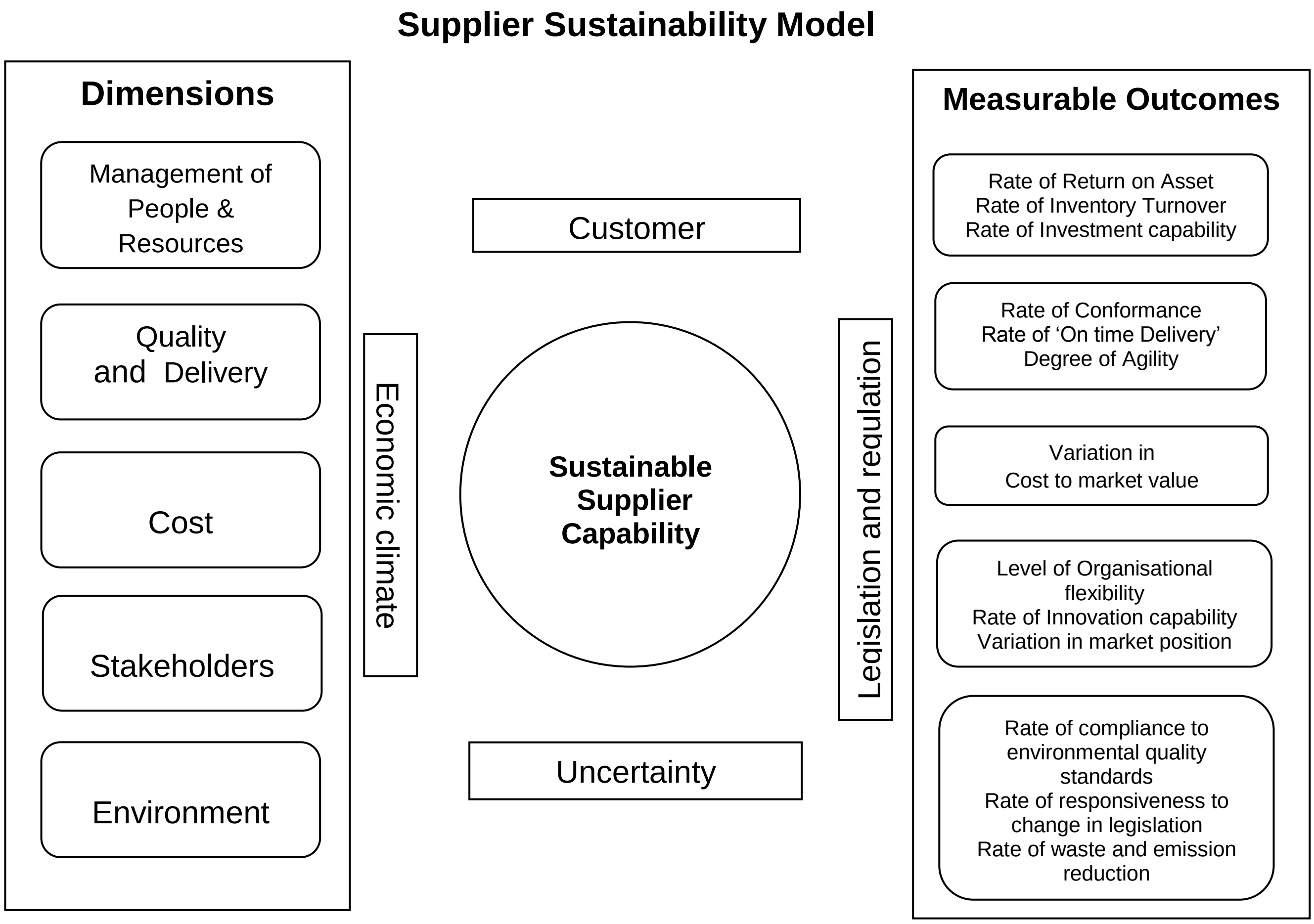


Figure 6-11: Supplier sustainability module

The measurable outcomes within the sustainability module are the PMs generated in Stage 1 of the sustainability assessment, which are both qualitative and quantitative.

The sustainability module was implemented as a system in Microsoft Excel. As explained in Chapter 5 (section 5.6), the Microsoft Excel software was used because it was familiar and accessible to industrial stakeholders as well as the researcher. The software also possessed the functionality required to develop the system, which allows mathematical calculations, graphical representation and storage.

6.4.1 Supplier sustainability module requirements

The system and information requirement in order to use the supplier sustainability system and obtain useful results are provided below.

1. Adequate knowledge of the proposed contract or project
2. Interaction with the either supplier or manufacturer project team
3. Sufficient knowledge of all sustainability dimensions and many of the PMs stated above
4. Basic skills in the use of Microsoft Excel software

These requirements must be met in order to assess the sustainability of suppliers at the bidding stage. With this background, the system benefits are provided below.

6.4.2 Supplier sustainability module benefits and architecture

The supplier sustainability assessment system has these main benefits namely:

- It enables the manufacturer to do a comprehensive evaluation of suppliers' performance when contracting, based on five dimensions at the bidding stage
- It enables the manufacturer to do a comprehensive evaluation of suppliers' sustainability over time when contracting, based on the dimensions at the bidding stage
- It provides assessment for suppliers for both product and service delivery
- It helps to highlight potential risk from the supply chain and provide recommendations in order to improve sustainability based on each dimension.

A user guide is provided within the module which is implemented through Microsoft Excel. The system architecture is presented in Figure (6-12).

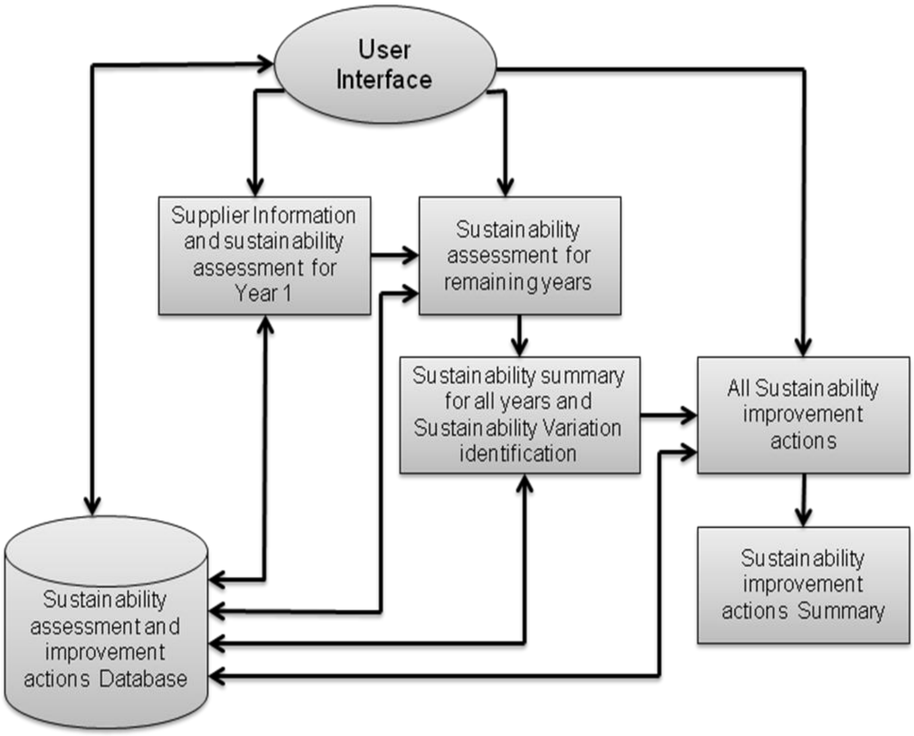


Figure 6-12: Supplier Sustainability Module Architecture

The module architecture describes the supplier sustainability assessment module. The architecture shows that the key activities are providing supplier information, qualitative assessment for year 1, and then qualitative assessment for rest of the project life cycle. From these, results are generated and the user then selects the appropriate improvement guidelines from those provided in order to improve supplier sustainability. The assessment results are stored in a systematic way so that the user can retrieve an existing assessment and also compare the results of different suppliers.

6.4.3 Supplier sustainability module input

For the each activity, the input required is as follows:

- Overall supplier information - supplier name, industry, position within industry, contracting arrangement, supplier stake in the contract as a percentage, prime contractor's stake in the supplier firm as a percentage and type of contract.
- Qualitative sustainability assessment - scores and weights for each sustainability dimension based on the PM for year 1. Next, the assessment for next four years of the project life cycle is also done.
- Supplier sustainability improvement guideline selection - supplier sustainability improvement guidelines.

- To retrieve the records of an existing supplier, supplier name is required.

An example of the supplier sustainability module input within Microsoft Excel is presented in Figure (6-13).

		Score (1,3,5)	Weight (1-5)	Weighted Score
1. Quality & Delivery				
Rate of Conformance over time	Quality Score (Quality Function Deployment (QFD)	1	3	3
Rate of Ontime Delivery over time (Quantity)	No of scheduled delivery - late deli	1	5	5
Agility to customer requirement change over time		3	4	12
Rate of Delivery lead time over time (Time)	Order delivery date - Order entry da	1	4	4
Rate of Defects over time	No. of requirement missed / Total No of Delivery	3	5	15
Rate of Stockout over time	1 - No. of orders unfulfilled / Total No of requirement missed	3	3	9
2. Management (People & Resources)				
Rate of Return on Asset overtime	Net Profit after Tax / Total assets	3	4	12
Rate of Staff Turnover over time	Total No. of leavers over a period x 100 / Avg total number employed over period	3	4	12
Adaptability to market changes over time		3	4	12
Rate of Human Resource Productivity over time	Performance Appraisal score	3	3	9
Rate of Inventory turnover overtime	Annual Net Sales / Inventory	3	4	12
Rate of Investment Capability over time	Cash + Accounts Receivable / Current Liabilities	3	5	15
Rate of Quality of training of employees overtime		5	4	20
3. Cost				
Variation in Cost of Income ratio overtime	Supplier price - Market price / 100	3	5	15
4. Stakeholders				
Rate of Organisational Flexibility over time		3	5	15

Important
This cell must not be left blank

Figure 6-13: Supplier sustainability module input screenshot

The supplier sustainability assessment is done over 5 years because the industrial interviews revealed that this was an ideal period of time to monitor the performance of a supplier in order to assess their sustainability. Also, sustainability is assessed by monitoring the trend and evaluating the variation in performance.

6.4.4 Supplier sustainability module output

As a result of these activities, the module outputs are performance measures (qualitative and quantitative), which are scored and weighted. Then a summary of the weighted scores are presented in graphical form. Upon generating the results, the module also offers recommendations for improvement from which the user can select suitable guidelines to suggest to the supplier in order to improve its sustainability position. The process and content of performing the assessment is further described below.

6.4.5 Method of assessment

The method of assessment is mainly qualitative, but it combines quantitative measures also. This is done for the five sustainability dimensions discussed above, using scores, weights and open-ended or closed questions based on the PMs. The response required for each PM could be either qualitative or quantitative, but after providing the actual value for the measure the user would convert the PM result to qualitative results by providing scores and weights in order to present all measures in a consistent format. This employs the same approach as the qualitative customer affordability assessment described in Chapter 5 (section 5.6.4).

Scores – these provide an indication of the capability of the supplier to remain sustainable in order to deliver an affordable solution which meets the customer requirement. These are assessed in three levels of high, medium and low represented as 1, 3 and 5. This means the lower the score the higher the capability as shown in Table (6-8).

Table 6-8: Sustainability Dimension Scoring

Score	Explanation
1	High capability for supplier sustainability
3	Medium capability for supplier sustainability
5	Low capability for supplier sustainability

Weights – these reflect the importance of the measure within each sustainability dimension to enable the supplier to remain sustainable in order to the deliver an affordable solution that meets the customer requirement. These are also assessed based on figures between 1 and 5, 5 being the highest and 1 the lowest, which is an inversion of the scoring mechanism. This means the higher the weight allocated, the higher the importance as shown in Table (6-9).

Table 6-9: Sustainability Dimension Weighting

Weight	Explanation
1	The sustainability dimension is unimportant
2	The sustainability dimension has little importance
3	The sustainability dimension has some importance
4	The sustainability dimension has more importance
5	The sustainability dimension has most importance

The scores and weights are multiplied to provide the weighted scores. The weights and scores have been inversely assigned in order to ensure accuracy. The logic behind this was fully explained in Chapter 5 (Section 5.6.4) as the same logic was applied for the qualitative customer affordability and supplier sustainability assessment.

Actual Amount – this is the amount of time, people or resources required to assess sustainability based on the PM under each sustainability dimension.

Prior to the assessment, a user guide worksheet was designed to provide the user with a description of terms and concepts used within the module worksheets and how to generate the information required to populate the module. The assessment is done by the user providing contextual information about the supplier and PM, and then converting them to scores and weights for the first year to generate weighted scores. This is done so that the user understands how the weighted scores are generated so they can provide the same for the remaining years. Next, the user is required to provide the weighted scores for the remaining four years. Then, the module generates an average of the weighted scores for sustainability measures over the five years; and yields output in traffic light system, tables and line and spider charts. The module is designed to assess sustainability for five years initially to be repeated every five years based on findings from industrial interaction. The scores are assigned based on the supplier capability within the project while the weights are assigned based on the importance of the sustainability measure within the project. The weighted scores are provided using a traffic light system as shown in Table (6-10)

Table 6-10: Sustainability module output

Colour	Capability Level	Weighted Score for each dimension	Level of risk
Green	High	<12	Low risk
Amber	Medium	>=12, <16	Medium risk
Red	Low	>=16	High risk

The sustainability summary worksheet provides a summary of weighted scores obtained from the analysis worksheet for the 5 years and an average under each sustainability dimension. These averages are presented in a line and a spider chart. This presents the results clearly to enable the user to monitor the variation in the supplier performance from one year to another and assess sustainability. Also, an explanation of how each dimension relates to supplier sustainability is provided. A set of improvement guidelines, which are provided from literature review and validated through the industrial survey for each sustainability measure, are provided within the module. The improvement guidelines are obtained by the user clicking the tick-boxes next to the improvement guidelines that are applicable and feasible to improve supplier sustainability. A summary report is then generated based on the selected guidelines, which the user can print off.

The storage sheets are designed to capture all input and output of the sustainability assessment and the improvement guidelines in order to allow the user to retrieve the data from the storage into the assessment sheets later on. In order to activate the storage sheets the user needs to

indicate the new supplier's assessment by clicking 'yes' in the dialogue box that appears at the start. In order to retrieve the data, the user is required to enter the supplier name in the cell next to a command button that loads the supplier data on the sustainability assessment worksheet.
On each worksheet command buttons are provided which help the user to navigate the module. The assessment could be carried out by the procurement, commercial or supplier engagement functions within the organisation. The measures, weights, score and improvement guidelines were validated with industrial experts from three defence companies. This was followed by the identification of a relevant case study within a prime contractor to validate the module. These are further explained in Chapter 9. Discussion sessions were held with project managers to understand the case study and populate the module to assess the financial and operational sustainability of one major supplier. This case study is presented in section 6.5.

6.4.6 Measures and dimensions for assessment

As explained above, these measures and dimensions were developed from literature review and industrial interaction and validated with industrial experts (Chapter 9). All the measures are assessed over time to measure supplier sustainability and they are detailed in Appendix L.

(1) Delivery & Quality – this dimension is concerned with those measures of quality for a product or service, which shows that it is fit for purpose and satisfies customer need. The measures under this dimension are provided below.

a) Rate of Conformance– this is measured based on the Quality Function Deployment (QFD) score. QFD is a detailed system for translating the needs and wishes of the consumer into design requirement for products and service (Terniko, 1997). The score of this analysis, which is based on various criteria, gives an indication of quality at one point in time and the trend in this score over a period of time gives the rate of conformance.

b) Rate of On-time Delivery (quantity) – this refers to the ability to deliver products and services at the desired quantity or scale. This is measured by finding what quantity or scale the requirement was delivered late. Again the trend in on-time delivery would indicate the rate of on-time delivery.

$$Rate\ of\ On\ time\ Delivery = No\ of\ scheduled\ delivery\ -\ late\ delivery \quad (6.5)$$

c) Agility to respond to customer requirement change – this refers to the ability to respond to short-term changes in demand or supply quickly and the smooth handling of external disruptions. This is measured by the speed of supplier response in comparison with industry average.

d) Rate of Delivery lead time (time) – this is similar to on-time delivery, but here the duration of time is being measured. It is aimed at identifying delay in lead time which is measured by finding out how long the supplier deviated from the agreed delivery date. As explained above, the trend in the dates would indicate the rate of delivery lead time.

$$Rate\ of\ Delivery\ lead\ time = Order\ delivery\ date\ -\ Order\ entry\ date \quad (6.6)$$

e) Rate of Defects - this refers to products or services that are not fit for purpose. This is measured by finding those orders for products and services that are not fit to fulfil the customer requirement.

$$Rate\ of\ Defects = \frac{No.of\ requirement\ missed}{Total\ No\ of\ Delivery} \quad (6.7)$$

f) Rate of Stock out - this refers to products that are not available due to unfulfilled orders. This is measured against agreed stock level.

All of these measures require trend analysis in order to identify the rate of meeting all of them as rate cannot be identified through a score at one point in time, rather by trend over time.

(2) Management (People & Resources) – as explained in section 6.3.1, this is focused on the supplier's ability to manage both human and material resources to deliver customer requirement and accessed with the following measures.

(a) Rate of Return on Asset - refers to profit earned in relation to the asset employed in delivering customer order. This is measured thus:

$$Rate\ of\ retun\ on\ asset = \frac{Net\ Profit\ after\ Tax}{Total\ assets} \quad (6.8)$$

(b) Rate of Staff Turnover - refers to how the supplier manages human resources to maintain a skilled and sufficient workforce that is able to deliver customer requirement. This is measured thus:

$$Rate\ of\ staff\ turnover = \frac{Total\ No.of\ leavers\ over\ a\ period}{Average\ total\ number\ employed\ over\ period} * 100 \quad (6.9)$$

(c) Adaptability to market changes– adjust to meet structural shifts in markets and modify supply network to strategies, products and technologies. This measured by the scores in Appendix L.

(d) Rate of Human Resource Productivity - refers to the ability of the supplier to manage its human resources to achieve maximum productivity. This is measured by the result of the *performance appraisal score* within the organisation.

(e) Rate of Inventory turnover – refers to how many times a supplier's inventory is sold and replaced over a period. Cost of goods sold is used in the calculation instead of sales because sales are recorded at market value while inventories are usually recorded at cost. This is measured thus:

$$Rate\ of\ inventory\ turnover = \frac{Cost\ of\ goods\ sold}{Average\ Inventory} \qquad (6.10)$$

(f) Level of Investment Capability– refers to supplier's capacity for further investment in business. This is assessed based on profitability and liquidity ratios as presented below.

$$Level\ of\ Investment\ capability = \frac{Cash + Accounts\ Receivable}{Current\ Liabilities} \qquad (6.11)$$

(g) Level of Quality of training of employees - refers to how the supplier invests in developing its human resources to improve their skill level and productivity. This is measured by the scores in Appendix L.

(3) Cost – refers to the financial investment (price charged by the supplier to the manufacturer) required to deliver the customer requirement. This dimension is concerned with one measure presented below.

Variation in Cost overtime - refers to the supplier price in comparison to the market price as shown below.

$$Cost = \frac{Supplier\ price - Market\ price}{100} \qquad (6.12)$$

(4) Stakeholders – refers to the supplier's ability to yield returns for the stakeholders such as customers and employees.

(a) Level of Organisational Flexibility - refers to the supplier's flexibility to diversify in order to deliver customer requirement. This would be assessed by the manufacturer providing a score based on its past performance.

(b) Variation in Market Position - assesses the supplier's market position either as a market leader or follower. This would be assessed by the manufacturer providing a score based on its past performance and available information from external organisation such as Dun and Bradstreet plc. The scores are shown in Appendix L alongside the other scores.

(c) Rate of Relationship Management - assesses the ability of the supplier to manage its relationship with customers and other stakeholders. This would be assessed by the manufacturer providing a score based on its past performance and available information.

(d) Rate of Innovation Capability - refers to the supplier's ability to develop innovative processes, products and services to deliver customer requirement. This would be assessed by the manufacturer providing a score based on its past performance and available information.

(5) Environment – refers to supplier's effort to employ environmental sustainability initiatives in its operations.

(a) Rate of compliance with environmental quality standards – refers to ability of the supplier to satisfy the relevant UK/European or International regulations and agreements on quality (e.g. AS9100 or IS0 9100). This is determined by the result of the International Organisation for Standardization (ISO) or SC21 assessment.

(b) Degree of waste reduction - refers to the level of effort employed in reducing waste and emissions. This is determined by the measure of the Carbon Footprint emission.

(c) Rate of Responsiveness to change in legislation over time- refers to the ability of the supplier to respond to new legislation and regulations. This would be assessed by the manufacturer providing a score based on its past performance and available information.

As stated for the delivery and quality dimension, all of the measures require trend analysis in order to identify the rate of meeting all of them. This cannot be identified through a score at one point in time, but rather by trend over time. The sustainability measures generated and dimensions were incorporated into a supplier sustainability module. This module was implemented using the Microsoft Excel Software.

6.5 Supplier sustainability improvement guidelines

After the assessment of a defence supplier at the bidding stage, it is important to monitor the performance of the supplier to ensure that they maintain a sustainable position over the project life cycle. Also, if the assessment result shows that a supplier is not sustainable, there is a need to take actions to correct this and improve the sustainability position where a substitute is not available. Different guidelines may be proposed to make a supplier operationally and financially sustainable and ensure that this is maintained over the life cycle. Therefore based on each sustainability dimension and PM, both quantitative and qualitative, a set of improvement guidelines were designed to improve sustainability and are presented in the Tables provided in Appendix M. These were obtained from literature review and validated through the industrial survey. The process involved in the implementation of the supplier sustainability module in Microsoft Excel is presented in the next section.

Supplier sustainability assessment process

The assessment process is presented in the form of a flowchart in Figure (6-14). This exercise should be undertaken as part of the bidding process which is explained in Chapter 4 (section 4.3.4). This presentation was chosen for the same reasons stated in Chapter 5 (section 5.7) and the notations used in the flowchart have been explained in the same chapter.

The flowchart provides a visual description of the steps involved within the process and the flow of information to illustrate how inputs are turned into outputs in Figure (6-14).

Like the qualitative customer affordability assessment (Chapter 5 – section 5.8), the parameters are designed for the implementation of the module in order to perform the following functions such as addition, multiplication, subtraction and division. Also to display results and ensure accuracy, functions and commands such as VBA Codes to activate the storage sheet and to upload previous assessment results, conditional formatting, VLOOKUP Function, Data validation, Tick boxes and Macros for copying and printing were also used. These are presented in Appendix M and demonstrated in the case study application. In order to understand the application of the profitability assessment and supplier sustainability assessment, a worked example is provided from the case study presented in Chapter 5 (section 5.10).

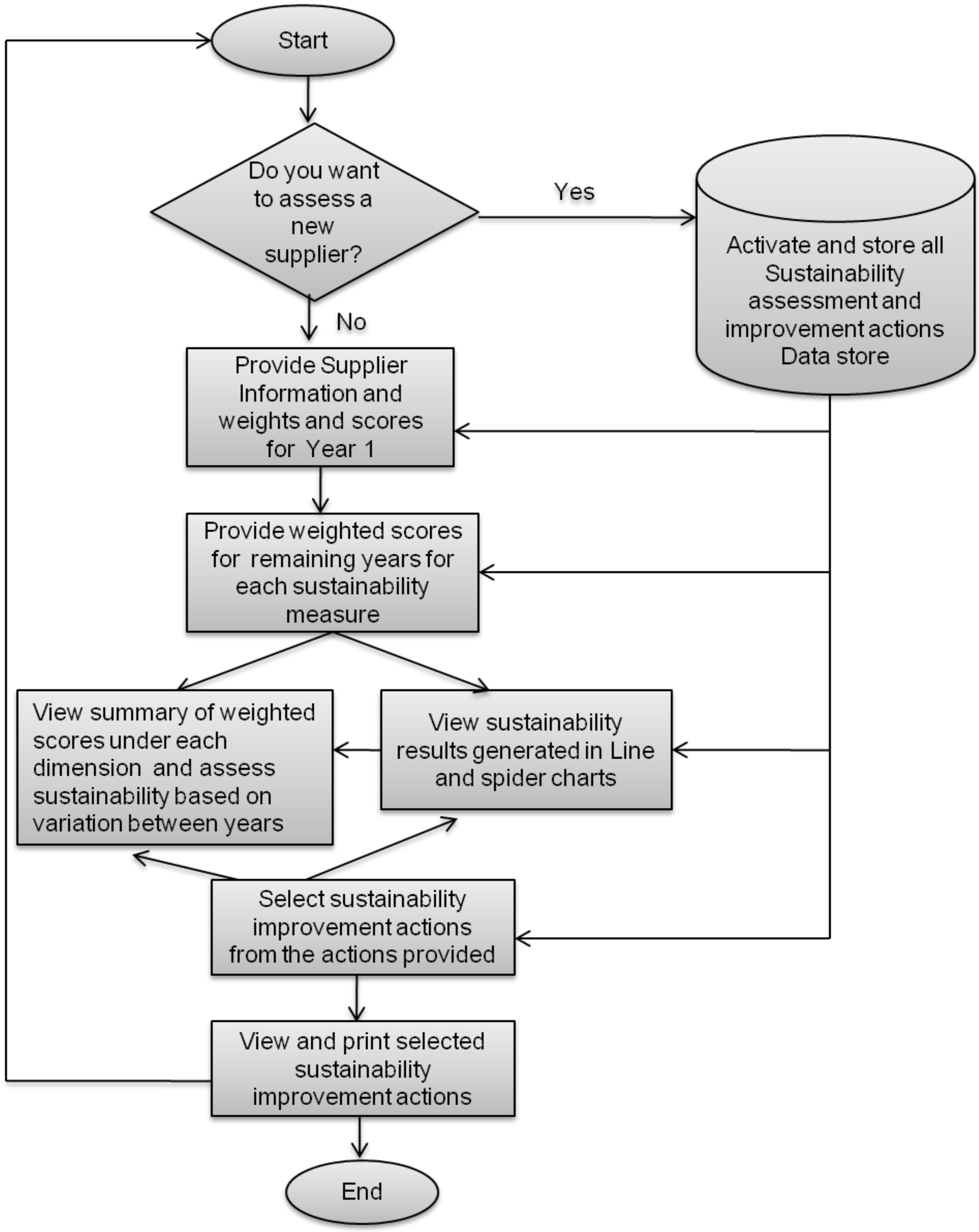


Figure 6-14: Supplier sustainability assessment process

6.6 Case study Application

The case study background was presented in Chapter 5 (section 5.10) along with the qualitative and quantitative customer affordability assessment. Its manufacturer profitability and supplier sustainability assessment are provided below

6.6.1 Manufacturer Profitability Assessment results

As mentioned in Chapter 5, the initial 5-year proposal would have produced a contract that was unaffordable to the customer and unprofitable to the manufacturer. Therefore, no manufacturer profitability assessment was performed initially. The profitability assessment with the new proposal, which formed the basis of the actual contract, is presented in Table (6-11). The values in Table (6-11) reveal that the total SP is the same amount as the CATS. This means the customer's budget was able to cover the cost and the minimum margin the manufacturer was prepared to accept, however there are violations in the values each year. The table also reveals that the contract would yield a positive margin for the first 8 years of the project, but a negative one in the last two years of the project (losses) giving a total margin of £1,353,615.98. This is due to the fact that the customer budget is usually distributed evenly across the life cycle, while the WLCC cost profile changes over the life cycle.

The PI of 0.13 reveals that the project is less affordable due to the violation of over £560,000 in the last two years. This means while the project is profitable overall (CATS/SP = 1), the violations in last two years as shown in Figure (6-15) could have a significant impact on overall profitability. This is an important element to take into account when considering cash flow. The PI helps decision makers to visualise the effect of violations along the project life cycle over the whole project.

The profile in Figure (6-15) shows that the CATS is a steady straight line as the budget is evenly spread across the 10 years. The SP line increases alongside the WLCC line to stay at the same level as the CATS in years 5 to 7 and rise above the CATS line in years 9 and 10. The total margin line, which is the profitability indicator, is the lowest overall and stays above 0 in year 1 to 8. The margin stays the same as previous years at some stages of the life cycle but generally falls each year, reducing to over -£330,000 in year 10. Overall, the total SP being the same as total CATS means the manufacturer could break even, but not much profitability is guaranteed.

The NPV calculation was done based on the MoD rate of 3.5% and this yielded a value of £11,249,020.75. The NPV value suggests that actual revenue over time will be less than £12,699,935.98. This signifies negative profitability within this case study. However, there could be the chance to review the contract after the first five years, and the manufacturer may re-negotiate with the customer in order to be able break-even and achieve some profit margin. The supplier sustainability assessment is presented in the next section.

Table 6-11: Case study 1 CATS and SP values - actual

Year	1	2	3	4	5	6	7	8	9	10	Total
Currency	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**
WLCC	890,160.00	890,160.00	1,000,000.00	1,000,000.00	1,114,000.00	1,114,000.00	1,118,000.00	1,120,000.00	1,500,000.00	1,600,000.00	11,346,320.00
Margin	379,833.60	379,833.60	269,993.60	269,993.60	155,993.60	155,993.60	151,993.60	149,993.60	-230,006.40	-330,006.40	1,353,615.98
Selling Price	996,944.97	996,944.97	1,118,864.36	1,118,864.36	1,247,133.71	1,247,133.71	1,250,943.69	1,253,483.68	1,678,931.54	1,790,690.97	12,699,935.98
CATS	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	12,699,935.98

$$PI = \frac{CATS}{SP}\left(1 - \left(\sum_{i=1}^{n}\frac{(P_i - S_i)}{S_i}\right) * \frac{1}{n}\right)$$

(ii) PI = 0.13

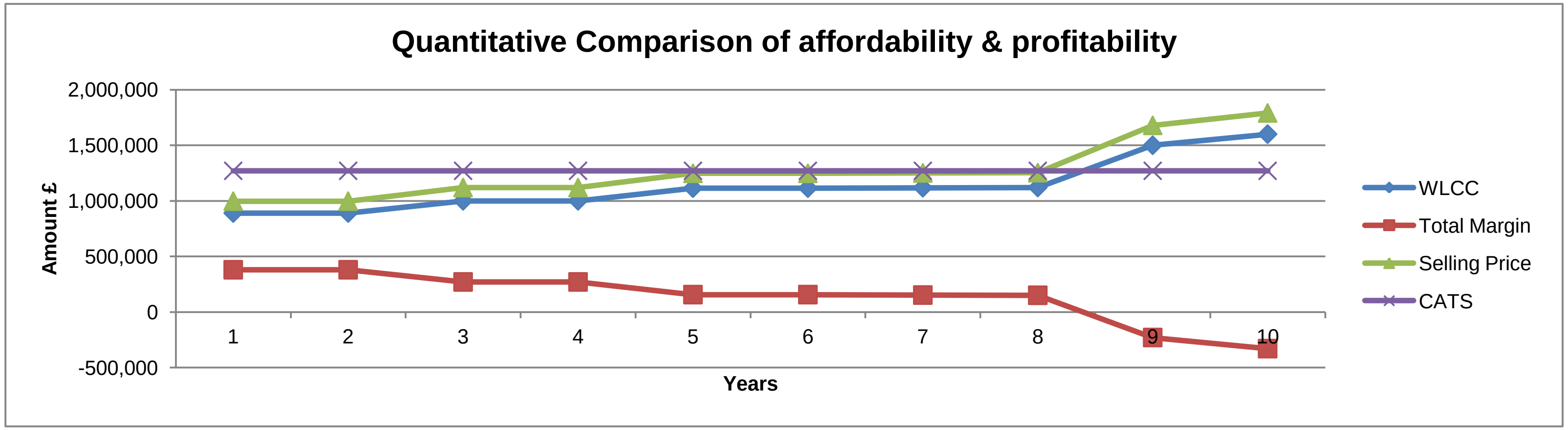


Figure 6-15: Case study 1 CATS, WLCC, Margin and SP profile

6.6.2 Supplier Sustainability Assessment results

Initially, the prime contractor was able to assess the sustainability of one of its supplier for only two years (Table 6-12) with the belief that the supplier's sustainability position would change after the first two years and the supplier might be replaced with another one. This has now changed since the contract was re-negotiated and the project lifecycle had increased to ten years. The sustainability assessment was done over five years as this was considered a suitable duration for such assessment (Table 6-13). This means the predicted sustainability assessment would be different from the actual. The supplier assessed is a sister-company, which means its current financial position was not a priority since the corporate company would be able to lend support if the need arose. The project was contracted on cost plus arrangement.

Table 6-12: Case study 1 Supplier sustainability assessment weighted scores-Predicted

Sustainability Factors	Year 1	Year 2
Quality and Delivery	11	11
Management (People & Resources)	10	10
Cost	25	25
Stakeholders	12	12
Environment	7	7

Table 6-13: Case study 1 Supplier sustainability assessment weighted scores-Actual

Sustainability Factors	Year 1	Year 2	Year 3	Year 4	Year 5
Quality and Delivery	11	14	14	16	13
Management (People & Resources)	10	10	10	10	10
Cost	25	25	25	25	25
Stakeholders	12	15	12	15	12
Environment	7	7	7	7	7

The initial assessment in Table (6-12) was done with the notion that the supplier sustainability position would not be the same over two years; hence there was little consideration for significant changes over the period. The Table showed that the supplier would be sustainable in the other dimensions apart from cost because it's pricing was high.

Being a sister-company, there was the opportunity if getting financial assistance from the corporate company. However, Table (6-13) shows that the supplier is sustainable (green cells) in terms of the environmental and management dimensions. The red cells for the cost dimension suggests the supplier prices were costly to the manufacturer while quality and delivery and stakeholder dimensions suggest the capability was kept at a satisfactory level (green and amber cells). The assessment is also presented in Figure (6-16) to illustrate the changes during the five-year assessment. The reasons for the changes have been enumerated in the assumptions presented in Chapter 5 (section 5.10) and the impact of these changes on supplier sustainability is further explained below.

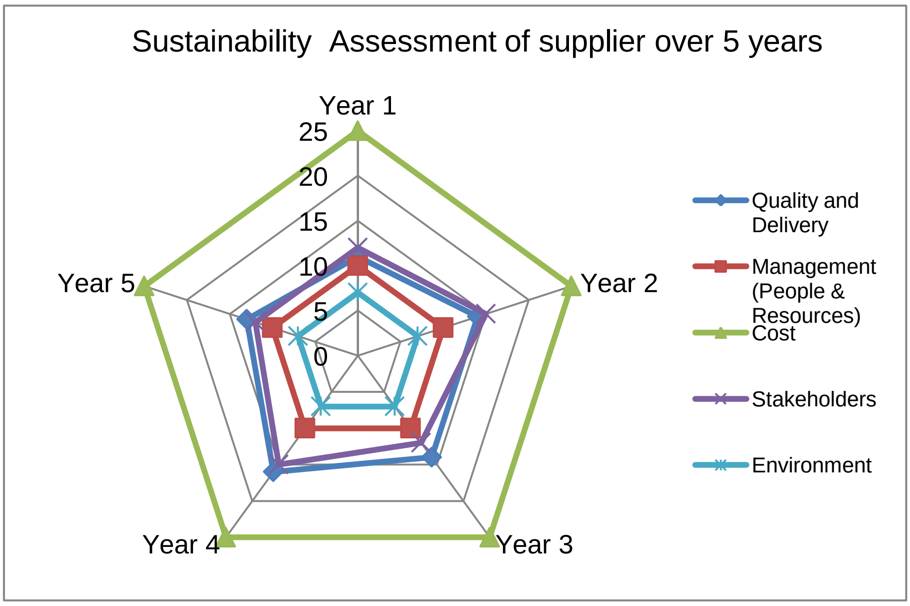


Figure 6-16: Case study 1 Qualitative Supplier Sustainability results

- Delivery & Quality - enhanced customer requirements and increased utilisation and usage rates of equipment in Afghanistan meant the supplier may not have the capability to absorb and adapt to the dynamics of the requirements and usage rates. Delivery lead-time could have been longer than expected and the supplier's solution may not fully conform to customer expectation during operations, leading to higher attrition and failure rates. This explains the reason for the increase in weighted scores for most of the five years of assessment meaning that the capability reduced over time.

- Management (People & Resources) – although the supplier employed the same level of resources throughout the lifecycle of project, the level of efficiency could have increased slightly to meet changing demand. The manufacturer believed that this dimension did not really change over the lifecycle, which explains why the weighted score was the same over the 5 years.
- Cost – Single source of component supply from a foreign major supplier resulting in monopoly of spares and repair capability meant the supplier prices were high which led to higher support costs to the manufacturer. The single source position (no competition) of the supplier meant that it had the ability to maintain the same high price over the five years. This is why the weighted score stayed at the highest through the sustainability assessment.
- Stakeholders – the supplier's ability to adapt to changing customer requirements was key to satisfying the stakeholder, but the supplier was not able to achieve this over time. This explains why the weighted score increased in years 2 and 4. However, the fact the weighted scores were lower in years 1, 3 and 5 suggests that the supplier would take steps to improve its capability to satisfy its stakeholders.
- Environment – the supplier solution did meet the environmental quality standards and this project was not affected by new environmental legislation, hence the weighted scores were low throughout the 5 years of assessment.

Overall the supplier sustainability position is favourable in all four dimensions but cost. This was the case because the supplier had the capability that was crucial to the delivery of the project and it charged higher prices for this. However it would be able to deliver the customer requirement, though it might take longer due to the dynamic nature of the requirement.

The supplier sustainability module offers some improvement guidelines which the supplier may take in order to minimise its cost and improve its capability to adapt to changing customer requirements as provided in Section 6.4. The prime contractor may propose these guidelines to its supplier and if taken, the supplier price could be reduced; however, this is subject to the supplier's willingness and feasibility to implement the suggested guidelines.

6.7 Summary

This Chapter first presented the other two perspectives of affordability which would form two modules within the overall affordability framework namely manufacturer profitability and supplier sustainability. It provided the factors affecting profitability while focussing on the quantitative factors. To represent the dynamic nature of profit over the life cycle of defence contracts, a PI was developed and employed. Also, in order to ascertain actual profitability, the NPV technique was employed to assess time value of money.

Furthermore, the Chapter describes the module developed to assess supplier sustainability based on qualitative dimensions and the selected PMs within them. The four stages of the sustainability assessment were enumerated within the Chapter. The supplier sustainability module includes some improvement guidelines developed to improve supplier sustainability based on the result of the sustainability assessment. The improvement guidelines are developed based on each measure and dimension of sustainability presented in this Chapter. Both profitability and sustainability assessments were implemented using Microsoft Excel and a real life case study application is presented within the Chapter. The next Chapter focuses on the overall affordability audit and overall affordability management, which apply to the entire affordability framework.

CHAPTER 7
AFFORDABILITY INFORMATION CAPABILITY AUDIT AND OVERALL AFFORDABILITY MANAGEMENT FRAMEWORK

7.1 Introduction

This Chapter presents an overall affordability framework which comprises an affordability audit, overall affordability management together with the three affordability perspectives already presented in Chapters 5 and 6. The affordability information capability audit assessment is aimed at assessing the availability of information to perform an affordability assessment. The audit assessment is based on five affordability factor groupings from the three perspectives across each phase of the CADMID cycle. It also considers five elements under the factor groupings which are common to defence contracts. It employs a system of scoring by assessing these factor groupings based on the elements to determine the information availability. The overall affordability management technique is concerned with deriving measures for managing overall affordability of the contract. This is achieved by employing the Key Performance Indicator (KPI) development methodology applied in Chapter 6 (section 6.4.2) to generate relevant PM based on the KPIs required to deliver a project.

7.2 Overall Affordability Framework

The interaction with industrial experts and the review of literature revealed that affordability was a concern for the three main partners within a defence contract who are the customer, manufacturer (prime contractor) and the low-tier supplier. The customer is keen to see that its requirement would be delivered within the budget allocation available, the prime contractor is concerned about the delivery of the customer requirement and maintaining the desired level of profitability and equally concerned about having suppliers that would be financially sustainable over the lifecycle of the contract. Therefore, the concept of the proposed overall affordability framework is one, which combines four modules and an affordability management methodology. The overall affordability framework was implemented as system using Microsoft Excel software. The affordability information capability audit assessment is aimed at assessing the level of information available to assess affordability prior to the assessment while the overall affordability management methodology is aimed at generating measures to manage the project affordability during the life cycle. As illustrated in Figure (7-1), the affordability information capability audit and the overall affordability management methodology apply to all three modules representing the three affordability perspectives.

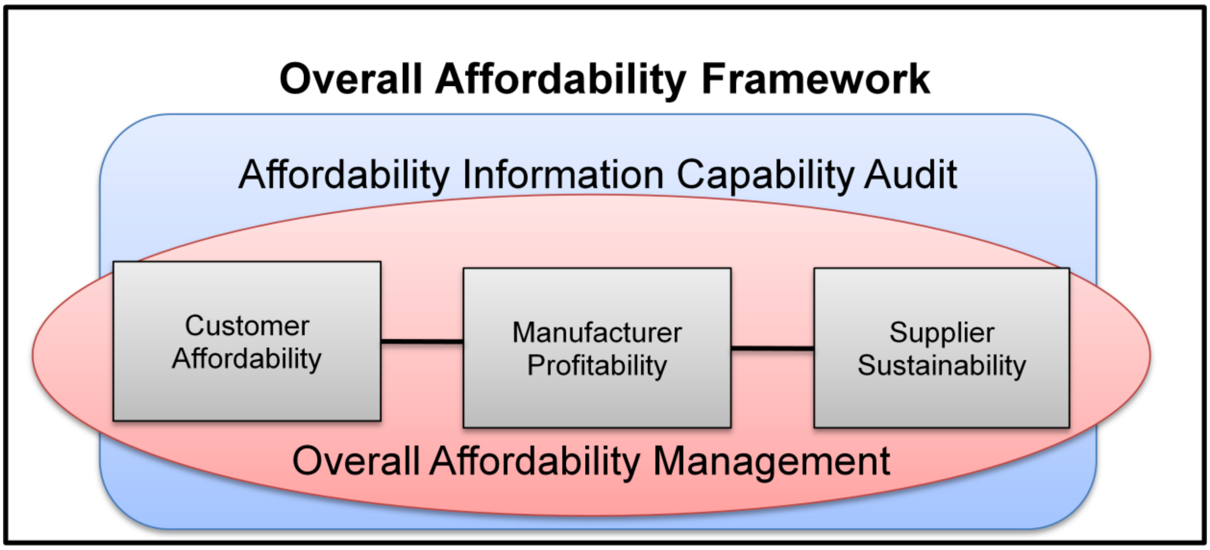


Figure 7-1: Overall Affordability Framework

Methodology for framework Development

As earlier mentioned in Chapters 2, 5 and 6, the interview protocol to investigate customer affordability, manufacturer profitability and supplier sustainability was informed by the literature review. The methodology, factors and measures employed in the framework development were obtained from the literature reviewed and the interview sessions conducted for the three affordability perspectives as explained in Chapters 5 and 6. The same is applicable to the affordability information capability audit and overall affordability management methodology. The affordability information capability audit was validated as a separate module within the framework. The overall affordability management methodology employed the same process of generating PMs for supplier sustainability; hence it was validated alongside the supplier sustainability methodology of generating PMs. The affordability information capability audit is described below.

7.3 Affordability Information Capability Audit

The affordability information capability audit is an assessment, which is aimed at determining the level of information that is available for performing an affordability assessment from the three perspectives at the bidding stage. The English dictionary describes an audit as an official examination and verification of accounts and records to assess the state of an organisation. Most audits are financial or operational assessment of company account and activities; however, in this case, the audit is focused on availability of information which forms the basis of the affordability assessment involving financial and non-financial aspects as seen in Chapters 5 and 6.

Defence contracts could last between 5 and 40 years (with 5 yearly reviews); hence it is needful to make informed decisions at the bidding stage, which requires appropriate information. One of these decisions is about whether the customer can afford the solution proposed by the solution provider. Affordability assessment is performed at the bidding stage (as explained in Chapter 4) before the contract is awarded which means the cost estimation and affordability assessment is done based on available information. Contract terms and conditions are agreed several years before the contract starts, hence the need for these assumptions to be made based on accurate information in order to assess and make provision for uncertainty involved in the contract. The availability of much data would not add any value unless data in endowed with relevance and purpose to be converted into valuable information (Drucker, 1988). Information here refers to any type of information that would be useful in affordability prediction, which includes financial and operational information. The next section provides the affordability factor grouping and elements which form the basis of the affordability information capability audit.

7.3.1 Affordability information capability audit factor groupings

The affordability audit assessment is based on the affordability factor groupings from three perspectives which are WLCC, CATS, contract type arrangement, customer requirement and other. These factor groupings were determined by the findings from industrial interaction and literature review.

- WLCC and CATS have been explained in Chapter 5 (section 5.4 and 5.5) as they are major factors of affordability from customer and manufacturer perspectives.
- Customer requirement would influence their willingness to pay for the offering, as explained in Chapter 2 (section 2.10).
- Contract type requirement refers to a combination of factors which affect affordability from customer, manufacturer and supplier perspectives such as the contract time scale, legislation, environment, economic climate, supply chain, quality.
- Other refers to any other factors which arise within an individual contract which is really important to the delivery of the contract.

The industrial interaction and literature review also helped to identify five elements (skills, tools, information, experience, software dependency) under which the affordability factor groupings would be examined.

- Skills – this refers to the technical ability and expertise of company employees that would be assigned to the contract.
- Tools –this refers the processes, techniques and instruments that could be employed in the delivery of the contracts
- Information – this refers to data or documentation relating to any aspect of the contract, released by either the customer or manufacturer.
- Experience – this refers to the expertise of the team in operating in the environment of the current contract e.g. land, water or air.
- Dependency – this refers to the contract's level of dependency on software (commercial or be-spoke), technology or hardware. The respondent would indicate what the contract is dependent on.

The factor elements form the facets upon which information capability is assessed under each affordability factor. The factors have been described in the previous chapters and summarised above. The elements were chosen as they represented the major capability required for the solution provider to successfully deliver the customer requirement considering the level of information and resources. These are assessed across the different phases of the CADMID cycle, including the Pre-bidding stage before the contract is awarded. These affordability factors and the elements were chosen based on review of literature as well as industry interaction.

7.3.2 Affordability information capability audit benefits

The aim of the audit is to determine the capability of the project team or decision makers to predict affordability of a project based on the level of information that is available to them at the bidding stage. For this reason, the affordability information capability audit module was developed to achieve the following:

- Assess the capability of the bidding team to determine the customer's affordability of a contract based on available information.
- Provide help with negotiation at concept stage and speed up the contract.
- Provide a 'quick look' to motivate teams in order to remove gaps in information availability as it emphasises areas for data collection.
- Include pictorial means of identifying information shortfall by allowing more than one assessment for a contract.

7.3.3 Affordability information capability audit module requirement

The information requirement to use the affordability audit module and obtain useful result are provided below.

1. Adequate knowledge of the proposed contract or project
2. Interaction with the either customer or manufacturer project team
3. Knowledge about all five affordability factor groupings stated above
4. Basic skills in the use of Microsoft Excel software

7.3.4 Affordability information capability audit module input

In order to perform the affordability audit based on the affordability factor groupings and the elements, a scoring mechanism was adopted. The scores were chosen based on the findings from literature and validated with industrial experts and the meaning of each score is presented in Table (7-1).

