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ConSERV : A Methodology for the Management of Capital Projects and Concurrent Engineering Design using Knowledge Based Technology.

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Abstract

Project management is a complex process that does not lend itself to traditional line management theories. Projects fail more times than they succeed, the measures of success and failure vary widely depending upon the management strategy and the focus of the project at the time of the assessment i.e. Cost, Time or Quality.
Most of the commercially available software packages developed for the use of project managers employ dated management theories and limited reasoning ability. With over 300 variations of software tools available to the project manager selecting the most appropriate packages is becoming increasingly more difficult.

Projects are managed by employing a subtle combination of elements of interdependent software tools and human expertise. Project management systems include a variety of management tools and techniques that are not equally applicable across all projects. This submission introduces ConSERV, a project management technique that uses a knowledge based risk driven approach, in which key elements of a multidisciplinary capital project are identified using the Win-prolog Flex facility.

ConSERV identifies the main project elements, including the risks, sensitivities and the project success criteria. The further use of knowledge based rules provides a framework in which the decisions made by the respective users can be challenged. ConSERV advises on the project management system best suited to manage the specific needs of the engineering design and project management issues.

The aims of the research described in this thesis are :-
i) To research and analyse project management decision making processes over the life of major capital projects, undertaken in accordance with established procedures.
ii) To identify, from the industrial case studies, failure mechanisms resulting from flaws in human decision making, the use of inappropriate management processes and the application of unsuitable project execution procedures.
iii) To apply an established KBS development technique (KLIC) in developing the ConSERV concept and selecting the demonstrator tools.
iv) To compare the effectiveness of traditional project management concepts and justify the need for a customised project management system.
vi) To build two limited application demonstrators of the ConSERV concept employing advanced reasoning and knowledge based technology.

The thesis argues that the complexities of managing multidisciplinary projects in a competitive technologically advanced environment demand more sophisticated methods to those presently offered. The methodology aims to minimise project failure by providing a structured risk driven procedure able to identify and customise a dynamic project management system designed specifically to meet the real needs of a project over its life cycle.
Using case studies the thesis aims to contrast the effectiveness of traditional project management software, against the proposed knowledge based alternative.
In support of this research work three academic papers have been published by the IJPM (International Journal of Project Management) Ref. Appendix B8 (Table 8).

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I would like to acknowledge the assistance of Tioxide Europe Ltd. and Lurgi UK Ltd. senior management, for allowing me unhindered access to confidential and historical data of the capital projects used as case studies in the industrial element of this research work.

I am especially indebted to Mr. C. Spenser (LPA) and Mr M. Pappas (IBIS Ltd) for their advice, support and assistance in developing demonstrator 'A' and to Autodesk for allowing me to acquire advanced software and licenses at discounted rates.

My thanks also go to the Association of Project Managers for allowing me to use and publish sections of the "APM Body of Knowledge" (1996) and to the Chaucer Group Ltd for allowing the publication of the Project Management Software Database.

I would also like to thank Mr. John Edge and his colleagues from the University of the West of England for their comments and advice regarding the application of this research.

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Dedicated to the memory of Diana
'The peoples Princess'
1961-1997

Preface

Having spent over twenty years as a professional engineer in project management and engineering design it is my considered opinion that human decision making ability in this area of engineering is seriously flawed. This argument formed the basis of my MSc. submission undertaken at Huddersfield University 1990-1993 entitled :-

"*An investigation into decision making processes in project management*"

This Ph.D. is very much an extension of the earlier MSc. research work and incorporates my own personal interests in the field of project management and engineering design.

Most projects demand that decisions are made under considerable pressure and all too often in areas that are outside of the project managers "zone of comfort". i.e. beyond his/her specific engineering discipline or level of expertise.

This pressure can lead to unsound decisions being made by the project manager, which are recognised as being major contributory factors to project failure.

The research work undertaken during both the MSc. and the Ph.D. has been essentially industry based, and has employed a variety of research techniques, specifically those identified by *Robson*[1] and *Phillips and Pugh*[2], who advocate that :-

"***Those students with a great deal of practical experience might consider work in the exploratory or problem solving approaches.***" Taking account of these comments the research work submitted in this dissertation involves "***an innovative variant***" of the existing, traditional project management methods.