Table 7-1: Affordability capability audit scores

Score	Explanation
1	No data
2	Insufficient data
3	Just enough data
4	Optimum level of data
5	Plenty of data

These scores are different from those employed in Chapters 5 (section 5.6) and 6 (section 6.4) which were aimed at assessing capability of the solution to deliver the customer requirement. Unlike the assessment done in Chapters 5 and 6 which also involves a weighting mechanism, this does not apply to the audit because the audit is only aimed at determining what information is available about the project which determines the confidence level in the assessments carried out for the three perspectives. The weight (importance) of information throughout the project is very high in order to make the right decisions. The audit would also help the bidding team to focus on getting more information where needed and indicate how the project could be affected by uncertainty. A set of questions is presented to which the user is required to provide scores between 1 and 5. The scores allocated would vary at different stages of the CADMID cycle with a general assumption that the information availability is usually higher at the earlier stages of the project life cycle than the latter stages. The next section explains the process of carrying out the audit.

7.3.5 Affordability information capability audit process

The user is required to provide scores based on the level of information available for each affordability factor grouping (Section 7.3.1), according to the factor elements under them for each stage of the CADMID cycle in order to generate an output. The module comprises of three main activities as presented in the architecture in Figure (7-2). The activities are; acceptance of user input (score) as shown in Table (7-2), generation of total scores under for the factor groupings based on the factor elements under each phases of the CADMID cycle (Table 7-3) and finally generation of a single score (average) for each affordability grouping under each phase of the CADMID (Table 7-4). The final result is presented both in numerical (scores) and graphical form as illustrated in the case study in section 7.5. These activities are all carried out in one main worksheet and the result of the audit is stored in a different sheet. Within the module, a user guide was designed to clarify the meaning of terms used within the module worksheets and how to provide the information required in the worksheet. A user interface was designed to allow the user provide the scores for the assessment.

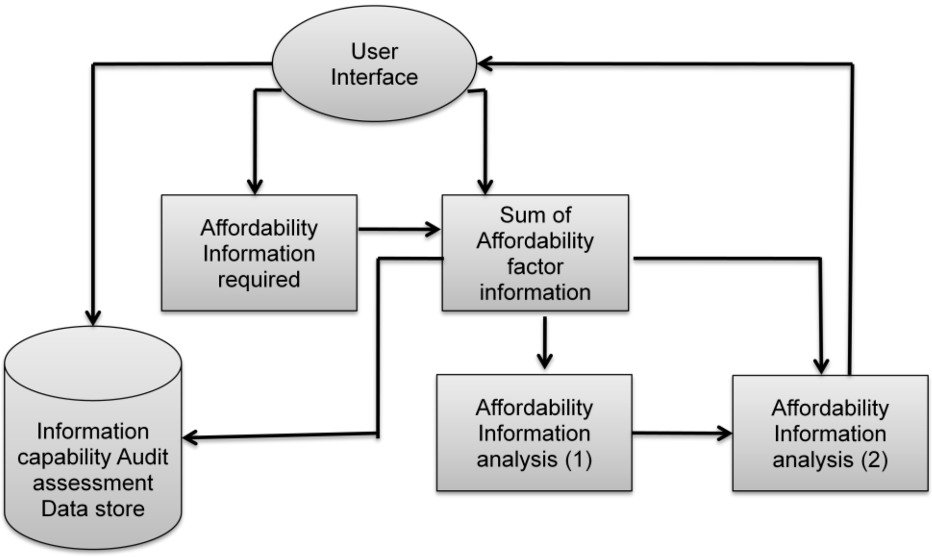


Figure 7-2: Information Capability Audit Module Architecture (Adapted from Bankole et al., 2009b)

This interface contains the five affordability factors groupings examined under the five elements. The questions which the user is required to provide scores for are presented under each element in Table (7-5). The first question under each element is aimed at assessing whether the solution provider or customer has information, tools and resources from a previous project, which could be applied to the current project. The second question aims to determine the level of information, tools and resources within the current project. The third question aims to determine the ease of access to/transferability of information, tools and expertise of the workforce into the current project. In response to these questions, the user would provide scores based on information availability.

Table 7-2: Affordability audit score allocation

	Each Affordability Factor Grouping					
Each Factor Element	**C**	**A**	**D**	**M**	**I**	**D**
Question 1	Score	Score	Score	Score	Score	Score
Question 2	Score	Score	Score	Score	Score	Score
Question 3	Score	Score	Score	Score	Score	Score
Total	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal

An example of the score allocation process within the Microsoft Excel software is provided in Figure (7-3).

	Customer Budget (CB)							Whole life cycle cost (WLCC)							Contract Type Arrangement (CTA)						
Information	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D
(i) Do you have information from similar project?	4	4	5	4	4	1	1	5	1	5	5	5	3	3	3	4	2	2	2	2	4
(ii) What is the level of information on current project?	5	4	5	5	2	3	3	4	3	3	5	3	3	5	2	4	5	3	3	2	1
(iii) What is the ease of interpretation of the information?	4	4	3	2	1		1	2	3	1	2	1	3	1	2	3	5	5	2	3	3
Total	13	12	13	11	7	[illegible]	5	11	7	9	12	9	9	9	7	11	12	10	7	7	8
Tools	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D
(i) Do you have available tool(s) from past project?	2	3	5	4	4	1	1	5	3	2	5	3	4	3	2	2	2	2	3	3	2
(ii) Are the tool(s) applicable to this project/ Do you have tools for this project?	3	4	3	3	5	3	1	3	5	5	5	3	3	3	2	3	5	3	3	3	3
(iii) What is the ease of use of the tool(s)?	4	5	4	4	3	2	4	3	4	1	1	2	1	2	1	2	5	5	3	3	2
Total	9	12	12	11	12	6	6	11	12	8	11	8	8	8	5	7	12	10	9	9	7
Skills	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D
(i) Do you have a team/individual from similar project?	5	5	3	3	1	3	1	5	5	5	5	3	1	2	2	2	2	3	3	3	3
(ii) Do you have man power currently available?	5	4	5	5	3	2	3	5	3	5	3	3	3	3	3	3	3	3	3	3	3
(iii) What is the level of expertise?	5	2	4	4	3	3	1	4	4	1	2	3	3	2	5	4	5	5	2	3	1
Total	15	11	12	12	7	8	5	14	12	11	10	9	7	7	10	9	10	11	8	9	7
Experience	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D	PB	C	A	D	M	I	D
(i) Has the team operated in this domain before?	5	5	3	3	4	2	1	5	5	5	5	2	2	2	5	5	2	2	3	4	3
(ii) Do you have expertise/knowledge from previous project to apply in the new one?	1	4	3	3	3	3	1	1	3	5	3	3	3	3	3	3	3	3	3	3	3
(iii) What is the ease of adaptability/transferability of previous experience to current project?	5	1	4	2	4	2	3	1	4	4	2	2	2	4	4	4	5	5	2	2	1
Total	11	10	10	8	11	7	5	7	12	14	10	7	7	9	12	12	10	10	8	9	7

Figure 7-3: Module flowchart

Table 7-3: Affordability audit score totals

Affordability Factor Groupings	Each CADMID Phase				
	Factor Element 1	Factor Element 2	Factor Element 3	Factor Element 4	Factor Element 5
Factor Grouping1	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal
Factor Grouping2	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal
Factor Grouping3	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal
Factor Grouping4	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal
Factor Grouping5	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal	ScoreTotal

Table 7-4: Affordability audit score average

Affordability Factors Grouping	A	D	M	I
Factor Grouping1	Average Score	Average Score	Average Score	Average Score
Factor Grouping2	Average Score	Average Score	Average Score	Average Score
Factor Grouping3	Average Score	Average Score	Average Score	Average Score
Factor Grouping4	Average Score	Average Score	Average Score	Average Score
Factor Grouping5	Average Score	Average Score	Average Score	Average Score

The process of performing the audit is presented in the module flowchart in Figure (7-4). The scores are added to generate total scores for each affordability factor grouping under each phase of the CADMID cycle. Then an average of all the total scores for each affordability factor grouping (combining all factor elements) is calculated to generate the audit score under each phase of the CADMID cycle.

Table 7-5: Information capability audit questions

Information (I)
Do you have information from similar project?
What is the level of information on current project?
What is the ease of interpreting the information?
Tools (T)
Do you have available tool(s) from past project?
Do you have tool(s) which are applicable to this project?
What is the ease of use of the tool(s)?
Skills (S)
Do you have a team/individual from similar project?
Do you have man power currently available?
What is the level of expertise?
Experience (E)
Has the team operated in this domain before?
Do you have expertise/knowledge from previous project to apply in the new one?
What is the ease of adaptability/transferability of previous experience to current project?
Dependency (D) - Technology, Software or Hardware
How dependent is this project on software application?
Do you have expertise/knowledge from previous project to apply in the new one?
What is the ease of adaptability/transferability of previous experience to current project?

The final scores are presented in colour-coded cells similar to the traffic light systems of green, red and amber. This is illustrated with a case study example later on in this Chapter.

The cells within the worksheet were formatted to only allow the values provided in the drop-down menu. Any value outside the numerical values of 1 – 5 would be rejected which helps to verify that the user input is appropriate. The user is expected to provide this information based on their expertise and knowledge in the domain and within the proposed contract. The output of the audit is further described in the next section.

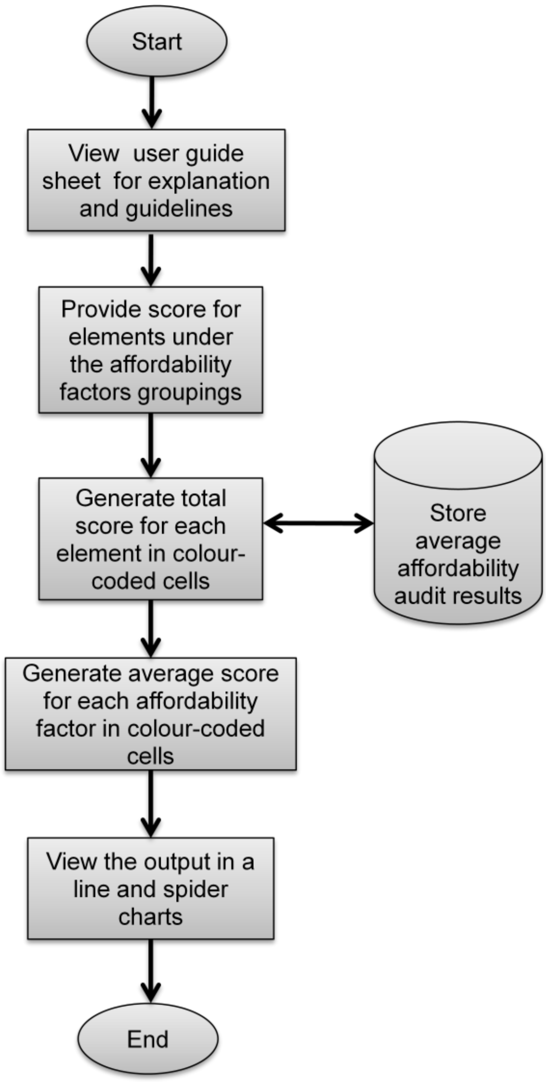


Figure 7-4: Module flowchart

7.2.6 Affordability information capability audit output

As mentioned earlier, the output of the audit is provided in the form of scores and bar and spider charts. The bar chart reflects information availability for each CADMID phase and the pre-bidding phase for each affordability factor grouping while the spider chart combines the information availability audit for all factors across all phases. An example of this is shown in the case study application (Section 7.4). This helps to present the results in a clearer format which is quicker to understand and help the decision making process.

Table 7-6: Stakeholders scores

Colour	Formatting	Values	Explanation
	Green	>=12=<25	Optimum/ plenty of data
	Amber	>=9, <11	Just enough data
	Red	=1,<8	No data/ Insufficient data

The results are displayed as shown in Table (7-3). The module has a data store which captures and stores a summary of the audit. This would allow a comparison of the audit results of different projects over time. The module output reflects the information availability for affordability prediction.

Cells coloured red have lower information availability and higher uncertainty, while cells coloured amber signify average information availability and medium level of uncertainty. The green-coloured cells signify high information availability and perceived to carry the lowest uncertainty. Cells coloured red highlight gaps in information availability that needs to be resolved. A contract with a high number of red cells might require higher provision for uncertainty.

The result of the audit would reveal the level of uncertainty potentially present within the project the bidding stage which needs to be mitigated. It would also highlight areas where more data is required while revealing the confidence level in the affordability assessment carried out for the three perspectives.

7.4 Overall Affordability Management

Since affordability is greatly influenced by the limitation in information availability, it is certain that uncertainties are inherent in the contract. In order to limit the impact of uncertainty, it is important to have a method of controlling and managing the project to ensure that it is affordable and being implemented within the resources available. This was part of the objectives of this research as shown in Chapter 3 (section 3.4) to develop a methodology to manage and control affordability from the three perspectives during the life cycle of a contract. Also, when the actual deviates from the target (un-affordability), steps could be taken to provide for the additional resources required to deliver the contract on time and within schedule and resources.

The causes of un-affordability were provided in Chapter 4 (section 4.3.7) and this reveals the need for an affordability management technique, which would help to manage the performance of the contract. As mentioned in Chapter 4 (section 4.3.8), techniques such as EVM and some parametric costing techniques are utilised to manage the performance of a defence project by measuring the value created through the use of resources. The affordability management of defence contracts require a credible cost estimate, a method of controlling project growth and a rich knowledge base.

In order to manage the performance of a contract, strategic objectives are defined and presented either in a Balanced Scorecard (Kaplan and Norton, 1996) or other form. The original Balanced Scorecard integrates lead indicators and lag indicators to provide four dimensions of measuring and managing performance. These are: customer, internal business process, learning and growth and Financial, these could be applied differently in different organisations. The recent MoD Acquisition operating framework presented some key areas for performance management for the Defence equipment Support De&S group which the researcher has grouped under three headings are presented in Figure (7-5). The defence customer's lead indicators (KPIs) are usually defined as performance cost and time while the lag indicators could be e.g. Urgent operational requirement compliant with 90% confidence levels or other KPIs provided in Figure (7-5).

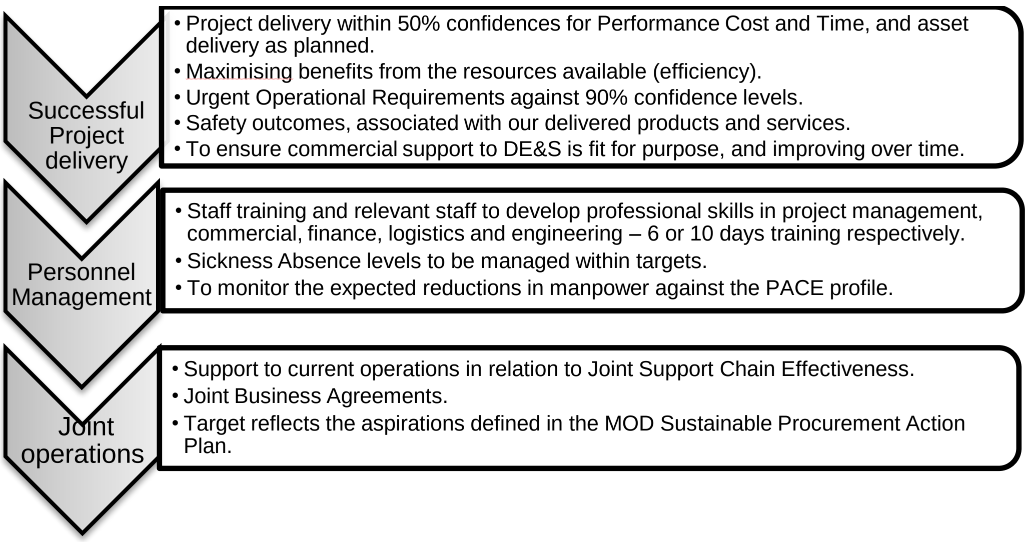


Figure 7-5: Adapted from De&S Performance measurement areas (AOF, 2010c)

Therefore, in order to directly employ these lead indicators in measuring the performance of the defence project in the key areas, a systematic methodology identified from literature was employed (Del Rey Chamoro, 2000). The same methodology was applied to derive PMs for supplier sustainability in Chapter 6 (section 6.4.2), and it is being adapted to derive PMs for affordability management, the steps followed are:

1. Understanding the Key Performance Area (KPA)
2. The conceptual description of the MA
3. Prioritisation and selection of the major MA based on the feasibility and importance scores
4. PM generation

Step 1: Understanding the KPA - this first step to identify and define the KPA in order to generate a lead indicator in the form of a MA. The KPA represent the top-level strategic aim of the organisation which form the viewpoint from which project affordability would be assessed. Each parameter in this step is explained in the template presented in Appendix N. A worked example is provided in this Chapter.

A List of KPA to ensure project affordability from the three perspectives is presented below.

- Project delivery within 50% confidences for Performance Cost and Time, and asset delivery as planned.
- Maximising benefits from the resources available (efficiency).
- UOR against 90% confidence levels.
- Sickness Absence levels to be managed within targets.

The chosen KPA is 'Project delivery within 50% confidence for Performance' which means the project must be delivered within 50% confidence level of desired performance. The KPA solution model is employed as shown in Table (7-7).

Table 7-7: Key Performance Area solution model

KPA model		**Opportunities for the measurement solution**
KPA		Project delivery within 50% confidence for Performance'
Impact on the Project delivery	Competitive Dimension	Performance
	Department	De&s
	How? Attribute	Failure of equipment to meet user requirement would require an assessment or redesign of the system which could increase manufacturing cost
MA		Improve equipment functionality and features to meet user requirement

Step 2: MA conceptual description – the MA is described in terms of the activity, input and output required to fully understand and carry out the action. As explained in Chapter 6 (section 6.4.2), the MA is defined in terms of feasibility and importance scores. The MA 'Improve equipment functionality and features to meet user requirement' is then described in terms of the

activity, input and output required to understand and carry out the MA. Several MAs could be generated from each KPA; so a major MA has been chosen and defined in terms of feasibility and importance scores as shown in Table (7-8).

Table 7-8: Measurable Actions model

MA model	Measurement action analysis
Measurable action	Improve equipment functionality and features to meet user requirement
Competitive Dimension	Performance
Activity description	Measurement of equipment functionality and align it with the user requirement
Inputs	1. Translate user requirement to systems design requirement and incorporate in project plan. 2.Investigate the performance of system components
Agents available	De&s: project management team, engineering team and solution provider: project management team, engineering team.
Outputs	Equipment output against user requirement
Measurable options	The possibilities to perform this measure are: Score of equipment performance to meet customer requirement
Overlapping	NO
Feasibility score	5
Importance score	4

Step 2 is repeated for different MAs to generate a list (Figure 7-6). From the list, the major MAs are selected based on feasibility and importance scores to be employed in deriving the PMs.

Step 3: Prioritisation and selection of the major MA based on the feasibility and importance scores - This is done based on feasibility and importance scores obtained through workshops with industrial experts as explained in Chapter 6 (section 6.4.2). The MAs with the highest feasibility and importance scores are then selected to be measured in order to derive PM to assess the affordability. The matrix was provided in Chapter 6, Figure (6-2) and another example is provided in Figure (7-6).

From the list of MAs shown in Figure (7-6), those MAs with the highest feasibility and importance scores are then selected to be employed in order to derive PM to manage and keep the affordable and achieve the KPA.

Measurable Actions:

MA1: Improve equipment functionality and features to meet user requirement
MA3: Investigate the time scale specified for user requirement delivery
MA7: Investigate how a rise in price of raw materials/components would affect cost and project delivery
MA8: Investigate how component obsolescence would affect cost and project delivery

Figure 7-6: Measurable Actions selection matrix

Step 4: PM generation – this last step helps to generate the PM for the KPA by applying the PM model. This is done based on some of the attributes described above. The process involves working back-to-front in order to identify the PM. The previous steps provide the context of the PM to help the user identify an appropriate PM from literature and industrial practice. The PM generated is shown in Table (7-9).

Table 7-9: Performance Measures Model

PM model	**KPI description**
PM	$\text{Score of requirement satisfaction} = \frac{\text{Degree of requirement compliance}}{\text{Overall requirement}}$
MA	Check to improve equipment functionality and features to meet user requirement
Competitive Dimension	Performance
Inputs	1. Translate user requirement to systems design requirement and incorporate in project plan. 2.Investigate the performance of system components
Activity description	Measurement of equipment functionality and align it with the user requirement
Agents available	De&s: project management team, engineering team and solution provider: project management team, engineering team.
Outputs	Equipment output against user requirement

The measure to manage the performance of project affordability in this example is a score of requirement satisfaction. This score applies to requirement for both products and services, which is measured against compliance with the customer requirement. The KPA states that the project must be delivered within 50% confidence level of desired performance. This can be measured at different levels including system level. This assessment focuses on system performance as an indicator of project delivery. The focus of this PM is to ascertain that a system/equipment/service has the functionality and features to meet user requirement. If the equipment or service fails to satisfy the customer need, the project would not be delivered. The customer would be less willing to pay for the project as it would be unaffordable. This measure would provide project managers with knowledge about the performance of the equipment during the project life cycle to know where improvement or re-design might be required to ensure that it meets the customer's expectation. It is important to be able to understand customer expectation (which could be higher than the equipment capability, sometimes) and ensure that it could be met in most cases. If the solution provider discerns that it would not be able to meet the customer's performance target, it could negotiate with the customer so a trade-off could be made. This measure helps the project managers ensure that the project can satisfy the customer requirement.

Other examples of PMs generated for KPAs or lag indicators are provided below.

- Order completion time
- Score of customer satisfaction
- Mean Time Between Failure of equipment
- Degree of spares availability
- Degree of Support availability
- Percentage of late delivery

Overall Affordability Framework Implementation

The overall affordability framework was designed to be implemented using the Microsoft Excel software as recommended by the industrial partners due to its functionality and accessibility to both industrial experts and researchers. The customer affordability, affordability information capability audit, supplier sustainability assessment and manufacturer profitability assessment were implemented as the modules within the overall affordability framework. The overall affordability management methodology is a template-based process which is employed to generate measures of performance; hence it is not implemented as a module within overall affordability software framework, but presented as a process of affordability management as shown in Figure (7-1).

The next section provides a case study illustration of the audit and management process.

7.5 Case study application

Affordability Capability Audit of Case Study 1

The background, customer affordability assessment, manufacturer profitability and supplier sustainability assessment of the case study were also provided in Chapter 5 (section 5.7). In this Chapter, the affordability audit results and the PMs generated are presented.

Four main affordability factor groupings were identified in order to assess information availability for the three perspectives. The 'other' factor grouping which was important to this project was 'obsolescence over time' so this was the fifth affordability factor grouping. As mentioned in Chapter 5, the project duration only covers the 'ADMI' phases of the CADMID. Therefore the project was assessed for each phase of the 'ADMI' under the five affordability factor groupings based on the questions under each factor element as explained in section 7.2.5. The assessment was done by allocating scores between 1 and 5 to show information availability within the project. This is shown in the Table (7-10). These scores are then summed up under each affordability factor grouping to obtain total scores based on each factor element under each phase of the 'ADMI' as shown in Table (7-11).

Most of the cells in Table (7-11) were green showing a higher level of information availability at each stage of the life cycle under each affordability factor. Though information availability on the customer budget for the 'I' phase was low, the other elements under the factor grouping had medium to high scores, resulting in a medium level of scoring overall.

Table 7-10: Case Study 1 Affordability Audit Table – Score allocation

	Customer Budget				Whole life cycle cost				Contract Type Arrangement				Requirement				Time Obsolescence			
Information	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**
(i) Do you have information from similar project	3	3	3	2	4	4	4	4	4	3	3	3	4	4	4	4	4	4	3	3
(ii) Level of information on current project	4	4	4	3	3	3	3	3	4	3	3	3	4	4	4	4	4	4	3	3
(iii) Ease of interpretation of the information	4	4	4	3	4	4	3	3	4	3	3	3	4	4	4	4	4	4	4	4
Total	**11**	**11**	**11**	**8**	**11**	**11**	**10**	**10**	**12**	**9**	**9**	**9**	**12**	**12**	**12**	**12**	**12**	**12**	**10**	**10**
Tools	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**
(i) Do you have available tool(s) from past project	4	4	4	3	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4
(ii) Are the tool(s) applicable to this project/ Do you have tools for this project	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	4	4	4	4
(iii) The ease of use of the tool(s)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Total	**12**	**12**	**12**	**11**	**12**	**12**	**11**	**11**	**12**	**12**	**12**	**12**	**12**	**12**	**11**	**11**	**12**	**12**	**12**	**12**
Skills	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**
(i) Do you have a team/individual from similar project	4	4	3	3	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4
(ii) Do you have man power currently available	4	3	3	3	4	4	3	3	4	4	3	3	4	4	4	4	4	4	4	4
(iii) Level of expertise	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4
Total	**12**	**11**	**10**	**10**	**12**	**12**	**11**	**11**	**12**	**12**	**9**	**11**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**
Experience	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**
(i) Has the team operated in this domain before	4	4	4	3	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4
(ii) Do you have expertise/knowledge from previous project to apply in the new one?	4	4	4	4	5	4	4	4	4	4	4	4	4	4	3	3	4	4	3	3
(iii) Ease of adaptability/transferability of previous experience to current project	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Total	**12**	**12**	**12**	**11**	**13**	**13**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**11**	**11**	**12**	**12**	**11**	**11**
Hardware Dependency	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**	**A**	**D**	**M**	**I**
(i) How dependent is this project on the application?	4	4	3	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	3	3
(ii) Do you have the application from previous project or is it easy to procure?	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4
(iii) Ease of application implementation into current project	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4
Total	**12**	**12**	**11**	**12**	**12**	**12**	**9**	**9**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**11**	**11**

Table 7-11: Case Study 1 Affordability Audit Table – Total Scores

Affordability Factor Groupings	**A**					**D**					**M**					**I**				
	I	T	S	E	D	I	T	S	E	D	I	T	S	E	D	I	T	S	E	D
Customer Budget	11	12	12	12	12	11	12	11	12	12	11	12	10	12	11	8	11	10	11	12
Whole life cycle cost	11	12	12	13	12	11	12	12	13	12	10	11	11	12	9	9	11	11	12	9
Contract Type Arrangement	12	12	12	12	12	9	12	12	12	12	9	12	9	12	12	9	12	11	12	12
Requirement	12	12	12	12	12	12	12	12	12	12	12	11	12	11	12	12	11	12	11	12
Time (T) Obsolescence	12	12	12	12	12	12	12	12	12	12	10	12	12	11	11	10	12	12	11	11

Next, an average of the scores was generated under each affordability factor grouping for the 'ADMI' phases. This is presented in Table (7-12).

Table 7-12: Case Study 1 Affordability Audit Result Table

Affordability Factors Grouping	**A**	**D**	**M**	**I**
Customer Budget	12	12	11	10
Whole life cycle cost	12	12	11	11
Contract Type Arrangement	12	11	11	11
Requirement	12	12	12	12
Obsolescence over Time	12	12	11	11

Despite the fact that obsolescence could increase the uncertainty involved within the project, the result in Table (7-12) shows that the cells are coloured green and amber which means the prime contractor has sufficient information about how to manage obsolescence in this project. All of the scores are between 10 and 12, suggesting that there is a relatively high level of information availability over the lifecycle. This could be due to the fact that the project already existed before the current prime contractor took over and it was able to capture historical data from the former prime contractor. Also because the current prime contractor already had some experience of dealing with the communications system.

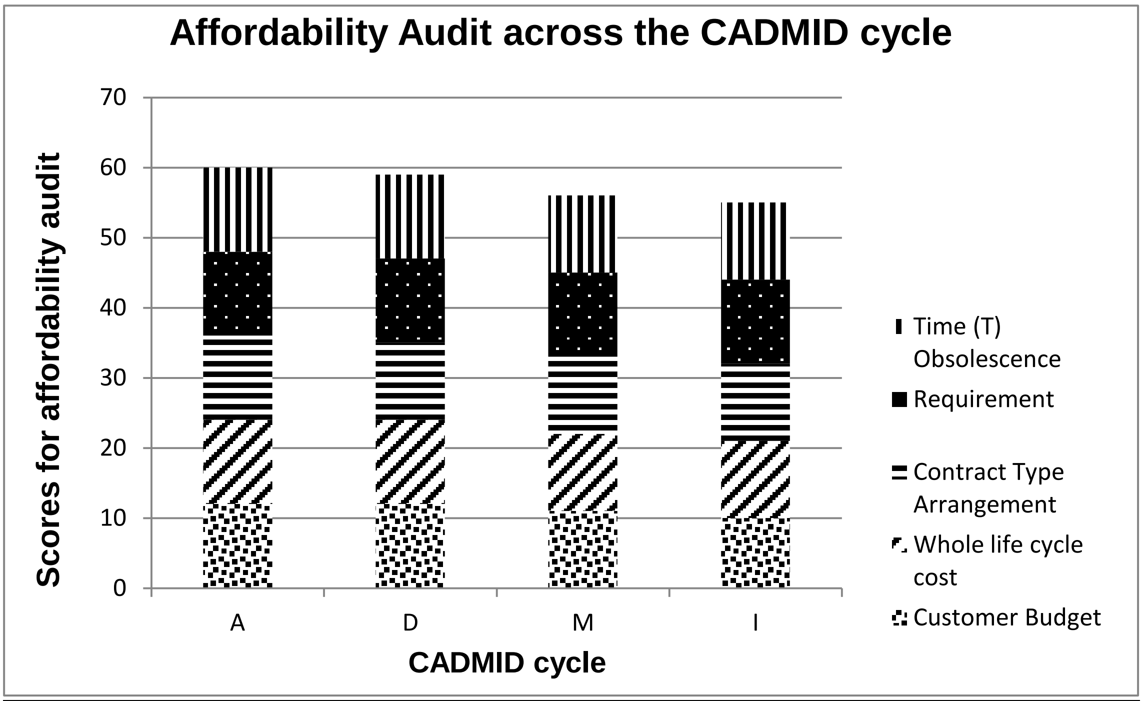


Figure 7-7: Case Study 1 Affordability Audit Result (1)

The same result presented in a bar chart (Figure 7-7) reflect higher level of information availability at the 'A' and 'D' (earlier) phases of the project life cycle and lower information availability at the 'M' and 'I' (later) phases. This means there is lower uncertainty in the earlier phases of the project life cycle and medium uncertainty at the latter phases.

From the spider chart (Figure 7-8), most of the factor groupings had high audit scores, meaning that there was high level of information availability for all the affordability factors groupings, suggesting lower levels of uncertainty. This also means there is good level of confidence in the affordability assessments made. An example of a KPA that could be applied in this case study has been provided in Section Appendix N. The next section summarises the Chapter.

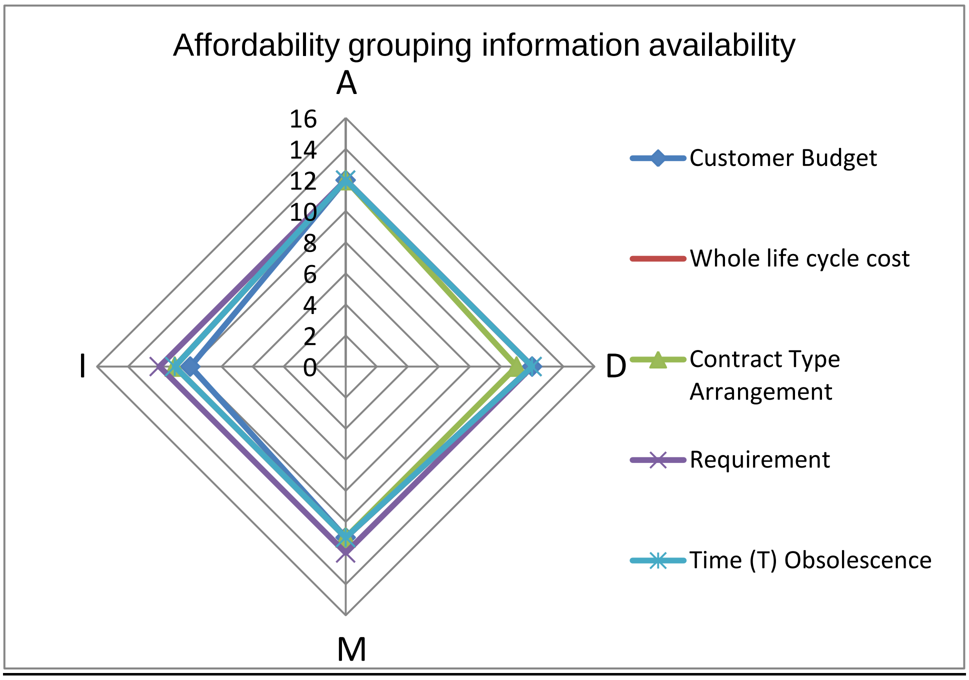


Figure 7-8: Case Study 1 Affordability Audit Result (2)

7.6 Summary

The overall affordability framework presented in this chapter provides a hypothetical description of a complex entity encompassing three other subject matters of customer affordability, manufacturer profitability and supplier sustainability including an audit and management process. Most of the subject matters can be presented as individual modules because they combine different elements within them, which require input to generate an output. Within this research, a framework has been designed to address the gap identified from the literature review and industrial interviews from the three affordability perspectives. This framework is implemented as a system using the Microsoft Excel software. Within this chapter, the focus of the proposed framework is to fulfil one of the objectives of the research as stated in Chapter 3 (section 3.4), which is closely aligned to the research gap identified in Chapter 4 (section 4.4). This is to develop an affordability management and control framework in whole life cycle cost estimation for defence contracts, focusing on three perspectives namely: customer affordability, manufacturer profitability and supplier sustainability.

The affordability information capability audit assessment which is designed to assess information availability for performing an affordability assessment based on five classifications of the affordability factors across each phase of the CADMID cycle. It employs a system of scoring these factor groupings under five elements based on information availability. The factor groupings are WLCC, CATS, customer requirement, contract type arrangement and 'other' while the elements are skills, tools, information, experience and dependency. The result of this assessment is presented using the traffic light system as well as graphical representations.

The overall affordability management technique is concerned with deriving measures for managing overall affordability of the contract. This is done through a systematic methodology similar to the one adopted in Chapter 6 (section 6.4.2). The methodology helps to derive PMs from MAs in order to manage project performance based on KPAs.

The effect of uncertainty in affordability assessment is examined in the next chapter by providing a method of incorporating changes in the quantitative factors of customer affordability and manufacturer profitability. The affordability information capability audit assessment provides a direction in terms of when uncertainty is higher or lower.

CHAPTER 8

A METHODOLOGY TO INCOPORATE DYNAMIC CHANGES IN AFFORDABILIY ASSESSMENT DUE TO UNCERTAINTY

8.1 Introduction

The previous chapter presented affordability information capability audit and overall affordability management techniques which apply to the overall affordability framework from the three perspectives. This Chapter further addresses one of the factors of affordability identified in Chapter 5 (section 5.4.1) which is uncertainty. The subject of uncertainty has been presented in Chapter 2 (section 2.11) and the current Chapter provides the application of a logic using two approaches in dealing with uncertainty. The logic comprises of two aspects. One is based on the AACE uncertainty ranges which were adopted and refined to develop three levels of uncertainty ranges to be applied in assessing the impact of uncertainty. The other aspect is based on the output of the affordability information capability audit and the uncertainty ranges. One approach applies the logic using a risk assessment software (crystal ball) in Microsoft Excel while the other is a futuristic approach applying the logic in an Anylogic model which combines systems dynamics and agent-based simulation to assess the impact of uncertainty on a defence project's affordability and profitability. This Chapter presents the process, method and implementation of this uncertainty assessment in both approaches.

8.2 Methodology

The interview protocol to investigate customer affordability, manufacturer profitability and supplier sustainability was informed by the literature review. The approach, factors and measures employed in this methodology to assess the impact of uncertainty in affordability assessment were obtained from the literature reviewed and the interview sessions conducted for the three affordability perspectives as explained in Chapters 5, 6 and 7. The importance of uncertainty on the affordability of defence contracts was identified from the industrial interaction and further investigated by consulting literature materials and industrial practice to identify approaches that are being adopted currently as well as future approaches. A methodology which involves logic using two approaches was developed and validated with industrial partners.

The details of the development are provided within this chapter while the validation is presented in Chapter 9 similar to the framework.

8.3 Uncertainty in quantitative assessment

The nature of long-term contracts like those within the defence industry means uncertainty would impact contract delivery. As stated in Chapter 2 (section 2.11), uncertainty is a potential deficiency in any phase or activity of the modeling process that is due to a lack of knowledge (Oberkampf, et. al, 2000). It causes a variation that can have either a negative or positive effect on a process, and it can have a minimal or significant impact on overall performance. For defence contracts, it can affect the schedule, delivery, cost and affordability of the project. This is due to insufficient data to inform contracting at the bidding stage since the customer may only be certain about the budget for next two years; a stochastic representation is more suitable for assessment. When uncertainty has a negative impact on the delivery of the project, it becomes a risk. Risk is a very common type of uncertainty that causes significant cost increases and drives a project towards unaffordability. Some negative types of uncertainty (risks) that should be considered during affordability analysis include unclear customer requirement, infeasible design, technology complexity or unavailability, uncertain or inadequate supplier capability, inadequate human resources and expertise and other disruptions to continuity of operations (Koury, 2010). Findings from this research reveal that uncertainty is inherent in both WLCC and CATS; hence the effort is made to assess the impact on these major factors of affordability and the assessment is done in a stochastic form. The logic adopted in representing uncertainty within the affordability framework has two aspects to it - the refined uncertainty ranges which are a parameter of accuracy and the affordability audit result which is a parameter of time. The first aspect formulates refined uncertainty ranges based on AACE uncertainty ranges identified from literature review, while the second utilises the output of the affordability audit to determine which stage of the life cycle to apply the uncertainty ranges. Both aspects of this logic are implemented to represent the impact of uncertainty following two approaches. The first approach implements the logic in a commercial risk assessment tool while the second approach applies the logic in an Anylogic model to represent the dynamic behaviour of the uncertainty. The second approach demonstrates a futurist approach by applying systems dynamic simulation and agent-based modelling. The two aspects of the logic are explained below followed by the two approaches.

8.3.1 Uncertainty assessment based on uncertainty ranges

The nature of defence contracts means that uncertainties and risks are inherent in the contracts due to the long-duration and the complexity of the customer requirement. This means that the WLCC estimation and customer affordability assessment performed at the bidding stage would not be the same as actual cost and spend profile throughout the life cycle of the project. For this reason, uncertainty was incorporated on the major quantitative factors affecting affordability, namely WLCC, CATS and SP (Chapters 5 – section 5.10.1 and 6 – section 6.6.1). Uncertainty was not incorporated on qualitative factors because the results that would be generated through the weighted scores would be erroneous. The qualitative weighted scores are not actual values; rather they provide an indication of affordability in terms of the qualitative factors. Also, in order to limit the level of subjectivity in the qualitative assessment, the assessments were carried out with groups of experts, which nullifies the need to incorporate uncertainty in the qualitative assessment. Uncertainty may be interpreted differently by different researchers and industrial experts, but in cost estimation it is considered as part of sensitivity analysis done after the cost estimate has been prepared. It is usually done together with risk assessment to develop minimum, most likely and maximum ranges for each risk element to identify the confidence level of the point estimate (GAO 2009). As stated in Chapter 2 (section 2.11), within this research, uncertainty is considered as the difference between actual and predicted cost or budget estimate, with risk being a major type of uncertainty. Uncertainty represents variability, which can be positive or negative, while risk is a type of uncertainty that has a negative impact on cost or budget.

The AACE guide (Christensen and Dysert, 2003) established five cost estimate classes from 1 to 5 based on the project definition. These classes are based on different characteristics, but the most important ones are the level of project definition, end usage of the estimate, estimating methodology, level of accuracy range and the effort and time needed to prepare the estimate. These are explained below.

- Level of project definition (primary) - This defines the level or degree of maturity and kind of information available to perform the cost estimate such as project scope definition, requirements documents, specifications, project plans, calculations, learning from past projects and other information required to define the project.

- End usage – This defines the end use or purpose for which the estimate was defined. The purposes include strategic evaluation, feasibility studies, funding authorization and budgets, project control. Usually, the higher the level of project definition in an estimate, the more useful it would be.
- Estimating methodology – This could be applied using two approaches which are stochastic and deterministic. The stochastic methodology involves the use of independent variable(s) in the cost estimating algorithms apart from a direct measure of the units of the item being estimated. The cost estimating relationships employed in stochastic methods are somewhat influenced by assumption. The deterministic methodology is not conditional upon significant assumption and the independent variable(s) are essentially a definitive measure of the item being estimated. An increase in the level of project definition transforms the estimating methodology from stochastic to deterministic methods.
- Expected accuracy range - This gives an indication of the degree of variation between the target cost and actual cost which is expressed as a +/- percentage range around the point estimate after application of contingency, the actual cost would fall within a range of the specified level of confidence. An increase in the level of project definition should improve the level of accuracy and yield a smaller +/- range.
- Effort to prepare estimate **-** This gives an indication of the cost, time, and resources required to prepare an estimate. The measure of this effort is typically expressed as a percentage of the total cost of the project. An increase in the level of project definition triggers an increase in the level of effort required to provide the estimate as well as cost. This cost refers to cost of performing the estimate, not the cost of delivering the project.

Of all these characteristics, the level of project definition is the primary one; hence the AACE guide established five cost estimate classes from 1 to 5 based on the project definition. Class 1 estimate signifies the highest project definition and maturity while class 5 signifies the lowest level of project definition. This means the closer a cost estimate is to class 1, the more deterministic the methodology would be and the better the expected accuracy range. All the primary and secondary characteristics are applied against each estimation class in Figure (8-1), however, the accuracy ranges are not percentages; rather they signify index value measured against a benchmark of 1.

	Primary characteristics	***Secondary characteristics***			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical +/- range relative to best index of 1 [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgment	4 to 20	1
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed, but Primarily Stochastic	2 to 6	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Primarily Deterministic	1 to 3	5 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	1	10 to 100

Figure 8-1: Generic Cost Estimate Classification Matrix (Christensen and Dysert, 2003)

The accuracy ranges in the AACE classification guide presented in the matrix in Figure (8-1) were refined by the researcher to derive accuracy ranges to assess the impact of uncertainty on the major quantitative factors of affordability. Since the scoring mechanism in the affordability assessment framework is done at three levels of high, medium and low, as shown in Chapter 5 (section 5.6.4), the ranges developed for uncertainty assessment are also designed at three levels for application within the affordability framework. The refined accuracy ranges for uncertainty are presented in Table (8-1).

8.3.2 Uncertainty assessment based on affordability audit results

In order to apply the right levels of uncertainty, the outcome of the overall affordability audit assessment is applied. As discussed in Chapter 7 (section 7.3), the audit assessment result gives a view of information availability at different stages of the life cycle. This provides the basis for uncertainty assessment so that the stages of the life cycle with the lowest information availability would have the highest uncertainty range being applied to it and the medium information availability would attract medium ranges, while the highest information availability would attract lowest uncertainty ranges. The audit result provides the rationale for uncertainty assessment using the ranges. This is applied in the case study in section 8.6.

The ranges for each level of uncertainty are presented Table (8-1).

Table 8-1: Uncertainty ranges

	Uncertainty Ranges
High	-20/+30%
Medium	-15/+20%
Low	-10/+10%

The refined accuracy ranges for uncertainty assessment have been validated with industrial experts as a good basis for assessing the impact of uncertainty in customer affordability assessment and manufacturer profitability assessment.

8.4 Uncertainty assessment using risk software

As mentioned earlier, the logic which has two aspects and is implemented in two approaches. The first approach uses the refined uncertainty ranges based on the affordability audit to assess the impact of uncertainty on the WLCC and CATS profile of the customer affordability assessment using the monte Carlo Simulation. This means that based on the result of the affordability audit, when information availability is high, low uncertainty ranges would be applied to the values, when information availability is medium, medium uncertainty ranges were applied, and low information availability attracts high uncertainty values. These uncertainty ranges were the input for the simulation which adopted the three-point estimation to give the minimum, most likely and maximum values. This was simulated through Monte carlo simulation within the Crystal Ball Software which employs random sampling of data to generate a range of results. The same could also be applied to the SP in the manufacturer profitability assessment using different software such as the montecarlo simulation in the Microsoft Excel Software or other risk assessment software such as @Risk, etc. The Crystall Ball software was adopted for this research because it is a recognised risk software that is used in academia and industry. The montecarlo simulation method is based on repeated computation of random sampling to yield results for a stochastic distribution. It provides results in the form of a distribution by adopting the uncertainty ranges and imposing them on the WLCC, SP or CATS profiles. A representation of the output was generated based on the uncertainty ranges and the affordability audit result using the Crystall ball software is provided in Figure (8-2).

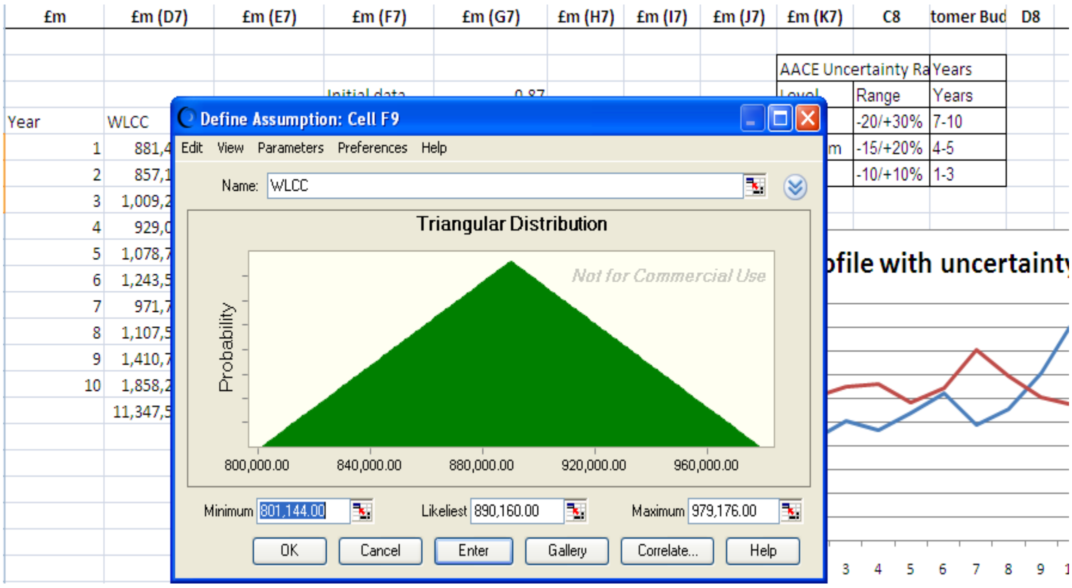


Figure 8-2: Crystal Ball Simulation

The result adopted a uniform distribution to provide the minimum, most likely and maximum values for each WLCC and CATS for the life cycle of the assessment. The bidding team could utilise the output of this assessment to form the basis of risk provision for a defence contract. This may be done based on the most likely values.

The second approach provides a futuristic method of assessment by representing the dynamic behaviour of agents as they interact at the bidding stage to perform the affordability assessment, as well as provide the platform to assess the impact of uncertainty on the assessment.

8.5 Uncertainty assessment using Anylogic tool (futuristic)

The second approach is a futuristic approach proposed to represent the effect of uncertainty in affordability assessment, which shows dynamic changes over the life cycle. For example, the case study which was introduced in Chapter 5 (section 5.10) revealed uncertainty in the project due to obsolescence issues. Also, there was a risk that the CATS would be insufficient to cover the WLCC of the project. This necessitated changes in the project at the biddings stage to spread the WLCC over a longer period of time, though other risks would arise during the lifecycle of the project. This shows that uncertainty is not static and it can change at different stages of the project life cycle. For example a new project which has features that are novel or be-spoke with low information availability would be associated with a high degree of uncertainty, which may reduce as the project unfolds and the features become much clearer. However, any additional or unforeseen requirement could increase the level of uncertainty. The second approach proposed in this research to assess the impact of uncertainty employs system dynamics and agent-based simulation in the Anylogic software. The AnyLogic model is a hybrid between a simulation software language and Java, developed by XJ Technologies. It is a platform that combines three modelling approaches, namely System Dynamics (SD), Discrete Event Simulation (DES) and Agent-Based Modelling (ABM). The Anylogic model allows hundreds of classes to be grouped under engine, analysis, presentation or connectivity to provide core simulation functionality. In combining the three modelling approaches, the Anylogic model provides a platform which provides the flexibility to understand the dynamic behaviours of agents or entities when cost parameters and policies are changed (Rosenfield et al., 1985) and evolution over time.

In order to incorporate dynamic uncertainty in affordability assessment, it is important to capture and present the various agents at the bidding stage and present the relationships between them and how the information passage can influence the behavior of the agents. For this reason, the SD and ABM modeling approaches are utilised within the AnyLogic model. Although the DES is suitable for presenting stochastic uncertainty within a system, SD proved to be more suitable in the modelling of the dynamic systems and their response, and was able also to identify important variables and causal linkages in a system (Macal and North, 2005). The ABM was also chosen in order to model the behaviour of agents. To achieve the objective of incorporating dynamic uncertainty, SD utilises a simulation process to apply uncertainty ranges to CATS and WLCC in order to aid the visualisation of changes in the behaviour of the agents. The combined approaches will help to capture the interactions and connectivity between the customer and manufacturer at the bidding stage of defence contracts, as well as the dynamic behaviour of the agents. Also, the interconnectivity between the agents would be represented while assessing the dynamic changes in the major factors (variables) such as WLCC, CATS and SP caused by uncertainty. The different state charts, variables, events, parameters, action charts, datasets and plots used in designing the model are explained below.

- State charts - these are used to define:
  - agent states or agent modes of operation
  - response to the external or internal signals or conditions
  - event and time ordering
- Action chart – a flow chart which provides more details of actions or decisions taking place in each state within the state chart. It would enumerate all attribute values of an agent at a particular instant (Albrecht, 2010).
- Event – refers to a change in an object state which occurs at an instant, and triggers an activity as a result which would not have occurred otherwise (Albrecht, 2010). This may be determined by specifying the time or as a result of another event or activity e.g. customer invites manufacturer to tender for a bid.
- Variables – refers to a value or model state that can change depending on conditions or on information passed during the simulation (pie software inc, 2010).
- Parameter – refers to a definable, measurable, and constant or variable characteristic, dimension, or value, selected from a set of data because it is important to provide an understanding of a situation (or in solving a problem) (business dictionary, 2010).
- Dataset – is an element in AnyLogic software that is capable of storing 2 dimensional (X, Y) data of type double, and maintaining the up-to-date minimum and maximum of the stored data for each dimension. This could be defined based on time dimension.
- Plot – this is a representation used to display the Y-values of a data set against corresponding X-values. This can also display several data sets simultaneously.

The application of both approaches of assessing uncertainty in affordability assessment is illustrated through a case-study example.

8.6 Case study application

The background of the case study was presented in Chapter 5 (section 5.10) with the customer affordability assessment. Within this chapter, the results of the affordability capability audit (Chapter 7 – Section 7.5.1) are employed with the uncertainty ranges to present the impact of uncertainty on the affordability assessment. The uncertainty range allocation for the case study with an actual life cycle of 10 years based on affordability capability audit results is presented in Table (8-2).

Table 8-2: Case study 1 uncertainty ranges

Uncertainty Level	Uncertainty Ranges	Life cycle
High	-20/+30%	7-10
Medium	-15/+20%	4-6
Low	-10/+10%	1-3

The allocation in Table (8-2) was based on the outcome of the affordability audit from Chapter 7 – Section 7.5.1, which was assessed based on the initial assumption that the contract would be awarded for 5 years. In the end, the lifecycle was stretched till 10 years. The initial assessment for five years revealed that uncertainty would be low at the start (high information availability) and gradually increase to medium level (medium information availability), meaning that further down the life cycle uncertainty would be high (low information availability). This informed the rationale behind the uncertainty allocation in Table (8-2). The actual customer affordability profile is presented in Table (8-3) and Figure (8-3).

Table 8-3: Case study 1 CATS and WLCC values-Actual

Year	1	2	3	4	5	6	7	8	9	10	Total
Currency	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**
WLCC	890,160.00	890,160.00	1,000,000.00	1,000,000.00	1,114,000.00	1,114,000.00	1,118,000.00	1,120,000.00	1,500,000.00	1,600,000.00	11,346,320.00
CATS	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	1,269,993.60	12,699,935.98

$$AI = \frac{CATS}{WLCC}\left(1 - \left(\sum_{i=1}^{n}\frac{(C_{i-}S_i)}{S_i}\right) * \frac{1}{n}\right)$$

(i) Affordability Index (AI) = 0.87

An AI of 0.87 shows that the project is less affordable, as it is less than 1. Although total CATS is higher than total WLCC, the violations in years 9 and 10 as shown in Figure (8-2) could have a major impact on the affordability of the project. This is the reason why the AI presents the project as being unaffordable. The AI is nearer to 1 than 0; hence the degree of unaffordability is low.

To assess the impact of uncertainty, the affordability audit results were applied to the WLCC and CATS values by applying the lower uncertainty ranges (higher information availability) at the earlier stages of the lifecycle, then medium ranges and the higher ranges at the latter stages of the life cycle. This was employed in carrying out three-point estimation which was conducted with the Monte Carlo simulation in the commercial risk software called Crystal Ball. The results are presented in Table (8-4) and Figure (8-4) below.

Table 8-4: Case study 1 CATS and WLCC values with uncertainty

Year	1	2	3	4	5	6	7	8	9	10	Total
Currency	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**	**£**
WLCC	883,134.90	917,554.52	964,678.51	1,004,242.71	1,126,349.56	1,118,437.30	1,176,861.98	1,185,773.23	1,570,245.13	1,693,765.18	11,641,043.02
CATS	1,254,627.65	1,262,608.68	1,304,883.91	1,244,617.06	1,319,613.20	1,290,980.33	1,200,864.31	1,393,775.25	1,280,143.59	1,227,194.05	12,779,308.03

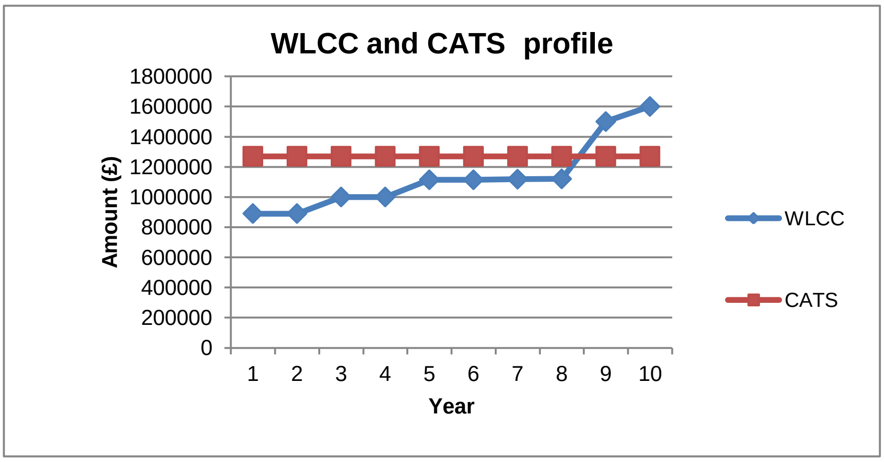


Figure 8-3: Case study 1 CATS and WLCC profile-Actual

AI with uncertainty = 0.85

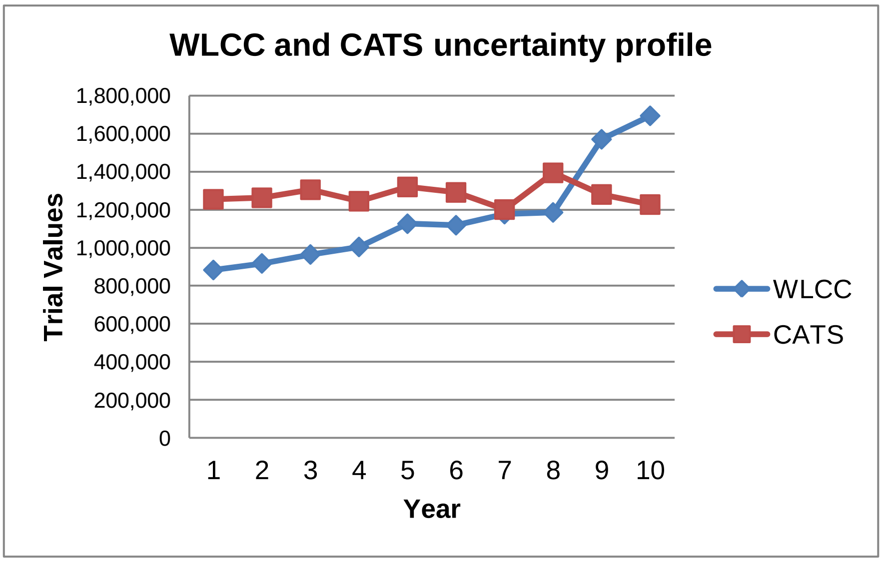


Figure 8-4: Case Study 1 CATS and WLCC profile with uncertainty

The impact of uncertainty is seen in the CATS and WLCC profiles which have changed. While the total CATS decreased by 1% and total WLCC increased by 3%, the spread of the CATS profile also completely changed. The actual CATS profile was evenly split each year, but the profile with uncertainty showed that the CATS profile is a curve rather than a straight line. Also, the WLCC profile with uncertainty has a higher rate of increase than the actual WLCC profile. The last WLCC value with uncertainty in year 10 was higher than the actual WLCC value in year 10. After uncertainty was incorporated an AI of 0.85 was generated, which shows that the project is less affordable as it is less than 1, and it is a little less than the actual AI of 0.87. This means the profile with uncertainty is less affordable than the actual profile, to a limited degree. The crystal ball software simulates using 800 instances of each value and the results from the first instance were presented above in Table (8-4) and Figure (8-4). Out of the remaining 799 trial instances, the instances which yielded the highest, medium and lowest AI were selected to be analysed alongside the frequency distribution of the 800 instances. This was done for five trials. The results of the first trial are shown below while the other four are provided in Appendix O.

(i) Trial instance 1 yielded AI results in the range of 0.6 and 1.23 and a standard deviation of 0.09 (Table 8-5). The standard deviation of 0.09 means that that most AI falls within +0.09 or – 0.09 of the mean which is 0.93. This means most AI results would fall between 0.85 and 1.01. This result is correct as most (66%) of the frequency of AI distribution fell between 0.85 and 1.01 (528 trial values out of 800). Also 25% of the AI values fall below 0.86 while 75% of the values fall below 0.99.

Trial Instance1-AI range

Ranges	Count
0.61-0.70	5
0.71-0.80	70
0.81-0.90	264
0.91-1.01	317
1.02-1.23	144
Total	800

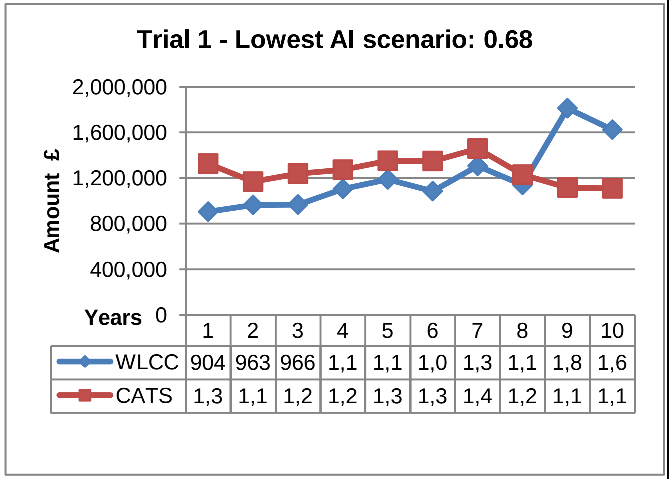
Trial Instance 1-AI Results

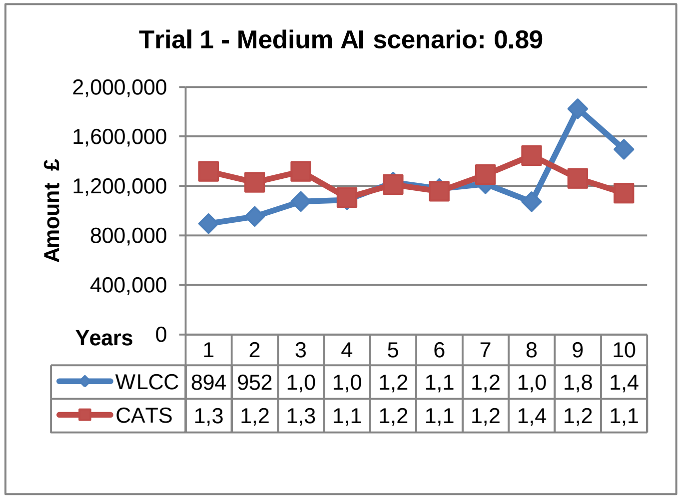
Average AI	0.93
AI>0.9	0.59
Std Dev	0.09
Median	0.93
Lower Quartile	0.86
Upper Quartile	0.99
Highest Quartile	1.23

Figure 8-5: Trial Instance 1 statistics

An AI comparison is done to examine the yearly amount of CATS and WLCC that generate the lowest, medium and highest AI. The AI distribution is expected to be between 0.1 and 1.2 or 0.1 and 1.6 in a distribution. With this range of AIs, the lowest AI scenario is around 0.2, medium, 0.5 and high, 0.9. For example, in a range of AI figures between 1 and 10, lowest AIs are between 1 and 3, 5 is middle and AIs closer to 10 are the highest. The benchmark AI figure is 1; hence AIs closest to 1, starting from 0.09, are the highest. This has informed the choice of the lowest, medium and highest AI scenarios to be compared in assessing the AI.

In order to assess the WLCC and CATS distribution of the lowest, medium and high or highest AI in this instance, three trial value profiles were chosen which are 341, 162 and 149. Since the range of the AI is between 0.6 and 1.23, the lowest AI of 0.6 is selected in addition to a medium of 0.89 and the highest, 1.23. Figure (8-5) contains the AI distributions while Figure (8-6) contains the WLCC and CATS profiles of the lowest, medium and highest AI in Trial Instance 1. In all three scenarios, the WLCC was lower than CATS initially, but WLCC rose to the same level or even rose above CATS in the last two of the 10-year project life cycle. In the lowest and medium AI scenarios, WLCC is higher than CATS in years 9 and 10. However, in the highest AI scenario, the CATS value meets WLCC value in year 9 to continue to stay above the WLCC in year 10. In all three scenarios, the WLCC and CATS values for each year is usually below or just over £1.4m, but in the lowest and medium scenarios, the WLCC figures increases to over £1.8m. This had a negative impact on the affordability (AI) of the project. The project affordability is not just affected by the total WLCC and CATS, but also by the individual values in each year. For example, if the CATS figure had risen at the same rate as WLCC in year 9 of the lowest and medium scenarios, the AI would have been higher in each case. CATS values increased by £300,000 in year 6, reduced by £400,000 in year 7 and increased again by £400,000 in year 8. This had no negative effect on the AI as the CATS stayed above the WLCC for most of the lifecycle. In the highest AI scenario, there was little difference between WLCC and CATS figures in year 10, while there were differences of £200,000 or more in the values in the 10th year of the lowest and medium scenarios. The differences in the WLCC and CATS figures for the lowest and medium scenarios had a negative impact on the AI. This exercise shows the importance of considering the individual CATS and WLCC figures over the life cycle of the project in assessing the dynamic nature of affordability, rather than focusing on the total WLCC and CATS figures at the end of the life cycle. The individual figures in each year can have significant impact on the final affordability of the project.





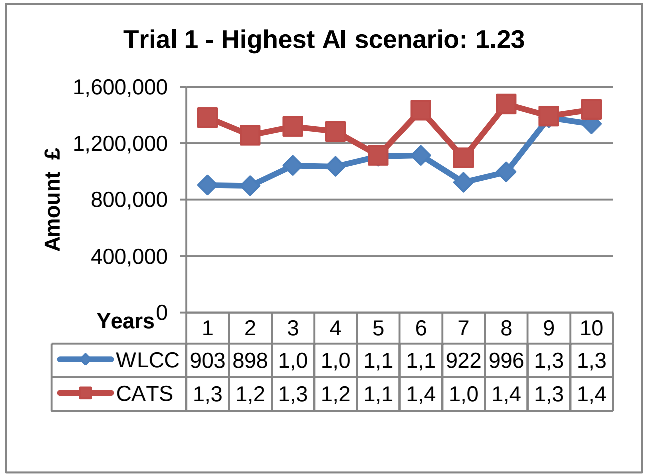


Figure 8-6: Trial Instance 1 - Profile comparison

A comparison of the trial instances was integrated with the individual assessments, but in summary the exercise has helped to visualise a spread of AI based on one single AI. The initial AI was 0.87 which is closer to 1. After five trials the highest AIs were 1.23, 1.57, 1.21, 1.27 and 1.25 with averages of 0.93, 0.86, 0.87, 0.89, 0.88, which means the actual AI could fall within the range of 0.86 to 0.93.

The results from the trial instances also proved that irrespective of an increase in the WLCC, if there is sufficient CATS to cover the cost in each year the AI will be as high as possible. This means a sufficient budget is required at each stage of the life cycle in order to deliver an affordable project.

8.6.1 Uncertainty assessment by incorporating dynamic changes

Example

The background, CATS and WLCC profiles of Case study 1 have been presented in Table (8-4). In section 8.2, the effect of uncertainty based on the monte carlo simulation within the crystal ball simulation has been presented. Within this section, the aim is to employ the Any Logic model to incorporate uncertainty and visualise the interactions between the agents. Only quantitative elements of the overall affordability assessment from the three perspectives were included in the model, the same as approach 1. Also for the purpose of simplicity the values that were used in this simulation are simple rounded values with the main aim of demonstrating the futuristic approach, rather than the actual data from the case study. The assessment was informed by literature review as well as the author's understanding of data gleaned from the case studies to provide a realistic set of values.

Agents

The agents who interact to make decisions at the biding stage are mainly the customer and the manufacturer. Though there could be interaction with the supplier, this is not illustrated in the model because the quantitative measures for supplier sustainability have been combined with the qualitative factors to be assessed based on scores and weights. 'Main' is an agent automatically created by the model to represent all other agents. Within the 'Main' agent, the affordability assessment process related to the external activities in Figure (4-5) of Chapter 4 (section 4.3.6) is briefly represented. Activities 5-10 start with the

MoD giving a round figure to the manufacturer and inviting them to tender, then evaluating tender response against contract requirement and value for money. If the contract is approved, further negotiation is done within time and cost parameters before the contract is finally agreed.

This is presented in a state chart in Figure (8-7).

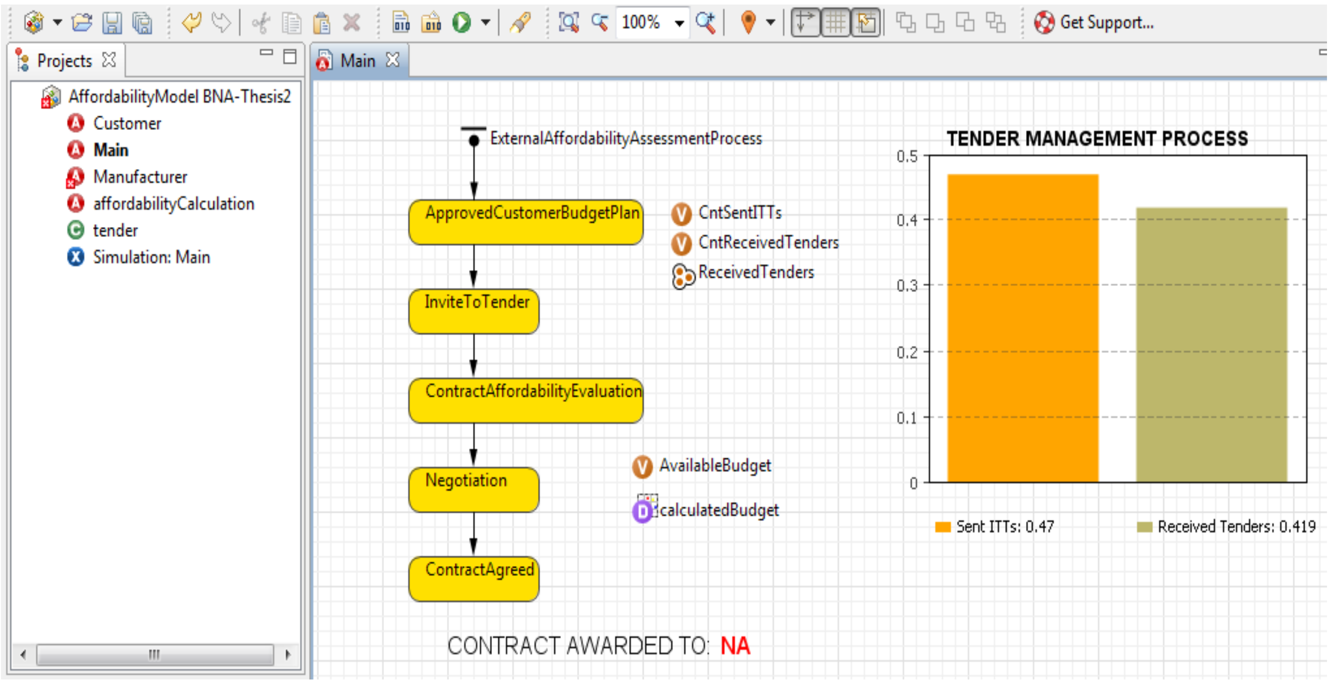


Figure 8-7: 'Main' agent

Within the 'Manufacturer' agent, the profitability assessment process adapted from section 4.3.8 in Chapter 4 is briefly presented. This shows the process of the manufacturer performing a whole life cycle cost estimate then doing a risk and uncertainty assessment with contingency. Then the margin is added on to generate the price after which a tender is submitted to the customer. This process is broadly presented in the state chart on the right in Figure (8-8) while the action chart on the left does the actual calculation of the whole life cycle cost to arrive at the price which is submitted to the MoD. This is linked with the contract affordability evaluation step within the 'Main' agent in Figure (8-7). The action chart is introduced because state charts within the Anylogic tool are static; hence calculations are only done through action charts.

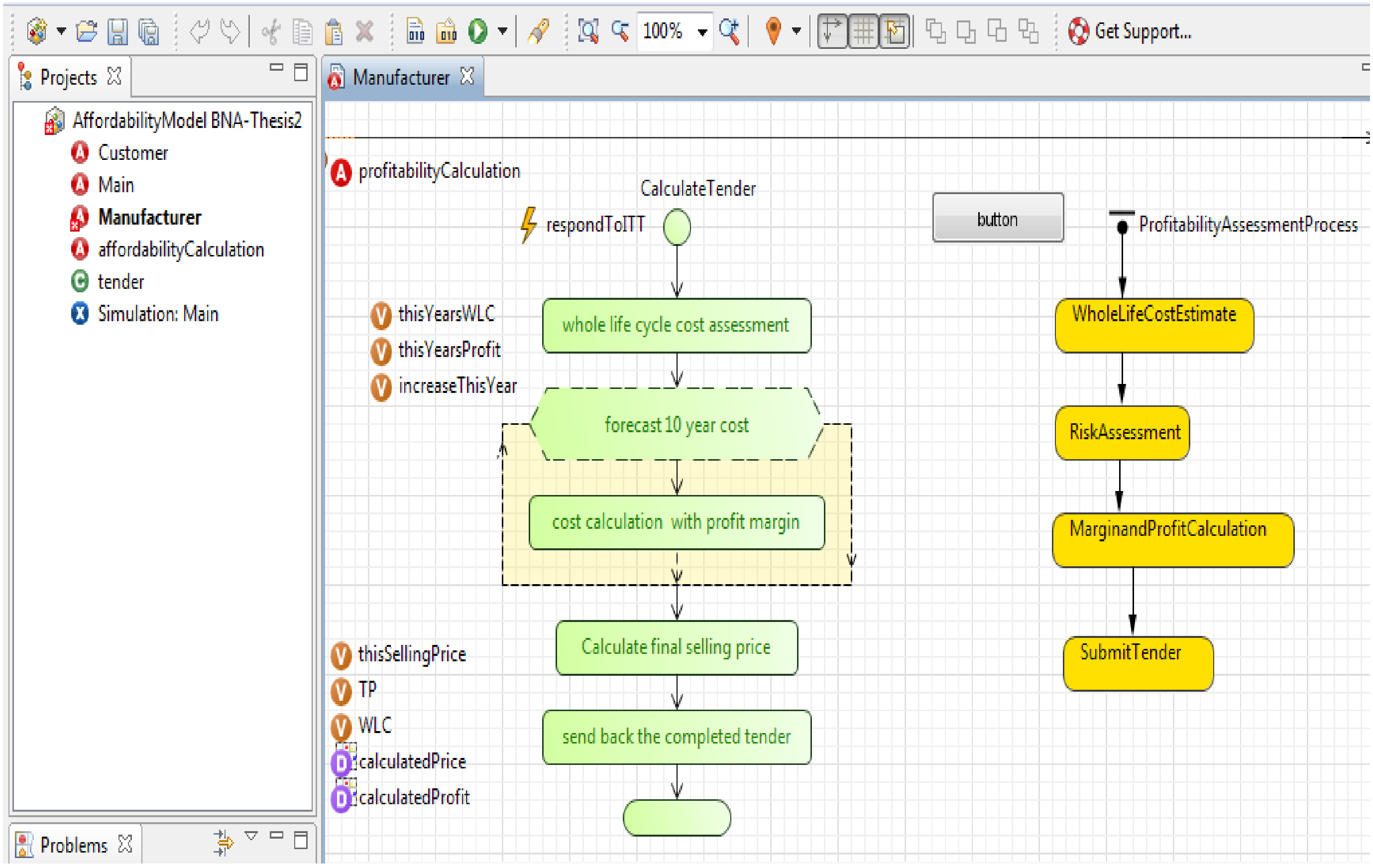


Figure 8-8: 'Manufacturer' agent

Within the 'Customer' agent, the budget allocation process from Figure (4-2) in Chapter 4 (section 4.3.2) is broadly presented at a high level in Figure (8-9). The process summarises the main activities involved in the three stages presented in section 4.3.2. It starts with stage 1(a and b) when the Treasury releases the top-level budget. The budget plan request first comes from the top level then to the departmental level. The budget plan estimate is then submitted at the departmental level and then the top level.

At stage 2, the financial planning team requests a reduction in the budget plan which is usually higher than the available budget. This is done at departmental level and sent back to the top level.

At stage 3 (a and b), the defence resource planning team may need to request a proposal for change in the defence program to the investment appraisal board to eliminate the gap between the reduced budget plan and the available budget. Value for money consideration is made and this may be forwarded to ministers for approval. Once this is achieved, the budget plan is approved.

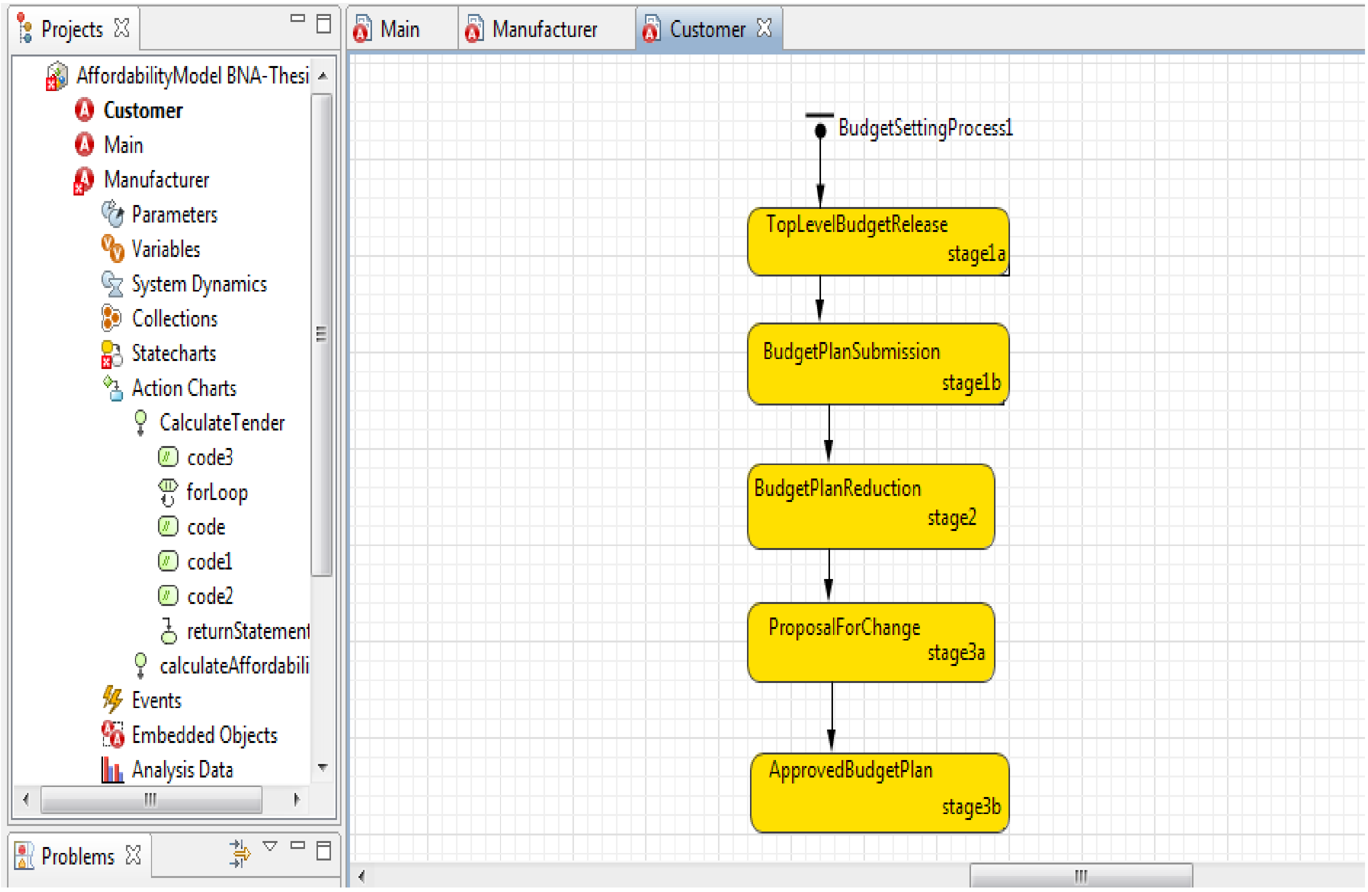


Figure 8-9: 'Customer' agent

Variables

The model combines different kinds of variables to perform the simulation. The plain variables were mostly static without changing while the flow aux variables were dynamic and were affected by the parameters. The 'Main' agent contains plain variables and a collection variable.

- *CntSentITTs* - Plain variable used to represent the number of ITTs sent to manufacturers by the customer)
- *CntReceivedTenders* – Plain variable used to represent the number of tenders received
- *ReceivedTender* – Collection variable used to add the number of tenders received
- *Available Budget* - Plain variable used to represent the budget available

The variables presented above are all input within the agent. The main output of the process is: *Contract Awarded to: No of manufacturers.*

The output presents the number of Tenders that were affordable based on the available budget. It means the manufacturers whose tenders are available could have potentially won the bid, but the contract would only be awarded after further negotiation. The bar charts in Figure (8-7) show the number of tenders sent out as well as the number returned.

The 'Manufacturer' agent contains the following plain variables.

- *thisYearsWLC* - Plain variable representing the whole life cost for one year
- *increaseThisYear* - Plain variable representing the increase in whole life cost for this individual year
- *thisYearsProfit* - Plain variable representing this year's profit
- *TP*- Plain variable representing the total profit over the life cycle of the contract e.g. 10 years
- *WLC*- Plain variable representing the total whole life cost over the life cycle of the contract
- *thisSellingPrice*- Plain variable representing the selling price for this individual year

These variables are attached to the action chart, which calculates the tender price to be sent by the manufacturer to the customer based on the whole life cost and the profit margin. The 'Manufacturer' agent also contains some flow aux variables and parameters which are presented in Figures (8-11) and (8-12). The process within the 'customer' agent is static and thus contains no variables.

Events

Events are used to schedule actions and trigger activities within the model. The events are employed to send the sum of variables to the dataset in order to allow them to be displayed in the plot. This allows the visualisation of the dynamic nature of the values at each stage of the simulation as seen in Figure (8-10). Within the 'Manufacturer' agent, the *Respond to ITT* event was employed which had the following rules.

```
CalculateTender()

/*
double thisYearsWLC = triangular(1.7,2.4,2.0);
double increaseThisYear = 0;
double thisYearsProfit = 0;

for (int i = 0; i < 10; i++) { //calcualte a 10 year forecast
       if (i < 1) {
       } else if (i < 4) {
             thisYearsWLC += thisYearsWLC * triangular(-0.1,0.1,0);
       } else if (i < 7) {
             thisYearsWLC += thisYearsWLC * triangular(-0.15,0.2,0.05);
       } else {
```

```
        thisYearsWLC += thisYearsWLC * triangular(-0.20,0.3,0.10);
    }

    WLC += thisYearsWLC;
    thisYearsProfit = thisYearsWLC*0.07;
    TP += thisYearsProfit;


    calculatedPrice.add(i,thisYearsWLC);
    calculatedProfit.add(i,thisYearsProfit);
    }
    thisSellingPrice = WLC + TP;

    //send back tender
    tender thisTender = new tender(thisSellingPrice, this.getIndex());
    get_Main().CntReceivedTenders++;
    get_Main().ReceivedTenders.add(thisTender);

    DataItem thisDI = new DataItem();
    thisDI.setValue(thisSellingPrice);
    get_Main().chart1.addDataItem(thisDI); */
```

The rules within the event specify the nature of the variables to be employed and set conditions for the calculation of the whole life cost and profit throughout the life cycle based on set parameters. It also instructs the action chart to send the Tender to the 'Main' agent in order to bid for the contract. Different rules are employed within the model. For example, a similar rule is employed to import and export data from Microsoft Excel into the Any Logic model.

In incorporating uncertainty into the whole life cost figure (WLC) and customer budget (CATS), three types of uncertainty incorporation were done: Plain uncertainty, Constant uncertainty and Variable uncertainty.

Plain uncertainty

Plain uncertainty means that the values over the ten-year life cycle will not be affected by the impact of uncertainty; hence no uncertainty ranges were applied to them and they will be static, requiring only plain variables. This means the initial data will not change but remain the same. These are shown in Figure (8-10).

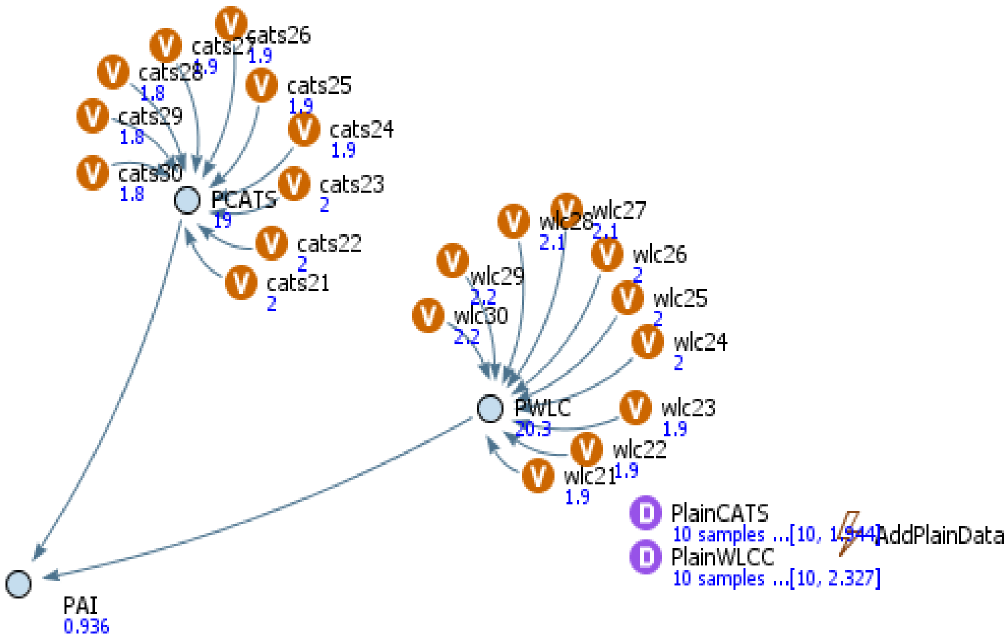


Figure 8-10: Plain uncertainty simulation

The values represented as plain variables in Figure (8-10) are presented in Table (8-5).

Table 8-5: CATS and WLCC values before uncertainty

Year	1	2	3	4	5	6	7	8	9	10	Total
Currency	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**
WLCC	1.9	1.9	1.9	2	2	2	2.1	2.1	2.2	2.2	20.3
CATS	2	2	2	1.9	1.9	1.9	1.9	1.8	1.8	1.8	19

Constant uncertainty

Constant uncertainty means uniform uncertainty ranges will be applied to all values across the ten years irrespective of the period within the life cycle. This requires flow aux variables since the initial data will be different from the data generated at the end of the simulation. These are shown in Figure (8-11). The WLCC and CATS values generated after the simulation are presented in Table (8-6).

However, it is important to note that the values presented on the plot in Figure (8-11) are an average of all the 100 runs rather than the final figures shown in the flow aux variables.

Rules for the values are:

*Cats Year 1 = 2.0*uniform(Min_Constant,Max_Constant)*

*Cats Year 2 = 2.0*uniform(Min_Constant,Max_Constant)*
*Cats Year 3 = 2.0*uniform(Min_Constant,Max_Constant)*
*Cats Year 4 = 1.9*uniform(Min_Constant,Max_Constant)*
*Cats Year 5 = 1.9*uniform(Min_Constant,Max_Constant)*
*Cats Year 6 = 1.9*uniform(Min_Constant,Max_Constant)*
*Cats Year 7 = 1.9*uniform(Min_Constant,Max_Constant)*
*Cats Year 8 = 1.8*uniform(Min_Constant,Max_Constant)*
*Cats Year 9 = 1.8*uniform(Min_Constant,Max_Constant)*
*Cats Year 10 = 1.8*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 1 = 1.9*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 2 = 1.9*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 3 = 1.9*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 4 = 2.0*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 5 = 2.0*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 6 = 2.0*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 7 = 2.1*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 8 = 2.1*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 9 = 2.2*uniform(Min_Constant,Max_Constant)*
*Wlcc Year 10 = 2.2*uniform(Min_Constant,Max_Constant)*

Rules for the minimum and maximum ranges are:

Min_ Constant , type: double, default value = 0.9
Max_Constant , type: double, default value = 1.1

The output of the simulation are presented in Figure(8-11) and Table (8-6)

Table 8-6: WLCC and CATS values with constant uncertainty

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Currency	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**
WLCC	1.74	1.9	1.93	2.12	2.11	1.85	2.16	2.03	2.03	2.35	20.22
CATS	1.92	2.05	1.82	1.94	1.98	2.02	1.72	1.63	1.91	1.8	18.79

After applying equation (i), an AI of 0.02 was generated which is very unaffordable.

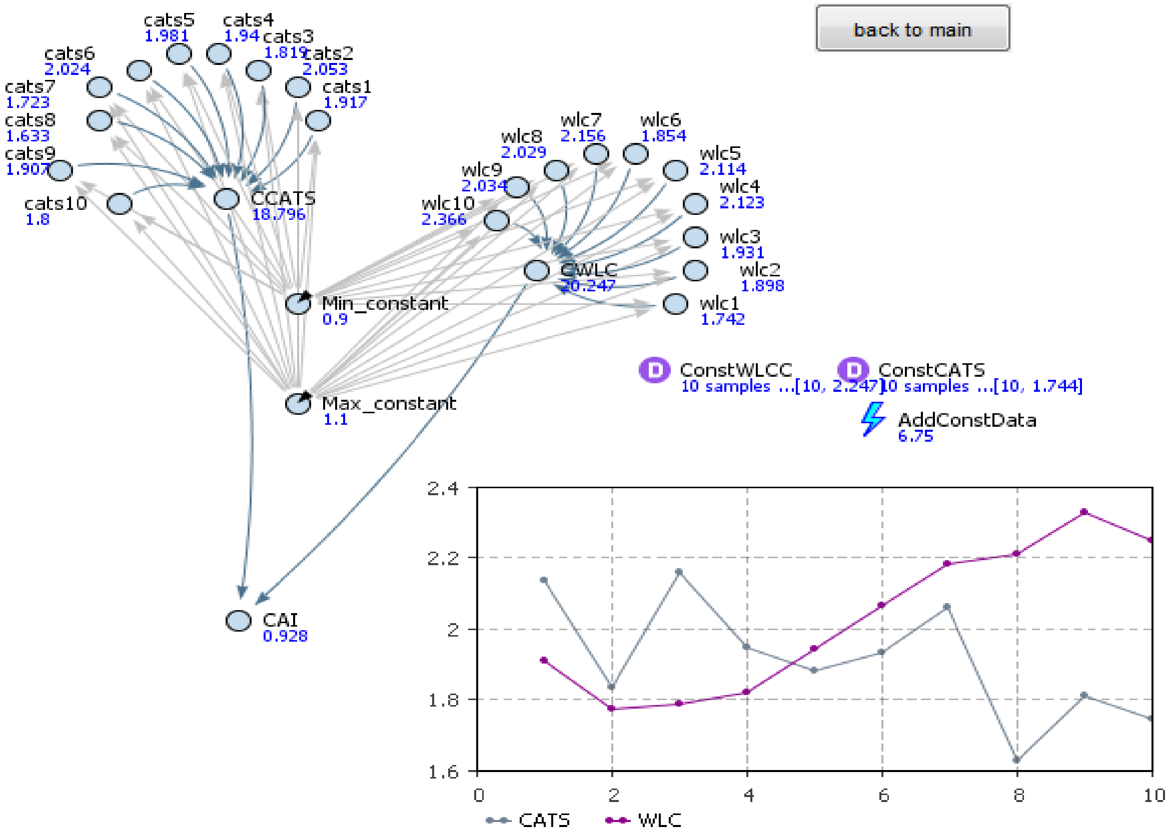


Figure 8-11: Constant uncertainty simulation

Variable uncertainty

Variable uncertainty means that the three levels of uncertainty ranges will be applied to all values across the ten years depending on the period within the life cycle. This also requires flow aux variables since there will be variance between the initial data and data generated at the end. These are shown in Figure (8-12).

This shows that there are three parameters with minimum and maximum ranges of uncertainty to incorporate into the simulation. Most of the rules used in the process are similar to those provided above but in this case three uncertainty ranges are applied to the variables, which are provided below.

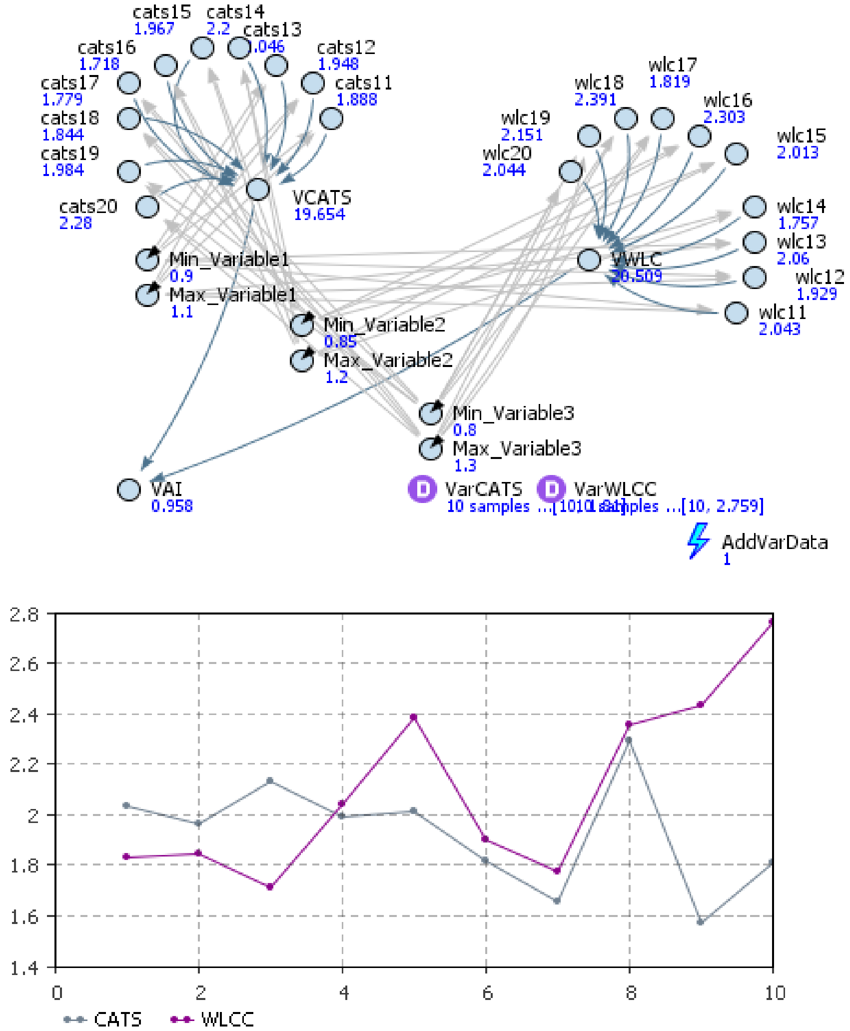


Figure 8-12: Variable uncertainty simulation

Rules for the minimum and maximum ranges are:

Min_Variable1, type: double, default value = 0.9
Max_Variable1 , type: double, default value = 1.1
Min_Variable2 , type: double, default value = 0.85
Max_Variable2, type: double, default value = 1.2
Min_Variable3 , type: double, default value = 0.8
Max_Variable3 , type: double, default value = 1.3

The WLCC and CATS values generated after the simulation are provided in Table (8-7).

Table 8-7: CATS and WLCC values with variable uncertainty

Year	1	2	3	4	5	6	7	8	9	10	Total
Currency	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**	**£m**
WLCC	2.04	1.93	2.06	1.76	2.01	2.3	1.82	2.39	2.15	2.04	20.5
CATS	1.89	1.95	1.05	2.2	1.97	1.72	1.78	1.84	1.98	2.28	19.66

The results obtained from the plain, constant and variable uncertainty simulations are compared below (Figure 8-13).