As an Autodesk registered developer I have been able to obtain software crucial to this research through the partnership agreement scheme which has been of enormous benefit to this work. namely ACAD13c4 and KINETIX 3D STUDIO.

The precursor to this research effort has been extensive and includes contributions from numerous representatives of major international organisations including :-

ICI, SmithKline Beecham, Lummus, ARAMCO, SAMAREC. Jacob Int. and Lurgi UK.

The research issues in this submission recognise the changing role of the professional project manager in which a considerable amount of 'expertise' is gradually being transferred from human to machine knowledge.

Terminology

List of Project Management terms used in this dissertation

Acceptance = Contractual Acceptance of the plant in keeping with the contract
ACWP = Actual cost of work performed, monetary value actually incurred in time.
AFC = Anticipated final cost, a monetary value
AHP = Analytic hierarchy process, a decision framework affording trade-offs.
AI = Artificial Intelligence
AOA = Activity on arrow technique in which the arrow is used to indicate an activity
AON = Activity on node technique which eliminates the need for dummy activities
BATNEEC = Best available technology not entailing excessive cost
BCE = Budget cost estimate
BCWP = Budget cost of work performed, monetary value of work scheduled in time
BCWS = Budget cost of work scheduled, monetary value of work to be done in time.
BE = Break even
BETA = Business Engineering and Technology Assessment
BOO, BOOT = Build Own Operate, Build Own Operate Transfer
BPEO = Best practical environmental option
BPR = Business Process Re-engineering
Cap. Ex. = Capital Expenditure also Cost Estimate
CCP = Change Control procedure
CDM = Construction and design management (recent (1994) legislation)
CE = Concurrent Engineering
CIMAH = The Control of Industrial Major Hazards Regulations 1984
Client = Customer, owner purchaser as per contract definition
COA = Course of Action
ConSERV = **Con**current **S**imultaneous **E**ngineering **R**esource **V**iew
CM = Configuration management, a management methodology
Contingency = In built slack, time and cost
CPA = Critical Path Analysis
CRINE = Cost Reduction in New Era
Damages = Consequential or liquidated as per contract
Decision Tree = Diagrammatic representation of possible alternatives (open network)
Domain = A particular field of knowledge suitable for embodying a KBS
EV = Earned value
EPA = Environmental Protection Act (1990)
Expert System = A narrower version of the KBS
FD = Fail to Danger rate, No. of times instrument is likely to fail to danger in a year
FMECA = Failure Modes, their Effects and criticality analysis
FEE = Front End Engineering, alternatively, PSE Pre sanction engineering
FS = Fail Safe
G.A's = General arrangement, drawings showing the arrangement of plant items.
GANTT = Table of task information and bar chart displaying program schedule
GP = Goal Programming
HAZOP = Hazard and Operability study
HAZAN = Hazard Analysis
HEART = Human error Assessment and reduction Technique
Heuristics = Rule of thumb knowledge that is often but not always theoretically correct
HSE = Health and Safety Executive
IJPM = International Journal of Project Managers
IPC = Integrated Pollution Control (Part 1 of EPA)
ITT/ITB = Invitation to Tender or bid, similar to RFP/RFQ Requests for quotation

Terminology (cont.)

List of Project Management terms used in this dissertation
ISM = Instrument Safety Method
JSWP = Job safe working practice
KBS = Knowledge Based System representation of knowledge in a specific domain
KLIC = KBS life cycle technique for developing knowledge based systems.
LTA = Lost time accidents, accidents resulting in time off work.
MAUT = Multiattribute utility theory, a decision making process allowing trade-off.
M.S. = Method Statement
MF1 = Model form of General conditions of contract, including tender agreement.
Multidiscipline = generic term for the collective engineering effort.
NEC = New Engineering Contract
Networks = The representation of activities in the form of connected elements.
NML = Non monotonic logic, a form reasoning that is based on contingent proofs
NPV = Net present value, monetary value of the plant at the time of the evaluation.
P&ID = Process and Instrumentation diagram.
PERT = Project Evaluation and Review Technique (form of CPA)
PEP = Project execution Plan
PFI = Project Failure Indicator, also Private Finance Initiative.
PW = Present Worth,
Probability = The chance of an event occurring under a specific set of conditions
QA = Quality Assurance
QFD = Quality function deployment
Qualia = Building bricks of consciousness, machine intelligence.
Resources = The people assigned and authorised to do work on the project
Risk-Benefit analysis = The work involved in identifying and evaluating risks
Risk assessment = The identification, estimate and appraisal of the risk
Risk estimating = Quantifying the impact and likelihood of risk
Risk exposure = The product of the financial impact value and its probability
Risk factor = The mathematical effect of probability (p) and impact (I) on a scale 0-1
Risk trigger = An event which can be identified to reduce risk to an acceptable level
ROI = Return on Investment
ROR = Rate of return, also known as profitability index, discounted cash flow return.
S - Curve = Trend technique plotting value of work done and work planned over time
Sanction = The decision to authorise investment i.e. commit to a Capital Expenditure
Scope = The defined and explicit list of works itemised within the contract
Sensitivity Analysis = Determining the stability of a project plan
SHE = Safety and Health Executive
Snag list = Outstanding items following the completion of contracted works, 'buts' list
SOW = Statement of work
Systemigrams = method of describing complex processes by semantics of natural lang.
TDT = Time Disturbance Technique
T.Q = Technical Query
TQM = Total Quality Management
THERP = Technique for Human Error rate prediction
User = The ultimate customer sometimes referred to as, End user.
VA = Value Analysis Techniques
V M = Value management
Variation = A change to contractors work order under terms of contract (V. Order)
WBS = Work Breakdown Structure hierarchical structure identifying work packages

Software Tools, Products and Associations referenced in the dissertation

Project management tools and products

ARTEMIS = Top range project planning tool
PRIMAVERA = Top range project planning tool
WORKFLOW = Cyco document management system
WORKCENTRE = Autodesk document management system
WINPROJ = Microsoft Project management software package
CA SUPERPROJECT = A mid range planning and scheduling tool
ON TARGET = A low level planning tool
MONTE CARLO = Risk management software package
ADMIT = An electronic document management system for project management

Engineering design tools and products

MATHCAD = Mathematical package able to perform statistical analysis.
TECHNICAL INDEX = An information library system with access to Standards
ACAD 12 and 13c4 = Draughting and CAD tool able to generate 2 and 3D drgs.
3D STUDIO MAX = A true 3D animation package
VISIO v4 = A flow charting tool with wide ranging capabilities

Costing tools and products

QUESTIMATE = A Cost estimating package

Knowledge based tools and developmental tools

FLEX PROLOG = LPA Knowledge based tool
ACAD 3D STUDIO MAX = A 3D animation package used to demonstrate concept

Decision Aids

LOGIC = Decision Tool employing Selective Expected Utility techniques

Process Modeling

WITNESS = A process modeling software package

References to the APM should read : The Association for Project Management (UK)
References to the PMI should read : The Project Management Institute (USA)

CONTENTS

PART 1 INTRODUCTION,CASE STUDIES AND SYSTEM DESCRIPTION

CHAPTER I *page No.*

1.0 Introduction

CHAPTER II

2.0 The art and science of managing projects

CONTENTS

CHAPTER III

page No

3.0 Analysis of industrial case studies

CHAPTER IV

4.0 Description of the ConSERV KBS concept

PART 2.0 DEVELOPMENT OF THE CONCEPT

CHAPTER V

5.0 The project management element

CONTENTS

CHAPTER VI

page No.

6.0 Design element of the ConSERV KBS concept

CHAPTER VII

7.0 The ConSERV 3D Model

PART 3 SOFTWARE DEVELOPMENT

CHAPTER VIII

8.0 The concept Process and Demonstrators

CONTENTS

PART 4 RESULTS AND SUMMARY OF RESEARCH

CHAPTER IX

page No.

9.0 Test procedures for the ConSERV concept

CHAPTER X

10.0 Summary, contribution to knowledge and beyond

CONTENTS

Appendices ***Page No***

CONTENTS

PHOTOGRAPHS

FIGURES

FIGURES

FIGURES

FIGURES

TABLES

Nomenclature

The nomenclature and symbology used in the body of this dissertation pertains to that associated with predicate and nonmonotonic logic.