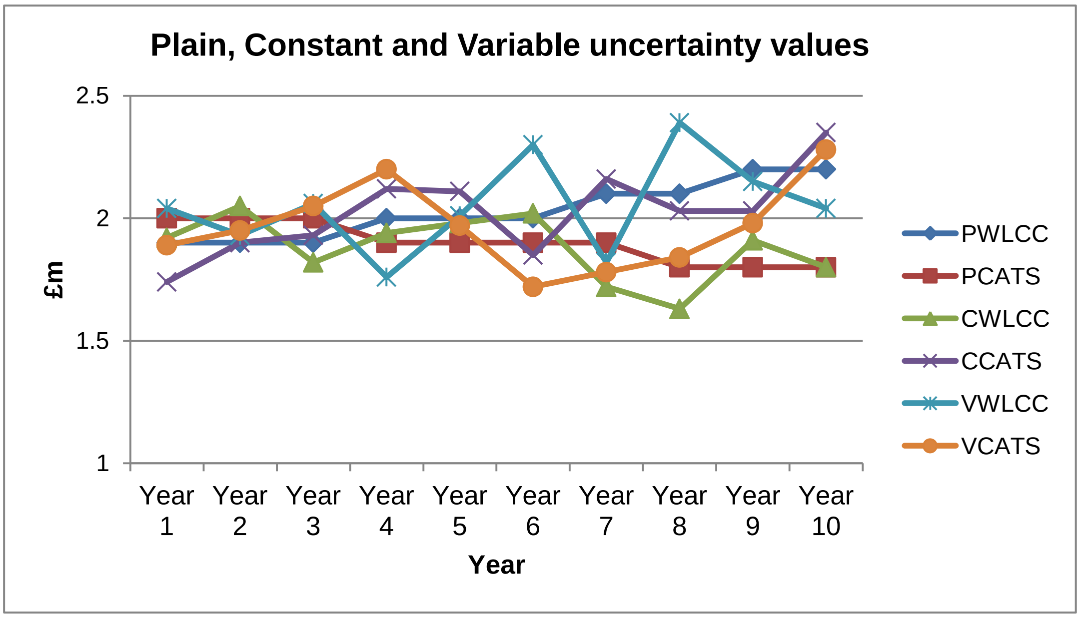


Figure 8-13: Plain, Constant and Variable uncertainty comparison

A comparison of the results of the plain, constant and variable uncertainty simulations shows that the lowest profiles were the Constant WLCC and Variable CATS followed by the Plain CATS. This means that the Constant CATS generated values that were lower than the Plain CATS. The most dynamic results were yielded from the Variable WLCC, which also has the highest total values. The Constant WLCC fell below the Plain WLCC. Total CATS generated from the Variable uncertainty distribution was higher than the initial CATS values (Plain CATS) while those from the constant uncertainty distribution were lower than the initial values. Also, the total WLCC generated from the Constant WLCC can be lower than the Plain WLCC while the Variable WLCC was higher than the Plain WLCC. The variable uncertainty distribution yield the least affordable results, while the constant uncertainty distribution yield more affordable results.

The result of the simulations may be extracted to Microsoft Excel for storage, through complex java coding.

It is equally possible to carry out the different types of uncertainty using the AnyLogic model, however, this would be more time consuming and iterative as the three cannot be done in parallel as shown in the AnyLogic model. Other advantages and disadvantages of the two approaches are presented below.

8.6.2 Advantages and Disadvantages of both approaches

Advantages of using risk software

Uncertainty assessment using the Crystal ball approach has the following advantages:

- It is relatively quick and easy to use.
- It provides a quicker way of extracting the result of the simulation.
- It is easy to install as an add-on to Microsoft Excel, hence there is little effort involved in installation and the cost is reasonable.
- It generates results for 800 trial values which is highly comprehensive.

Disadvantages of using risk software

The disadvantages of uncertainty assessment using the Crystal ball approach are:

- It does not provide a platform for integrating different simulation techniques.
- The software licence must be bought separately like any other risk software and cannot be installed on multiple computers.
- It doesn't provide a visual representation of the simulation or changes to initial values while simulating. Plots have to be manually created at the end of the simulation.

Advantages of using Anylogic tool (futuristic)

On the other hand, uncertainty assessment using the AnyLogic approach has the following advantages:

- It provides a platform for integrating different simulation techniques.
- It provides a process view of the activities carried out by the different agents at the bidding stage.
- It allows a simultaneous visual representation of the dynamic changes in the simulation in graphical form.
- It allows the multiple assessment and simulation of many values which can be linked to flow charts to show the cause of changes in the actions or states of the agents.

Disadvantages of Anylogic tool (futuristic)

The disadvantages of uncertainty assessment using the AnyLogic approach are:

- It can require complex java coding to link or synchronise certain elements within the model or externally to Microsoft Excel or Access.
- The software licence must be bought separately like any other risk software, though multiple license keys can be obtained to install the software on multiple computers.
- It requires a high level understanding of user need in order to gain value from the software.
- A considerable amount of time is required to get the model set up and working effectively, depending on the complexity.

It is clear that both approaches have different advantages and disadvantages over the other. The first approach is widely used in the defence sector solely for cost estimation rather than for affordability assessment. As the practice of affordability assessment becomes more popular, this approach would be the quicker one to employ using any risk software. However, the second approach is more futuristic as only a few organisations are currently employing the AnyLogic model in cost estimation. It will take longer to generate interest and become widely used, as it requires more financial and technical investment to set up and run. Also, personnel using the model will need training in order to use it to maximum capacity.

8.7 Summary

This Chapter was focused on incorporating uncertainty in affordability assessment, which is mainly done for the quantitative factors involved in the assessment. The logic which was developed and applied had two aspects to it. One was based on the result of the affordability information capability audit presented in Chapter 7, while the other was based on the refined AACE uncertainty ranges presented in Chapter 8. The logic was first applied using Microsoft Excel and incorporating risk assessment software (Crystal Ball) to assess the impact of uncertainty on quantitative affordability factors. A second approach was also presented and is proposed for the future. This is the AnyLogic model, which combines system dynamics and agent-based simulation to assess the impact of uncertainty on defence project affordability. Finally, the advantages and disadvantages of both approaches were presented in this Chapter with case study application.

CHAPTER 9

VALIDATION OF THE DEVELOPED FRAMEWORK

9.1 Introduction

This Chapter describes the integration of the modules from the three perspectives with the affordability information capability audit into one affordability framework. It also provides details of the validation process which is done through interaction with industrial partners and application of the framework to four real life cases within civil and defence industries and the analysis of results.

9.2 Integrated framework

The overall affordability framework comprises the three affordability perspectives namely, customer affordability, manufacturer profitability, supplier sustainability and an affordability information capability audit. In addition to this, the affordability management methodology was also developed to provide a process of controlling the project to ensure it remains affordable. The details of development of each module within the framework have been described in previous chapters; therefore this Chapter focuses on the validation of the framework which is implemented as a system using the Microsoft Excel software with the industrial partners.

This chapter is focussed on validating the logic behind the affordability framework as well as the results generated through the system. This was done by improving the integrated framework based on the feedback from industrial experts as well as populating the system with data from real life contracts and analysing the results.

Apart from validating the modules, it also helps to validate the rationale adopted for assessing the impact of uncertainty on the case studies. This is done by imposing uncertainty on the predicted data and comparing this with the actual to identify the level of variance. The application of the anylogic tool to provide a futuristic approach to assess the impact of uncertainty on customer affordability was also validated with an academic expert since the tool is not common or widely used in industry.

Methodology for Validation

Industrial Participation

The initial validation sessions were mainly conducted with the same companies involved at the development stage of the framework while final validation was done with experts from other companies. Initial validation focussed on the concepts, factors, measures and descriptions for each affordability perspective while final validation included the case study application with actual cost information to populate the framework. Generally one or two experts from each company were involved in validating the logic in the framework and content of the system as well as providing actual information. Their profiles have been provided in Chapter 4 as Business development leader and Head of procurement and sub-contract manager in company A, Set assurance team leader and Assistant head of equipment plan in company B, Statistics and life cycle cost modelling lead in company C and the programme manager and others whose profiles were presented in Chapters 5 and 6. However, at the final validation and case study application, expert from three companies were involved. The second company was a consultancy company which had the experience of managing projects both within civil and defence aerospace sectors with customer and manufacturer organisations. The choice of the companies was based on their ability and willingness to provide actual information from a project to populate the system. The profiles of these experts involved in the final validation are provided in Table (9-1 to 9-3).

Table 9-1: Company A Interviewee profile

Job role	Responsibilities
Company Director	14 years of functional experience in production/operations, cost estimating, commercial/contracts, business development, programme management and customer support. Experience as commercial officer of a multi-million dollar international joint venture who is presently engaged in consultancy and training in many of these areas on both an industrial and an academic basis.

Table 9-2: Company B Interviewee profile

Job role	Responsibilities
Programme manager	Responsibility covers Design Services, Tasking & Subcontractor Management on Bowman and ComBAT and Information and Platform (CIP) Long Term System Support Contract.
Supplier Engagement	Responsible for the long-term support of defence contracts with a core role in supplier engagement and international Logistics support.

Table 9-3: Company C Interviewee profile

Job role	Responsibilities
Statistics and Modelling LCC Analysis Lead	Responsible for life cycle costing analysis with focus on risk and uncertainty assessment of defence contracts

It was not possible to validate the application of the anylogic tool, with industrial experts because those companies who provided case studies for the validation were not using the tool for uncertainty assessment. Anylogic is uncommon tool within industry though it is being applied in academia. Also in order to validate the tool, the user has to download a trial version of the tool or get a full licence to download the tool on their computer systems which industrial experts were unable to do due to their company policies. This shows that the tool is a futuristic initiative within industry. For this reason, the tool was validated with a post doctoral researcher who is knowledgeable about the application of the model in uncertainty assessment. The researcher has conducted a 3-year research in the area of assessing the impact of uncertainty in whole life cycle costing.

Table 9-4: Academic Interviewee profile

Job role	Responsibilities
Post Doctoral Researcher	Conducted 3-year of research in uncertainty modelling with some experience in the application of anylogic

Validation Process

The process of validation included case study sessions which were carried out with the industrial partners. The sessions were usually conducted at the prime contractor's site, in sessions of 120, 180 and 240 minutes with experts whose profiles are provided above. In total, the validation and case study sessions lasted over 40 hours. The fourth case study session was carried out at Cranfield University as it was more convenient for the expert to come to the university premises. During each session, the researcher usually provided an explanation of the affordability framework and the implemented system with its objective, capability and the business benefits to the industry. This could be done in form of the PowerPoint presentation prior to the demonstration of the system itself. Prior to the session the researcher had communicated the information requirement industrial partners in order to ensure that the relevant data required to populate the system for the three perspectives was available. During the session, the industrial expert provided the background of the case study to help the researcher gain an understanding of the nature of the case study. Next the affordability system was populated by the researcher going through the affordability audit and the three perspectives and entering the data in the system to generate an output. In some sessions, the industrial expert may not have all the information required to populate all the three perspectives or they may not have the time to go through all the modules in the same session. In such cases, the researcher arranged other sessions to conclude the validation or obtain relevant information through the post or e-mail from the industrial expert. At each session, feedback and suggestion were given by the industrial expert on how to improve the system. After the system output was generated, it was discussed with the industrial experts to determine how realistic the output was. In addition to this, the validation exercise was aimed at checking the logic of the framework and the capability of the system. Therefore, questionnaires were designed in order to capture the opinion of the industrial experts. Their suggestions were assessed and the system was modified at the discretion of the researcher to ensure the system achieves the aim of the research activity. The outcomes of the validation sessions are provided in Table (9-5).

Questionnaires

During the validation stage, a questionnaire was designed for industrial experts and academic researcher to complete which focused on the logic, applicability, benefits, usability and limitations of the implemented affordability framework as well as the uncertainty assessment methodology. Like the previous questionnaires (used for data collection), they contained both open-ended and closed questions. The respondents were required to provide responses to the questions and suggest ways of improving the affordability system and anylogic approach to uncertainty assessment. The responses from the questionnaires were acknowledged and relevant changes were made to the affordability system by the researcher. While the questionnaires used for final validation are provided in Appendices I and P, some examples are provided below.

1. How logical is the affordability assessment framework presented in this system?

1	2	3	4	5	6	7	8	9	10
Totally Invalid	Valid with major deficiencies				Valid with minor deficiencies				Totally Valid

2. Could it be applicable for other sectors with long-term projects, e.g. construction or nuclear?
3. Is the system applicable at other stages of the CADMID cycle?
4. How would the system benefit the bidding team?
5. How would the system improve affordability, profitability and sustainability assessment?

6. What are the strongest features of the system?

Some experts were able to complete the questionnaire while others gave verbal suggestions during the validation sessions, which were recorded by the researcher. The questionnaire designed to validate the application of the anylogic tool to assess the impact of uncertainty in affordability assessment was completed by the post-doctoral researcher.

Table 9-5: Outcomes of all Validation Sessions

Subject area	Validation Session	Respondent	Outcome
Customer Affordability	*Affordability Workshop*	Project Managers, Forecasting Managers, Business Development Manager and Life cycle Cost Analyst from customer organisation and three manufacturer firms	• Clarification of the manufacturer's view of affordability • Refinement of the weighting and scoring mechanism of the affordability factors. • Refinement of the affordability factors to be included in the system • Improvement of affordability system.
Customer Affordability	*Semi-structured Interviews*	Financial Managers, Forecasting Managers from customer organisation	• Clarification of the views of affordability from the customer's perspective and how it differs from the manufacturer perspective. • Identification and explanation of further affordability factor and factor components. • Clarification of the weighting mechanism of the affordability factors • Expansion of contract platforms • Improvement of affordability system.
Manufacturer profitability	*Semi-structured Interview*	Project Managers, Finance team Members, Engineers and Functional Experts from manufacturer organisation	• Clarification of the manufacturer's view of affordability and the process of profitability assessment. • Understanding the elements considered in profitability calculation together with financial and non-financial elements that affect profitability • Validity of the refined AACE uncertainty ranges and the crystal ball software for uncertainty assessment
Supplier sustainability	*Semi-structured Interviews*	Project Managers, Supplier management team member, Risk managers from manufacturer organisation	• Clarification of the manufacturer's view of supplier sustainability and the ways of assessing supplier performance. • Refinement the definition of supplier sustainability. • Clarify and refining the supplier sustainability measures. • Allocating weights and scores for sustainability measures
Uncertainty assessment	*Semi-structured Interview*	Post Doctoral Researcher in Uncertainty	• Validity of the logic and suitability of applying the anylogic tool in uncertainty assessment. • The advantage of representing time in uncertainty assessment as well as providing an integrated platform to view different agents was highlighted • Improving the clarity of the variables and parameters used in the tool • Clarification of the input provided in the tool. • Technical drawbacks in the application of the tool

The response from the validation was acknowledged and used to improve the application of the anylogic tool where applicable. The background, results and analysis of each case study are provided in the next section. The profiles of the respondents have been provided in Chapters 4 (section 4.2.3), 6 (section 6.2.2) and 9 (section 9.2.1).

9.3 Further case studies

Case study 1 has been presented in the previous chapters (5, 6, 7and 8) as the development case study. Within this Chapter, three validation case studies are presented.

9.3.1 Case study 2

Background

Case study 2 is based on a two-year single bid, firm price contract between a prime contractor and a major defence customer. The contract was aimed at providing support for systems within a communications programme. It replaced an initial support contract otherwise known as Bridging strands which provided initial support to the communications programme as it entered service with UK Land Army, Bridging strands contract which lasted for three years. The programme consisted of a tactical communications system integrating digital voice and data technology to provide secure radio, telephone, intercom and tactical internet services in a modular and fully integrated system. The programme included the conversion of over 18,000 platforms, including vehicles, helicopters, naval vessels, landing craft and fixed head quarter buildings. This case study consisted of repair, maintenance, spares provision, 24hr help desk, incident reporting, post design services tasking to rectify known faults, provision of technical publications, reliability and maintainability modelling, provision of field service support and a reference laboratory to replicate faults. The bidding team included the Capture manager, Bid manager, Programme manager, Technical experts and Finance team members.

9.3.2 Affordability capability audit

Similar to case study 1, data from case study 2 were applied to the overall affordability system and results generated were analysed for the affordability information audit and the three affordability perspectives. The result of the Audit assessment is presented in Table (9-6).

Table 9-6: Case Study 2 Affordability Audit Table

	Average of each component of the factor groupings			
Component/ Factor Grouping	CB	WLCC	CTA	R
Information	15	13	12	12
Tools	15	12	12	12
Skills	15	15	12	12
Experience	15	15	15	12
Dependency	11	11	11	12

The results in Table (9-6) have been presented in a different format from case study 1 due to the short life cycle of the contract. In order to make a better presentation and analysis of the assessment, the results have been presented in terms of the factor groupings and factor components, rather than factor groupings and the CADMID cycle since the contract only has the 'I' phase. The information capability audit for the case study was performed based on the four main affordability factor groupings in the audit module within the system. The cells are mainly coloured green with three amber cells. With average scores between 11 and 15, this means there is a relatively high level of information availability over the lifecycle.

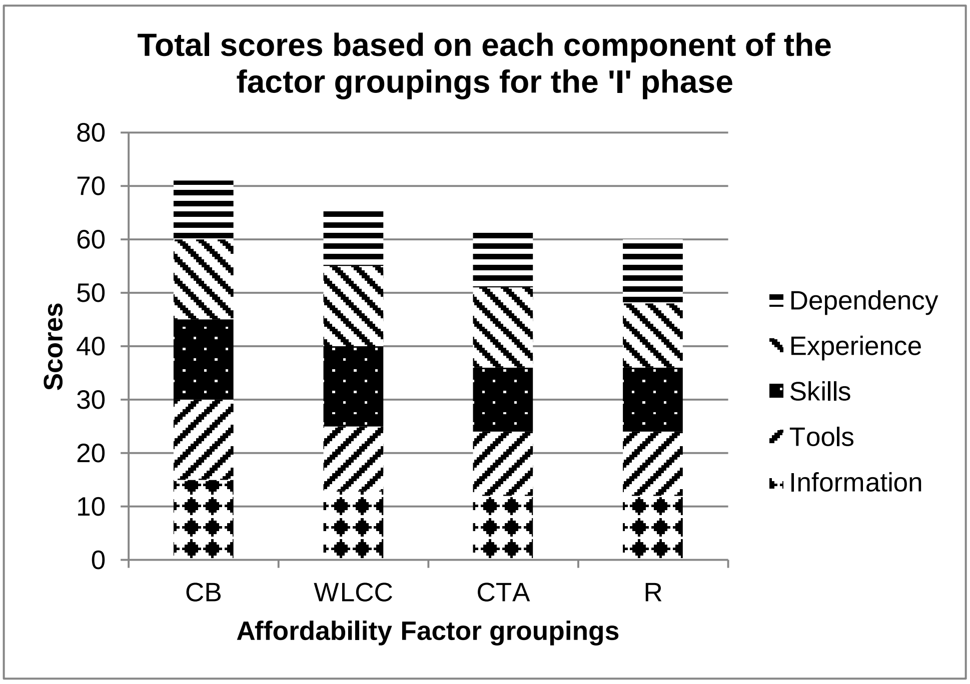


Figure 9-1: Case Study 2 Affordability Audit Result

This could be as a result of the prime contractor's involvement in similar projects relating to the same programme and it was able to secure historical data from these projects e.g. from case study 1. Case Study 2 contains the 'I' phase of one aspect the programme while the case study 1 covers the ADMI phase of another part of the programme.

This means the current prime contractor has some experience of dealing with the communications system. Also higher scores for the CATS and WLCC reveals some transparency by the customer in revealing the available budget and the manufacturer's effort to provide the best cost estimate based on the customer requirement. The bar chart in Figure (9-1) reflects higher level of information availability about CB, WLCC and contract type arrangement while least information is available about the customer requirement. This suggests lower level of risk based on the other three factor groupings, but potentially medium risk in terms of the customer requirement, because the customer requirement could change during the life cycle of the contract.

9.3.3 Customer affordability assessment

Quantitative assessment results

The predicted WLCC and CATS values are presented for the 2 years in Table (9-7) while the actual values are presented in Table (9-8).

Table 9-7: Case study 2 CATS and WLCC values - Predicted

Years	1	2	Total
Currency	**£**	**£**	**£**
WLCC	£52,200,000.00	£52,340,845.00	104,540,845
CATS	£65,000,000.00	£65,000,000.00	130,000,000

Table 9-8: Case Study 2 CATS and WLCC values – Actual

Years	1	2	Total
Currency	**£**	**£**	**£**
WLCC	£49,000,000.00	£66,150,000.00	115,150,000
CATS	£63,810,372.50	£61,810,000.50	125,620,745

The reasons for the changes between actual and predicted are explained below:

- WLCC lower than planned overall, due to customer not taking up all post design services tasks offered by manufacturer, however WLCC still increased by 3.5% in year 2 due to exchange rates.

- Manufacturer and supplier resource profiles were substantially lower than those originally bid.
- Development increments slowed down due to user inability to cope with complexity of kit.
- One mid life upgrade programme was cancelled hence reducing support costs.
- The customer was directed to make in service savings due to fiscal government reviews and defence cuts across all programmes by reducing the budget by £2m in year 2.

Table (9-7) which is the predicted information does not have any violation in both years as total WLCC was over £104m while CATS was £130m. The customer was willing to provide over £25m excess due to some deficiencies passed on to the project from the Bridging strands project. The customer was aware that the project carried a medium to high level of risk, hence the need to invest more than the standard WLCC to provide contingency against the problems faced within the previous project. However, the actual CATS and WLCC values in Table (9-8) shows a reduction in CATS despite an increase in the WLCC.

The AI was calculated by employing the actual values in Table (9-8) in the AI equation (i).

The AI of 1.01 which is higher than 1, shows that the project is just affordable. This is because violation only occurred in one of the two years and the total CATS was higher than WLCC. The AI also means that the project would be profitable. The actual profile shows that the budget is not evenly spread across both years due to a £2m decrease in CATS in year 2. Although there is a significant cost increase of over £17m in the WLCC profile in year 2, the sum of WLCC is still less than CATS which makes the project affordable since the violation only occurs in year 2.

In order to further understand the impact of uncertainty on the case studies, uncertainty was incorporated in the predicted data to assess the variance between the actual and predicted data based uncertainty. Uncertainty assessment was based on the result of the affordability audit for each case study incorporated using the crystal ball software. The values generated after incorporating uncertainty presented in Table (9-9) and compared in Figure (9-2).

Table 9-9: Case study 2 Uncertainty CATS and WLCC values

Years	1	2	Total
Currency	£	£	£
WLCC	49,966,100.84	49,110,438.10	99,076,538.94
CATS	64,709,657.12	65,626,686.27	130,336,343.39

The values presented in the charts in Figure (9-2) reveal that there is a variance between the values generated from the uncertainty assessment and the actual values. The uncertainty assessment results and the actual results for the first year are very similar, but the uncertainty assessment for year 2 of the WLCC varied greatly from the actual by over £17,000. This shows that the tools or methodology employed to assess the impact of uncertainty and risk may not be able to provide the actual values, but they generate results which could be closer to actual. The value in the results produced is that it would enable the project team to make adequate provision for possible cost escalations. Also it could guide the project team in taking steps to ensure that project remains affordable and the manufacturer profitability is sustained. This result shows that the rationale adopted for assessing the impact of uncertainty on the case studies is appropriate. This is further confirmed by other case studies.

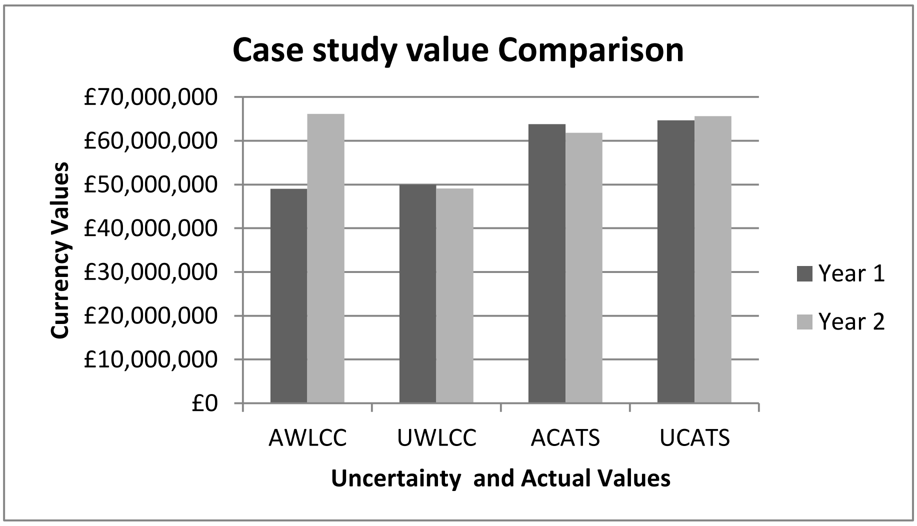


Figure 9-2: Uncertainty results comparison with actual data

Qualitative Assessment results

The qualitative assessment was carried out by allocating scores and weights to generate the weighted scores based on the actual information as explained in Chapter 5 (section 5.8). The maximum weighted score allowed is 25 while the minimum is 1 with lower scores signifying higher capability. The weighted scores for qualitative customer affordability assessment are presented in Tables (9-10) and (9-11). The weighted scores in Table (9-10) were allocated based on the predicted information and re-allocated to produce the weighted scores in Table (9-11) based on the actual information. The weighted scores reveal that the project is highly affordable as the weighted scores are between 7 and 12, however the overall weighted scores in Table (9-10) has higher scores than those in Table (9-11). The actual assessment is also presented in Figure (9-3).

Table 9-10: Case Study 2 Qualitative customer affordability weighted scores – Predicted

Affordability Factors	Year 1	Year 2
Requirement	7	7
Environment	8	8
Value For Money	7	7
Supply chain	7	7
Quality	12	12

Table 9-11: Case Study 2 Qualitative customer affordability weighted scores – Actual

Affordability Factors	Year 1	Year 2
Requirement	9	7
Environment	7	7
Value For Money	9	9
Supply chain	9	10
Quality	10	10

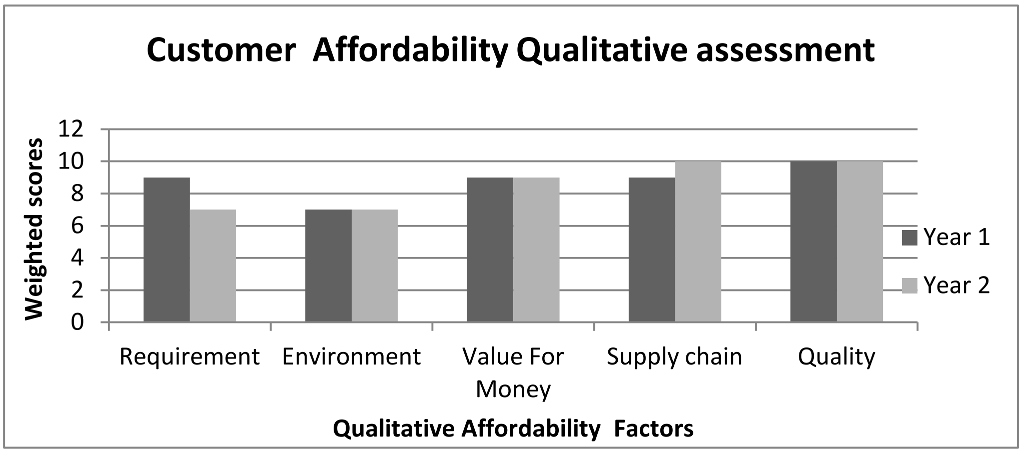


Figure 9-3: Case Study 2 Qualitative customer affordability actual results

1. Requirement – initial customer requirement was reduced as the customer did not take up all post-design service tasks provided by the manufacturer. Also the TRL of the solution was so high that some development increments were slowed down to allow the user become more familiar with the kit and to be able to use it. This is the reason why the weighted score reduced over the two years meaning that the capability of the solution improved over the life cycle.
2. Environment – the solution was environmentally friendly and disposal was not considered within the contract. This is the reason why the weighted score stayed the same over the life cycle. Also, this factor was not important within this contract.
3. Value For Money – the manufacturer was able to provide the solution at reasonable cost. Also resources were maximised as customer requirement was delivered despite the fact that the manufacturer and supplier resource profiles were lower than those originally bid. The solution also satisfied the key performance indicators at medium level. However, customer inability to cope with kit complexity did not aid customer satisfaction which explains the cause for the actual weighted scores increased to 9 in comparison with the predicted weighted score of 7 and this was maintained over the lifecycle.
4. Supply chain – the supply chain encompassed three countries namely, the USA, UK and Canada. For this reason, the WLCC was increased due to exchange rate fluctuations. Also the supplier resource profiles were substantially lower than those

originally bid hence this would have affected the supplier capability and the supplier price increase in year 2. This is why the actual weighted score for suppliers was higher than those predicted and the score in year two was higher than year 1.

5. Quality – The level of innovation within the project was so high that the customer struggled to keep up with it. This is why the actual weighted scores were lower than predicted meaning the actual quality of solution was higher than predicted. Overall, the customer requirement was delivered at the desired quality and this capability was sustained over the 2 years. This explains why the weighted scores stayed the same over the two years.

While the project is affordable in terms of all the factors, steps could still be taken to improve it affordability in terms of quality and supply chain. The suggestions for improvement are provided in Chapter 5, section 5.9.

9.3.4 Supplier sustainability assessment

The prime contractor assessed the sustainability of a major supplier over the two years and the results are presented in Table (9-12) and Figure (9-4). For the supplier sustainability, only the actual data was available which is presented above. Table (9-12) and Figure (9-4) show that the supplier was generally more sustainable in the first year than the second year. While the weighted scores for the management and environment stayed the same over the years, the other three dimensions did change.

Table 9-12: Case Study 2 Supplier sustainability assessment

Sustainability Dimensions	Weighted scores	
	Year 1	Year 2
Quality and Delivery	16	14
Management (People & Resources)	11	11
Cost	12	20
Stakeholder	12	13
Environment	4	4

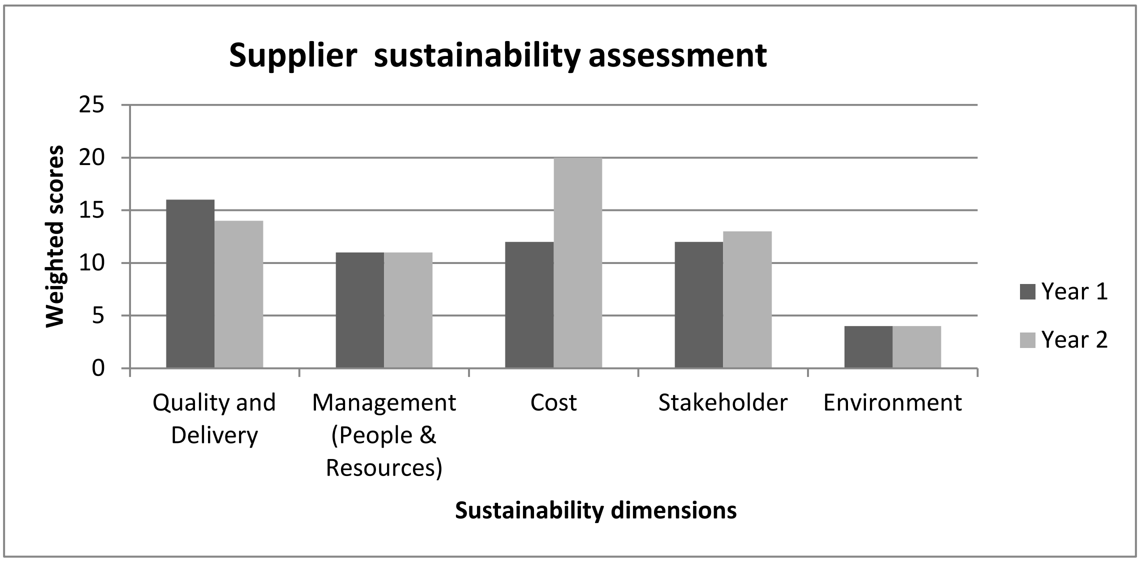


Figure 9-4: Case Study 2 Supplier Sustainability results based on sustainability dimensions

- Delivery & Quality – As mentioned earlier, the supplier's offering was highly innovative that the customer struggled to keep up with it. The measure of conformance was low in year 1, which the supplier tried to correct in year 2 hence a reduction in the weighted scores. This means the supplier's capability to deliver a better offering which was more suitable for the customer improved to a degree over the two years.
- Management (People & Resources) – the supplier maintained the same level of people and resources generally over the two year period, hence the weighted scores were the same over the two years. The supplier's inventory turnover might have reduced in year 2 with a reduction in customer demand for post-design services, but overall the supplier's capability in management did not change over the two years.
- Cost – the impact of exchange rates on the supplier's cost led to a 3.5% increased in the second year which also resulted in increased WLCC of the manufacturer's offering in year 2 despite a reduction in customer demand for the post-design services and cancellation of the mid life upgrade programme offered by the manufacturer.
- Stakeholders – the weighted scores for the supplier's capability to manage its stakeholders increased slightly meaning that the supplier's capability did not improve in the second year. While the supplier was able to maintain its market position, innovation and flexibility, its relationship management capability would have declined in the second year.

- Environment – the supplier's capability to comply with environmental standards was maintained over the period, hence this explains why the weighted score remained the same over the two years.

The system offers some improvement guidelines which the supplier could take in order to improve performance based on quality and delivery, stakeholder management and cost. As shown in Appendix M.

9.3.5 Manufacturer profitability assessment

The predicted and actual profitability profile over the two years are provided in Tables (9-13) and (9-14).

Table 9-13: Case Study 2 Manufacturer profitability assessment – Predicted

Year	1	2	Total
Currency	£	£	£
SP	52,252,422.48	52,252,422.48	104,504,845
CATS	65,000,000	65,000,000	13,000,0000

Table 9-14: Case Study 2 Manufacturer profitability assessment - Actual

Year	1	2	Total
Currency	£	£	£
WLCC	49,000,000.00	66,150,000.00	115,150,000.00
Total Margin	14,810,373.00	-4,339,628.00	10,470,745.00
SP	54,306,700.00	71,314,045.00	125,620,745.00
CATS	63,810,372.50	61,810,372.50	125,620,745.00

The predicted values show that CATS was higher than WLCC over the life cycle, hence the project is viewed to be profitable. However, due to a number of factors, WLCC and CATS profile changed and the actual WLCC and CATS values are provided in Table (9-14). Table (9-14) reveals that the total SP is the same amount as the CATS. This means the project is profitable to cover the WLCC with a margin. Also it shows that there is an increase in WLCC between years 1 and 2 and a decrease in CATS, due to government reviews and budget cuts. The PI was calculated by employing the actual values in Table (9-14) using the PI equation as explained in Chapter 6.

Overall, a margin of £10,470,745 was generated, but the effect of the violation in year 2 is seen in the PI generated. The PI of 0.85 means that the project is less affordable as the PI is closer to 1 than 0. The degree of unaffordability is just 15% which means the violation in year 2 could have a minor impact on the profitability of the project and cashflow management overall.

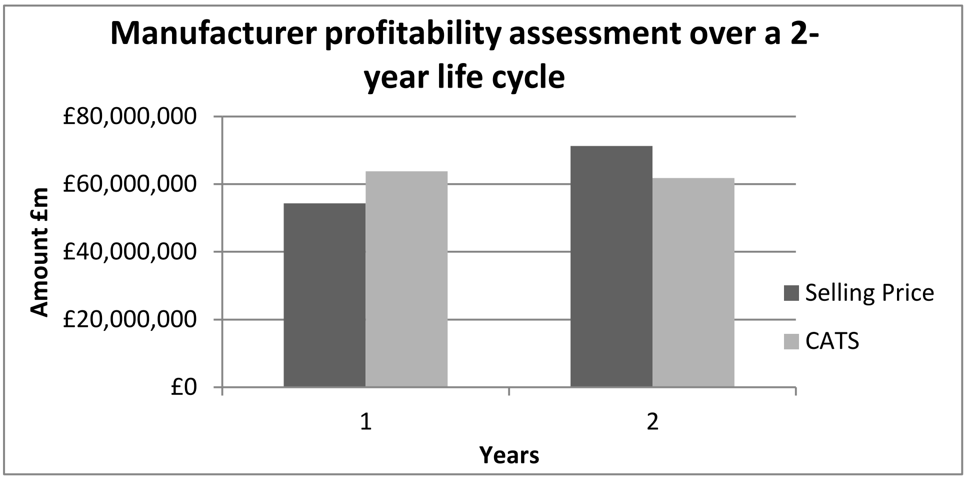


Figure 9-5: Case Study 2 CATS and WLCC actual profile

Figure (9-5) shows that the CATS was not evenly spread across both years unlike other projects because of the £2m reduction in CATS as mentioned above. The SP increases in year 2 due to increase in WLCC. The total SP being the same as total CATS means the manufacturer would break even with a margin of 9%.

9.3.6 Case study 3

Background

The case study is based on a six-year single bid, firm price contract between a prime contractor and a major defence customer. The contract was focussed on the provision of batteries for Radio Systems support of 34,000 systems and subsystems. The project covers the 'CADM' phases of the CADMID cycle so 'CAD' phases last for 4 years while the 'M' phase lasts for 2 years. The price for the contract to supply secondary and primary battery units and chargers in support of the system prime contract was evenly spread over the six years. The Customer budget was initially £45million spread over the same period hence the affordability issue. Some trade off was done on the customer requirement to get a major supplier involved in the contract. The prime contractor finally agreed the contract at a value of £47million (initially £49million) with the customer and a suitable subcontract value. The success of this project was very crucial as failure in availability of the batteries for theatre use could means significant damage to UK military capability. The project was assessed after the project had been contracted and started.

9.3.7 Affordability capability audit

A similar approach to the previous case studies has been applied to case study 3, hence the result of the Audit assessment is presented in Table (9-15).

Table 9-15: Case Study 3 Affordability Audit Table

	CADMID CYCLE			
Affordability Factors	**C**	**A**	**D**	**M**
Customer Budget	12	12	11	11
Whole life cycle cost	12	12	12	9
Contract Type Arrangement	12	12	12	10
Requirement	11	11	10	10

The Information capability audit for the case study was performed based on the four main affordability factor groupings across the CADM phases. Half of the cells are coloured green while the other half is coloured amber. This means that there is high to medium level of information availability over the lifecycle. The prime contractor has been involved in other parts of the whole programme; hence this has helped to secure some information. However, this part of the programme is different due to the nature of products involved and the fact that the project includes the concept stage through to the manufacture stage. This requires a lot of expertise from the prime contractor. The audit scores range from 9 to 12 suggesting that there is sufficient information to perform the assessment.

The bar chart (Figure 9-6) shows that there is higher level of information availability for the 'C' and 'A' phases of the CADMID, sufficient in the 'D' phase and satisfactory level in the 'M' phase. This means in assessing the impact of uncertainty on the quantitative factors, the assumption would be to impose the lowest uncertainty on the CAD phases in the first four years and medium uncertainty in phase 'M' which last for years 5 and 6.

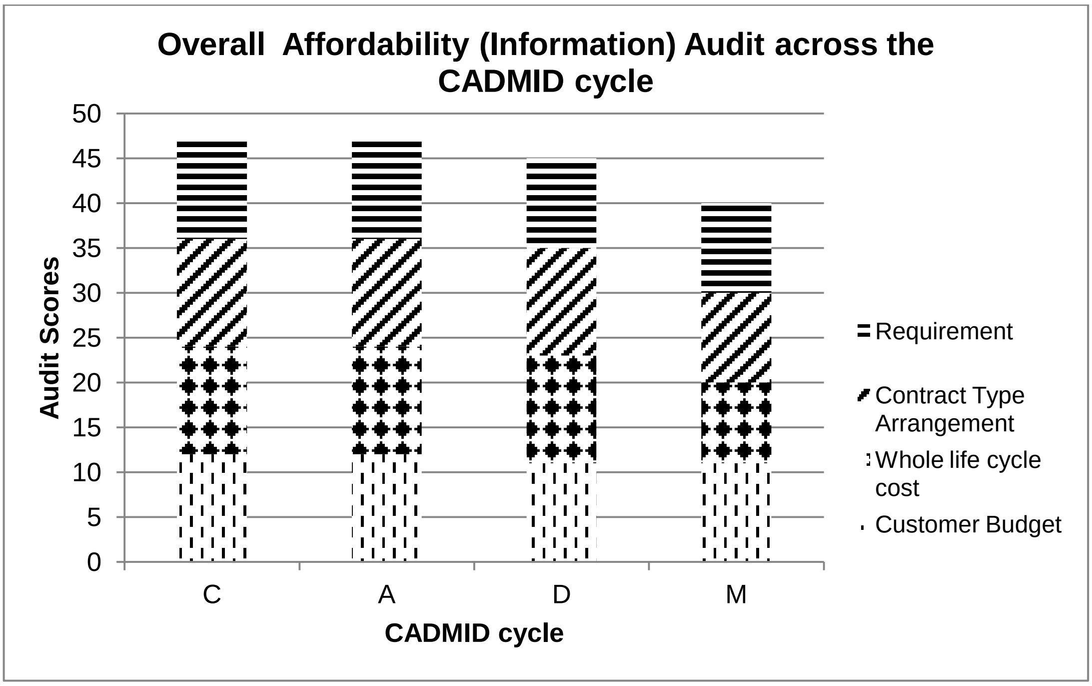


Figure 9-6: Case Study 3 Affordability Audit Result (1)

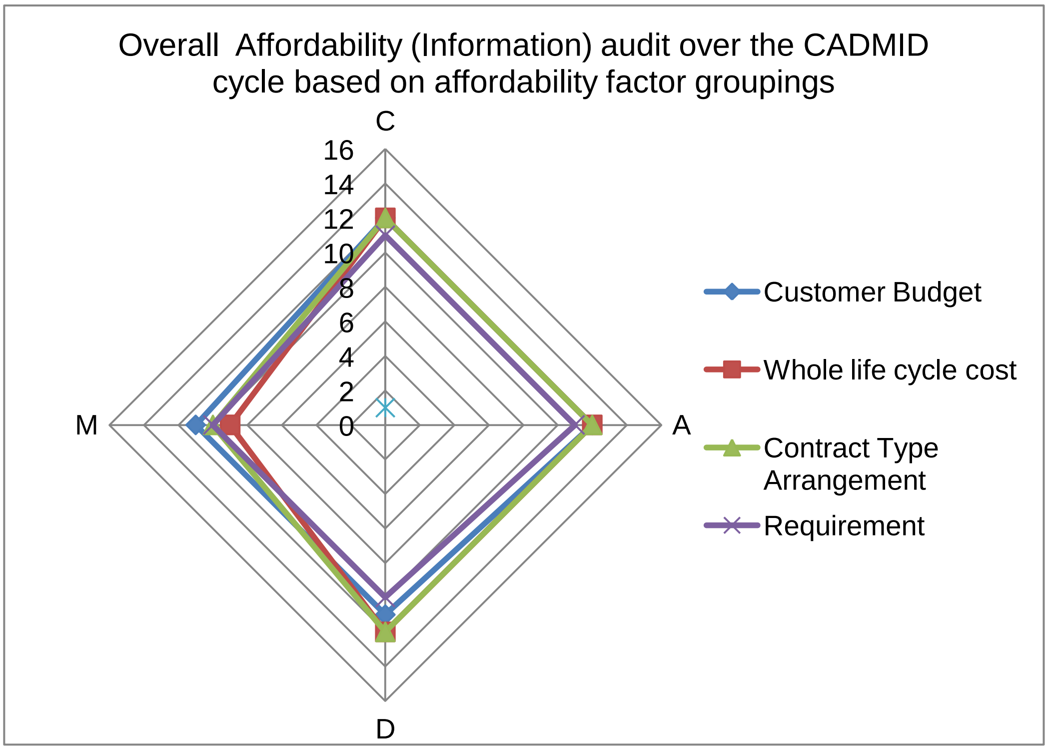


Figure 9-7: Case Study 3 Affordability Audit Result (2)

From the spider chart, (Figure 9-7) most of the factor groupings had medium to high audit scores, meaning that there was high level of information availability for most the affordability factors groupings with medium scores for the 'M' phase for the WLCC and customer requirement. This suggests low to medium levels of uncertainty.

9.3.8 Customer affordability assessment

Quantitative assessment results

The WLCC and CATS profiles for the six years are presented below.

Table 9-16: Case study 3 CATS and WLCC values – Predicted

Year	1	2	3	4	5	6	Total
Currency	£	£	£	£	£	£	£
WL CC	7,064,180	7,064,180	7,064,180	7,064,180	7,064,180	7,064,180	42,385,080
CATS	7,833,333	7,833,333	7,833,333	7,833,333	7,833,333	7,833,333	47,000,000

Table 9-17: Case study 3 CATS and WLCC values - Actual

Year	1	2	3	4	5	6	Total
Currency	£	£	£	£	£	£	£
WLCC	6,900,000	7,000,000	9,200,000	11,300,000	9,400,000	7,300,000	51,100,000
CATS	7,833,333	7,833,333	7,833,333	7,833,333	7,833,333	7,833,333	47,000,000

Table (9-16) shows the prediction that CATS was higher than WLCC over the life cycle and in each individual year, meaning that the project is affordable while Table (9-17) shows actual figures where total WLCC was higher than CATS over the life cycle which means the project was unaffordable overall.

The actual project was different from the predicted due to the following reasons presented below:

- Increased WLCC due to battery failure
- Batteries were subject to several major reliability and safety incidents resulting in a large amount of retesting, rework and modifications to existing designs
- Batteries were also deemed too heavy for use as life cycle was not as long as promised by manufacturer hence the soldiers had to carry more batteries to keep radios functioning. To solve this problem the manufacturer initiated weight reduction improvements to be carried out by the supplier resulting in increased development costs.

- Poor supplier performance also meant batteries were late for milestone deliveries.
- The manufacturer initiated wide array of supplier and product improvement initiatives to bring budget under some form of control circa in 2009 and 2010.
- Many problems persisted with the batteries, but supplier could not be changed due to monopoly.

There were violations during half of the project life cycle in years 3, 4 and 5 of over £6m. The actual values generated an AI of 0.15 which shows that the project is very unaffordable due to the violation in CATS and WLCC profile during the project life cycle.

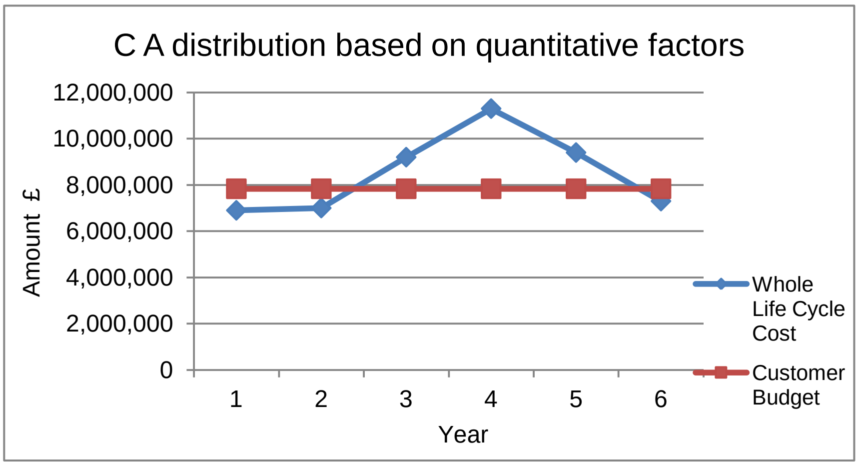


Figure 9-8: Case Study 3 CATS and WLCC profile

The profile on Figure (9-8) shows that CATS is a steady straight line across the life cycle meaning that there is an even spread of the customer budget. The WLCC rises above the CATS in years 3, 4 and 5 to drop just below CATS in year 6 which means the project is unaffordable. This was due to failure in product performance and lower life cycle of products leading to demand for higher product volume and weight reduction improvements without additional investment from the customer. This led to year-on-year increase in WLCC.

Similar to the previous case study, uncertainty was incorporated on the predicted values and the values generated were compared with the actual values. The values generated from the impact of uncertainty are resented in Table (9-8). The comparison between the two sets of values is done below in Figure (9-9).

Table 9-18: Case study 3 Uncertainty CATS and WLCC values

Description/ Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Currency	£	£	£	£	£	£	£
AWLCC	6,900,000	7,000,000	9,200,000	11,300,000	9,400,000	7,300,000	51,100,000
UWLCC	7,165,588	7,134,652	6,885,845	7,464,754	7,104,906	7,302,692	43,058,437
ACATS	7,833,333	7,833,333	7,833,333	7,833,333	7,833,333	7,833,333	47,000,000
UCATS	8,457,544	7,967,386	7,615,291	7,290,166	8,116,401	7,438,132	46,884,920

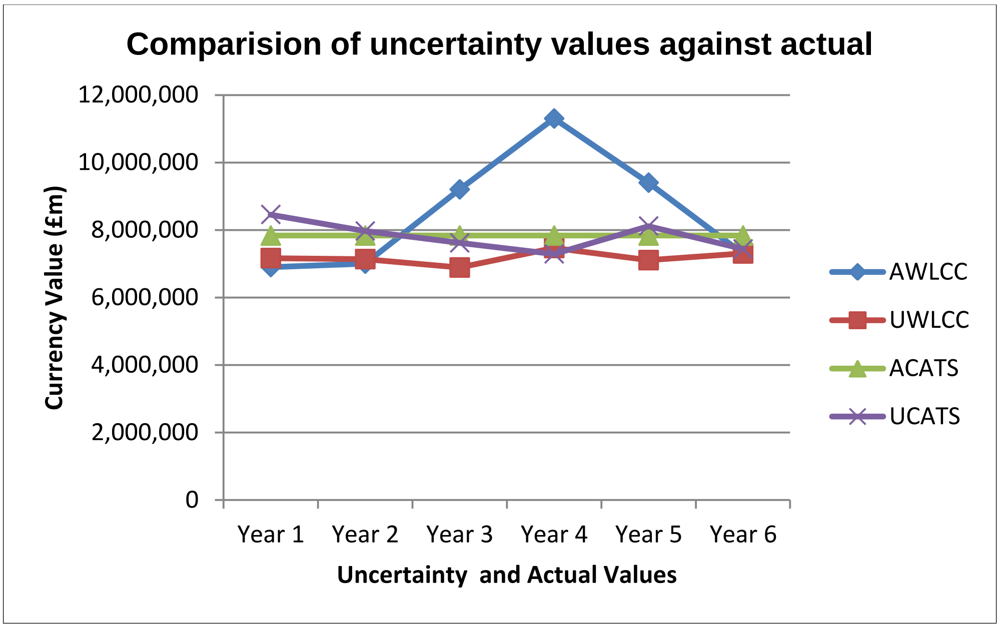


Figure 9-9: Uncertainty results comparison with actual data

The values presented in the charts in Figure (9-9) reveal that there is a variance between the values generated from the uncertainty assessment and the actual values. The uncertainty assessment results and the actual results for the first two years were similar, especially the actual and the uncertainty values generated for CATS. However, years 3 to 6 of the actual WLCC varied greatly from the uncertainty values by over £5m. This was due to the unexpected cost increase in delivering the customer requirement due to product failure. This also shows that the tools or methodology employed to assess the impact of uncertainty and risk may not be able to predict unexpected occurrences, though they can provide a guide for the project team to mitigate and reduce the impact of uncertainty.

Qualitative Assessment results

The predicted capability of the solution presented in Table (9-19) showed that the project was predicted to be affordable by meeting the customer requirement, having a reliable supply chain and comply with environmental standards (green cells). It may not be able to achieve the desired level of quality and it may require more investment hence, low VFM (red cells).

Table 9-19: Case Study 3 Qualitative customer affordability weighted score – predicted

	Weighted scores					
Affordability Factors	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Requirement	10	10	10	10	10	10
Environment	5	5	5	5	5	5
Value For Money	17	17	17	17	17	17
Supply chain	7	7	7	7	7	7
Quality	20	20	20	20	20	20

Table 9-20: Case Study 3 Qualitative customer affordability weighted score – Actual

	Weighted score					
Affordability Factors	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Requirement	16	16	20	22	25	22
Environment	7	7	10	12	15	12
Value For Money	22	22	25	25	25	25
Supply chain	11	11	15	17	20	17
Quality	20	20	22	22	25	25

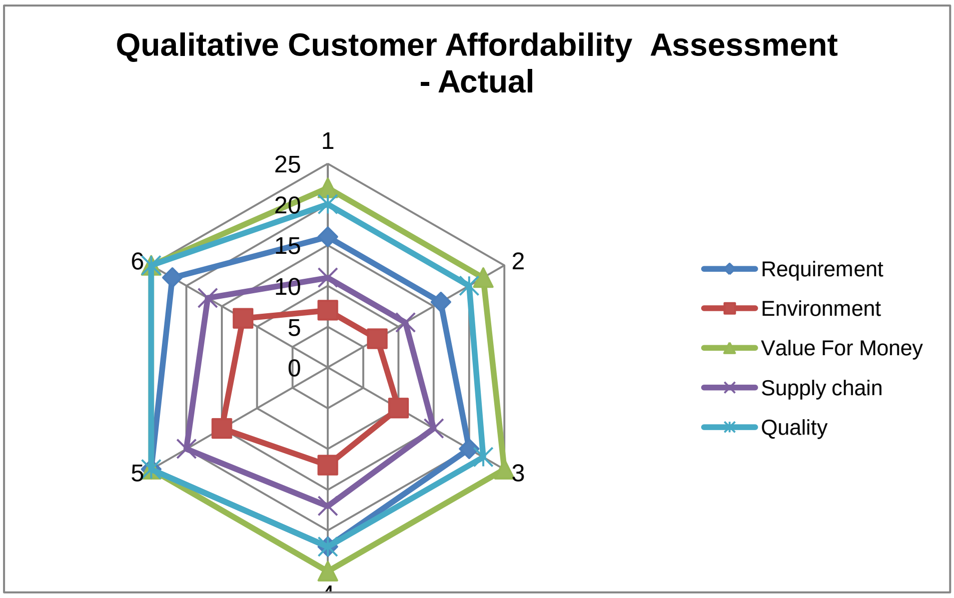


Figure 9-10: Case Study 3 Qualitative customer affordability results -actual

The actual performance of the project a shown in Table (9-20) and Figure (9-10) reveals the following:

1. Requirement – The project was not able to deliver customer requirement as shown by several major reliability and safety incidents. The large amount of retesting, rework and modifications to existing design required as a result of the incidents meant that customer requirement could not be delivered within the budget allocated. The manufacturer tried to manage the situation, by imposing weight reduction improvements to be carried out by the supplier, however this problem started early on in the development phase. Though it was identified in year 3 by the end-users in the delivery phases, it still carried on till year 5. Additionally there wasn't a high degree of flexibility within the project to adapt to change in customer requirement. Also the batteries produced had a lower life cycle than expected due to product failure.
2. Environment – The project was delivered to meet environmental standards and had a short term plan for disposal. This improved in year 2 and stayed constant for the rest of the life cycle.
3. Value For Money – The manufacturer was not able to provide the solution at the agreed WLCC due to the failures of the batteries. Within this project, the role of the manufacturer was that of a systems integrator rather than technical manufacturer, hence the capability of the solution was highly dependent on the supplier who had the

expertise in delivering the solution. In this example, although the supplier had the know-how in the manufacturing of special batteries used for the radio systems; it lacked the capability to deliver these particular products. For this reason, the solution did not satisfy the key performance indicators and no savings in cost or resource usage were achieved. The success of the manufacturer's intervention is seen in the slight improvement over the lifecycle in terms of all the affordability factors.

4. Supply chain – the supply chain involved in delivering this project was a small one, due to the nature of the products. The selected supplier in this project was the only one with the knowledge and experience of manufacturing and delivering the special batteries, however it lacked the capability to deliver this project to meet customer requirement. Also its poor performance also meant the batteries were late for milestone deliveries which carried penalties. Some of these penalties were rolled back to the suppliers to stimulate improvement. The supplier capability was satisfactory at the start of the project, but declined overtime. The manufacturer could not switch suppliers because it would be required to cover the high switching cost without any additional investment from the customer.
5. Quality - The solution did not require a high level of innovation, yet it was not delivered to meet customer satisfaction. This is due to the reasons explained above which meant the solution was not fit for purpose since the desired quality was not achieved the first time. Despite the measures taken by the manufacturers, there was still a decline in the quality of the batteries over time.

Overall, the customer requirement was not delivered at the desired quality and the customer was not satisfied. The poor performance of the supplier had a negative effect on the delivery of the project as a result which the manufacturer has decided to stop contracting with this supplier in the future after some considerations. Recommendations for improvement are provided within the affordability system (Chapter 5, section 5.9) to improve project affordability based on each of the affordability factor components. However, this is an exceptional case and the manufacturer needed to take drastic measures to save its contracts in the future by contracting with foreign suppliers and accepting higher WLCC where necessary.

9.3.9 Supplier sustainability assessment

Table 9-21: Case Study 3 Supplier sustainability assessment weighted scores - Predicted

Sustainability Dimensions	Weighted scores					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Quality and Delivery	23	23	23	23	23	23
Management (People & Resources)	18	18	18	18	18	18
Cost	15	15	15	15	15	15
Stakeholder	13	13	13	13	13	13
Environment	12	12	12	12	12	12

Table 9-22: Case Study 3 Supplier sustainability assessment weighted scores - Actual

Sustainability Dimensions	Weighted scores					
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Quality and Delivery	23	25	25	25	25	23
Management (People & Resources)	18	20	20	20	20	18
Cost	15	15	15	15	15	15
Stakeholder	13	15	15	13	15	13
Environment	12	15	15	15	15	12

Both Tables (9-21) and (9-22) are similar in their assessment of supplier sustainability. Though most of the weighted scores are consistent throughout the life cycle, Table (9-22) reflects some changes which occurred which are displayed in Figure (9-11).

Overall while the supplier was financially sustainable and did not go out of business, it was not operationally sustainable to deliver customer requirement to meet expectation.

The supplier's performance in terms of the sustainability dimensions are explained below.

- Delivery & Quality – the batteries were not delivered to meet the level of quality desired by the customer. Delivery lead-time was longer than expected and the supplier's solution did not fully conform to customer expectation during operations with major reliability and safety incidents resulting in a large amount of retesting, rework and modifications to existing designs. The increased weighted score throughout the lifecycle of the project means that the capability reduced overtime without any noticeable improvement

- Management (People & Resources) – There is a suggestion that supplier had a reasonable level of resources to deliver the products. However with low inventory turnover and low investment capability, the supplier capability was inadequate to deliver the product required by the customer at the desired quality. Also the supplier was not adaptable to changes in customer requirement. While the customer requirement was not very dynamic, the supplier was unable to provide the products to meet the performance desired. This capability did not improve for most of the project life cycle, but there was a slight improvement in year 6.

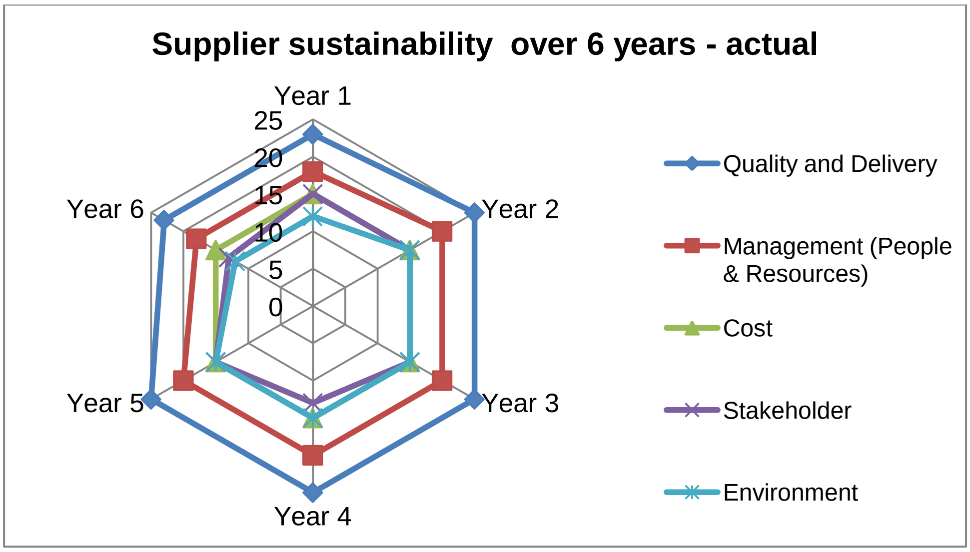


Figure 9-11: Case Study 3 Supplier sustainability results

- Cost – Even though the supplier was a single source supplier of these batteries in the UK, its price which is a cost to the manufacturer was reasonable and satisfactory. This was one of the main reasons why the manufacturer contracted with the supplier in order to save costs since its competitor pricing in the foreign market were higher.
- Stakeholder – There is a suggestion that supplier had a good relationship with its stakeholders prior the commencement of the project and it was a good market player. The product was not highly innovative; hence the supplier's capability was also satisfactory in this area. While the supplier seemed to be flexible at the start of the project, it was unable to demonstrate the flexibility to provide satisfactory products to the customer. The supplier tried to sustain its relationship with its

customer (the manufacturer) over the life cycle of the project. Overall the stakeholder dimension was satisfactory over the life cycle of the project.

- Environment – the supplier's products met the environmental quality standards and there was no new environmental legislation affecting the project. Overall the environment dimension was satisfactory over the life cycle of the project.

The supplier's capability was not sustainable in terms of quality and delivery as well as the management of people and resources. The poor performance of the products cause the customer to reduce its budget for the contract (to the manufacturer) and the manufacturer also imposed the penalties and weight reduction improvements on the supplier in order to improve the supplier performance. However this did not lead to significant improvement in the supplier's products as the products still failed and needed some rework. This means customer requirement was not satisfied, although the supplier seems sustainable in the terms of cost, stakeholder relationship and the environment. The system offers some improvement guidelines which the supplier could take in order to improve its sustainability; however as stated earlier this example is exceptional as the overall sustainability of the supplier was not satisfactory over the lifecycle of the project. The outcome of this contract has caused the manufacturer to re-consider its operations with the supplier and decided it would consult foreign suppliers in the future, though this might attract higher costs.

The sustainability of the supplier could be improved by selecting appropriate measures from Section 6.4.

9.3.10 Manufacturer profitability assessment

Table 9-23: Case Study 3 Manufacturer profitability assessment – Predicted

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	Total
Amount	£	£	£	£	£	£	£
WLCC	7,064,180.24	7,064,180.00	7,064,180.00	7,064,180.00	7,064,180.00	7,064,180.00	42,385,080.24
Total Profit	769,153.09	769,153.33	769,153.33	769,153.33	769,153.33	769,153.33	4,614,919.76
Selling Price	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	47,000,000.00
CATS	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	47,000,000.00

Table (9-23) shows the predicted figures while Table (9-24) provides the actual figures for WLCC, SP and CATS. As shown under the customer affordability assessment, the project is running at a loss as the total CATS amount is less than the WLCC. While the cost and budget in years 1 and 2 provide a profit margin, years 3 to 5 yielded significant losses which caused the whole project to be unprofitable.

Table 9-24: Case Study 3 Manufacturer profitability assessment – Actual

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
Amount	£	£	£	£	£	£	£
WLCC	6,900,000.00	7,000,000.00	9,200,000.00	11,300,000.00	9,400,000.00	7,300,000.00	51,100,000.00
Loss	933,333.33	833,333.33	-1,366,666.67	-3,466,666.67	-1,566,666.67	533,333.33	-4,100,000.00
Selling Price	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	7,833,333.33	47,000,000.00
CATS	7833333.33	7833333.33	7833333.33	7833333.33	7833333.33	7833333.33	47000000.00

The cumulative loss of over £4m is based on the WLCC, without any profit margin. The project was unprofitable for the reasons explained under the customer affordability and supplier sustainability assessment. Despite making a loss, the manufacturer chose to deliver this project because it was part of a bigger programme known as the Bowman Programme. This means that the loss generated by this project would be offset by profit from other parts of the whole programme consisting thousands of platforms for various communication systems.

9.3.11 Case study 4

Background

The case study relates to a civil aerospace contract called Thermal Anti-Icing (TAI) exhaust plume. This whole project lasts for 30 years, but this contract is only for the 'I' phase of the project lifecycle which is for 20 years. As seen in some contracts, this phase of the CADMID also has its own horizontal CADMID cycle within that phase. This is the reason why the audit assessment is done for the CADMID cycle. A problem which was not detected during wind tunnel and aircraft certification testing occurred while the aircraft was in service. During the 'I' phase of the civil aircraft, a flight component located along the wing trailing edge of the port side wing surface started discolouring. In order to understand the problem better, test instrumentation was employed and the results revealed that the problem was isolated to one location on the Port wing only where the discolouration had been observed. The problem could be caused by:

i. Higher than predicted exit temperature; and
ii. The re-attachment of the TAI exhaust plume which was assumed to break up and disperse in the free air-stream.

In order to solve the problem caused by the re-attachment of the TAI exhaust plume, it was necessary to identify who would bear the cost since the contract duration was for 30 years and the problem occurred in year 7. Components supplied by different suppliers were tested and the result meant that the problem could not be associated with a supplier component so the manufacturer who had overall responsibility for the maintenance of the aircraft; had to bear the cost. This meant there was no direct customer budget. For problems of this nature, a provision is made at the bid stage to make sure in-service problems such as this does not put the project into a loss making situation.

The possible solutions were:

i. Redesign and re-qualify flight component to new higher temperature
ii. Change aircraft manuals to deter certain steep climb manoeuvres
iii. Reduce TAI delivery temperature to reduce TAI exhaust temperature
iv. Redesign of leading edge to divert TAI exhaust stream to prevent plume re-attachment.

However, cost considerations revealed that:

i. The cost of Scenario 1 was prohibitive ($59.3m) even though a limited retrofit program was devised and agreed which would reduce the cost significantly.
ii. Scenario 2 was rejected by the Customer;
iii. Scenario 3 was technically unfeasible; therefore
iv. For affordability considerations Scenario 4 was adopted.

The project was funded from the risk provision within the yearly payment received from the customer. For this case study, there was no predicted data as the assessment was performed after the project had been contracted and begun.

9.3.12 Affordability capability audit

The result of the information capability audit is presented in Table (9-25). The affordability audit for case study 4 was performed based on the four main affordability factor groupings including an additional grouping called time-related benefit.

Table 9-25: Case study 4 affordability audit table

	CADMID CYCLE					
Affordability Factors	**C**	**A**	**D**	**M**	**I**	**D**
Customer Budget	10	10	11	12	11	3
Whole life cycle cost	8	8	8	8	8	3
Contract Type Arrangement	11	11	11	11	11	3
Requirement	11	11	11	11	10	3
Time-related benefit	12	12	12	12	12	3

This factor was important to be included because a major requirement in solving the problem was a flight test which must be carried out on an aircraft with the same system as the one currently involved in the project. It would be too expensive to manufacture another aircraft for the testing, so a similar aircraft must be available without having to build one. The prime contractor was able to locate another aircraft which was in its design and manufacture phase and this was used in testing and approving the solution. This time-related benefit created by identifying a similar aircraft saved the prime contractor $millions. Most of the cells are coloured amber; some are coloured red while a few are coloured green. This means that there is medium level of information availability overall. While the prime contractor has been involved in the project before the 'I' phase, there was limited information about the exhaust problem which is the focus of this case study. Several tests needed to be carried out in order to identify the cause of the problem and the resources available to solve the problem. The audit scores range from 3 to 12 suggesting that information availability is just enough for most of the project life cycle but very low for the disposal phase. The bar chart (Figure 9-12) shows that there is highest level of information available for the 'M' phase. There is a good level of information available for most of the other phases apart from the disposal phase with the least amount of information. This means in assessing the impact of uncertainty on the quantitative factors, the assumption would be to impose the medium uncertainty on phases CADMI and high uncertainty on the disposal phase.

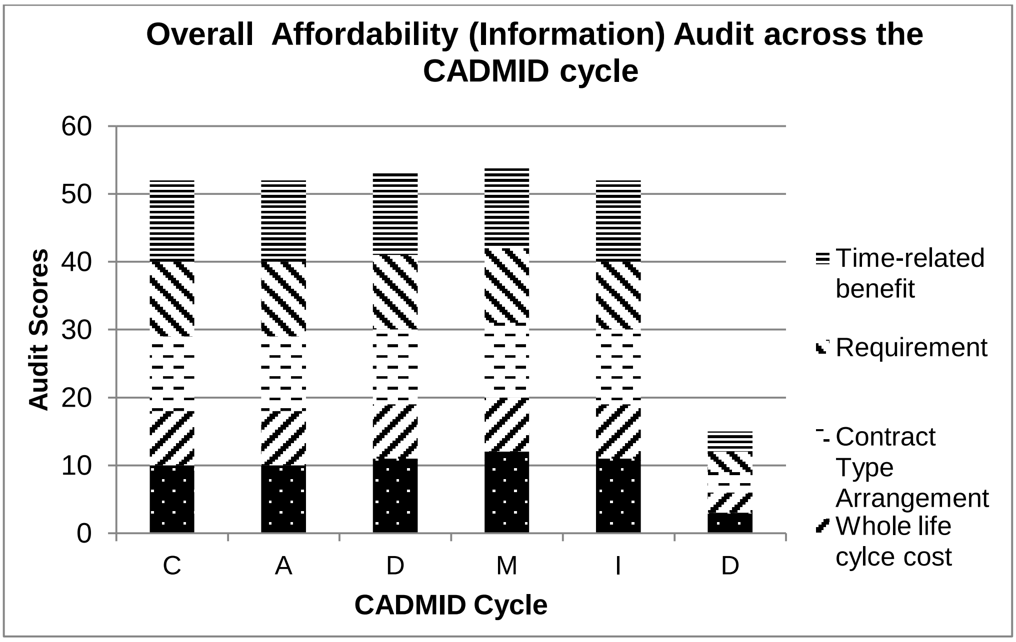


Figure 9-12: Case Study 4 Affordability Audit Result (1)

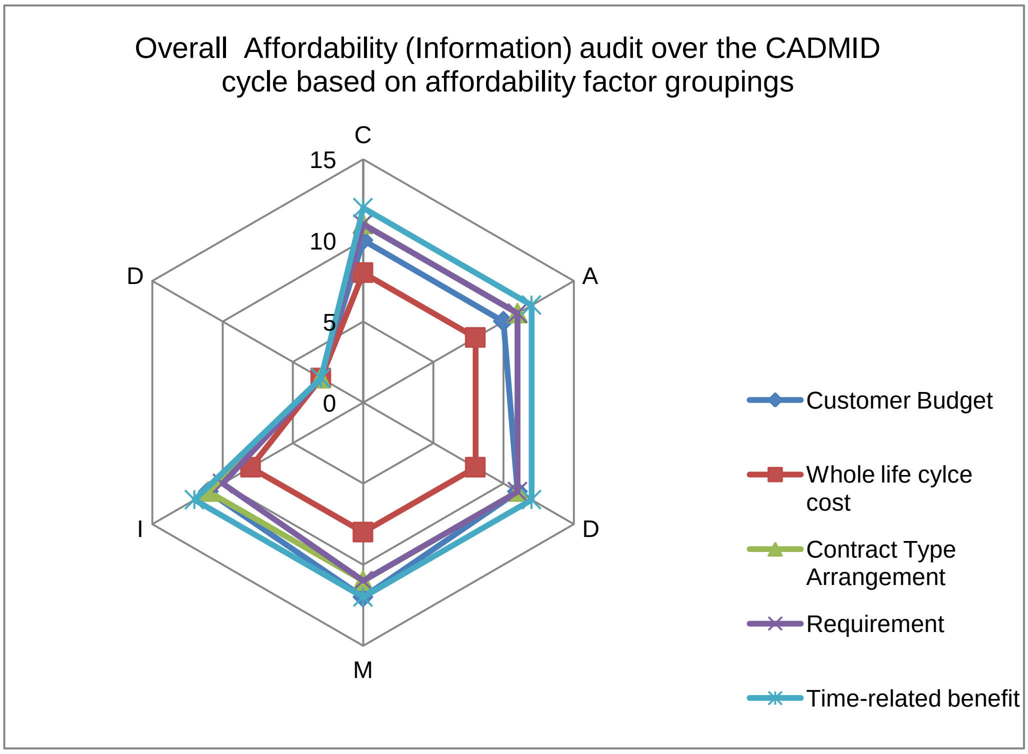


Figure 9-13: Case Study 4 Affordability Audit Result (2)

From the spider chart (Figure 9-13); most of the factor groupings had medium audit scores, apart from the WLCC. This suggests that there was sufficient information available for most the affordability factors groupings but the information about WLCC was very limited since the cost assessment was just being carried out after the problem occurred. This suggests medium to high levels of uncertainty.

9.3.13 Customer affordability assessment

Quantitative Assessment

The WLCC and CATS profile is presented for the 20 years in Table (9-26). The Table shows that CATS (risk provision) was higher than WLCC in the first 6 years of the project. Once the problem occurred in the 7th year, the WLCC was over 14 times the CATS. For the remaining years, the customer budget in each single year was still higher than the cost in each year, but the overall, total CATS was higher than total WLCC. The AI generated was -13.02, meaning that the project is very unaffordable. The AI took account of the impact of the major violation in year 7 though overall CATS was higher than WLCC.

The profile on the line chart (Figure 9-14) shows that CATS is a steady straight line above the WLCC for most of the lifecycle, but in year 7, WLCC rose to over $4,000 higher than CATS.

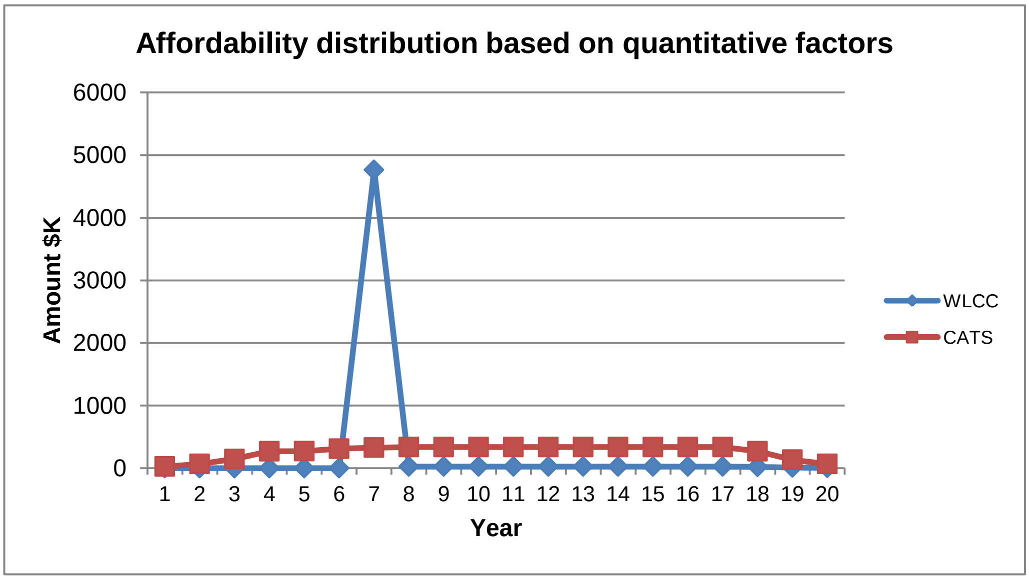


Figure 9-14: Case Study 4 CATS and WLCC profile

Table 9-26: Case Study 4 CATS and WLCC values

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Currency	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	
WLCC	0	0	0	0	0	0	4762.6	26	26	26	26	26	26	26	26	26	26	20.8	10.4	5.2	5059
CATS	27	67.4	146.1	269.7	271.9	310.1	328.1	337.1	337.1	337.1	337.1	337.1	337.1	337.1	337.1	337.1	337.1	269.7	134.8	67.4	5263
(WLCC-CATS)/CATS	-1	-1	-1	-1	-1	-1	13.51	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	13.51

Table 9-27: Case study 4 Uncertainty CATS and WLCC values

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Currency	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K
UWLCC	5,158.67	25.63	25.60	24.49	26.02	26.06	23.87	27.00	26.52	25.87	23.96	20.65	8.88	5.08
UCATS	312.72	366.88	363.63	336.79	329.98	348.32	338.48	336.83	341.19	308.16	323.29	279.88	110.02	65.42

Table 9-28: Case Study 4 Qualitative customer affordability weighted score

	Weighted scores														
Affordability Factors	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Requirement	9	12	10	10	10	10	10	10	10	10	10	10	10	10	10
Environment	6	8	8	11	12	8	9	8	13	18	18	18	18	18	18
Value For Money	6	10	10	10	14	14	13	14	16	14	14	14	14	14	14
Supply chain	5	8	10	10	10	10	10	14	16	8	8	8	8	8	8
Quality	3	10	12	12	12	14	16	18	12	12	12	12	12	12	12

Similar to the previous case studies, uncertainty was incorporated on the predicted values and the results compared with the actual values. The values generated from the impact of uncertainty are presented in Table (9-27). The comparison between the two sets of values is done below in Figure (9-15).

The values in Table (9-27) only covers 14 years because it was not possible to simulate the values for actual years 1 to 6 because the WLCC was 0 in all six years. For this reason, uncertainty was only imposed on values from years 7 to 20. So 'Year 1' in Table (9-27), is the actual 'Year 7' in Table (9-26). A comparison between actual values for Years 7 to 20 and those generated from the impact of uncertainty are presented in Figure (9-15).

Figure (9-15) reveals that the actual and uncertainty values for both WLCC and CATS are very similar, though the uncertainty values seem to be slightly higher than the actual. This is because a low level of uncertainty was imposed on the actual values. This shows that the tools or methodology employed to assess the impact of uncertainty are best utilised when information availability is high which reduces the impact of uncertainty.

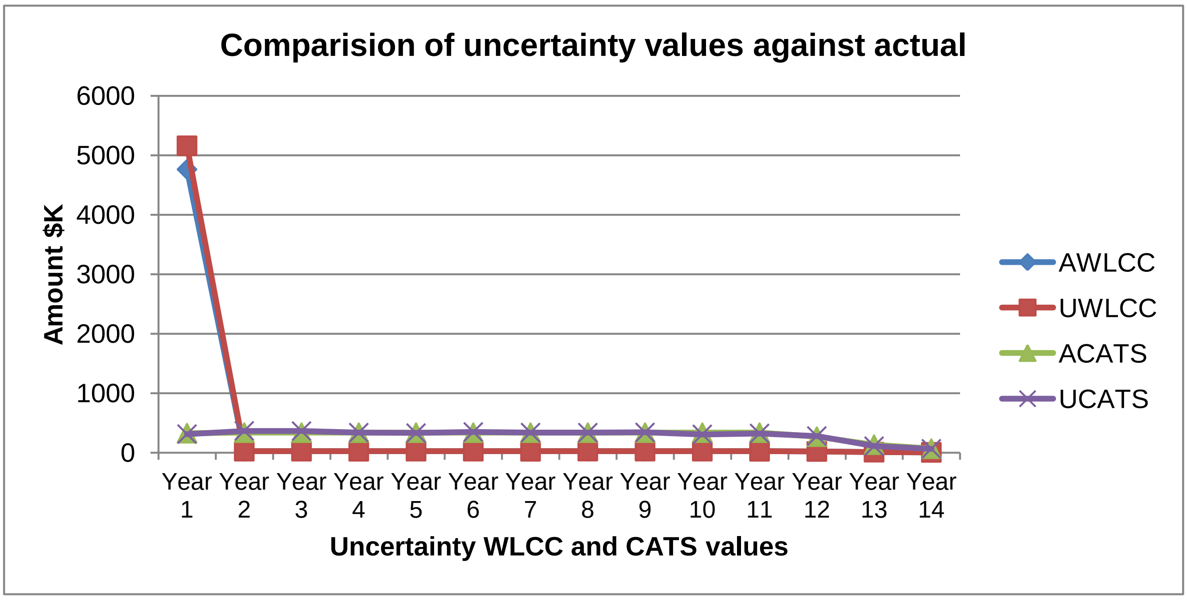


Figure 9-15: Case study 4 Uncertainty results comparison with actual data

Qualitative Assessment

Table (9-28) and Figure (9-16) show that for the first 4 years, the project is affordable with green cells based on all 5 affordability factors. From years 5 to 7, there are amber cells based on VFM and quality since the problem occurred in year 7. This means that resources were being utilised to maintain the aircraft at the right quality. As a result of the problem in year 7, quality of the aircraft fell below acceptable level in year 8 (red-coloured cells) while more resources were being employed to correct the problem. Perhaps the supply chain were not experienced in dealing with this particular problem leading to increase in supply chain costs between years 8 and 9. From year 9 till year 15, good level of quality were achieved and maintained (green-coloured cells). The project was reasonably affordable based on the VFM factor from years 5 to year 15 (amber-coloured cells). However, the project was less affordable based on the environment factor from years 10 to year 15 (red cells) due to challenges of disposal of the waste generated in the process of correcting the problem. The project was very affordable based on the requirement factor throughout the 15 years (green cells). The qualitative customer affordability assessment was only done for 15 years based on current visibility since the total life cycle was 20 years and some things might change before the end of the first 15 years. Recommendations for improvement are provided to improve customer affordability especially in terms of the environment, VFM and quality in Chapter 5, section 5.9.

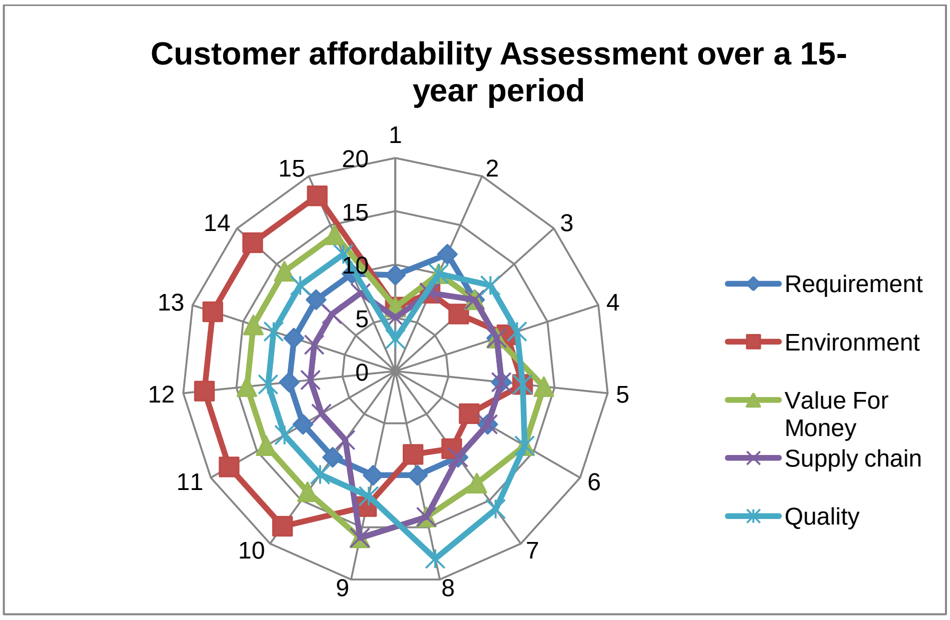


Figure 9-16: Case Study 4 Qualitative customer affordability results

9.3.14 Manufacturer profitability assessment

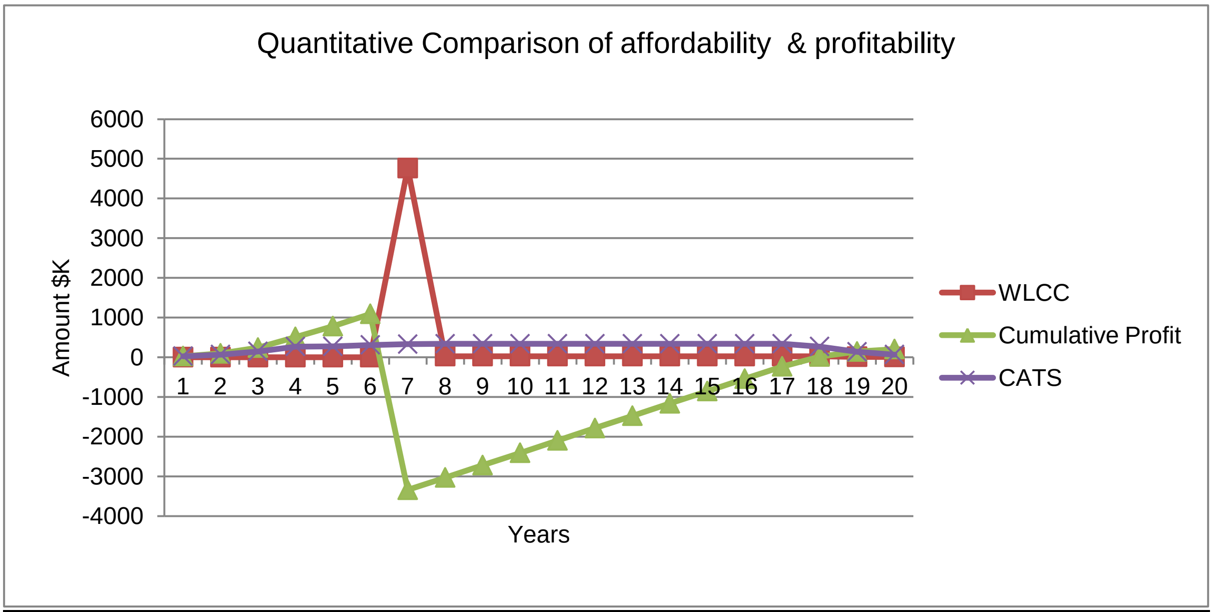


Figure 9-17: Case Study 4 manufacturer profitability results

Table 9-29: Case Study 4 Manufacturer profitability over 20 year

Amount	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K
	Yr 1	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**	**Yr 6**	**Yr 7**	**Yr 8**	**Yr 9**	**Yr 10**	**Yr 11**	**Yr 12**	**Yr 13**	**Yr 14**	**Yr 15**	**Yr 16**	**Yr 17**	**Yr 18**	**Yr 19**	**Yr 20**
WLCC	0	0	0	0	0	0	4763	26	26	26	26	26	26	26	26	26	26	21	10	5
CATS	27	67	146	270	272	310	328	337	337	337	337	337	337	337	337	337	337	270	135	67
Cumulative Profit	27	94	241	510	782	1092	-3342	-3031	-2720	-2409	-2098	-1787	-1476	-1165	-854	-542	-231	18	142	204

This project does not involve the manufacturer selling a project to the customer, rather the manufacturer trying to spend its risk provision to address a problem, therefore the profitability assessment is done in order to assess whether the manufacturer can still make a profit or get some benefit after addressing the problem. This is the reason why the Table (9-29) and Figure (9-17) do not contain a selling price, rather a cumulative profit column. Also the PI would not be applicable since there is no selling price. Table (9-29) shows that there was positive cumulative profit from years 1 to 6 until the problem occurred in year 7, leading to cumulative loss till year 18, before cumulative profit is generated again. Although the yearly budget (risk provision) was higher than yearly cost apart from in year 7, the cumulative profit was negative until year 18.

The results show that the manufacturer is still able to gain minimal benefit after providing a solution to the problem over the long term.

The supplier sustainability assessment was not carried out due to insufficient data availability. This case study reflects how time could have a positive impact on customer affordability and manufacturer profitability in a project. If the project had stopped earlier than year 18, no benefit or profit would have been generated, but over time, sufficient customer budget was generated to cover the cost.

9.3.15 Cross case comparison

A comparison of the four Case studies is done in Table (9-30) and explained below

Table 9-30: Case study Comparison

Comparison Dimension	Case Study 1	Case Study 2	Case Study 3	Case Study 4
Duration	10 years	2 years	6 years	20 years
CADMID phase	Covered the 'ADMI' phases of the CADMID cycle	Covered only the 'I' phase of the CADMID cycle	Covered only the 'CADM' phase of the CADMID cycle	Covered only the 'I' phase of the CADMID cycle, but this has a horizontal CADMID within the phase.
Worth/Selling Price	Over £11m	Over £125m	£47m	Over $5m (£3.2m)
Nature of contract	Assessment, Development and Manufacture of In-Service provision of communications systems	Provision of support for systems within a communications program	Provision of secondary and primary battery units and chargers in support of the military radio systems	Re-design of aircraft edge to divert TAI exhaust stream to prevent plume re-attachment
Affordability Audit	Generally, high–to-medium information availability meaning, but more uncertainty about later years of the project	High–to-medium information availability meaning less uncertainty	Medium information availability, meaning medium uncertainty	High information availability in other phases but low in the 'D' phase. This means low uncertainty until the 'D' phase
Customer Affordability-quantitative	AI of 0.87 was generated due to significant violation in years 9 and 10 of over £560,000. However, total CATS was higher than WLCC	AI of 1.01 was generated showing that the project is affordable.	AI of 0.15 was generated due to significant violation in years 3, 4 and 5 of over £6m. Hence the contract was unaffordable	AI of -13.02 was generated due to the major violation in year 7 which was over 14 times the CATS value in the year. However total CATS was higher than WLCC
Customer Affordability-qualitative	Contract was affordable based on most of the factors, but VFM and quality	Contract was affordable as the weighted scores are between 7 and 10	Contract was unaffordable due to product failure so the weighted scores are between 7 and 25	Contract was generally affordable as the weighted scores are between 3 and 18, but less affordable in terms of environmental factor later in the project life
Manufacturer Profitability	PI of 0.13 was generated due to the violation mentioned above. However, total CATS equal to the SP	PI of 0.85 was generated due to the violation in year 2. However, total CATS equal to the SP, so the contract is profitable	Contract ran a loss of over £4m due to cost escalation from product failure leading to violations in years 3 to 5	No selling price in this case, hence no PI was generated. Overall the CATS was sufficient to cover the WLCC of the Exhaust problem
Supplier Sustainability	Supplier was sustainable based on most dimensions, but cost and quality	Supplier was sustainable based on most dimensions, but may potentially need to improve the sustainability in terms of cost and quality	Supplier was not sustainable based on most dimensions, but environment and stakeholder. There is a need to improve sustainability in all dimensions	Insufficient information to carry out supplier sustainability

The duration of the Case studies varied from 2 to 20 years. Three of them were from the defence sector while one of them was from the civil aerospace sector. Three of the covered the 'I' phase in addition to other phases of the CADMID meaning they were involved the operational and service phase which may have higher levels of uncertainty in comparison with the earlier phases. They are generally high value contracts with the lowest costing over $5m and the highest over £125m. Most of the contracts were involved in delivery service and support to communications systems apart from one which was mainly aimed at repairing the exhaust plume of an aircraft.

Most of the contracts had high to medium information availability. This was because the prime contractor of three of the four contracts had prior experience of dealing with the contracts. Then the fourth case study had high information availability because the contract was already being delivered and it was easier to obtain more information about the aircraft.

Case study 2 was most affordable because the customer was willing to invest more than required in the contract in order to ensure that some problems encountered from the previous contract were resolved. Though the actual WLCC increased and the CATS reduced, it was still sufficient to deliver a very affordable and profitable contract. Case study 1 was the next affordable contract because the total CATS was higher than WLCC, though it had a high violation in the last two years, leading to an AI lower than 1. The contract was equally profitable to the manufacturer. Case study 4 was least affordable but better than Case study 3 which was unaffordable. Though Case study 4 had a negative AI of -13.02, the total CATS was still higher than WLCC, hence the manufacturer was able to make a very low profit. However this contract is different from the others because it is mainly based on a problem which was resolved by using the risk provision rather than actual CATS. Therefore it had no SP and no PI. Case study 3 was totally unaffordable. Though it generated an AI of 0.15, total CATS was lower than WLCC. This is the only Case study where this occurred due to product failure and re-testing which increased WLCC. Most of the problem came from the supplier, yet it was not possible to cancel the contract or change supplier in during the life cycle of the contract, though penalties were imposed. The prime contractor was able to survive the loss with profit gained from other parallel projects.

For the two Case studies, where the suppliers were sustainable, there was always the need to improve on the cost and quality dimensions. This suggests a general challenge due to the nature of the defence contracts i.e. the complexity of customer demand against the capability of the prime contractors and their suppliers. Case study 4 could not provide supplier sustainability data, but Case study 3 also showed that the supplier was not sustainable in terms of most dimensions including cost and quality.

In all cases, the results provided by the overall affordability system are realistic and they reflect real business challenges with the differences shown between predicted and actual data. This shows that uncertainty is inherent in complex defence contracts which have a long duration and adequate provision must be made to accommodate this.

The case studies reveal that the overall affordability system is applicable to both civil and defence aerospace projects to assess the customer affordability, supplier sustainability and manufacturer profitability. The system also provides visibility of the level of uncertainty associated with a project through the information capability audit and the quantitative assessment which provide a view of the resources available to deliver the project over the lifecycle. The qualitative assessment examines the capability of the manufacturer's solution as well as suppliers to fulfil the customer requirement and remain sustainable throughout the life cycle of the project. In the next Chapter the research contributions of the overall affordability framework which is implemented in the affordability system are provided.

9.4 Summary

After each validation session, feedback and suggestion were given by the industrial expert on how to improve the overall affordability system which was implemented by the researcher. After the system output was generated, it was discussed with the industrial experts to determine how realistic the output is. In addition to this, the validation exercise was aimed at checking the logic and the capability of the system. Therefore, the results of the questionnaires provided by the industrial experts were assessed and the system was modified at the discretion of the researcher to ensure the system achieves the aim of the research activity.

The system was employed to four case studies with life cycle varying from 2 to 20 years covering different phases of the CADMID cycle. The actual and predicted information were presented and compared for three case studies and the results show that the information available determines the type of result that would be generated. The system also provides suggestion for improvement for the customer affordability assessment and manufacturer profitability assessment.

The next chapter contains a discussion of the thesis and concludes based on each chapter of the thesis.

CHAPTER 10
DISCUSSION AND CONCLUSION

10.1 Introduction

The previous Chapter described the integration of the affordability framework including the validation process with industrial partners and case study application. This Chapter presents discussions of main research themes and conclusions of the research activity. It highlights the limitations of the current research and suggests future activities to advance the research in the area.

10.2 Discussion

This section is focussed on discussing key observations of the research. These observations are discussed based on the stages of the research as presented in Chapter 1, Figure (1-5) and implemented in Chapters 2 to 9 of the thesis.

10.2.1 Literature review

The literature review was focussed on reviewing affordability across different sectors (section 2.4.1), particularly affordability of long-term contracts such as availability and capability contracts in the defence sector. It also reviewed themes related to affordability from the three perspectives such as life cycle costing, budget setting, customer values, customer willingness to pay and uncertainty. The various definitions of affordability from the different sectors were reviewed to identify the three affordability perspectives as well as the factors that are common across the industries (section 1.4 and Chapters 5, 6 and 7). These formed the major factors affecting affordability (section 5.4.1).

Though the subject of affordability was studied in the literature, little effort had been employed in identifying the perspectives of affordability. Measurement techniques for affordability assessment exist in some sectors, but this is insufficient to achieve the aim of the affordability research. Generally, most of the articles reviewed were within the aerospace sector, hence the information obtained from the sector provided a good foundation for further research in the defence sector. From the review, customer affordability, manufacturer profitability and supplier sustainability were identified as the different perspectives of affordability. It also helped to identify some factors, measures, metrics, methodologies and dimensions employed in assessing each perspective. However the gap identified has been presented in Chapter 2 (section 2.12), which is summarised below.

- There is a need for metrics to perform qualitative assessment of customer affordability, because qualitative factors affect customer affordability at varying degrees within different contracts. The metrics should include a system of capturing and representing the importance of each factor.
- There is a need for a profitability assessment methodology to calculate a competitive selling price taking account of uncertainty and violations across the life cycle of the project due to changes in WLCC and CATS at the start of the project.
- The nature of defence projects integrates both products and service, however most measures of supplier performance are focussed on products and processes. The intangible nature of services creates a challenge in measuring the delivery of services. The best attempt to provide a method of assessing economic sustainability by the EFQM initiative provided a generic framework for all sectors. There is a need for measures that assess the ability of suppliers to sustain service delivery over the life cycle of the project within the defence sector.

Finally the novelty in the area of affordability necessitates the need to further investigate the affordability perspectives and establish the links between them. Also there is a need to investigate the factors affecting affordability from each perspective to know how they could affect affordability from each perspective and how they could change over the duration of the project. One of these factors is uncertainty which is an existing research area. There is a need to find the most suitable approach to assess the impact of uncertainty. The literature review helped to identify the trend of research in terms of definitions, affordability factors and measurement techniques in the area of affordability across different industry sectors in order to identify the research gap. This provided a focus for the research activity in order to cover existing gap, especially in the defence sector. One criticism of the review is that it covered more materials within the aerospace and defence sectors more than other sectors. This was due to the availability of literature materials in the subject area which is still in its infancy.

10.2.2 Research methodology

Upon identifying the research gap, the research aim and objectives were formulated based on the findings from the review. The main aim was to develop an affordability assessment and management framework at the bidding stage for defence contracts from the three perspectives.

In order to capture the current practice of affordability assessment in the defence industry, different research techniques were reviewed such as case-study research, content analysis, field research, industrial interviews, action research involving questionnaire development and interviews techniques. The most suitable method for this research was case-study research which was carried out in four stages involving project aim definition and state-of-the-art literature review; interview and questionnaire protocol development; data collection and initial framework and tool development (industrial interviews), and validation sessions and case studies.

Some advantages of case-study research are:

- It provides a triangulation of both qualitative and quantitative approaches by combining field research and industrial interviews to capture industrial practice and employing content analysis and meta-analysis in the review of literature.
- It allows the researcher gain a balanced view about the research area to identify gaps within literature and industrial practice.
- It enables the development of solutions which would be both relevant to industrial practice and contribute to academic knowledge.
- It provides the best opportunity to understand complex subject areas.

Some disadvantages of case-study research are:

- It may generate many findings or data which may be difficult to manage or lead to distraction from the research aim.
- It may not generate much quantitative data to justify assumptions or recommendations.

This research methodology was comprehensive enough to gain knowledge about the subject area and develop a framework from the research findings which was validated.

10.2.3 Current state of affordability assessment in industry

The research methodology was implemented to capture the current state of affordability assessment in industry (defence sector) for the three perspectives. The significant data was obtained from three defence companies. Experts with knowledge and experience in cost estimating, bid assessment and affordability assessment were included in the industrial interviews. Also questionnaires were developed for each affordability perspective which were administered during the semi-structured interviews mainly in face-to-face meetings and over the phone.

The customer affordability assessment was done based on two major factors namely WLCC and CATS which are the output of the cost estimation process and the budget allocation process.

The budget allocation process is a rigorous process involving different departments within the customer organisation during the planning round. While the MoD reflects an increase in the budget spend between 2007 and 2010, the practical reality as expressed by many defence manufacturers, reveals that many defence projects are suffering as a result of inadequate provision of funding. This could be due to:

- The increase in budget was with operational expenditure while budget for defence equipment and support did not witness any increase
- Customer requirement is not increasing at the same rate as the customer budget.

The effect of this is that budget allocation is inadequate to cover the WLCC of defence projects. While some recommendations have been provided by Gray, 2009, it would take time and culture change to implement many of them. The affordability assessment process shows that the major factors considered WLCC and CATS which were also identified through the literature review.

The manufacturer profitability assessment at the bidding stage when contracting for defence projects is focussed on generating a competitive offer or selling price. In non-competitive government contracts, the UK MoD controls the level of profit by stipulating the BPR for the manufacturer. This profitability of the defence manufacturer is also affected by the other drivers which are both qualitative and quantitative in nature, one of which is uncertainty. The main challenge is to find a suitable method of representing the effect of uncertainty and violation that occurs over the life of the project.

The defence customer is interested in creating partnership agreements with suppliers to encourage closer working relationship and for mutual benefits of risk-share and reward. The sustainability of supplier and contractors is indispensable to realise the benefits of partnership. While companies have developed criteria for supplier selection at the bidding stage, limited effort is employed to assess the long term financial and operational sustainability of suppliers. Suppliers are affected by factors such as dynamic customer requirement, financial stability, competition and take-over, hence the need to ensure their sustainability by focusing on performance measures which give an indication of long-term sustainability. The following challenges were identified from industrial interactions.

1. No uniform definition of affordability existed in industry; hence the academic definition could be adopted and validated for industry application.
2. There was no standard method of predicting or measuring affordability accurately in terms of qualitative and quantitative factors affecting affordability.
3. A suitable method for assessing the impact of uncertainty on WLCC and CATS is required for realistic customer affordability assessment.
4. A suitable method for assessing the impact of uncertainty on profitability by taking account of time and the impact of changes in WLCC and CATS over the life cycle of the project is required.
5. There is a need to develop suitable measures for assessing supplier's financial and operational sustainability which considers the delivery of products and services.

The industrial interviews were effective in understanding the current processes, techniques and tools employed in industry as well as the challenges. It also helped to compare industrial practice with the findings from literature. The strength of the industrial interviews is that both the customer and manufacturer organisations were involved. Interview sessions were held with experts from major companies in the defence sectors in the practice of affordability assessment and cost estimation. One downside to the industrial interviews is that while more than three companies were approached, only three of them were able to provide significant time and resources to conduct the survey, nevertheless the findings have been confirmed by experts from other companies during special events which were focused on the defence sector.

10.2.4 Customer affordability assessment module

A combination of the findings from industrial interaction and literature review was employed to develop the customer affordability module within the overall affordability framework. The module was designed at assessing the customer's affordability position as well as to provide improvement guidelines to improve the affordability position of the project.

The customer affordability assessment module was developed based on the five major qualitative and two quantitative factors out of a total of 14 factors affecting customer affordability. The factors were chosen as identified during the industrial interaction as the most important factors affecting customer affordability. Uncertainty, which could pose a risk to the project was also identified and treated as a common factor which applies to all the other factors. Quantitative assessment was done by refining the existing AI identified from literature to make it more appropriate for the defence sector. Since the qualitative factors could affect customer affordability at varying degrees within different contracts, it was required that the metrics included a system of capturing and representing the importance of each factors.

The qualitative assessment was done by a scoring and weighting mechanism where the scores give an indication of actual capability while the weight signifies the importance of the factor to the project. The weights were standardised across all the factors while scores were defined for each factor elements individually. The module was implemented as a system using the Microsoft Excel software due to its functionality and accessibility to both industrial experts and researchers. The results were provided inform of the AI score, the traffic light systems and line and spider charts.

The customer affordability assessment module also included a set of guidelines for improving customer affordability. These were designed based on the findings from literature and industrial interaction and focussed on each customer affordability element.

The strength of the module was the clarity and transparency of the logic and the elements involved in the customer affordability module. This made it easier to validate the module with industrial experts. The module is repeatable and adaptable to suit the assessment of customer affordability within the defence sector because it allows the user (manufacturer or customer) to add an extra factor affecting customer affordability in place of the factor – 'other'. Also the choice of implementation in Microsoft Excel meant that the system could be easily accessed by researchers and industrial experts. However, the limitation of

Microsoft Excel is that it may not be able to store large amount of data unlike Microsoft Access. This could create a challenge when a lot of assessment has been done over time. The storage space may not allow beyond a certain limit. Some challenges were encountered because some of the functions required visual basic coding which the researcher was not familiar with. Also it was not possible to obtain training in visual basic, but this challenge was overcome by seeking experts from the ICT department and an industry contact who was an expert in programming and building cost systems.

10.2.5 Manufacturer profitability methodology and supplier sustainability assessment module

Similar to the customer affordability module, supplier sustainability module and manufacturer profitability methodology were also developed to address the gaps identified in industry.

Literature review and industrial interaction revealed that manufacturer profitability was a mature research area; however, the main challenge to incorporating a time element in assessing manufacturer profitability. This required a suitable method for assessing manufacturer profitability in order to calculate a competitive price by taking account of changes over the life cycle of the contract. In order to address this challenge, a PI was developed similar to the AI. The PI was based on a similar technique to the AI by providing a view of the SP and CATS over the life cycle of the project and assessing the impact of violations on the profitability of the manufacturer. Only the quantitative factors affecting profitability were employed as this was most suitable in achieving the aim of the research.

The literature review in chapter 2 (section 2.6) revealed that most of the research activity in the area of supply chain management or supplier performance management does not focus on the long-term sustainability of suppliers. Sustainability literature usually focuses on environmental, economic and social dimensions, but there is little effort in considering financial and operational dimensions. The closest effort to provide a method of assessing economic sustainability by the EFQM initiative is generic as it is designed to apply to all sectors. This means that there is a need for measures that assess the ability of suppliers to sustain service delivery over the life cycle of the project within the defence sector. First the researcher developed and validated a definition of supplier sustainability for the defence and aerospace sectors. Then, the supplier sustainability module was developed which provides a methodology to address the gap. It drew on the findings from literature review and industrial practice to identify dimensions for supplier sustainability within the defence environment. The supplier sustainability module was designed to provide a methodology to assess the financial and operational sustainability of defence suppliers. From the literature reviewed, five dimensions of sustainability were identified, which formed the basis of the assessment. In order to generate PMs under each dimension, a KPI methodology identified from literature was employed. The methodology which involves some logical steps to be taken provided a set of templates in order to derive PM was refined to make it more suitable for deriving PMs for supplier sustainability. One of the steps involved in the methodology was focussed on selecting the most suitable MAs using feasibility and importance scores in order to generate appropriate PMs under each sustainability dimension which were both qualitative and quantitative. After obtaining the PMs, a scoring and weighting mechanism similar to the qualitative customer affordability assessment was employed to assess the supplier sustainability based on the PMs. The module was implemented as a system similar to the customer affordability module and the results were provided inform of the traffic light systems and line and spider charts. Also a set of guidelines to improve the sustainability of defence suppliers were provided based on the findings from literature and industrial interaction. It provides a single methodology and a uniform presentation to give a comprehensive assessment of supplier sustainability in the defence industry. It provides tangible measures to assess supplier sustainability in the defence industry as well as guidelines based on each measure to improve the sustainability of defence suppliers to deliver an affordable solution to meet customer requirement over the project life cycle. The system implementation also provided the functionality of re-calling previous sustainability assessment of suppliers as well as comparing the results from different suppliers.

The strength of the manufacturer profitability methodology and supplier sustainability module is similar to those presented above for the customer affordability module. The manufacturer profitability methodology contributed to knowledge by incorporating changes over time in the profitability of defence contracts.

Challenges were faced in defining the difference between supplier performance measures which already existed in industry and academia and supplier sustainability measures. Also it was challenging to generate a method of quantifying these qualitative factors (same as customer affordability qualitative factors) as well as the challenge of identifying individual scores for each PM after developing the overall scores and weights. However, these challenges were overcome by consulting relevant literature and industry articles and validating the development with the industrial experts.

10.2.6 Overall affordability audit and affordability management framework

The success of any defence contract or level of accuracy of cost estimates or affordability assessment is dependent upon the level and quality of available information. This is the aim of the overall affordability information capability audit which is conducted to assess the capability of the affordability assessment based on the information available. It gives a degree of confidence in the affordability assessment. The audit was carried out based on four main affordability factor groupings which represented both the qualitative and quantitative affordability factors for all three perspectives. The affordability factor groupings were further examined based on five factor elements which were focussed on the resources required to deliver the project. The affordability factors and the elements were chosen based on review of literature as well as industry interaction. The audit is done by allocating scores for each affordability factor grouping based on the factor elements. The affordability information capability audit was also implemented using the Microsoft Excel software. The results are presented in a similar way to the customer affordability and supplier sustainability assessment.

In addition to the effect of information availability on the success of defence contracts, the long duration of defence contracts could also pose a challenge to the successful delivery. This increases the effect of uncertainty in defence contracts which necessitates the need for a method of monitoring and controlling the project to ensure an affordable implementation. Current practice of performance measurement is carried out with the definition of strategic objectives which could be presented either in a Balanced Scorecard containing lead indicators and lag indicators or in another form. The MoD's AOF presented key areas for performance management which were classified by the researcher into three categories. In order to achieve improvement in these areas, some performance indicators must be employed. The knowledge management solution methodology employed in generating PM for supplier sustainability was also employed in generating the PMs for affordability management. By going through the steps presented in the templates, appropriate measures were developed such as requirement satisfaction score, mean time between failures, percentage of strategic suppliers etc.

The strength of the overall affordability information capability audit is that it gives an indication of the level of confidence in the result of the affordability assessment. Also it helps to highlight gaps in information availability and reveals the levels of risk during the stages of the project lifecycle which is useful when assessing the impact of uncertainty. The affordability management methodology provides a form of monitoring and control in order to maintain affordability. The limitation of the affordability management methodology is that it is not widely known to have been applied by in academia and industry.

10.2.7 Incorporating dynamic changes in affordability assessment due to uncertainty

As earlier mentioned, defence contracts are affected by uncertainty which is dynamic and could impact the project in different ways. For this reason it was important to assess the impact of uncertainty on defence contracts. The incorporation of uncertainty on qualitative factors would generate erroneous results; hence the assessment was carried out on quantitative factors. The logic applied in the assessment combined two aspects to it. The logic combined time and range parameters from the refined uncertainty accuracy ranges and the results of the affordability information capability audit. The uncertainty ranges refined from the AACE uncertainty accuracy ranges which consisted of three levels (high, medium and low) and the application of the affordability information capability audit result provided a guide to the stages of the life cycle to apply the uncertainty ranges. One application of the logic was done using commercial uncertainty assessment software (crystal ball) which was recognised in academia and industry. The second application was a demonstration of a futuristic approach using the AnyLogic model. The model combines system dynamics and agent-based model simulation to assess the impact of uncertainty on a defence project's affordability and profitability. The main contribution and advantage of this approach is that it helps to visualise changes in the behaviour of agents based on results of the assessment. The futurist approach however has a major limitation because it is not widely known and employed within industry. Also the technical complexities highlighted in Chapter 8 (section 8.6.2) may create a challenge. Though the AnyLogic model may be used by a few defence companies in the area of risk assessment, none have visualised or used it for affordability assessment. Future research could go to further develop this approach and further validate it.

Framework Integration and Validation

The proposed framework for customer affordability, manufacturer profitability and supplier sustainability were integrated and implemented in an affordability assessment system. The logic and content of the proposed framework was validated at the development stage as well as after completion. In addition to this, the logic for assessing the impact of uncertainty was validated. A total of four case studies were applied to the framework, one at the development stage and three at completion. The case studies were from two manufacturer organisations within the defence sector had life cycle between 2 and 20 years were focussed on delivering communications systems, supporting communications programme and repairing an exhaust plume of an aircraft. The case studies included different phases of the CADMID cycle, but all of them included the In-service phase.

The results the case studies varied from being affordable to being unaffordable, but generally, most of the AIs were less than 1, due to the effect of the violations during the life cycle. The outcome of the validation proved that the affordability framework employed a good rationale and it was capable of being used to assess the affordability of defence contracts at different stages of the life cycle. The framework is repeatable and adaptable to suit different contracts within the defence and civil aerospace sectors as seen in the case studies.

10.3 Achieving research objectives

The success of the research activity in achieving the research objectives stated in Chapter 3 (section 3.4) is presented below.

- Investigate the industrial context of this research in order to capture the current practice (AS-IS) of customer affordability, supplier sustainability and manufacturer profitability within the defence sector.

This objective was achieved in Chapter 2 by conducting a comprehensive literature review of the concept of affordability from the three perspectives of the customer, manufacturer and supplier. This helped to understand current research in customer affordability across different sectors and identify the gap within the defence sector. The conclusion drawn from this research concerning the objective is that it provided adequate knowledge to help identify the gaps which could be filled by the research activity. Also in Chapter 4 by conducting the state-of-the-art research on current practice of cost estimating, budget setting and affordability assessment from the perspectives of the customer, manufacturer and supplier. Similar to the first objective, this helped to understand industrial practice in cost estimation, budget allocation practice, customer affordability, manufacturer profitability and supplier sustainability assessment and identify the current challenges in practice within the defence sector. The conclusion drawn from this research concerning the objective is that it provided a good understanding of industrial practice in order to identify the gaps which could be filled by the research activity.

- To investigate the qualitative and quantitative factors affecting customer affordability and how to generate the customer Affordability Index (AI) to measure customer affordability.

This objective was achieved in Chapters 2, 4, 5 and 9 by conducting state-of-the-art research in academia and industrial practice. Chapters 2 and 4 helped to identify gaps from industrial practice and academic research in order to provide a direction for the research activity. After initial review, further industrial collaboration was carried out in the development of the customer affordability module which included quantitative (AI) and qualitative assessment of customer affordability based on the major factors identified from the industrial interviews. A weighting and scoring method was developed for the qualitative assessment of customer affordability. This also helped to develop guidelines for improving customer affordability based on each factor. The module was validated with expert opinion and industrial case studies. This objective helped to develop a customer affordability module with qualitative and quantitative assessment to fill some of the gaps identified from industrial practice and academic research.

- To investigate the factors affecting manufacturer profitability and how to generate the manufacturer Profitability Index (PI) to measure manufacturer profitability.

This objective was achieved in Chapters 2, 4, 6 and 9 by conducting state-of-the-art research in academia and industrial practice. After identifying the gaps in Chapters 2 and 4, the manufacturer profitability methodology was developed in Chapter 6 to reflect the changes in WLCC over the lifecycle of the project in generating a competitive selling price. This was mainly a quantitative assessment of PI which was similar to AI based on the major factors of profitability identified from the industrial interviews. The methodology was validated with expert opinion and industrial case studies. This objective helped to develop a methodology to assess manufacturer profitability taking account of the violations during the project life cycle to fill some of the gap identified from industrial practice and academic research.

- To investigate the dimensions of supplier sustainability and measures for assessment.

This objective was achieved in Chapters 2, 4, 6 and 9 by conducting state-of-the-art research in academia and industrial practice of supplier sustainability assessment. After identifying the gaps in Chapters 2 and 4, there was the need to define supplier sustainability within the context of this research. The review of sustainability literature helped to define five dimensions for supplier sustainability and a KPI methodology from literature was employed to generate measures of supplier performance to assess long term operational and financial sustainability under each dimension within the supplier sustainability module. These measures which are quantitative and qualitative were used in assessing supplier sustainability based on a similar scoring and weighting mechanism to qualitative customer affordability to generate results. This objective helped to develop a supplier sustainability assessment module including guidelines for improving supplier sustainability based on each dimension. The module was validated with expert opinion and industrial case studies.

- To develop a methodology to assess information capability for affordability assessment at the bidding stages.

  This objective was achieved in Chapters 2, 4, 7 and 9 by conducting state-of-the-art research in academia and industrial practice of affordability. The findings revealed the challenges of obtaining the sufficient data at the bidding stage of defence contract. Therefore there was the need to determine the level of information availability prior to assessing the affordability of the contract. This informed the development of the affordability information capability audit which helped to assess the level of information availability based on four main affordability factor groupings and five elements (resources) as explained in Chapter 7. This objective helped to highlight areas where information is required in order to reduce the impact of uncertainty. It also provides the confidence level in the affordability assessment. The audit was validated with expert opinion and industrial case studies.

- To develop a methodology to manage and control affordability during a project life cycle.

This objective was achieved in Chapters 2, 4, 7 and 9 by conducting state-of-the-art research in academia and industrial practice. The findings revealed the need to manage and control the project to ensure it is affordable through the life cycle. This required the development of measures to assess performance as well as guidelines to improve performance. This was achieved by adopting the KPI methodology previously applied in Chapter 6 for supplier sustainability assessment to also generate measures for improving overall affordability management based on the MoD key performance areas. The methodology had been validated with expert opinion; hence it was applied to generate performance measures to manage the overall affordability of the project.

In summary, this research has been able to achieve its initial objectives and went beyond them to also provide two approaches to incorporating uncertainty in affordability assessment which was validated with expert opinion and industrial case studies.

- Investigate the impact of uncertainty on affordability assessment over the project life cycle

Similar to the other objectives, the literature and industrial review identified uncertainty as one of the factors affecting project affordability. Uncertainty is a factor which could affect all the other factors of customer affordability, hence it was important to identify a suitable approach for assessing the impact of uncertainty on affordability. In Chapter 8, a logic which comprises of two aspects was developed based on academic review and good practice in industry. One is based on the AACE uncertainty ranges which were adopted and refined to develop three levels of uncertainty ranges to be applied in assessing the impact of uncertainty. The other aspect is based on the output of the affordability information capability audit and the uncertainty ranges. Both are implemented in the logic which is applied in two approaches. The first approach applies the logic using a risk assessment software (crystal ball) in Microsoft excel while the other is a futuristic approach applying the logic in an Anylogic model which combines systems dynamics and agent-based simulation to assess the impact of uncertainty on a defence project's affordability and profitability. Both aspects of the logic have been validated with industrial experts and the first approach has been fully validated as it uses established software which was applied to case studies. The second (futuristic) approach also includes the two concepts, but the application of the model for affordability assessment has been validated with an academic researcher rather than industrial experts.

The final objective to validate the integrated affordability framework which comprises of all the modules and methodologies explained above was carried out in Chapter 9.

10.4 Research contributions and limitations

10.4.1 Main contributions

The research activity contributed to existing knowledge focusing on the three perspectives of affordability including assessing the impact of uncertainty.

(1) Customer affordability: The customer affordability factors identified through the research were refined to derive qualitative and quantitative factors for customer affordability for the defence sector. Also the existing measure of assessing customer affordability was refined to provide a quantitative measure of customer affordability. Metrics for qualitative assessment of customer affordability based on the major qualitative factors were also developed in addition to guidelines for improving the customer affordability. The factors, measures, metrics and guidelines for improvement were validated with industrial expert opinion and case studies (Chapters 2, 5 and 9). The contributions are summarised below:

- Development of uniform definition of customer affordability was developed and validated with industrial experts
- Identification of customer affordability factors for the defence sector
- Development of metrics to perform qualitative assessment of customer affordability which includes a system of capturing and representing the importance of each factor
- Refinement of Affordability Index to give an accurate quantitative assessment of customer affordability taking account of time
- Development of guidelines for improving customer affordability.

(2) Manufacturer profitability: The research activity reviewed existing research in the area of manufacturer profitability to identify measures of profitability. The measure was refined to take account of violation between cost and customer budget over the life cycle of the project. This was validated with industrial expert opinion and case studies (Chapters 2, 6 and 9). The contributions are summarised below:

- Development of a definition for manufacturer profitability focussing on profitability assessment at the bidding stage
- Development of a measure to assess the manufacturer profitability at the bidding stage of defence project based on the cost estimates. This measure reflects the impact of changes in customer budget and project cost over time.

(3) Supplier sustainability: The research activity involved the review and evaluation of existing research in the area of sustainability and supplier performance measurement. This enabled the development of a definition of supplier sustainability in the defence industry and identification of dimension of sustainability. A systematic approach was employed to generate measures of financial and operational sustainability of suppliers within the defence sector. These measures were applicable to both products and services. Also the guidelines for improving the sustainability of suppliers were identified. The dimensions, measures and guidelines for improvement were validated with industrial expert opinion and case studies (Chapters 2, 6 and 9). The contributions are summarised below:

- Development of a definition of supplier sustainability in terms of financial and operational sustainability
- Development of dimensions that are related to the financial and operational sustainability of suppliers in the delivery of defence contracts
- Identification of qualitative and quantitative measures of performance (for each dimension) to assess the ability of suppliers to sustain service delivery over the life cycle of the project within the defence sector
- Development of guidelines for improving supplier sustainability.

(4) Assessing the impact of Uncertainty in affordability assessment: The research activity developed logic to assess the impact of uncertainty on customer affordability and manufacturer profitability based on the result of the affordability information capability

audit and the uncertainty ranges. The affordability information capability audit was developed within the research in order to determine the information available to assess affordability from the three perspectives. This provided a guide to know the level of uncertainty at each stage of the lifecycle. Also the AACE uncertainty ranges identified within literature were refined to provide three levels of uncertainty ranges to be applied to the cost and customer budget values during the life cycle of the project. The research activity also identified a futuristic approach to apply the logic in an Anylogic model which combines systems dynamics and agent-based simulation to assess the impact of uncertainty on a defence project's affordability and profitability (Chapters 7, 8 and 9). The first approach was validated with industrial expert opinion and case studies and the second approach was validated with a post-doctoral researcher. The contributions are summarised below:

- Development of a robust logic to assess the impact of uncertainty based on information availability at different stages of the project life cycle (time) and uncertainty ranges (parameter)
- Identification of two approaches to represent the impact of uncertainty in affordability assessment namely;
  (i) Monte carlo simulation in a risk software (crystal ball)
  (ii) Futuristic approach using Anylogic tool.

(5) Affordability management technique: The research activity led to the development of technique to derive measures for managing overall affordability of the contract. This was done through a systematic methodology similar to the one adopted in Chapter 6. The methodology helps to develop performance measures from key performance indicators or performance areas which are used to measure manage the performance of defence projects over the life cycle to maintain affordability.

10.4.2 Limitations of the research

The limitations of the research are presented below.

- The focus of the research is on defence contracts so the framework was developed to suit this sector. Though the validation included a case study from civil aerospace sector, the rest were from the defence sector.

- The framework was implemented using Microsoft Excel; hence the functionality and features of the system are narrowed down by the software.
- Due to the novelty of the Anylogic tool within industry, the futuristic approach to incorporating uncertainty using the AnyLogic model could only be validated with an academic researcher rather than an industrial expert.

10.5 Future research and conclusion

Based on the limitations presented above, future research could be undertaken in the following activities:

- Further development and application of the affordability framework to extend to other sectors with long-term contracts such as oil and gas, nuclear etc. This would require an investigation to ensure that the factors, lifecycle, measures and dimensions are applicable to these industry sectors. In order to apply the framework to other industries, major calibrations would be required to ensure relevance to the particular industry, and implementation is done using robust software with significant storage capability.
- In applying the framework to other sectors, the concept of customer willingness to pay (section 2.10) could be applied to improve customer affordability.
- The budget setting procedure could be further investigated in order to identify methods or tools to help improve the current practice and the associated challenges.
- The suggested guidelines for improving customer affordability and supplier sustainability could be further refined to derive a smaller set of major guidelines to form best practice guidelines to improve customer affordability and supplier sustainability across sectors.
- The process of generating measures for supplier sustainability and affordability management could be further refined to ensure that every parameter included in the process is important and essential to the final performance measure.
- The futuristic approach to incorporate uncertainty could be further developed and validated with industrial experts and cases studies from other sectors.
- More effort could be employed to improve the affordability framework towards commercialisation. This could include implementing the framework using other software such as Microsoft Access.

In conclusion, the research aimed to develop an affordability assessment and management framework at the bidding stage for defence contracts, from the perspectives of the customer, manufacturer and supplier. The research activity undertaken in order to fulfil the aim employed a comprehensive methodology to review existing literature and capture industry practice to present the current state of affordability. This helped to identify the research gap which informed the framework development. The research output achieved the development and validation of the following:

- A uniform definition of affordability for academia and industry
- A comprehensive method of customer affordability assessment including qualitative and quantitative factors of affordability with guidelines for improvement
- A comprehensive method of supplier sustainability assessment including qualitative and quantitative measures for long-term operational and financial ability with guidelines for improvement
- An improved methodology to assess manufacturer profitability which takes account of changes over time
- Logic for assessing the impact of uncertainty on affordability which combines two aspects.

This demonstrates the novel and significant contribution of the research to the body of knowledge in affordability.

REFERENCES

Aerospace Airworthiness Consultancy Enterprises (2010), *Acquisition Support*, available at: http://www.aace.co.uk/acquisitionsupport.php (accessed 19th November, 2010).

Albrecht, M. C. (2010), *Introduction to Discrete Event Simulation*, available at: http://www.albrechts.com/mike/DES/Introduction%20to%20DES.pdf (accessed 15th November 2010).

Al-Churaiz, Y. and Enshassi, A. (2005), "Ability and willingness to pay for water supply service in the GAZA strip", *Building and Environment,* Vol. 40, p.1093–1102

Anderson, J. C., and Narus, J. A. (2004), *Business Market Management: Understanding, Creating and Delivering Value* (2nd ed), Upper Saddle River, New York.

Anderson, W. E. and Mittal V. (2000), "Strengthening the Satisfaction-Profit Chain", *Journal of Service Research,* Vol. 3, p.107- 120.

AOF (2008), *Technology Readiness Levels (TRLs) Ministry of Defence,* available at: http://www.aof.mod.uk/aofcontent/tactical/techman/content/trl_applying.htm. (accessed 19th July 2010).

AOF (2010a), *What is Through Life Capability Management (TLCM)?,* available at:http://www.aof.mod.uk/aofcontent/operational/business/capabilitymanagement/capabilitymanagement_whatis.htm (accessed 7th November 2010).

AOF (2010b), *The CADMID cycle*, available at: http://www.aof.mod.uk/aofcontent/strategic/guide/lifecycles/sg_cadmid.htm?zoom_highlight= (accessed 2nd October 2010).

AOF (2010c), *Performance Management within Defence Equipment and Support (DE&S)*, available at: http://www.aof.mod.uk/aofcontent/operational/org/des/des_performance.htm, (accessed 7th November 2010).

Asiedu Y. and Gu P. (1998), "Product life cycle cost analysis: state of the art review", *International Journal of Production Research*, Vol. 36, No. 4, p.883 - 908.

Atkinson, A. et al. (2001), *Management Accounting* (3rd ed), Prentice Hall, England.

Atrill, P. and Mclaney, E. (2007), *Management Accounting for Decision makers*, Prentice Hall, Harlow, England.

Aurich, J.C., Fuchs, C. and Wagenknecht, C. (2006), "Life cycle oriented design of technical Product-Service Systems", *Journal of Cleaner Production*, Vol. 14, No. 17, p.1480-1494.

Baines, S. T., Lightfoot, H.W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock J., Angus, J., Bastl., M, Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I, Wilson, H. et al., (2007), "The state-of-the art in Product Service System", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, Vol. 221, No. 10, p.1543-1552.

Baker, H. (2010), *BAE Job Cuts 'Will Wipe Out British Skills'*, available at: http://news.sky.com/skynews/Home/Business/Defence-Giant-BAE-Systems-Responds-To-Government-Cuts-By-Planning-To-Axe-1400-Jobs/Article/201012215850576?f=rss (accessed 18th January 2011).

Ball, P. (1996), *Introduction to Discrete Event Simulation*, available at: http://masters.donntu.edu.ua/2006/kita/kondrakhin/library/art6.htm#Developments & trends, (accessed 15th November 2010).

Ball, P.D. and Bititci, U.S. (2006), "Supply Chain management diagnostics and improvement approach", *Control (Institute of Operations Management)*, Vol.32, No.4, p.20-24.

Bankole, O.O., Roy, R., Shehab, E. and Cheruvu, K. (2009b), "An affordability system to assess information availability in defence projects", in: *Proceedings of DET2009 6th International Conference on Digital Enterprise Technology, Advances in Soft Computing,* Vol. 66/2010, 14-16 December 2009, Hong Kong, p.1613-1626.

Bankole, O.O., Roy, R., Shehab, E. and Wardle, P. (2009a), "Affordability assessment of Industrial product service system in the aerospace defence industry", in: *CIRP IPS2 Conference 2009, on Industrial Product Service Systems*, 1-2 April 2009, Cranfield University, U.K.p.230-238.

Bankole, O.O., Roy, R., Shehab, E., Cheruvu, K. and Johns, T. (2010b), "Product-Service System Affordability in Defence and Aerospace Industries: State-of-the-art and Current Industrial Practice", *International Journal of Computer Integrated Manufacturing,* In Press.

Bankole, O.O., Shehab E., and Cheruvu K. (2010a), *Affordable Defence project – reality or fantasy? Project Control Professional*, The journal of the Association of Cost Engineers, Vol.48, No 6, November 2010.

Bever, B. and Collofello, J. (2002), "An investigation of techniques for addressing software affordability", *IEEE Aerospace Conference Proceedings,* p.5-2577-5-2585

Bhimani, A., Horngren, C.T., Datar, S. and Foster, G. (2008), *Management and Cost Accounting* (4th ed), Prentice Hall, Essex, England.

Boehm, B. (1998), *Software Development Cost Estimation Approaches – A Survey,* available at: http://csse.usc.edu/csse/TECHRPTS/2000/usccse2000-505/usccse2000-505.pdf (accessed 19th December 2010).

Bojarski, A.D., Laínez, J. M., Espuña A. and Puigjaner, L. (2009), "Incorporating Environmental Impacts and Regulations in a Holistic Supply Chains Modeling: An LCA Approach", *Computers and Chemical Engineering,* Vol.33, p.1747-1759.

Bradbery, R. (2005), Development of a descriptive framework for affordability engineering. (MSc Thesis), Cranfield University, School of Industrial and Manufacturing Science, Cranfield, UK.

Business dictionary (2010), *Parameter*, available from:
http://www.businessdictionary.com/definition/parameter.html#ixzz16qzPc9U9
(accessed 30th June 2010).

Cameron, A., Ewen, M., Ross-Degnan, D., Ball, D. and Laing, R. (2008), "Medicine prices, availability, and affordability in 36 developing and middle-income countries: a secondary analysis", *The Lancet,* Vol. 373, No. 9659, p.240-249.

Centre for Transit-Oriented Development and Centre for Neighbourhood Technology (2006), *The Affordability Index: A New Tool for Measuring the True Affordability of a Housing Choice,* The Urban Markets Initiative, Market Innovation Brief, available at: http://www.brookings.edu/reports/2006/01_affordability_index.aspx (accessed 20th November 2007).

Cho, H. and Pucik, V. (2005), "Relationship between innovativeness, quality, growth, profitability and market Value", *Strategic Management Journal*, Vol. 26, No.6, p.555–575.

Christensen, P. and Dysert, L. (2003), *AACE International Cost Estimate Classification System TCM Framework: 7.3 – Cost Estimating and Budgeting*, AACE International Recommended Practices, available at: http://www.aacei.org/technical/rps/17r-97.pdf
(accessed 15th November 2010).

Chytka, T., Brown R., Shih, A., Reeves, J. and Dempsey, J. (2006), "An Integrated Approach to Life Cycle Analysis", in: *11th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference,* Vol. 3, 6 - 8 September 2006, Portsmouth, Virginia, p.1-15.

Creswell, J.W. (2007), *Qualitative inquiry & research design: Choosing among five approaches* (2nd ed), Thousand Oaks, CA: Sage.

Cushway, G. (2006), "Availability Contracting – Making Defence Procurement Smarter", *Defence Management Journal*, Issue 32, available at: http://www.frost.com/prod/servlet/market-insight-top.pag?docid=64867589 (accessed 19th January 2009).

Datta, P. and Roy, R. (2009), "Cost Modelling Techniques for Availability Type Service Support Contracts: a Literature Review and Empirical Study", *Proceedings of the 1st CIRP IPSS Conference,* 1-2 April, 2009, Cranfield University, Cranfield, UK, p. 216-224.

Dean, E. B. (1995), "Parametric cost deployment", *Proceedings of the Seventh Symposium on Quality Function Deployment*, June, Nov., MI, USA, p.27-34.

Dean, E. B. and Unal, R. (1992), Elements of designing for cost. *Proceedings of AIAA 1992 Aerospace Design Conference*, February, Irvine, CA.

Del Rey Chamoro, F. (2000), *Performance Measurement in Knowledge management,* (Msc thesis), School of industrial and manufacturing science, Cranfield University.

DeMarco, A. A. (2005), *Making the Case for program Affordability management*. Price Systems Report, available at: http://www.pricesystems.com/solutions/AffordabilityManagement.asp (accessed 4th November 2009).

Drucker, P. F. (1998), *The Coming of the New Organization*, Harvard Business Review*,* Harvard Business School Press, January-February, p. 1-19.

Dun and Bradstreet (2003), *Sales and Market Solution: Key Business Ratios*, available at: http://kbr.dnb.com/help/KBR_Quick_Ref_Guide_0103.pdf (accessed 21st February 2010).

EFQM (2010), *EFQM Framework,* available at: http://www.efqm.org/en/Home/aboutEFQM/TheEFQMExcellenceModel/FundamentalConcepts/tabid/169/Default.aspx (accessed 1st August 2010).

Emmons, D. L., Lobbia, M., Radcliffe, T. and Bitten, R.E. (2010), "Affordability Assessments to Support Strategic Planning and Decisions at NASA", *Aerospace Conference, 2010 IEEE,* 6-13 March 2010, Big Sky, MT, p. 1 - 13

Erkoyuncu, J. A., Roy, R., Shehab, E. and Wardle, P. (2009), "Uncertainty challenges in service cost estimation for product-service systems in the aerospace and defence industries", *Proceedings of the 1st CIRP IPSS Conference*, Cranfield University, Cranfield, p. 200-206.

Erkoyuncu, J. A., Roy, R, Shehab, E. and Cheruvu, K. (2011), "Understanding service uncertainties in Industrial Product- Service System cost estimation", *International Journal of Advanced Manufacturing Technology,* Vol. 52, Nos. 9-12, p. 1223-1238.

Erlendsson, J. (2002), *Value For Money Studies in Higher Education,* available at: http://www.hi.is/~joner/eaps/wh_vfmhe.htm (accessed 4th June 2009).

Fankhauser, S. and Tepic, S. (2007), "Can poor consumers pay for energy and water? An affordability analysis for transition countries", *Energy Policy*, Vol.35, No. 2, p.1038-1049.

GAO, (2009). *GAO Cost Estimating and Assessment Guide.-Best Practices for Developing and Managing Capital Program Costs. United States Government Accountability Office,* available at: http://www.gao.gov/new.items/d093sp.pdf (accessed 20th June 2010).

Goedkoop, M., van Haler, C., te Riele, H., and Rommers, P. (1999), *Product Service-Systems, ecological and economic basics* - Report for Dutch Ministries of Environment (VROM) and Economic Affairs, The Netherlands, available at: http://teclim.ufba.br/jsf/indicadores/holan%20Product%20Service%20Systems%20main%20report.pdf (accessed 20th June 2010).

Graham, G. and Hardaker, G. (1998), "Defence Sector Procurement and Supply Chain Relationships", *Supply Chain Management: An International Journal*, Vol. 3, No. 3, p.142-148.

Gray, B. (2009), *Review of Acquisition for the Secretary of State for Defence: An independent report by Bernard Gray*, available at: http://www.mod.uk/NR/rdonlyres/78821960-14A0-429E-A90A-FA2A8C292C84/0/ReviewAcquisitionGrayreport.pdf (accessed 1st December 2009).

Greenfield, T. (1996), *Research Methods: Guidance for Postgraduates*, Arnold.

Gunasekaran, A., Patel, C. and McGaughey R. E. (2004), "A framework for supply chain performance measurement", *International Journal of Production Economics*, Vol.87, p.333–347.

Gunasekaran, A., Patel, C. and Tirtiroglu E. (2001), "Performance measures and metrics in a supply chain environment", *International Journal of Operations and Production Management*, Vol.21, p.71–87.

Gupta, Y. P. (1983), Life cycle cost models and associated uncertainties. In *Electronics Systems Effectiveness and Life Cycle Costing*, NATO ASI Series, Vol. F, J. K. Skwirzynski (ed.) (Berlin: Springer) p.535-549.

Hancock, K. E. (1993), "Can Pay? Won't Pay? or Economic Principles of Affordability," *Urban Studies*, Vol. 30, No. 1, p.127-145.

Handfield, R.B. and Nichols, E.L. (1999), *Introduction to supply chain management*, New Jersey, Prentice hall.

Hart, S. L. (1997), "Beyond Greening: Strategies for a Sustainable World", *Harvard Business Review,* Vol.75, p. 66-76.

Harvey, L. (2009), *Analytic Quality Glossary*, Quality Research International, available at: http://www.qualityresearchinternational.com/glossary/ (accessed 30th June 2010)

Harvey, L. and Green, D. (1993), "Defining Quality", *Assessment and Evaluation in Higher Education*, Vol.18, No.1, p. 9 - 34

Hennessy, P., Gray, L. and Sherwell, P. (2009), *Climate Summit Ends in Chaos and 'Toothless' Deal*, available at: http://www.telegraph.co.uk/earth/copenhagen-climate-change-confe/6845929/Climate-summit-ends-in-chaos-and-toothless-deal.html (accessed 30th December 2009).

Hirschey, M. (2009), Fundamentals of Managerial Economics, (9th ed), Cengage Learning, OH, USA.

Hollmann (2006), *What are Cost Engineering and TCM?,* available at: http://www.aacei.org/mbr/whatIsCE.shtml (accessed 19th November 2010).

Kaplan, R. and Norton, D. (1996), *The balanced scorecard: translating strategy into action*, Harvard Business School Press, Boston, Massachusetts.

Kenessey A., Buisson, B. and McKenzie, R. (2005), *Producer price index for services: Pricing Methods. 20th meeting of the Voorburg Group, Helsinki, Finland*, available at: http://www.oppapers.com/essays/Pricing-Methods/157695 (accessed 30th December 2010).

Kim, E., Wells Jr., W. and Duffey, M. (2003), "A model for effective implementation of Earned Value Management Methodology", *International Journal of Project Management,* Vol. 21, p. 375–382.

Kim, K. and Renaud, B. (2009), "The Global House Price Boom and its Unwinding: An Analysis and a Commentary", *Housing Studies*, Vol.24, No.1, p.7–24.

Kim, S.W. (2007), "Organizational Structures and the Performance of Supply Chain Management", *International Journal of Production Economics,* Vol.106, p.323-345.

Koury, B. (2010). The Affordability Challenge. *Price Systems,* available at: http://www.pricesystems.com/presentations/affordability_toolkit.pdf (accessed: 15th November 2010)

Kroshl, W.M. and Pandolfini, P.P. (2000), "Affordability Analysis for DARPA Programs", *Johns Hopkins APL Technical Digest*, Vol. 21, No.3, p.438 – 447.

Labuschagne, C., Brent, A.C. and Van Erck, R.P. (2003), "Assessing the Sustainability performances of industries", *Journal of Cleaner Production,* Vol.13, No.4, p.373-385.

Lee, H. L. (2004), "The Triple-A Supply chain", *Harvard Business Review*, October 2004, p.102-112.

Macal, C. and North, M. (2005), *Tutorial on agent-based modelling and simulation, Proceedings of the 2005 Winter Simulation Conference, M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, eds*, available at: http://www.kent.ac.uk/secl/philosophy/jw/reasoning/2009/Macal%20North%2005%20-%20Tutorial%20on%20agent-based%20modelling%20and%20simulation.pdf (accessed: 15th September 2010).

Marasco, A. (2008), "Third-party logistics: A literature review", *International Journal of Production Economics*, Vol.113, No.1, p.127-147.

Meier, H., Roy, R. and Seliger, G. (2010), "Industrial Product-Service Systems - IPS²", *CIRP Annals Manufacturing Technology*, Vol. 59, Issue 2, p. 607-627.

Milne, C. (2000), "Affordability of basic telephone service: an income distribution approach", *Telecommunications Policy,* Vol. 24, p. 907-927.

Milne, C. (2004), *Towards defining and measuring affordability of utilities – a discussion paper*, PUAF Communications discussion paper, Available at: http://www.antelope.org.uk/affordability/PUAF_affordability_discussion_paper.pdf, (Accessed 24th April 2009).

Ministry of Defence (2005), *Defence Industrial Strategy: Defence White Paper*. The Stationery Office (TSO), London Cm 6697.

Ministry of Defence (2007), *Report on the 2007 General Review of the Profit Formula for Non-competitive government contracts*. The Stationery Office (TSO), London.

Ministry of Defence (2008), *Partnering Handbook for Acquisition Teams,* available from: http://www.aof.mod.uk/aofcontent/tactical/toolkit/downloads/part/partnering.pdf (Accessed 24th April 2009).

Ministry of Defence (2009), *Report on the 2009 Annual Review of the Profit Formula for Non-competitive government contracts*, available at: http://www.mod.uk/NR/rdonlyres/2C810965-1069-43CF-ACC7-26B88AF3522D/0/090130_2009ar_final.pdf (accessed 19th January 2010).

Ministry of Defence (2010), *Defence Fact Sheet: Urgent Operational Requirements (UOR),* available at: http://www.mod.uk/DefenceInternet/FactSheets/UrgentOperationalRequirementsuor.htm (accessed 1st August 2010).

Minkiewicz, A.F. (2006), "Tackling the Cost Challenges of Systems of Systems, PRICE Systems"*, in: Systems and Software Technology conference, The Journal of Defence Software Engineering,* May1, 2006, p. 10-14.

Mohr, J. and Spekman, R.E. (1994), "Characteristics of Partnership Success: Partnership Attributes, Communication Behavior, and Conflict Resolution Techniques", *Strategic Management Journal*, Vol.15, p. 135-152.

Neuman, L. W. (2006), *Social Research Methods: qualitative and quantitative approaches* (6th ed), Pearson international Edition.

Mutchler, J. and Krivo, L. (1989), "Availability and affordability: Household adaptation to a housing squeeze", *Social Forces*, Vol.68, No.1, p. 241-246.

National Aeronautics and Space Administration, (2010), *What is EVM?,* available at: http://evm.nasa.gov/ (accessed 1st August 2010).

Nogal M. (2006), *Development for framework for Affordability Engineering Measurement*, (Msc thesis), Decision Engineering Centre, School of Applied Sciences, Cranfield University, Cranfield, UK.

North Atlantic Treaty Organisation, (2007), *Methods and Models for Life cycle costing, Final Report of Task Group SAS-054, June 2007*, available at:

http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-SAS-054///$$TR-SAS-054-ALL.pdf (accessed 1st August 2010).

Oberkampf, W., DeLand, S., Rutherford, B., Diegert, K. and Alvin, K. (2000), *Estimation of Total Uncertainty in Modeling and Simulation*, Sandia Report Sand 2000-0824 Unlimited Release**,** April 2000, available at: http://prod.sandia.gov/techlib/access-control.cgi/2000/000824.pdf (accessed 1st August 2010).

Oke, S.A. (2004), "An analytical model for the optimization of maintenance profitability", *International Journal of Productivity and Performance Management,* Vol.54, No.2, p.113-136.

Pie software inc, (2001), *Definition of a variable,* Available from: http://www.piesoftwareinc.co.uk/textonly/variable.html, (accessed 15th November, 2010).

Presutti, Jr D. and Mawhinney, R. J. (2007), "The Supply Chain- FINANCE Link", *Supply Chain Management Review*, p. 32-38.

Rains, D. A. (1996), "Naval Ship Affordability", *Naval Engineers Journal*, Vol.108, No. 4, p. 19–30.

Ray, A., (2006). *A cost model for affordability for aircraft components* (unpublished Msc thesis), Queens University, Belfast.

Ray, A., Roy, R. and Baguley, P. (2006), "Developing a Framework for Affordability Engineering", *The 4th International Conference on Manufacturing Research (ICMR 2006),* Liverpool John Moores University, 5th – 7th September 2006, ISBN 0-9553215-0-6, p. 11-16.

Reagan, L. (2004), *Affordability Management in a Performance-Based World*, Price systems, p.1-6. available at: http://www.pricesystems.com/research/white_papers.asp (accessed 21st October 2009).

Reagan, L. (2005), *Affordability Simulation: Cost Analysis in a Simulation Environment*, Price systems, available at:

http://www.pricesystems.com/research/white_papers.asp (accessed 21st October 2009).

Redman, Q. and Stratton, G. (2001), "Why Affordability is a systems engineering metric", *Digital Avionics Systems, the 20th Conference,* Vol.1, p.4B3/1 - 4B3/12.

Rese, M. and Karger, M. (2008), "Measuring the Price Ceiling for Flexible Product Service Systems Under Dynamic Preferences – A Real Options Approach", *3rd Annual Conference on Business Market Management*, St. Gallen 2008.

Rese, M., Strotmann, W. and Karger, M. (2008), "Which Industrial Product Service System Fits Best? - Evaluating Flexible Alternatives Based on Customers' Preference Drivers", *Journal of Manufacturing Technology and Management,* In Press.

Roark, C. and Kiczuk, B. (1996), "Open Systems: a process for achieving affordability", *IEEE Aerospace and Electronics Systems Magazine,* Vol. 11, No.9, p. 15-20.

Romero Rojo, F. J., Roy, R., Shehab, E. and Wardle P. (2009), "Obsolescence Challenges for Product-Service Systems in Aerospace and Defence Industry", *Proceedings of the 1st CIRP IPSS Conference,* 1-2 April, 2009 Cranfield University, Cranfield, UK, p. 255-260.

Rosenfield, D.B., Copacino, W.C. and Payne, E.C. (1985), "Logistics planning and evaluation when using 'What-If' simulation", *Journal of Business Logistics*, Vol. 6 No. 2, p. 89-119.

Roy, R. and Cheruvu, K. (2009), "A competitive framework for Industrial Product Service Systems", *International Journal of Internet Manufacturing and Services,* Vol. 2, No.1, p. 4-29.

Russell, J.D. (2007), "Composites Affordability Initiative: Successes, Failures - Where do we go from here?" *Sampe Journal,* Vol.43, No.2, p. 26-46.

SC21, (2009), *21st century supply chain Awareness presentation*, available at: http://www.sbac.co.uk/pages/80338686.asp (accessed 21st October 2009).

Schrage. P. D. and Mavris, D. (1994), "Technology for Affordability – How to define, measure, evaluate and implement it?" *The American Helicopter Society 50th Annual Forum*, 11-13 May 1994, Washington DC., p.1039 -1053.

Schrage, P.D. (1999), "Technology for Rotorcraft Affordability Through Integrated Product/Process Development", *American Helicopter Society 55th Annual Forum,* 25-27 May 1999, Montreal Quebec, Canada, p. 1-19.

Semple, J. (2007), *Review into Affordability Housing Final Report*, Department for Social Development in Northern Ireland. available at: http://www.dsdni.gov.uk/consultation-review_affordable_housing.pdf (accessed 21st October 2009).

Seuring, S. and Muller, M. (2008), "From a Literature Review to a Conceptual Framework for Sustainable Supply Chain Management", *Journal of Cleaner Production*, Vol.16, p.1699-1710.

Shields, M. D. and Young, S. M. (1991), "Managing product life cycle costs: an organizational model", *Cost Management*, Autumn, p. 39-52.

Smith, E. G. (2006), "Leveraging profitability in low-margin markets", *Journal of Product & Brand Management,* Vol.15, No.6, p.358-366.

Smyth, P. (2005), "Water and wastewater Finance and Pricing", *Taylor and Francis Group LCC.*, p. 309-323

Sticker, J.M. (2002), "Turbine Engine Affordability", 38th *AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit,* 7-10 July 2002, Indianapolis, Indiana, p. 3619 – 3621.

Supply Chain21 (2009), *21st Century Supply Chain Awareness Presentation*, available at: http://www.sbac.co.uk/pages/80338686.asp (accessed October 21st 2009).

Supply-Chain Council, (2009), *Supply-Chain Operation Reference-Model (SCOR Overview, Version 8.0)*, available at: http://archive.supply-chain.org/galleries/default-file/SCOR%2080%20Overview%20Booklet2.pdf (accessed 21st October 2009).

Tatham, P. (2005), "Efficient in Peace but Effective in War: Meeting the Challenge of the Military Supply Chain - An Agenda for Research", *Supply chain Practice*, Vol.7, No.2, p.42-57.

Taylor, C. (2003), *UK Defence Procurement Policy, Research Paper 03/78, International affairs and defence section*, *House of Commons Library,* available at: http://www.parliament.uk/documents/commons/lib/research/rp2003/rp03-078.pdf (accessed 1st August 2010).

Terniko, J. (1997), *Step-by-Step QFD Customer-Driven Product Design* (2nd ed), CRC Press LLC, Florida, USA.

The BBC, (2010, *Trident costs must come from MoD budget, Osborne says*, available at: http://www.bbc.co.uk/news/uk-10812825 (accessed 1st August 2010).

The First Post (2010), *Strategic Defence Review looking like a train crash*, available at: http://www.thefirstpost.co.uk/68995,news-comment,news-politics,strategic-defence-review-looking-like-a-train-crash-army-navy (accessed 21st September 2010).

Trkman, P. and McCormack, K. A. (2009), "Conceptual Model for Managing Supply Chain Risk in Turbulent Environment", *International Journal of Production Economics,* Vol. 119, No. 2, p. 247-258.

Trkman, P., McCormack, K., Valadares de Oliveira M.P. and Bronzo Ladeira, M. (2010), "The Impact of Business Analytics on Supply Chain Performance", *Decision Support Systems*, Vol.49, No.3, p. 318–327.

Tsolacos S., McGough T., and Thompson B. (2005), "Affordability and performance in the industrial property market", *Journal of Property Investment and Finance*, Vol. 23, No.4, p.311–328.

Van Raaij, M. E. (2005), "The strategic value of customer profitability analysis", *Marketing Intelligence and planning*, Vol.23, No.4, p. 372-381.

Whicker, L., Bernon, M., Templar, S. and Mena, C. (2009), "Understanding the Relationships Between Cost and Time to Improve Supply Chain Performance", *International Journal of Production Economics*, Vol. 121, No. 2, p. 641-650.

Wood, F. (1996). *Business accounting*, Volume 1. Pitman.

Yin, R.K. (2009), *Case Study research: Design and Methods* (4th ed.) Thousand Oaks, CA: Sage.

Young, R. and Reagan, L. (2004), *Program Affordability Management Centre of Excellence,* Price systems, available at: http://www.pricesystems.com/research/white_papers.asp (accessed 7th November 2009).

Zintl, R. (2001), "Rational Choice as a Tool in Political Science", *Associations*, Vol. 5, No. 1, p. 35-50.

APPENDICES

Appendix A – Introductory Interview Questionnaire

PSS-Cost Project, Decision Engineering Centre, Cranfield University

Introductory Visit March 2008 to All industrial partners

FAMILIARISATION QUESTIONNAIRE

1. Scope of the estimate

SE.1.1 What is the scope of the estimate in programme terms, e.g. for United Kingdom MoD contracts
what stages of the CADMID/CADMIT cycle are included?

SE.1.2 What is the scope of the estimate in technical terms, e.g. coverage of interfaces, platform
integration costs, evolutionary increments, in-service support?

SE.1.3 Are disposal costs considered within the life cycle cost considerations? (9 Mins)

2. Programme Baseline

SE.2.1 Is there an agreed master data and assumptions list (MDAL) e.g. that supports translation of
programme requirements into a defendable cost estimate? (4 Mins)

3. Cost Breakdown Structure

CBS.3.1 Describe the CBS that you employ in capability contract?

CBS.3.2 Does the CBS for capability contracts differ from the CBS' of the past?

CBS.3.3 Has a cost breakdown structure (CBS) been agreed with the customer consistent with the
level of detail that was (or will be) used to produce the estimate?

CBS.3.4 If a CBS is in use, where has it drilled-down (e.g. for de-risking) has the corresponding detail been
added to the MDAL to support the audit process?

CBS.3.5 If a CBS is in use, is its scope and structure based on any particular standard (e.g. as mandated by
the customer or to comply with legacy practices)?

CBS.3.6 If a CBS is in use, at what LCM stage was it first created and through which LCM stages is it
intended to maintain it (e.g. to support cost metrics)? (10 Mins)

4. Data Collection & Analysis

DCA.4.1 Where historical costs have been collected, what strategies have been used to analyze it (e.g.
simple statistics, investigating anomalies, visualization?

- Where have you stored data, how easy is it to retrieve? (Using SAP?)

- What kind of data could we expect concerning capability contracts? (Could ask what is
capability contract?)

5. Method Selection

MS.5.1 What commercial or in-house tools are used to make estimates (e.g. parametric, simulation,
optimisation, decision support, historical trends analysis)?

MS.5.2 What process assets (e.g. LCM, BMS) have you invoked in support of cost estimating, price build-
up, managing uncertainty and risk, and phase reviews?

MS.5.3 What rationale was used to select the estimating method(s) for the programme (e.g. by analogy,
expert opinion, extrapolation, parametric, or bottom-up)?

MS.5.4 Are there shortcomings in the available estimating methods that need to be addressed outside of the
immediate project (e.g. cluster or functional level)?

MS.5.5 Where do we focus within a contract? Which areas should we concentrate on?

6. Whole life cycle cost estimation

WLCC.6.1 How does the WLC estimation process change when a WLC approach is taken?

WLCC.6.2 Which are the main cost drivers in capability contracts? (E.g. major 3)

WLCC.6.3 How do you compare estimates with the actual and how do you use this information to improve
methods?

7. Capability Contract Process

CCP.7.1 How do agree a price with the customer?

CCP.7.2 Could you please describe the business environment for each capability contract? (What are the
challenges, expectations, cost drivers, uncertainties and risks?)

CCP.7.3 Do you have standard pro-formas for capability contracts? If so what are they?

CCP.7.4 What is the effort at the bidding stage?

8. Capability Contract-Customer relations

CE.8.1 What has changed from delivering just a product to a PSS model in terms of relations with customers?

9. Summary

S.9.1 What kind of data can we get in the future?

S.9.2 What kind of future interaction can we embark on?

Appendix B – Customer Affordability Questionnaire

PSS-Cost Project, Decision Engineering Centre, Cranfield University

2nd Visit - 2nd July 2008 to MoD de&s, Bristol

QUESTIONNAIRE ON CUSTOMER AFFORDABILITY

Aim - Current Practice in Customer Affordability at MoD de&s
- Why is Customer Affordability important for MoD de&s

1. Bidding Stage (BS) (20min)
BS.1.1. How is Affordability predicted at the bidding stage (Flow chart description)?
BS.1.2. Which people are involved in bidding process? (Maybe IPD)
BS.1.3. How do you know decide your spending ability at the Bidding stage on a particular project?
BS.1.4. When do you release this to suppliers?

2. Affordability Measurement (AM) (40 min)
AM.2.1. What is your understanding/definition of affordability?
AM.2.2 What factors drive/ affect your Affordability?

- Qualitative
- Quantitative

AM.2.3 How do you assess the Affordability of a project? (Real Options Approach?)
AM.2.4 How can you monitor affordability yearly to check against the target?
AM.2.5 Why is this important to you?
AM.2.6 How do you control the project?

- Tools such as Earned Value Management
- Performance measures (e.g. Balance Score card can I obtain examples of these?)

AM.2.7 How does Affordability change from sale of product to a contract?
AM.2.8 What additional risks come in terms affordability when you got to availability contracts – the financial burdens does this put on you as the customer?
AM.2.9 Is Affordability accounted for in the Service Level Agreement?

3. Customer Value (CV) (20mins)
CV.3.1 How do you define Customer Value? – Customer 1 and Customer 2.

CV.3.2 How do you measure Customer Value? – Customer 1 and Customer 2. (Value for Money benchmark VFMB)
CV.3.3 Is there a Link between Customer Value and Customer Affordability?
CV.3.4 Is there a Link between Customer Value and Customer Loyalty?
CV.3.5 How does quality affect Customer Value and Affordability?
CV.3.6 How does pricing affect Customer Value and Affordability?
CV.3.7 How does Service affect Customer Value and Affordability?

4. Willingness To Pay (WTP) (20mins)
WTP.4.1 Is there a difference between what you can afford and what you are willing to pay or are they both the same thing?
WTP.4.2 Do you think the manufacture/ service provider can influence your willingness to pay? How?
WTP.4.3 Is there a Link between Affordability and Customer Value/ Satisfaction?
WTP.4.4 How can we improve Affordability?
WTP.4.5 Are there existing rules for Affordability?
WTP.4.6 How can these improved?

5. Budget Setting (BUS) (8 mins)
BUS. 5.1. Do you have any budget setting process or target setting for a contract?
BUS. 5.2. What is the process of setting a budget?
BUS. 5.3. How can affordability metrics and factors affect the budget setting process?

Any further information that I need to know, but I've missed out?

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Appendix C – Manufacturer Profitability Questionnaire

PSS-Cost Project, Decision Engineering Centre, Cranfield University

3rd Visit – 22nd July 2008 to BAE Systems, Portsmouth

QUESTIONNAIRE ON MANUFACTURER PROFITABILITY

Aim - Current Practice in Profitability Measurement at BAE Systems
- How does Profitability affect the capability contract?

Profitability Prediction (40 mins)
PP.1 When does Finance get involved in the bidding process?
PP.2 How do you assess profitability at the bidding stage?
PP.3 What tools are used in predicting/ measuring profitability at the bidding stage?
PP.4 Could I obtain copies/demonstration of the document/tools?
PP.5 Is profitability only cash or more like benefit?
PP.6 How do you measure profitability? (E.g. NPV, IRR etc).
On a piece of equipment/
On a system consisting of many components?
On a platform?
PP.7 How do you consider profitability in a contract and a portfolio of contract?
PP.8 What information is needed to make the prediction?
PP.9 How is profitability ensured over the life cycle?
PP.10 What are the issues/challenges in predicting long-term profitability?
PP.11 Is profit for the total life cycle or on a yearly basis?
PP.12 Is cash flow considered at the bidding stage?
PP.13 How is the impact of supply chain on profitability considered at the stage?

Profitability Factors (Factors Affecting Affordability) (20mins)
PF.1 How does the Whole life Cost affect profitability?
PF.2 How does customer budget constraint affect profitability?
PF.3 How do you account for interest rates in profit calculation?
PF.4 How do you account of inflation in profit calculation?
PF.5 What is profit margin allowed in this contract?
PF.6 Is this information disclosed to the customer?
PF.7 What is the difference between risk profit and non-risk profit?
PF.8 How is each applied in accounting for capability contracts?
PF.9 How does the transfer of risk from customer to manufacturer affect profitability?
PF.10 Does this project have a fixed price? How does that affect profitability?

Profitability Control (15 mins)
PC.1 What are the financial controls employed within the contract?
PC.2 What process is adopted in doing this?
PC.3 How effective is the use of EVM?
PC.4 What factors do you consider along with cash profit?
PC.5 How do you manage cost impact from suppliers?
PC.6 How can the project be managed to improve profitability?

Uncertainties and Risk (10 mins)
UR.1 What are the uncertainties involved in profitability prediction?
UR.2 What are the risks involved in the event of failure to achieve the profitability targets?

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Appendix D – Supplier Sustainability Questionnaire

PSS-Cost Project, Decision Engineering Centre, Cranfield University

3rd Visit – 22nd July 2008 to BAE Systems, Portsmouth

QUESTIONNAIRE ON SUPPLIER SUSTAINABILITY

Aim - Current Practice in Supplier Management at BAE Systems
- How does Supplier sustainability affect the capability contract?

Supplier Selection
SS.1. At what stage is supplier selection done?
SS.2. What is the procedure for supplier selection once the bid has been won?
SS.3 What tools are used in predicting/ measuring the supplier?
SS.4. Could I obtain copies/demonstration of the document/tools?
SS.5. What factors are taken into consideration in the selection process?
SS.6. Which people are involved in selection process?
SS.7. How much knowledge/information is available about supplier capability?
SS.8. What is the role of suppliers in maintaining capability contracts over the life cycle?
SS.9. What are the issues/challenges in predicting long-term sustainability?

Supplier Relationship
SR.1. How is the relationship with suppliers maintained over the lifecycle?
SR.2. How much information is released to supplier about the whole capability contract?
SR.3. How does the supplier's financial state affect the delivery of the capability?
SR.4. What are the market forces that affect suppliers?
SR.5. How are suppliers affected by these market forces?
SR.6. How does this impact your operations and the contract?

Supplier Measurement
SM.1. How are supplier performance measured? E.g. copy of spider diagram representation or copy of supplier questionnaire?
SM.2. What factors do you consider in measuring suppliers?
SM.3. How do you assess sustainability of a supplier when you award them a contract?
SM.4. How do you consider the sustainability of a contract and a portfolio of contract?

SM.5. What can cause the project to change suppliers during the contract life cycle?
SM.6. How does this supplier change affected the delivery of the capability?

Uncertainties and Risk
UR.1 What are the uncertainties involved in supplier sustainability prediction?
UR.2 What are the possible risks arising from the suppliers?
UR.3 How do you mitigate these risks?
UR.4 What financial burden does this pose to the manufacturer?

Affordability (15mins)

AFF.1 How can you monitor affordability yearly to check against the target?
AFF.2 Why is this important to you?
AFF.3 How do you apply EVM metrics to control the project?
AFF.4 Does asymmetry of information exist in this project?
AFF.5 Is this project going through a transition phase? How does that affect affordability?

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Appendix E - Budget Setting Questionnaire

PSS-Cost Project, Decision Engineering Centre, Cranfield University

5th Visit – 11th March 2010 to MoD de&s, Bristol

QUESTIONNAIRE ON BUDGET SETTING

Aim – To understand the process of budget setting in defence contracting.

1. How would do you carry out the Budget setting activity? Procedure, Flow chart, Budget templates available?
2. How would do you carry out the Budget setting activity? Procedure, Flow chart, Budget templates available?
3. What are the factors/elements that are considered in /factors that affect BS?
4. What is the nature of each factor in turn - dynamic or do they vary depending on time and other variables/ importance of each factor?
5. At what level is the Budget Set?
6. What is the BS cycle- when and how long?
7. Which employees are involved in the activity?
8. What is the level of interaction with other groups e.g. IPTs, Bidding Team, Project Team?
9. What is the level of information available to Budget Setting Team?
10. What are the current challenges facing the BS process?
11. How could this process be improved?
12. What would be the customer (MoD)'s confidence level about the budget? How certain is the budget (level of uncertainty)?
13. Do you monitor the budget spend yearly to check against the target? What step are taken to align actual spend with budget?
14. How much flexibility is allowed within the budget?
15. Are budgets renegotiated at any stage/ What can cause renegotiation?
16. How do you evaluate how realistic or accurate the budget is?
17. How do existing projects (esp. those with cost over runs) affect the BS process?

18. How can the BS process help the affordability assessment or how can affordability assessment help the BS process?
19. Is there any important information I have missed out?

Any further information that I need to know, but I've missed out?

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Appendix F - Review Meeting Questionnaire

PSS-Cost Project
Review Meeting, MoD, Abbey Wood, Bristol
Date: 20.01.2009

AFFORDABILITY VALIDATION QUESTIONNAIRE

Aim: To capture the view and suggestion for improvement of industrial partners on Affordability audit tool

Name of respondent…………………………………………………………………………

1**.** Please tick a suitable box for the following questions.
Is there a need for an affordability assessment tool for the defence and aerospace industries at the bidding stage?

☐ Yes ☐ No ☐ Not sure

2. Could you assess the usefulness of the presented tool to your company/project?

☐ Useful ☐ Not useful

(a) Please provide reasons for your answer
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(b) What improvement are needed to make the tool more useful to your project?
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3. (a) Please tick the appropriate boxes for each affordability factor listed below based on how relevant the tool is, for affordability assessment as well as the level of information available on each factor at the bidding stage

Affordability Factors	Relevance (Low 1 2 3 4 5 High)	Availability of information (Low 1 2 3 4 5 High)
(i) Customer Budget		
(ii) Whole Life Cycle Cost		
(iii) Political Climate		
(iv) Requirement		
(v) Legislation		
(xi) World Economic Climate		
(xii) Global Competition		
(xiii) Supply Chain		
(ix) Performance Related Measure		
(x) Quality		

3. (b) Please suggest any other relevant factors to be included in the audit

Affordability Factors	Relevance (Low 1 2 3 4 5 High)	Availability of information (Low 1 2 3 4 5 High)
(i)		
(ii)		
(iii)		

4 (a) Please put a score to elements (ITS) included in the audit based on their relevance.

Factors Elements	Relevance
(i) Information (ii) Tools (iii) Skills	1 2 3 4 5 Low ☐☐☐☐☐ High ☐☐☐☐☐ ☐☐☐☐☐

4 (b) Please list and score other elements which should be considered in the audit?

Factors Elements	Relevance
(i) (ii) (iii)	1 2 3 4 5 Low ☐☐☐☐☐ High ☐☐☐☐☐ ☐☐☐☐☐

5. Please tick the boxes which applies to the benefit of the presented tool to your project/company

	Benefits	Yes	No	Adequate
1	Assess the capability of ther bidding team to judge the customer's affordability of a project			
2	Highlight gaps in the availability of information required to measure affordability at different stages of the CADMID			

Please suggest other possible benefits
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Appendix G - ACAT Validation Session Questionnaire

PSS-Cost Project
Interview session, MoD, Abbey Wood, Bristol
Date: 3.02.2009

AFFORDABILITY VALIDATION QUESTIONNAIRE

Aim: To capture the customer's view of affordability factors and validation of Affordability audit tool

Name of respondent……………………………………………………………………

1. Affordability Factors

Other Factors and brief explanation

(a)………………………………………………………………………………………………
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(b)………………………………………………………………………………………………
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(c)………………………………………………………………………………………………
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(d)………………………………………………………………………………………………
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Affordability Factors	Weight (%) (1 – 12)	Availability of information
		1 2 3 4 5
(i)		Low ☐☐☐☐☐ High
(ii)		☐☐☐☐☐
(iii)		☐☐☐☐☐
(iv)		☐☐☐☐☐
(v)		☐☐☐☐☐
(xi)		☐☐☐☐☐
(xii)		☐☐☐☐☐
(xiii)		☐☐☐☐☐
(ix)		☐☐☐☐☐
(x)		☐☐☐☐☐

Affordability Elements

Questions
Information (I)
- (i) Do you have information from similar project
- (ii) Level of information on current project
- (iii) Ease of interpretation of the information

Tools (T)
- (i) Do you have available tool(s) from past project
- (ii) Do you have tools for this project
- (iii) The ease of use of the tool(s)

Skills (S)
- (i) Do you have a team/individual from similar project
- (ii) Do you have man power currently available
- (iii) Level of expertise

a. Affordability Index (AI)

$$= \frac{CATS}{WLCC}\left(1-\left(\sum_{i=1}^{n}\frac{(C_i - S_i)}{S_i}\right)\frac{1}{n}\right)$$

* $\frac{\text{WEC.9+L.11+Q.10 +SC.12+R.13+GC.9+PRM.12+PC.13+U.11}}{1000}$

Where:

CATS = what the Customer has Available to Spend
WLCC= Whole life cycle cost
Ci = Cost incurred in the ith year
Si = Expected spending ability of the customer for the ith year
i = the years where cost exceeds the expected spending ability of the customer in that year.
n = total number of years the cost has exceeded the spending

Please suggest other possible suggestions.
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Appendix H – DAAT Validation Session Questionnaire

PSS-Cost Project
Validation session, MoD, Abbey Wood, Bristol
Date: 20.07.2009

Affordability Questionnaire on Detailed Affordability Analysis Tool (DAAT)

Aim: To Validate Detailed Affordability Analysis Tool

Name of respondent…………………………………………………………………………………
Job Role
…………………………………………………………………………………………………..........
…………………………………………………………………………………………………..........

Relevance and content

Please tick a suitable box for the following questions.

2. Is there a need for an affordability assessment tool for the defence and aerospace contracts at the bidding stage?

☐ Yes ☐ No

3. What is the need(s) you would like this tool to meet within your projects?

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……………………………………………………………………………………………………
……………………………………………………………………………………………………

4. Are the affordability factors included within the tool sufficient to assess affordability?

☐ Yes ☐ No

If not, please provide new **factors and components** which are necessary for inclusion within the tool with explanation

Affordability Factors	Components
1.	
2.	
3.	

5. Are the components **under existing affordability factors** in the tool sufficient to assess affordability?

☐ Yes ☐ No

If not, please provide other **components** under existing factors which are necessary for inclusion within the tool with explanation

Affordability Factors	Components
1. Requirement	
2. Value for Money	
3. Environment	
4. Quality	
5. Supply chain	

6. Affordability component scores

(i) Low level of data (Score 1) - this refers to no or low data availability between customer and contractor.

(ii) Medium level of data (Score 3) - this refers to a situation where adequate data or information is provided.

(iii) High level of data (Score 5) - this refers to a situation where data or information provided is much more than adequate e.g. a detailed MDAL with a URD, including information about the supplier base.

Is the **scoring** mechanism for the factor components in the tool sufficient to assess affordability?

☐ Sufficient ☐ Improve

Please suggest possible improvements

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7. Affordability factor weighting

Affordability Factors	**Explanations**
Score 1	The affordability factor is unimportant in relation to the project
Score 2	The affordability factor has little importance in relation to the project
Score 3	The affordability factor has some importance in relation to the project
Score 4	The affordability factor has more importance in relation to the project
Score 5	The affordability factor is most important in relation to the project

Is the **weighting** mechanism for the factor components in the tool sufficient to assess affordability?

☐ Sufficient ☐ Improve

Please suggest possible improvements

………
………
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8. **Types of contracts** (Roy and Cheruvu, 2009)

- Incentive contracts
- Fixed-Price Contracts
- Cost-Reimbursement Contracts
- Indefinite-Delivery Contracts
- Time-and-Materials, Labour-Hour, and Letter Contracts
- Spiral development contracts

Are the **contract types** included in the tool representative of most defence contracts?

☐ Yes ☐ No

If not, please provide other **contract types** with explanation

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2.………
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3.………
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9. Types of Platform

- Air-Manned and Unmanned - Unmanned airborne systems, including UAVs, aerostats
- Consumer - Intended for commercial applications, typically home or business use
- Ground-Fixed - Any immobile terrestrial non-commercial product, including antenna dishes, buildings, bridges. Fixed land-based systems
- Ground-Mobile - Mobile land-based systems, including trucks and trains
- Industrial - Intended for use in an industrial environment
- None - No selection of a Platform knowledge base
- Sea - Surface sea-based systems, including naval and commercial ships
- Space-Manned and Unmanned – Manned and unmanned space systems, including telecommunications and remote sensing satellites, and exploratory interplanetary vehicles.
- Submersible (Submersible sea-based systems, including military submarines and commercial submersibles)

Are the **platform types** included in the tool representative of most defence contracts?

☐ Yes ☐ No

If not, please provide other **platform types** with explanation

1.………
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2.………
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3.………
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10. **Affordability Prediction (output)**

Please comment on the presentation of the output of the prediction (e.g. Bar charts, line charts, spider diagrams, Figures and Tables

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Ease of Use

1. Please provide comments about the tool in terms of:

(i) Layout…………………………………………………………………………………………………
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(ii) clarity…………………………………………………………………………………………………
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(iii) use of colour…………………………………………………………………………………………
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(iv) ease of navigation………………………………………………………………………………
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2. How might the tool be further improved?

(i) Layout…………………………………………………………………………………………………
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(ii) clarity…………………………………………………………………………………………………
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(iii) use of colour……………………………………………………………………………………
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(iv) ease of navigation……………………………………………………………………………
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Affordability factors and components

Qualitative factors

a. **Requirement** - This refers to the technical and functionality prerequisite demanded by the customer which forms the basis of the contract.

(a) Interoperability of systems and equipment - This refers to the ability of software and hardware on multiple machines from multiple vendors to communicate.

(b) Liability allocation - This refers to the level of clarity in the definition of responsibility and risk (for the activities and operations) in the proposed solution.

(c) Schedule - This refers to the plan for performing tasks and work packages, specifying the resources required and allotted time for each part of the solution in order to deliver to customer satisfaction.

(d) Performance, cost and time targets- There is a need to identify trade offs between performance, time and cost within the proposed solution.

(e) Flexibility - This refers to the ability of the proposed solution to adapt to changes in customer requirement.

2. Environment - This refers to the responsibility of firm towards the environment to ensure that activities and operations are environmentally friendly to ensure sustainability.

(a) Plan for disposal - This refers to the long-term plan for the demolition or remanufacture the end of the life of the equipment.

(b) Sustainability initiative - This refers to the developing initiatives or schemes to encorage the use of materials and processes which are environmentally friendly.

3. Value For Money (VFM) - This means that the proposed solution should provide value to the customer given the level of investment made.

(a) Efficiency - This refers to the ability to fulfil customer requirement while reducing resource usage

(b) Effectiveness - This refers to the capability and competence to fulfil the customer requirement.

(c) Economy -This refers to ability to deliver customer requirement whilst achieving savings in cost, time or effort.

(d) Performance-Related measure - This refers to ability of the proposed system to have desired performance upon delivery

(e) Availability - This refers to the degree to which a system suffers degradation or interruption in its service to the customer as a consequence of failures of one or more of its parts. Also availability at the project level

(f) Technology innovation - This refers to the technological development to achieve customer satisfaction in the proposed solution.

4. Supply chain - This refers to the interaction between prime and sub-contractors who are partnered to deliver the customer requirement.

(a) Type of contractor - This aims to determine whether the contract was being awarded to a Prime contractor or individual suppliers.

(b) Certification status - This aims to establish whether that the certification status and the maturity of the contractor's quality management system is satisfactory to the customer.

(c) Contractor relationship - This aims to establish the level of relationship between the customer and the contractor.

(d) Scope of the supply chain - This aims to determine length of the supply chain in terms of the percentage of major contractors are domestic or foreign.

(e) Financial capability -This aims to determine whether the contractor's financial capability is satisfactory.

(f) Price - This aims to determine whether the contractor's price is satisfactory?

5. Quality - This refers to the totality of features and characteristics of a product or service in the propsed solution that bear on its ability to satisfy customer needs.

(a) Innovation - This refers to the ability of the solution provider to design an innovative offering that is valuable to the customer.

(b) Regulations and Standards -This refers to UK, European or International regulations and agreements that contractors need to satisfy and those that affect the proposed solution (e.g. AS9100).

(c) Requirement delivery - This aims to establish whether the proposed solution would be able to satisfy customer requirement e.g. (fitness for purpose and getting it right the first time).

Quantitative factors

1. Whole life cycle cost - This refers to estimate of acquisition and operational cost involved in a project is usually presented prior to contracting, across the project life cycle.

2. Customer Budget - This refers to the financial capability of the customer to procure and support the project over its lifecycle.

Appendix I - Affordability Model Validation Questionnaire

PSS-Cost Project Validation Meeting,

Rolls Royce, Bristol on 06.05.2010

Aim: To validate the methodology and content of the Affordability System and obtain suggestion for improvement

Respondent:

LOGIC - Framework

1. How logical is the affordability assessment framework presented in this system?

1	2	3	4	5	6	7	8	9	10
Totally Invalid	Valid with major deficiencies				Valid with minor deficiencies				Totally Valid

Please describe deficiencies if any

....

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Possible suggestion for improvement

....

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2. Is the framework suitable for affordability assessment the bidding stage from the three perspectives?

1	2	3	4	5	6	7	8	9	10
Totally Unsuitable	Suitable with major deficiencies				Suitable with minor deficiencies				Totally Unsuitable

If unsuitable, please describe why.

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Possible suggestion for improvement

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………...

3. Is the system applicable at other stages of the CADMID cycle?

………...
………...
………...

GENERALISABILITY

4. How generalisable is the system within the defence sector?

………..………………………
……..

5. Could it be applicable for civil aerospace?

………..………………………
…….

6. Could it be applicable for other sectors with long-term projects, e.g. construction or nuclear?

………
………

RESPONSIBILITY

7. What organisation should use the system, supplier organisation or customer organisation or both? Why?

………..………………………
……..
………..

8. What team or department should have ownership or responsibility of the system within the company?

………..………………………
……..

9. How could the team or department owning the system maintain it?

………..………………………
……..

BENEFITS OF THE SYSTEM TO INDUSTRIAL PRACTICE

10. How would the system benefit the bidding team?

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……..

11. How would the system improve affordability, profitability and sustainability assessment?

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USABILITY OF THE SYSTEM

12. (a) What are the strongest features of the system?

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(b) What are the weakest features of the system?

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13. (a) How appropriate are the terminologies used within the system?

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(b) Please suggest possible improvement

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14. (a) How appropriate are the results presentation within the system?

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(b) Please suggest possible improvement

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15. Please provide comments and suggest improvement about the system in terms of:

(v) **Layout**...

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(vi) **clarity**...

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(vii) **use of colour**……………………………………………………………………………
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(viii) **ease of navigation**…………………………………………………………………
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16. Is the system flexible enough to be applied with different levels of information availability?

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……..

17. (a) Are the customer affordability qualitative and quantitative factors provided in the system sufficient to assess customer affordability?

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……..

(b) Are the supplier sustainability qualitative and quantitative factors provided in the system sufficient to assess supplier sustainability?

………..………………………
……..
……..

(c)Are the manufacturer profitability quantitative elements provided in the system sufficient to assess manufacturer profitability?

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……..

18. (a) Are the customer affordability improvement actions provided in the system sufficient to improve customer affordability?

………..………………………
……..
……..

**(b) Are the supplier sustainability improvement actions provided in the system
sufficient to improve supplier sustainability?**

....

....

....

(c) Could you please suggest profitability improvement actions to improve manufacturer profitability?

....

....

....

19. Is the basis (AACE uncertainty range) for applying uncertainty in the quantitative figures (WLCC, CATS, Total profit) suitable to achieve the objective of the system?

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20. Is the crystal ball software used in applying uncertainty in the quantitative figures suitable to achieve the objective of the system?

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21. Please comment on the duration of time it takes to populate the system for a case study?

....

....

LIMITATIONS OF THE SYSTEM

22. What are the potential limitations and challenges in using system?

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23. What are the potential limitations and challenges in implementing the system in a company?

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24. How could be background of the people filling the system affect the output?

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Appendix J – Mathematical parameters of the assessment process

The process of conducting the affordability assessment has been described above and the mathematical parameters are presented in this section. An overview of all the mathematical parameters is presented in Figure (5-8)

The parameters are described below as well as the worksheet where they have been applied.

(1) Background Macro VBA Code - Home Sheet

This VBA code asks the user if a new project is being assessed through a message box. If the project is new, then the storage sheet would be activated to store the results of the overall affordability audit of information capability, customer affordability and manufacturer profitability assessment otherwise the assessment results would not be stored. This is the decision box below.

```
Sub background()

Dim new_project As Integer

new_project = MsgBox("Do you want to start a new project?", vbYesNo)

If new_project = 6 Then
    Call goto_a_specific_sheet_and_cell("Afordability&Prfitability Store", "A3")
    ActiveCell.EntireRow.Copy
    While ActiveCell.Value <> "" 'find empty row
        ActiveCell.Offset(1, 0).Activate
    Wend


    ActiveCell.PasteSpecial xlPasteValues
End If






Call goto_a_specific_sheet_and_cell("Project Information", "A1")
```

Figure K-1: VBA Code

(2) Data validation – Project information Sheet

The Data validation facility is used on cells D11, D17 and D21 to provide a list of options for the user to choose from in a drop-down box within in each cell.

(3) Fraction of violation - Assessment Quantitative (AI) Sheet

(4) (D9-D10)/D10 - This formula is applied to calculate the difference between the cost and budget value as a fraction of the budget for each individual year.

(5) Conditional Formatting (1) - Assessment Quantitative (AI) Sheet

Conditional Formatting is applied to the cell containing the fraction of violation as described in the below.

Colour	Value
Green	< 0
Amber	= 0
Red	> 0

(6) IF Function - Assessment Quantitative (AI) Sheet

IF(D11>0,1,0) - This formula is applied to return the value 1 if the specified cell (containing the fraction of violation) value is >0 or return 0 if the cell value is <0. This is done in order to calculate the 'n' within the Affordability Index (AI).

(7) Conditional Formatting (2) - Assessment Quantitative (AI) Sheet

Conditional Formatting is applied to the cell containing the AI as described in the below. This is done to show the degree of affordability based on the index.

Colour	Value
Green	> 1
Amber	Between 0.5 &1
Red	< 0.5

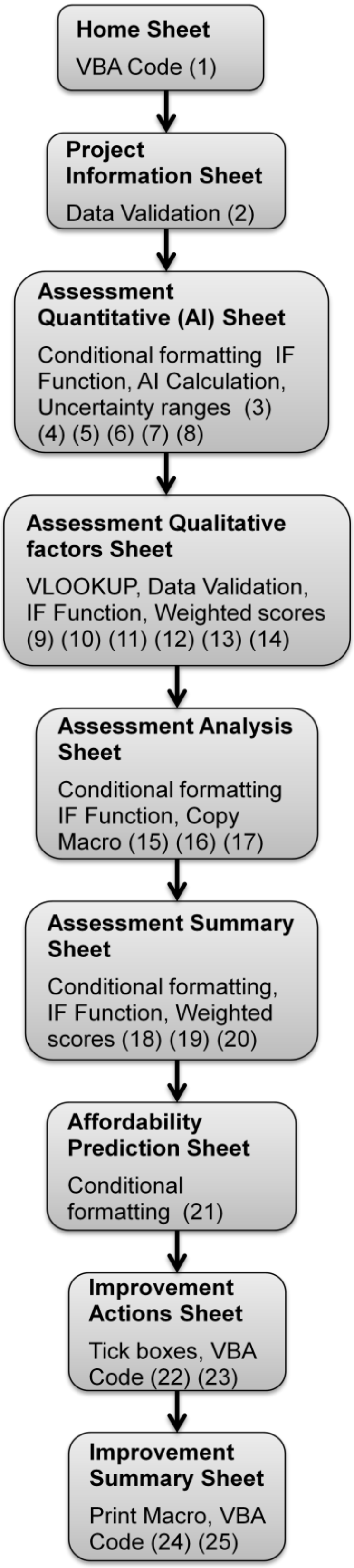


Figure K-1: Mathematical formula employed in the affordability assessment process

(8) Affordability Index (AI) calculation - Assessment Quantitative (AI) Sheet

$$AI = \frac{CATS}{WLCC}\left(1 - \left(\sum_{i=1}^{n}\frac{(C_i - S_i)}{S_i}\right) * \frac{1}{n}\right)$$

where Ci = Cost incurred in the ith year
Si = Expected spending ability of the customer for the ith year
i = the years where cost exceeds the expected spending ability of the customer in that year.

n = total number of years the cost has exceeded the spending
CATS = customer budget
WLCC = Whole life cycle cost

(I)CATS > 0
(ii) Where Budget is 0, replace with 1
(iii) If Sum of WLCC < Budget or Cost = Budget, then only apply CATS/WLCC
(iv) If Sum of WLCC > Budget, then apply full AI.

H28*(1-(D11+H11)*(1/I28)) - This formula is applied to calculate the AI based on the variables explained above.

(9) VLOOK UP - Assessment Qualitative factors Sheet

VLOOKUP(F6,'Assessment User Guide'!A249:B251,2,FALSE) - This formula is applied to return a value by looking up the value in the next column of the specified worksheet, column and range. This is designed to provide a general explanation of each score for the customer affordability assessment.

(10) Data validation - Assessment Qualitative factors Sheet

The Data validation facility is used in most cells to provide a list of scores and weights for the user to choose in each cell

(11) Comment - Assessment Qualitative factors Sheet

Comments are inserted into cells within the 'score' column in order to provide specific explanation for each customer affordability factor component.

(12) IF Function - Assessment Qualitative factors Sheet

IF (M11>=3,"High importance", "Low importance") - This formula is applied to return the value High importance if the specified cell (weight) value is >=3, and return low importance of otherwise.

(13) Average - Assessment Qualitative factors Sheet

AVERAGE(K27:K28) - This formula is applied to weights and scores customer affordability factor components that generate two results in order to average them and return one value in the analysis and summary sheet.

(14) Product - Assessment Qualitative factors Sheet

=C12*D12- This formula is applied to calculate the weighted score by multiplying the weight and score.

(15) Conditional Formatting - Assessment Analysis Sheet

The traffic light system colours are applied to cells containing the weighted scores for each year using the formatting shown in the Table below.

Formatting	Values
Green	=1,<12
Amber	>=12, <16
Red	>=16,=<25

(16) IF Function - Assessment Analysis Sheet

IF(C43=TRUE, 'Low risk', 'High risk') - This formula is applied to return the value 'Low risk' or 'High risk' in many cells depending on numeric or character values specified in each cell. Conditional formatting is also applied based on various conditions.

High risk
Low risk

TRUE value varies e.g. TRUE can be 'individual suppliers', 'Long term' relationship etc.

(17) Copy Data Macro - Assessment Analysis Sheet

This macro is assigned to the **'Copy Assessment across life cycle'** button to copy the weighted scores from Year 1 to the remaining years within the assessment.

(18) Round Average Weighted scores- Assessment summary Sheet

ROUND(('Assessment Analysis'!E19+'Assessment Analysis'!E20+'Assessment Analysis'!E21)/3,0) – This formula generates an average of the weighted scores for each customer affordability factor for each year.

(19) Conditional Formatting - Assessment summary Sheet

Conditional formatting is applied as shown in item 15

(20) IF Function - Assessment summary Sheet

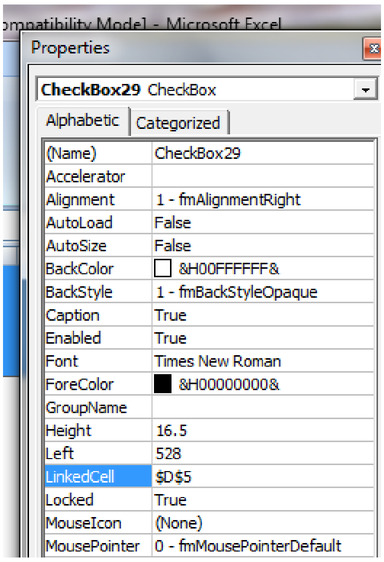
If Function is applied as shown in item 16

(21) Conditional Formatting - Affordability Prediction Sheet

Conditional formatting is applied as shown in item 6

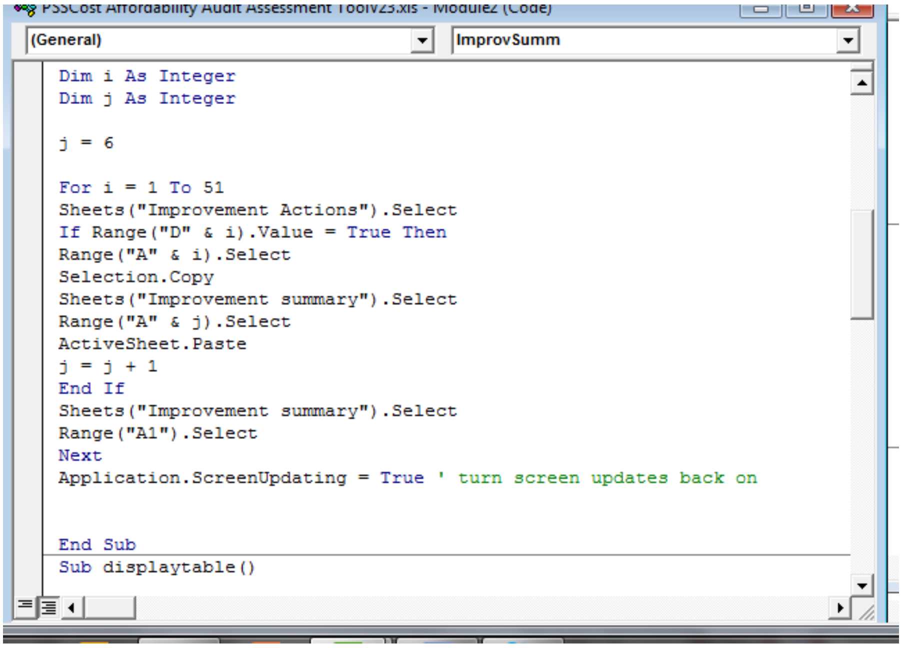
(22) Tick boxes - Improvement Actions Sheet

When the user ticks the box a 'True' or 'False' response is displayed in the cell linked to it. This helps to select specific improvement actions which are needed to improve the customer affordability of a project.



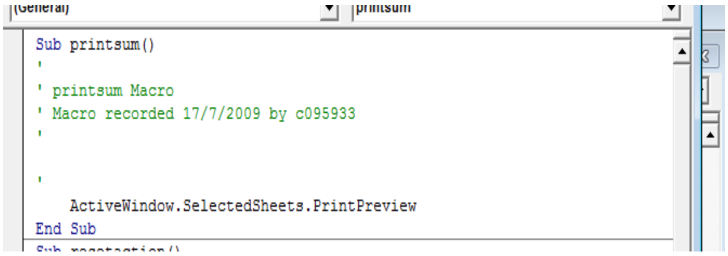
(23) VBA Code - Improvement Actions Sheet

The VBA code attached to the 'CA Improvement Summary' button searches the cells within the improvement actions sheet and selects the cells to the left of the boxes which have been ticked to yield 'True' response and copies them unto the next sheet. The 'screen update' enables it to look through each cell one after the other and paste them accordingly on the next sheet.



(24) Print Macro- Improvement summary Sheet

This macro is attached to the 'Print' button and it captures the selected customer affordability improvement actions to generate a report for the user to preview, ready for printing.



(25) VBA Code - Improvement summary Sheet

The VBA code attached to the 'Reset' button reminds the user to ensure that the selected improvement actions have been printed prior to clearing the sheet.

```
End Sub
Sub resetCAaction()
'
' resetCAaction Macro
' Macro recorded 17/7/2009 by c095933
Dim Response As VbMsgBoxResult
Response = MsgBox("Do you want to clear current actions?" & vbCr & "Please ensure you have printed a summary of
If Response = vbYes Then Range("A5:D135").Select
    Selection.ClearContents
    'Sheets("Improvement Actions").Select
    Range("A5").Select
End Sub
```

All these parameters were applied in implementing the customer affordability system using Microsoft Excel to generate both qualitative and quantitative results of customer affordability as well as providing suggestions for improvement.

Appendix K – Supplier Sustainability Measures

Boston Matrix Categories

Four categories used in the matrix are explained below.

- *Question Marks* are also referred to as Problem Child(ren) which require low market share and capable of yielding high market growth. They may not be generating much revenue currently, but there is a potential that the market for them would grow and much revenue would be generated in the future, turning into stars or cash cows. The opportunity should be carefully considered.

  In the context of sustainability performance measurement, MAs in this category are very feasible with available, data or evidence so the PMs can be easily employed, however they are not important presently. The organisation would need to consider the **opportunity of utilising the PMs generated from these MAs to demonstrate to stakeholders that it is doing above and beyond what was required by the DOs or strategic pledges**. Potentially they could become important in the future; hence it is worth the effort of collection evidence to demonstrate the PMs in this category.
- *Stars* require high market share and they yield high market growth. The organisation is well established in the market and it is experiencing growth. Stars are yielding sufficient revenue for the business so the next step would be to maintain market share and exploit other prospects to generate increased revenue.

  In the context of performance measurement, MAs in this category are highly important and there is sufficient evidence to use them to demonstrate the achievement of DOs and strategic pledges. The PMs generated in this category are highly important and must be maintained and monitored continually to compare performance overtime.
- *Dogs* require low market share and they yield low market growth. This means the company is not competitive in the market and much effort and investment would be required to compete. Growth in the market would be slow therefore the company needs to decide if it is worth any extra investment or effort to improve the dogs.

In performance measurement terms, the MAs in this area have low importance and they are not feasible. These MAs are not important and less attention should be placed on them unless their important scores increase. It may not be necessary to generate PMs for MAs in this category

- *Cash Cows* require high market share, but yield low market growth presently. The organisation is competitive within the market, but the market is not growing. Though future opportunities are limited, the organisation could consider how to exploit the possible opportunities since it is well established in the area.

  In performance measurement terms, MAs in this category are very important, but there is little data or evidence to employ the PMs under the MAs. Much effort must be employed to improve the feasibility of the MAs on this category as they are related to the DOs and strategic pledges.

MAs with the highest feasibility and importance scores (cash cows, stars and question marks) could be selected in order to derive PM to demonstrate the achievement of DOs and strategic pledges. However priority was given to the stars and cash cows which are most important. These were carried forward to the fourth step to generate PMs as presented in Figure (3) (MA1, MA2, MA3, MA4, and MA7).

Supplier Sustainability Measure generation process

The four-step process applied to generate measures for supplier sustainability assessment in Chapter 6 is explained below.

Step 1 – Understanding the lag indicator

Table M-1: Lag indicator solution model

Sustainability Dimension model		**Opportunities for the measurement solution**
Sustainability Dimension		Sustainability dimension to be measured
Entities (outcomes)		How the dimension can affect a project
Impact on the Project	Competitive Indicator	A key performance indicator (e.g. time, performance or cost)
	Department	The department associated with the project
	How? Attribute	How the project delivery is affected by the sustainability dimension.
MA		What should be done in order to monitor the performance of supplier in the project delivery?

Step 2 – Identify different measurements for key MA

Table M-A: MA model

MA model	MA analysis
MA	What should be done in order to monitor the performance of supplier in the project delivery?
Competitive Indicator	A specific KPI factor
Activity description	Activity to carry out in order to measure supplier performance.
Inputs	Inputs required to perform the measurement
Agents available	Personnel involved in the measurement
Outputs	Outputs expected with the measurement
Overlapping	If there are other projects being implemented in the company that can affect the MA
Feasibility score	How feasible is a concrete measurable action (0-10)
Importance score	The importance of the MA according to the department's need (0-10)

Step 3 – Prioritisation and selection of the major MA

Step 2 is repeated for different MAs to select the most important MA in deriving the PMs based on the feasibility and importance scores.

Step 4 – PM model

Finally, the PM model is then developed to generate the PM for KPA.

Table M-3: PM Model

PM model	KPI description
PM	Measure of performance based on sustainability factor
MA	What should be done in order to monitor the performance of supplier in the project delivery.
Competitive Indicator	A key performance indicator (e.g. time, performance or cost)
Inputs	Inputs required to perform the measurement
Activity description	Activity to carry out in order to measure supplier performance.
Agents available	Personnel involved in the measurement
Outputs	Output expected with the measurement

Appendix L – Supplier Sustainability Detailed Scores

Table N-1: Delivery & Quality Scores

Rate of Conformance over time	
Score	Definition
1	High QFD score
3	Medium QFD score
5	Low QFD score
Rate of On-time Delivery over time (Quantity)	
Score	Definition
1	>99%-100% on-time delivery
3	>95%-<99% on-time delivery
5	90%-<95% on-time delivery
Agility to respond to customer requirement change over time	
Score	Definition
1	responds to short-term changes quickly and maintain quality
3	responds to short-term changes gradually and maintain quality
5	responds to short-term changes slowly
Rate of Delivery lead time over time (Time)	
Score	Definition
1	Same as agreed lead-time (days)
3	Close to agreed lead-time (days)
5	Strongly deviates agreed lead-time (days)
Rate of Defects over time	
Score	Definition
1	Low defect rate against industry average
3	Medium defect rate against industry average
5	High defect rate against industry average
Rate of Stock out over time	
Score	Definition
1	=agreed stock level
3	>agreed stock level
5	<agreed stock level

Table N-2: Management (People & Resources) scores

Rate of Return on Asset	
Score	Definition
1	High ratio compared to industry average
3	Medium ratio compared to industry average
5	Low ratio compared to industry average
Rate of Staff Turnover	
Score	Definition
1	Low turnover against industry average
3	Medium turnover against industry average
5	High turnover against industry average
Adaptability to market changes	
Score	Definition
1	responds to structural market changes quickly and maintain quality
3	responds to structural market changes gradually and maintain quality
5	responds to structural market changes slowly
Rate of Human Resource Productivity	
Score	Definition
1	High score against target
3	Medium score against target
5	Low score against target
Rate of Inventory turnover	
Score	Definition
1	Ideal turnover against industry average
3	High turnover against industry average
5	Low turnover against industry average
Level of Investment Capability	
Score	Definition
1	>1 Liquidity ratio
3	=1 Liquidity ratio
5	<1 Liquidity ratio
Level of Quality of training of employees	
Score	Definition
1	Highly trained with chattered status and equivalent based on industry standards
3	Ideal training level with desired qualification based on industry standards
5	Poor training level with low qualification based on industry standards

Table N-3: Cost scores

Variation in Cost overtime	
Score	Definition
1	Same as industry average
3	Close to industry average
5	Strongly deviates from industry average

Table N-4: Stakeholders scores

Level of Organisational Flexibility	
Score	Definition
1	High degree of flexibility
3	Medium degree of flexibility
5	Low degree of flexibility
Variation in Market Position	
Score	Definition
1	Market Leader
3	Market Follower
5	Poor- Performer
Rate of Relationship Management	
Score	Definition
1	High Balanced score card output
3	Medium Balanced score card output
5	Low Balanced score card output
Rate of Innovation Capability	
Score	Definition
1	Highly innovative beyond customers expectation and investment in research and development
3	Fairly innovative beyond customers expectation without investment in research and development
5	Lacks innovation beyond customers expectation and without investment in research and development

Table N-5: Environment scores

Rate of compliance with environmental quality standards	
Score	Definition
1	>=99.5% compliance
3	>=95% compliance
5	>=90% compliance
Rate of waste & emission reduction	
Score	Definition
1	High level of effort – Low emission
3	Medium level of effort – average level of emission
5	Poor- Performer– High emission
Rate of Responsiveness to change in legislation	
Score	Definition
1	contractor is quick to comply with new legislation
3	contractor gradually complies with new legislation
5	contractor is very slow to comply with new legislation

Appendix M – Supplier Sustainability Improvement actions

(1) Quality & Delivery (1.1 Measure of conformance, 1.2 On time Delivery, 1.3 Agility, 1.4 Delivery lead time, 1.5 Defects, 1.6 Stock out).

Table O-1: Improvement actions - Quality & Delivery

1.1a Ensure that customer requirement are clearly captured by the supplier
1.1b Work closely with customer to design the requirement
1.1c Engage the design/delivery team to ensure that technical aspects of solution is designed to meet customer requirement
1.2a Ensure that adequate materials and labour is available to deliver customer requirement within the terms of the contract
1.2b Ensure that a realistic schedule is designed to fully meet customer requirement
1.3a Ensure that adequate materials and labour is available to deliver customer requirement within the terms of the contract
1.3b Ensure that a realistic schedule is designed to fully meet customer requirement on time
1.4a Implement an effective Enterprise Resource Planning (ERP) system that calculates Economic Order Quantity and presents the result in a clear manner so employees can respond appropriately.
1.4b Ensure that adequate materials and labour is available to maintain stock level agreed with the customer
1.5a Consider implementing quality management techniques such as Total Quality Management and Six Sigma to reduce defects
1.5b Invest in employee training in order to achieve best results from the implementation of quality management techniques.
1.6a Develop collaborative relationship with other industrial partners and promote a smooth flow of information as much as possible
1.6b Draw up contingency plans and develop crisis management teams
1.6c Consider holding appropriate level of inventory buffer of inexpensive but key components
1.6d Maintain good cash flow/financial position to provide the investment which may be required to respond to short-term market changes

(2) Management (People & Resources) (2.1 Return on Asset, 2.2 Staff Turnover, 2.3 Adaptability, 2.4 Human Resource Productivity, 2.5 Inventory turnover, 2.6 Investment Capability, 2.7 Quality of training of employees).

Table O-2: Improvement actions - Management (People & Resources)

2.1a Invest in quality training and development of employees in order to up-skill the workforce
2.1b Provide adequate information and tools to enable employees deliver the optimum output
2.2a Consider motivating employees by offering better remuneration packages and appreciating employee contribution
2.2b Ensure that employees get a work-life balance
2.2c Ensure that the management encourages feedback from employee (including employees planning to leave)
2.2d Identify and invest in activities that deliver employee satisfaction
2.3a Implement cost (waste) reduction techniques like Lean principles in order to reduce expenses and increase profitability
2.3b Explore and employ better investment solutions to increase return on assets
2.3c Investigate company processes to identify major problems using techniques such as Root Cause Analysis (RCA) and plan improvement efforts to improve return on investment.
2.4a Implement cost (waste) reduction techniques like Just in Time (JIT), Kanban and lean principles in a way that best suits the company in order to reduce excess inventory
2.4b Investigate company processes to identify major problems using techniques such as RCA and plan improvement efforts to improve inventory turnover.
2.4c Employ suitable marketing principles to increase sales/revenue
2.5a Negotiate longer payment terms with vendors whenever possible to improve the cash circulation
2.5b Divert resources from less profitable products to products yielding higher returns
2.5c Review profitability on various products and services and identify problems or opportunities to increase profitability
2.5d Investigate company processes to identify major problems using techniques such as Root Cause Analysis (RCA) or other process improvement method and plan improvement efforts to improve investment capability
2.6a Improve employee training by peer-mentoring within the organisation
2.6b Identify employee's strengths and weaknesses in order to provide strategic training
2.6c Recognise training as an investment and establish measurable returns in order to justify the investment with senior management
2.6d Provide avenue for employees to apply the ideas and skills during training (learn by doing) where applicable
2.6e Consult companies who are specialist in offering quality training with the flexibility to adapt to the company's need
2.7a Implement an effective system of predicting future demand and supply e.g. suitable ERP Tools which presents output in a clear manner
2.7b Develop a robust decision making process which includes the output from forecasting tools and current data from test markets in order to overcome possible misalignments or errors in forecasts
2.7c Invest in research and development to keep abreast of technology evolution and how it would affect the business

3. Cost (3.1 Cost to Market Value).

Table O-3: Improvement actions - Cost

3.1a Ask for justification of supplier's price and perform audits where applicable
3.1b Identify means of offering extra value to the customer, within the price
3.1c Employ cost reduction techniques like lean principles in order to reduce cost and improve competitiveness

4. Stakeholders (4.1 Organisational Flexibility, 4.2 Market Position, 4.3 Relationship Management, 4.4 Innovation Capability).

Table O-4: Improvement actions – Stakeholders

4.1a Invest in quality training and development of employees in order to improve their capability to innovate
4.1b Provide adequate information and tools as well as opportunity to encourage employees to innovate
4.1c Ensure that organisational culture and structure encourages employee innovation
4.1d Encourage knowledge-sharing between individuals and teams within the organisation
4.2a Ensure that organisational culture and structure allows the company to adapt to changing customer demand at individual (managers) and corporate level.
4.2b Encourage a workforce that is fairly responsive to change building experiences from the past
4.3a Investigate company processes to identify major problems using techniques such as RCA, Strength, Weakness, Opportunities and Threats (SWOT) analysis and Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis and plan improvement efforts to improve market position.
4.3b Invest in specific technology and innovation management activities which combines external and internal technology audit to improve firm's performance and market position.
4.3c Investigate best practice principles which have been successful within the industry and apply them to suit specific needs within the organisation
4.4a Improve communication and information flow between the company and stakeholders.
4.4b. Investigate best practice principles which have been successful within the industry and apply them to suit specific needs within the organisation.
4.4c Invest in quality training and development of employees in order to improve their relationship management capability.

5. Quality (5.1 Quality standards, 5.2 Degree of waste reduction, 5.3 Responsiveness to new legislation).

Table O-5: Improvement actions – Quality

5. Environment
5.1a Ensure that company processes and their output are complaint with current environmental standards
5.1b Consult the project team and/or customer to identify ways of operating to meet environmental quality standards
5.2a Set up a process to provide company with updates on environmental quality standards
5.2b Ensure enough flexibility to adapt to environmental quality standards in good time
5.3a Investigate company processes to identify problems areas using techniques such as RCA and plan improvement efforts to reduce waste and emission
5.3b Investigate best practice principles which have been successful within the industry and apply them to suit specific needs within the organisation.

The Root Cause Analysis (RCA) presents techniques that used to investigate and resolve reliability-related problems affecting equipment performance such as Fault Tree Analysis, Ishikawa (Fist-bone) diagram etc.

Strengths, Weakness, Opportunities and Threats (SWOT) analysis is a simple systematic method of evaluating an organisation's strategic position to identify its strengths and weaknesses against its opportunities and threats in the commercial environment.

The mathematical parameters employed in the sustainability assessment process are presented in Figure (O-6).

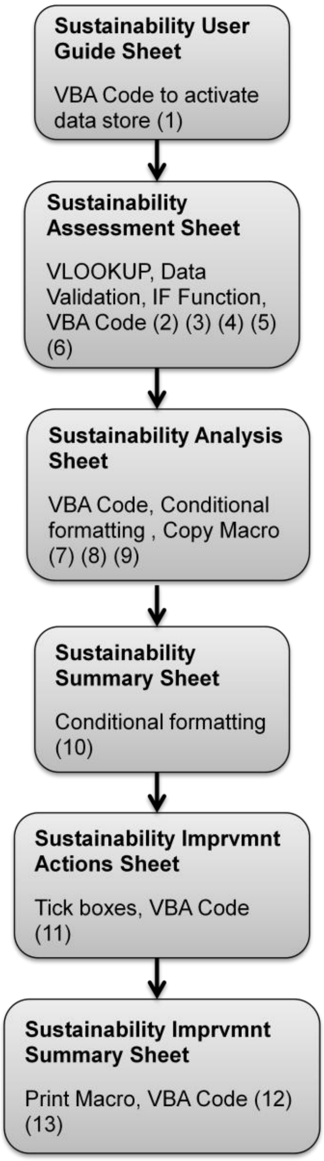


Figure O-6: Mathematical parameters employed in the profitability assessment process

Appendix N – Affordability Management PMs Examples

Explanation

Step 1 – Understanding the lag indicator

Table P-1: Key Performance Area solution model

KPA model		Opportunities for the measurement solution
KPA		The lag indicator used to assess the performance of the project
Impact on the Project delivery	Competitive Dimension	The Lead indicator affecting the KPA
	Department	The department associated with the project
	How? Attribute	How the project delivery is affected if the KPA is not achieved.
MA		What should be done in order to monitor the performance of the project delivery.

Step 2 – Identify different measurements for key MA

Table P-2: Measurable Actions model

MA model	Measurement action analysis
Measurable action	What should be done in order to monitor the performance of the project delivery.
Competitive Dimension	The Lead indicator affecting the KPA
Activity description	Activity to carry out in order to measure project affordability
Inputs	Inputs required to perform the measurement
Agents available	Personnel involved in the measurement
Outputs	Outputs expected from the measurement
Measurable options	The possibilities of performing the measure (possible measurement options)
Overlapping	If there are other projects being implemented in the company that can affect the MA
Feasibility score	How feasible is a concrete measurable action (0-10)
Importance score	The importance of the MA according to the department's need (0-10)

Step 3 – Prioritisation and selection of the major MA

Step 2 is repeated for different MAs to select the most important MA in deriving the PMs based on the feasibility and importance scores.

Step 4 – PM model

Table P-3: Performance Measures Model

PM model	KPI description
PM	PI to measure project performance based on MA
MA	What should be done in order to monitor the performance of the project delivery.
Competitive indicator	The Lead indicator affecting the KPA
Inputs	Inputs required to perform the measurement
Activity description	Activity to carry out in order to measure project affordability.
Agents available	Personnel involved in the measurement
Outputs	Output expected from the measurement

A worked example which covers all the steps explained above is shown below.

Example 1

Step 1 – Understanding the lag indicator

The lag indicator is managing major supplier to keep additional supply chain cost within 90% confidence level.

Table P-4: Lag indicator solution model

KPA model		Opportunities for the measurement solution
Lag indicator		Equipment to achieve desired performance
Impact on the Project delivery	Competitive Dimension	Performance
	Department	De&s
	How? Attribute	Faults and failures when equipment is tested to assess performance
MA		Detection and correction of faults and reduction of failure to improve equipment performance in order to meet user requirement

Step 2 – Identify different measurements for key MA

Table P-5: MA model

MA model	Measurement action analysis
MA	Detection and correction of faults and reduction of failure to improve equipment performance in order to meet user requirement
Competitive Dimension	Performance
Activity description	Measurement of the improvement of equipment performance as a result of corrections made during testing
Inputs	1. Investigate the performance of system components 2. Identification and correction of faults and failures within system 3. Equipment test result to ensure desired features and functionality are available
Agents available	De&s: project management team, engineering team and solution provider: project management team, engineering team.
Outputs	To measure equipment performance in order to deliver capability
Measurable options	The possibilities to perform this measure are: Performance measurement criteria National and international standards of performance
Overlapping	NO
Feasibility score	9
Importance score	10

Step 3 – Prioritisation and selection of the major MA

Step 2 is repeated for different MAs to select the most important MA in deriving the PMs based on the feasibility and importance scores.

Step 4 – PM model

Finally, the PM model is then developed to generate the PM for KPA.

Table P-6: PM Model

PM model	KPI description
PM	Mean Time Between Failure (MTBF) = $\frac{\sum(\text{downtime}-\text{uptime})}{\text{Number of failures}}$
MA	Detection and correction of faults and reduction of failure to improve equipment performance in order to meet user requirement
Competitive Dimension	Performance
Inputs	1. Investigate the performance of system components 2. Identification and correction of faults and failures within system 3. Equipment test result to ensure desired features and functionality are available
Activity description	Measurement of the improvement of equipment performance as a result of corrections made during testing
Agents available	De&s: project management team, engineering team and solution provider: project management team, engineering team.
Outputs	To measure equipment performance in order to deliver capability

The aim of this measure is to ascertain that a system/equipment can meet the performance requirement within a project. It is necessary that components making up the equipment comply with relevant national and international standards in other to receive approval. The equipment performance can be ascertained by running performance and reliability tests to ensure that the equipment uptime is at the level desired by the customer. If the equipment does not deliver the functionality and performance desired by the customer, the customer is less willing to pay for it. This could lead to the end of a project if the system cannot be corrected or redesigned to meet the project requirement as it would not be affordable.
This measure would help project engineering managers detect faults and failures in component and equipment and take corrective measures at the early stages of the design and manufacture in order to ensure that the final output meets performance requirement.

Example 3

Step 1 – Understanding the lag indicator

The lag indicator is to deliver the project within the specified period.

Table P-7: Lag indicator solution model

KPA model		**Opportunities for the measurement solution**
Lag indicator		Managing major supplier to keep additional cost within 90% confidence
Impact on the Project delivery	Competitive Indicator	Cost
	Department	De&s
	How? Attribute	Failure to manage supplier could result in a delay in project delivery if supplier runs into financial difficulty or goes bankrupt
MA		Strategic partnering with supplier to ensure demand is planned carefully to achieve continuous income for supplier sustainability

Step 2 – Identify different measurements for key MA

Table P-8: MA model

MA model	Measurement action analysis
MA	Strategic partnering with supplier to ensure demand is planned carefully to achieve continuous income for supplier sustainability
Competitive Indicator	Cost
Activity description	Measurement of supplier ability to remain stable during project life when steady demand is guaranteed
Inputs	1. Data concerning component availability in the market 2. Data concerning financial position of supplier and estimated demand for component over project lifecycle
Agents available	De&s: project management team, supplier management team and supplier: project management team, supply management team.
Outputs	Planned component demand and availability
Overlapping	NO
Feasibility score	8
Importance score	8

Step 3 – Prioritisation and selection of the major MA

Step 2 is repeated for different MAs to select the most important MA in deriving the PMs based on the feasibility and importance scores.

Step 4 – PM model

Finally, the PM model is then developed to generate the PM for KPA.

Table P-9: PM Model

PM model	KPI description
PM	Percentage (%) of Strategic suppliers $= \frac{\text{No of suppliers that deliver late}}{\text{Total no of suppliers}} \times 100$
MA	Strategic partnering with supplier to ensure demand is planned carefully to achieve continuous income for supplier sustainability
Competitive Dimension	Cost
Inputs	Component availability and supplier performance
Activity description	Measurement of supplier ability to remain stable during project life when steady demand is guaranteed
Agents available	De&s: project management team, supplier management team and supplier: project management team, supply management team.
Outputs	To outline the supplier sustainability over project life

This measurable action could have four possible KPIs because delay in project delivery could be caused by a number of factors. These include:

- ease of design (complex engineering projects)
- desire for design flexibility
- availability of suitable contractors/project managers, and contractors financial stability
- political considerations
- budget constraints vs performance of completed project.

(http://www.mcmullan.net/eclj/delivsys.html)

A number of KPIs can be generated from this measurable action such as:

- Time - This could be measured through a schedule and project plan based on the Work Packages and Work Breakdown Structures. Tools such as Gantt charts are used in planning the time frame allocated to each task.

It would be measured by: Actual time Taken for project completion (Gantt chart)

- Spares supply - This could be measured through a schedule and project plan based on the work packages. It would be measured as:

$$\text{Spares availability} = \frac{\text{Parts available}}{\text{Total Parts in system}} * 100$$

- Support supply – This could be measured by: Support availability

This would be determined by different support activities such as maintenance, obsolescence etc.

The aim of this measure is assess the effect of time in product delivery. Some projects have a strict deadline which means the capability might not be required after a space of time. If the project cannot be delivered within the time limit, it is could not be viewed as being unaffordable. Usually, the longer a project overruns, the higher the cost involved.

This measure can provide project managers with the knowledge they need and sound a warning about the feasibility of delivering a project within a time scale.

One option to resolve this challenge could be divide the projects into various tasks with deliverables at each stage. This would help to monitor the project closely and provide or inject extra resources to ensure these deliverables are met. The injection of extra resources could lead to increased cost for example, if additional man hours need to be bought in or more investment is needed to acquire more sophisticated systems to speed up the process.

The other approach could be to reach an agreement with the customer that the project would deliver a minimum level of requirement within a specified time and deliver the full output in the long term with a specified time frame.

This measure helps the project in strategic planning of the project delivery over the entire lifecycle to reduce operational cost and ensure the overall output is delivered within the specified time.

Appendix O – Uncertainty Assessment Trial instances

Trial instance 2 yielded AI results in the range of 0.3 and 1.6 and a standard deviation of 0.14. This means that most AI falls within +0.14 or -0.14 of the mean which is 0.86. This means most AI results would fall between 0.7 and 0.9. This result is correct as most of the AI distribution comes between 0.72 and 1 (619). Also 25% of the AI values fall below 0.77 while 75% of the values fall below 0.96.

Trial Instance 2 - AI range

Ranges	Count
0.3-0.4	1
0.4-0.5	12
0.5-0.6	19
0.6-0.7	68
0.7-0.8	144
0.8-0.9	217
0.9-1.6	339

Trial Instance 2 - AI Results

Average AI	0.863885
AI>0.9	0.42375
Std Dev	0.142727
Median	0.882259
Lower Quartile	0.770642
Upper Quartile	0.966035
Highest Quartile	1.565438

Figure Q-1: Trial Instance 2 statistics

In order to assess the WLCC and CATS distribution of the lowest, medium and high or highest AI, three trial value profiles were chosen which are 398, 634 and 666. The distribution of trial values within Trial Instance 2 is presented in Figure (Q-1).

Figure (Q-2) contains the WLCC and CATS profiles which produced the lowest, medium and high AI of 0.37, 0.6, and 0.99. Unlike Trial Instance 1, where the highest AI was selected, a high AI scenario was selected in this case. The purpose of the AI comparison is to examine the yearly amount of CATS and WLCC which generates each AI and compare the yearly values from the lowest level to the highest. Usually the AI distribution is expected to between 0.1 and 1.2 or 1.6. Where the AI distribution is in this form, the AI to be compared would be 0.2, 0.5 and 0.9, but in Trial instances 1 and 2, there has been no AI less than 0.36. This is the basis for selecting the AIs for comparison. In all three scenarios, the WLCC was lower than CATS initially, but WLCC rises to same level or above CATS, is any of the last two of the 10-year project life cycle.

The cost and spend curves for the lowest and medium AI scenarios are similar, hence it is interesting to discover the cause for the difference of 0.23 in the AI generated. The CATS and WLCC curves in the lowest AI followed a similar pattern until year 7 when a slight increase in CATS is followed by a decrease in WLCC. For the medium AI scenario, the CATS and WLCC curves were getting closer from year 5 to come very close in year 8, before an increase in year 9. The major difference in lowest and medium AI scenarios is seen in years 9 and 10. In the lowest AI scenario the WLCC profile increased by approximately, £500,000 in year 9 and a further £300,000 in year 10 while the CATS profile decreased by over £10,000 in year 9 and further decreased by over £40, 000 in year 10. Due to higher decrease in CATS value in year 10 for the medium AI scenario it might be expected that the AI generated should be higher than that of the lowest AI scenario. However, nearness of the CATS and WLCC values between years 5 to 8 in the medium AI scenario led to the medium scenario generating a higher AI than that of the lowest scenario. This also means that there was more CATS overall in the medium scenario than the lowest scenario. In the highest scenario there was an increase in CATS of over £200,000 in year 5 and a decrease of over £300,000 (year 6) which later increased from year 7 till the end of the project life cycle.

However the high decrease in CATS in year 6 didn't have a negative effect on the AI as the CATS in most of the years stayed above the WLCC in the high scenario. Though the CATS profile in the high AI scenario had higher variations than lowest and medium scenarios, most of the values for each year stayed above the WLCC values. The results of trial instance 2 reveals that the irrespective of the value of the increase in WLCC if there is sufficient CATS to cover the cost in each year, the AI would be as high as possible. This means sufficient budget is required at each stage of the lifecycle in order to deliver an affordable project.

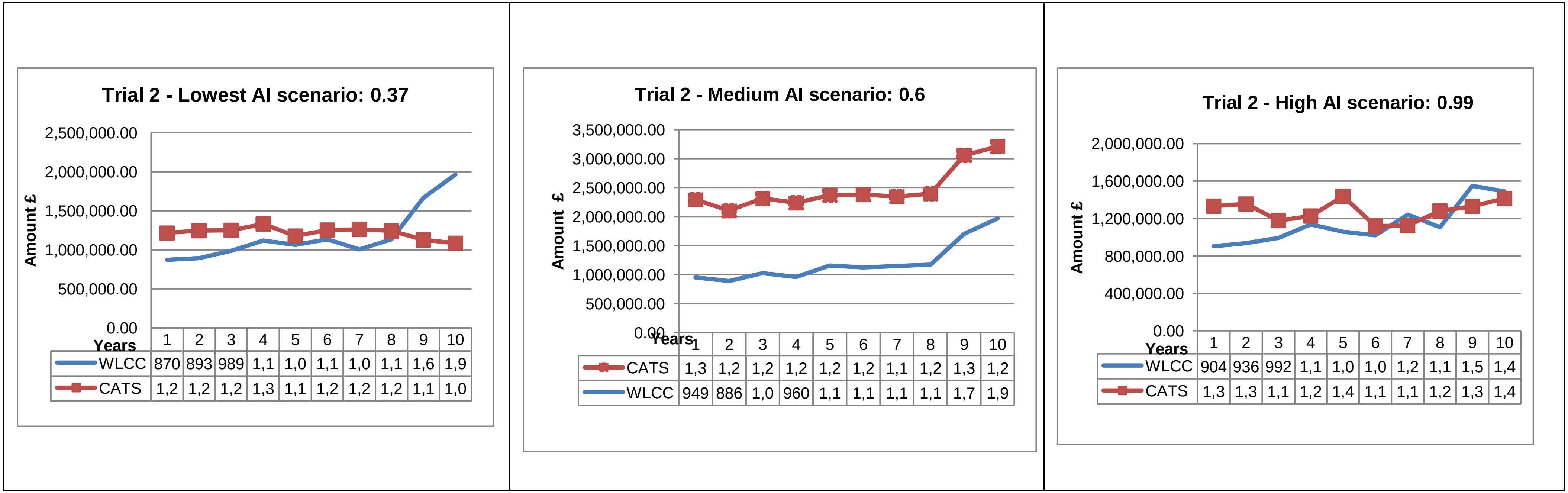


Figure Q-2: Trial Instance 2 - Profile comparison

Trial instance 3 yielded AI results in the range of 0.61 and 1.5 and a standard deviation of 0.10. As explained earlier with trial 3 values, the standard deviation of 0.10 means that that most AI falls within +0. 10, -0.10 of the mean (0.94) i.e. between 0.84 and 1.04. This result is correct as most the frequency of AI distribution comes between 0.81 and 1.04 (600). Also 25% of the AI values fall below 0.88 while 75% of the values fall below 1.

Trial Instance 3 - AI range

Ranges	Count
0.11-0.20	0
0.21-0.30	0
0.31-0.40	0
0.41-0.50	0
0.51-0.60	0
0.61-0.70	3
0.71-0.80	56
0.81-0.90	211
0.91-1.50	530

Trial Instance 3 - AI Results

	Trail 3
Average AI	0.94
AI>0.9 (63%)	0.66
Std Dev	0.10
Median	0.23
Lower Quartile	0.8778429
Upper Quartile	1.00
Highest Quartile	1.49

Figure Q-3: Trial Instance 3 statistics

The three trial value profiles chosen in order to assess WLCC and CATS distribution are 133, 162 and 697. The distribution of trial values within Trial Instance 3 is presented in Figure (Q-3). Figure (Q-4) contains the WLCC and CATS profiles which produced the lowest, medium and highest AI of 0.70, 0.95, and 1.49. In this trial instance, the highest AI was selected because the range of AI distribution was the smallest of the five trial instances and smaller than expected range mentioned earlier.

The profiles in each scenario differs from each other, however one commonality is that the WLCC and CATS were spaced out initially, but they get closer to each other during the life cycle till WLCC profile rises to same level or above CATS, in any of the last five of the 10-year project life cycle. In year 5 of the medium scenario, the WLCC value rises above the CATS value, while WLCC value is close to the the CATS value in year 6 (slight decrease) and this occurs again in year 7 of the lowest scenario. Within this trial instance, CATS and WLCC values meet in all three scenarios. While the lowest scenario is mentioned above, this occurs in year 5 of the medium scenario and year 10 of the highest scenario. The fact this happens in all three scenarios, yet different AI were generated in the end means that there are many factors affecting customer affordability. The meeting of CATS and WLCC profile may not have a negative effect on the affordability of a project. The point where CATS and WLCC meet is similar to a break event point where although there is no profit, there are no losses either. In this case, the AI equation of WLCC/CATS states that an index of 1 means the project is just affordable, no unaffordability. However, this only occurs in one year out of ten meaning that total affordability of the project depends on the values for the remaining 9 years.

In the lowest scenario, the WLCC profile had violations of £100,000 increase and decrease between years 5 and 8, but a major increase of £300,000 in year 9 and £400,000 in year 10. On the other hand, the CATS profile had a major decrease of £400,000 in year 9 and slight increase of £200,000 in year 10. The impact of the higher increase in WLCC profile without a corresponding increase in CATS resulted in the lowest AI scenario.

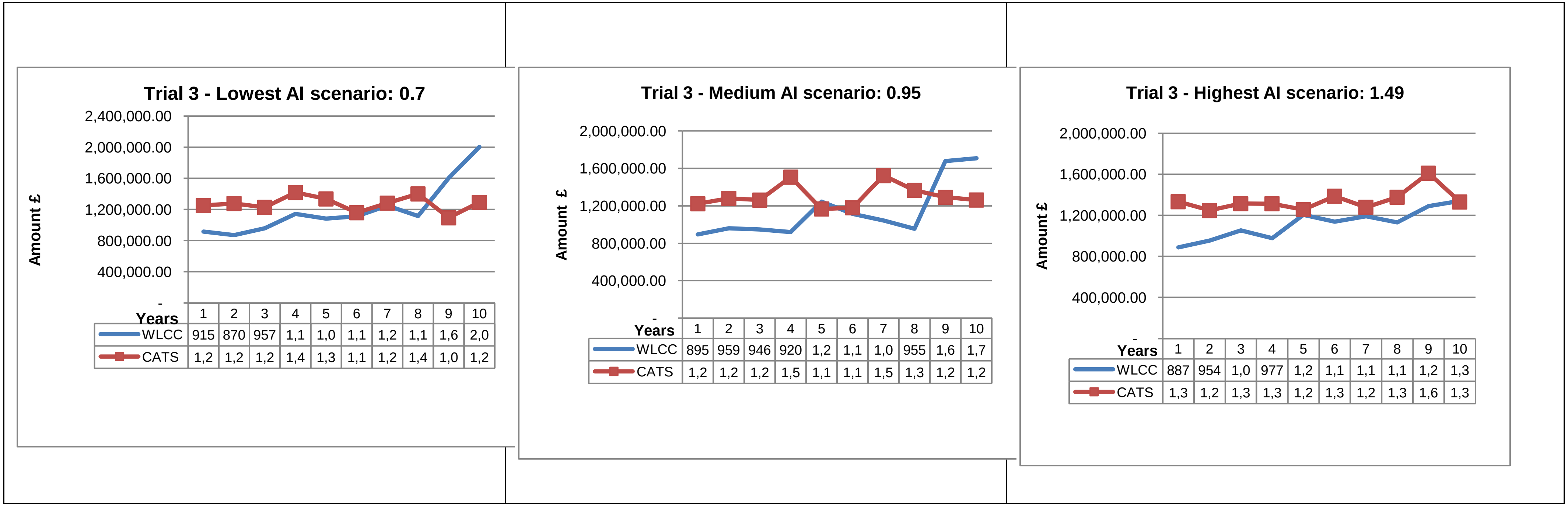


Figure Q-4: Trial Instance 3 - Profile comparison

Trial instance 4 yielded AI results in the range of 0.2 and 1.4 and a standard deviation of 0.14. As explained earlier with trial 2 values, the standard deviation of 0.14 means that that most AI falls within 14% of the mean which is 0.89. This means most AI results would fall between 0.75 and 1.03. This result is correct as most the frequency of AI distribution comes between 0.70 and 1.4 (725). Also 25% of the AI values fall below 0.80 while 75% of the values fall below 0.99.

Ranges	Count
0.20-0.29	1
0.30-0.39	1
0.40-0.49	7
0.50-0.59	17
0.60-0.69	49
0.70-0.79	118
0.80-0.89	183
0.90-1.4	424

	Trail 4
Average AI	0.89
AI>0.9	0.53
Std Dev	0.14
Median	0.91
Lower Quartile	0.80
Upper Quartile	0.99
Highest Quartile	1.26

Figure Q-5: Trial Instance 4 statistics

In assessing the WLCC and CATS distribution of the lowest, medium and high or highest the AI to be selected for comparison are 0.2, 0.5 and 0.9 with the trial profiles 46, 75 and 79. These AI have been chosen because the AI distribution ranges from 0.2 and 1.4. The distribution of trial values within Trial Instance 4 is presented in Figure (Q-5).

Figure (Q-6) contains the WLCC and CATS profiles of the lowest, medium and high AI. In all three scenarios, the WLCC was lower than CATS initially, but WLCC rises to same level or above CATS, is any of the last three of the 10-year project life cycle. The cost and spend curves for the lowest and medium AI scenarios are similar, except that the WLCC and values meet (same) in year 9 for the lowest profile while CATS remained higher in the medium profile.

There was significant increase in WLCC profile of £900,000 between years 8 and 10 in the lowest scenario while there was a higher increase of over £1m between years 7 and 10 in the medium scenario. Nevertheless the medium scenario generated a higher AI because CATS

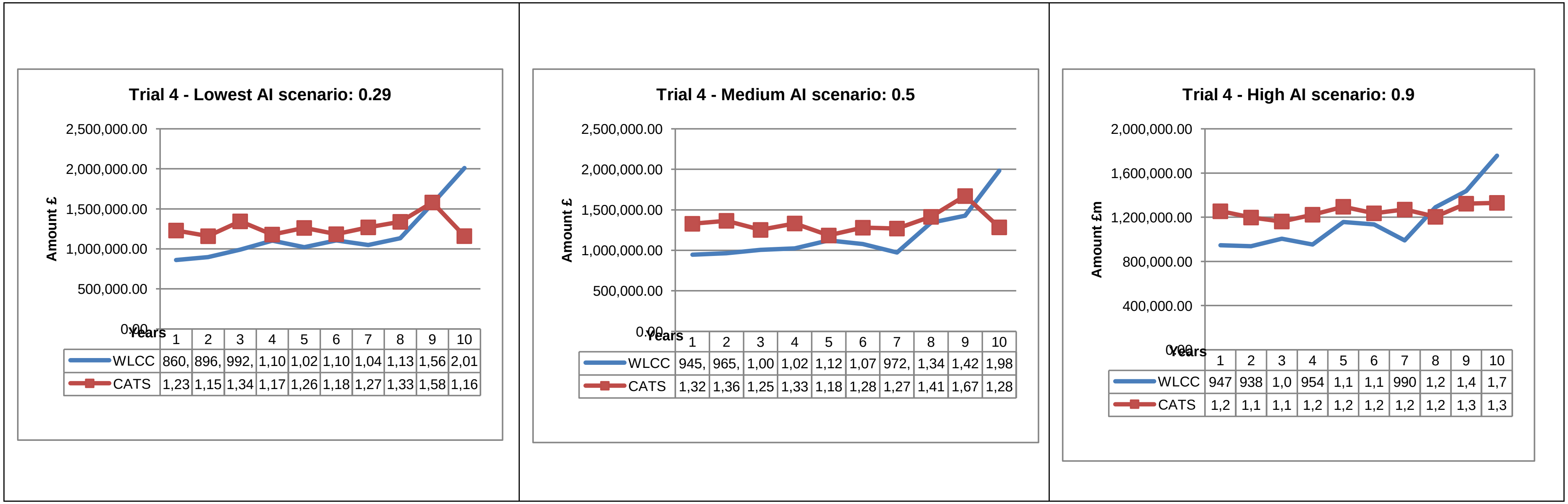


Figure Q-6: Trial Instance 4 - Profile comparison

values were always higher than WLCC in each year apart from the last year for the medium scenario. While the CATS value in the lowest scenario was almost the same as WLCC in year 9 (£15,000 difference) and fell below WLCC in year 10 this caused a difference in the AI generated. It interesting to note that the CATS profile fell below the WLCC in years 8, 9 and. 10 of the high scenario, yet the profiles generated the highest AI of the three scenarios. This was mainly due to the fact that total CATS in the high scenario was higher than the those in the medium and lowest scenarios since there was no reduction in the CATS in year 10 for the high scenario. The results of trial instance 4 further supports the idea that irrespective of the an increase in WLCC if there is sufficient CATS to cover the cost in each year, the AI would be as high as possible. This means sufficient budget is required at each stage of the lifecycle in order to deliver an affordable project.

Trial instance 5 yielded AI results in the range of 0.11 and 1.25 and a standard deviation of 0.15 meaning that most AI falls within +0.15, -0.15 of the mean which is 0.88. This shows most AI results would fall between 0.72 and 1.03. This result is correct as most the frequency of AI distribution comes between 0.70 and 1.25 (711). Also 25% of the AI values fall below 0.79 while 75% of the values fall below 0.98. In assessing the WLCC and CATS distribution of the low, medium and high or highest scenarios, the AI to be selected for comparison are 0.29, 0.51 and 0.91 with the trial profiles 715, 127 and 114. 0.29 AI was chosen as that was the only AI generated in the range of 0.2- 0.29. The distribution of trial values within Trial Instance 5 is presented in Figure (Q-7). Figure (Q-8) contains the WLCC and CATS profiles of the low, medium and high AI. Trial instance 5 results are very unique as each profile for the high, medium and low scenarios are very different unlike the other trail instances which similar profiles for WLCC and CATS. In all three scenarios, the WLCC was lower than CATS initially, but WLCC rises to same

Trial Instance 5 - AI distribution

Ranges	Count
0.10-0.19	2
0.20-0.29	1
0.30-0.39	3
0.40-0.49	12
0.50-0.59	21
0.60-0.69	50
0.70-0.79	121
0.80-0.89	207
0.90-1.30	383

Trial Instance 5 - AI Results

	Trail 5
Average AI	0.88
AI>0.9	0.53
Std Dev	0.15
Median	0.89
Lower Quartile	0.79
Upper Quartile	0.98
Highest Quartile	1.25

Figure Q-7: Trial Instance 5 statistics

level or above CATS, in any of the last two of the 10-year project life cycle. There is an exception in the highest scenario where the CATS values fell below WLCC in year 5. However, this did not have a negative effect on the AI as there was no significant increase in WLCC over the life cycle. This shows that while one violation could have a major impact on the AI generated over the lifecycle, this depends on the other values within the profile (both WLCC and CATS).

For the low scenario, the CATS value plummeted by over £700,000 in year 10 which had a major impact on the AI generated though WLCC only increased by around £160,000. This explains why the profile generates a low AI. For the medium scenario, the WLCC value rose by almost £500,000 in year 9 and nearly £400,000 in year 10. This is why the profile generates a medium AI. In the high scenario, the WLCC and CATS curves were usually close to each other with the CATS profile above the WLCC apart from year 5 and 10. It is interesting that though the high scenario generated the highest AI, the total CATS (approximately£13,289,000) in the low scenario is higher than the total CATS in the high scenario (approximately £13,055,000). The cause for the major difference in the AI generated was caused by a higher WLCC (approximately £11,615,000) for the low scenario in comparison with the high scenario WLCC (approximately £10,368,000). Also the spread of WLCC against CATS each year is the cause of violations which could have a significant impact of the AI. This means to improve project affordability, there is a need to have sufficient budget to cover the WLCC overall spread yearly to cover yearly.

In summary this exercise has helped to visualise a spread of AI based on one single AI. The initial AI was 0.87 which is closer to 1, the ideal AI. After five trials the highest AIs were 1.23, 1.57, 1.21, 1.27 and 1.25. With the averages of 0.93, 0.86, 0.87, 0.89, 0.88 which provides a range from 0.86 to 0.93 meaning that the actual AI could fall within that range.

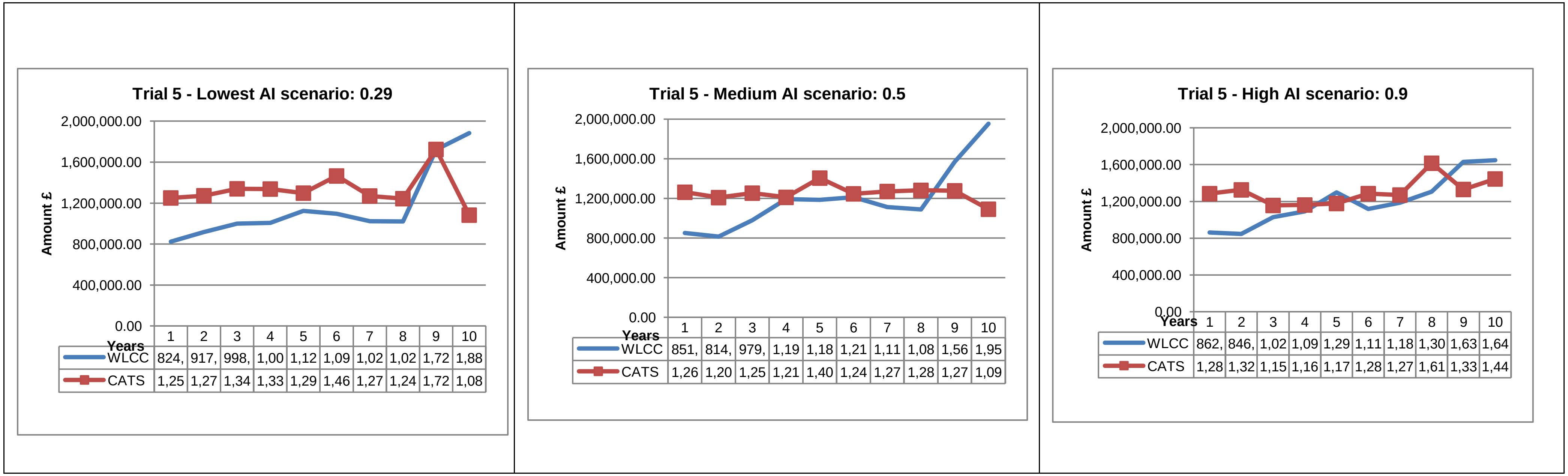


Figure Q-8: Trial Instance 5 - Profile comparison

Appendix P – Uncertainty Tool Validation Questionnaire

Affordability Research Validation, Cranfield University on 13.06.2011

Aim: To validate the methodology and content of the Anylogic tool for uncertainty consideration in Affordability assessment and obtain suggestion for improvement

Respondent: Post Doctoral Researcher

LOGIC FOR TOOL APPLICATION

5. How logical is the anylogic tool to assess the impact of uncertainty in affordability assessment?

1	2	3	4	5	6	**7**	8	9	10
Totally Invalid	Valid with major deficiencies				Valid with minor deficiencies				Totally Valid

Please describe deficiencies if any – *The tool provides some dynamic representation over time, but generally provides a static view of uncertainty and the user would need update the considerations over time. However, it the approach follows industry best practice by using three-point estimates. Along these lines, the tool also needs to help people to define the three points.*

………

……

Possible suggestion for improvement

………

6. Is the tool suitable for uncertainty assessment of project affordability at the bidding stage from the three perspectives?

1	2	3	4	5	6	**7**	8	9	10
Totally Unsuitable	Suitable with major deficiencies				Suitable with minor deficiencies				Totally Unsuitable

If unsuitable, please describe why - *The tool is suitable for this purpose; however there may be issues with the black box characteristics, where the results may be questioned. Also the assessment (in defining the three points) could be questioned to be subjective. The approach should not vary across the perspectives as the methodology should be applicable for each of the contexts.*

……...

Possible suggestion for improvement

……..

……...

USABILITY OF THE TOOL

7. (a) What are the advantages of using the tool?

………*Mainly to get an understanding of whether the project is affordable to the customer and profitable to the OEM. But the uncertainty side also adds value by building a measure of confidence in to the analysis. The time dimension is also an important feature of the tool.*

………..………………

(b) What are the disadvantages of the tool?

Lack of experience in using AnyLogic; Java programming; required level of background knowledge to be able to understand the model; lack of ease to make alterations/additions to the tool;

……..……………

8. (a) How appropriate are the charts, graphs and flow diagrams used within the tool?

…The charts are useful

………..…………

(b) Please suggest possible improvement

Would link the manufacturer and customer targets ; Would make the inputs to the charts clearer;

……..………

9. (a) How appropriate are the results presentation within the tool?

…They are appropriate

………..…………

(b) Please suggest possible improvement

…Mainly I would like guidance as to when I should stop the simulation by looking at the results…

……..

10. Please provide comments and suggest improvement about the application tool for uncertainty assessment in affordability of defence contracts in terms of:

(i)Names of agents, variables and parameters? ………*Agents are clear. The role of the suppliers would be a good addition to the model.*

(ii)Variables- *these are not very clear due to the abbreviations it is hard to know what each variable is doing. Similarly the case for parameters.*

……

(iii) Clarity of the link between those mentioned above in (i)
This is not very clear

……

(iv) **Clarity of description of processes**
…An upfront description would facilitate further understanding. There is room for improvement on this.

……

(v) Clarity and link between input and output
Relatively good in terms of representation of outputs given the inputs from the simulation. But the actual inputs to the tool are not very clear and how/where these get used is a bit ambiguous.

……

11. Given the number of variables, please comment on the appropriateness of the tool.
Refer to questions 1 and 2 above

……..………………

5. Please comment on the visual presentation of the variables and action charts within the agent tabs?
The charts are good, but need guidance on how I can use these at presentations and for demonstrative purposes.

……..………………

6. Please comment on the functionality within the tool for the purpose of uncertainty assessment of the affordability of defence contracts.
Really depends on how you collect the data for the tool. The ideal would be to have an initial interface e.g. through MS Excel that collects the data and then I should just be able to view what the simulation is doing.

……..………………

7. **Please comment on the duration of time it takes to populate the tool and generate results?**

Not sure.

……..………………

BENEFITS OF THE TOOL TO INDUSTRIAL PRACTICE

8. **How would the tool benefit the bidding team, especially in comparison with other risk software like @risk or crystal ball?**

The main benefit is the integrated picture of the customer and the OEM. This will facilitate better planning over the life cycle of the project from a number of dimensions (e.g. cost, schedule and performance)

……..………………

9. **How could the tool aid affordability assessment?**

It could facilitate to change the affordability level by understanding the customer's position against the OEMs profitability. Additionally, based on the uncertainty level the affordability level could be shifted to reach a more/less confident position.

……..………………

LIMITATIONS OF THE TOOL

10. **What are the potential limitations and challenges in using the tool?**

Need high level input as it will be hard to collect the actual information requirements specified in the tool. Need to collect subjective data and a protocol to guide with this elicitation. The use of AnyLogic is also a constraint. Also, availability of information related to both the customer and the OEM might be an issue

……..………………

11. **What are the potential limitations and challenges in implementing the tool in a company in comparison to existing risk assessment tools like @risk or crystal ball software?**

Lack of availability of AnyLogic. Java programming requirements. Simulation knowledge.

……..………………

12. **How could the background of the people using the tool affect the output?**

In particular in terms of risk bias and over confidence – these can affect the uncertainty assessment

………..