Default logic, epistemic logic and temporal logic symbology is also used in this submission.

1.0 Predicate First Order Logic (FOL)

A proposition is a sentence that declares a fact that is either true or false.

$\rightarrow$ = The *implication connective* < proposition 1 > $\rightarrow$ < proposition 2> typically $p \rightarrow q$

$\leftrightarrow$ = The biconditional connective $p \rightarrow q$ and $q \rightarrow p$ typically $p \leftrightarrow q$

$\wedge$ = The *conjunction* (AND)

$\vee$ = The *conjunction* (OR)

$\neg$ = The *negation* (NOT) alternatively ~

$\varnothing$ = The *empty* set

$\subseteq$ = The *subset*

$\in$ = *membership* of a set $\notin$ = not a member set

S = The *universal set*

$\forall$ = The *universal quantifier* used to describe the fact that an open sentence is converted to a true proposition for all substituted values of the variables. The proposition $\forall x \in \mathbf{X}$, $P(x)$ is referred to as a universally quantified proposition (All, every and each)

$\exists$ = The *existential quantifier*, used to describe the fact that an open sentence is converted to a true proposition for at least one of the substituted values of the variables. The proposition $\exists x \in \mathbf{X}$, $P(x)$ is referred to as an existentially quantified proposition. (There exists, there is, some, at least one)

$\cap$ = The *intersection* of two sets

$\cup$ = The *union* of two sets

R = The symbol used to define a *relation*, the general form of the binary relation is

$R=\{(x,y) : x \in A, y \in B \text{ and } P(x,y)\}$ where $P(x,y)$ is an open sentence.

Nomenclature (cont)

2.0 Nonmonotonic logic (NML)

Nonmonotonic logics are contingent proofs whose conclusions may become invalidated in light of further information.

W = The set of probable *world histories*

$\vdash$ = The meta-symbol used to make general statements i.e. if $S \vdash q$ then $S \cup (p) \vdash q$ for any p.

L_{pt} = Temporal probability logic language

$\prec$ = Incremental time interval

$\Leftrightarrow$ = The equivalence symbol is used to express past time formula

$\Rightarrow$ = Used to denote relationship between past and future, Antecedent about past $\Rightarrow$ consequent about future.

Time = Relative to any one point in time, only one possible past exists but numerous futures exist

Facts and Events = Facts hold and events occur over intervals and sub intervals of time.

Event types = An event type is a general class of events

Event token = An event token is a unique sub group of the event type and occurs once in any world history.

Possibility = Relative to a given point in time, the past is inevitably true or false

Chance = Objective probability in which the past is either 0 or 1, and is a function of the state of the world up to the current moment in time.

PML = Propositional meta language

AEL = Autoepistemic logic (extends classical logic with operator L which is read as "it is believed that")

NML = non monotonic logic (extends classical logic by the use of an operator M, "it is consistent that")

● = The temporal operator representing the last moment in time

□ = The temporal operator representing always in the future (it is necessary that..)

○ = The temporal operator representing the present moment in time

◊ = The temporal operator representing sometime possibly in the future (it is possible that..)

Modal operators

□ (INEV) e.g. $\Box_t(\varnothing)$ indicates that $\varnothing$ is inevitably true at time t.

◊ (PROB) e.g. $\Diamond_t(\varnothing)$ indicates that $\varnothing$ is possibly true at time t.

E.g. The probability of $\varnothing$ at time t is at least α is expressed as $P_t(\varnothing) \geq \alpha$ (Shorthand for $P_t(\neg\varnothing) \geq 1-\alpha$

Nomenclature (cont)

3.0 Knowledge representation

Consistency in the representation of knowledge requires that human expression is standardised. The following standardisations of human beliefs have been used in this submission :-

3.1 Representation of Verbal uncertainty consistent with probabilistic interpretation

Numerical Value	Level of belief
0.0	impossible
0.1	highly unlikely
0.2	very unlikely
0.3	quite unlikely
0.4	less probable
0.5	possible
0.6	quite probable
0.7	quite likely
0.8	very likely
0.9	highly likely
1.0	Definite

3.2 Representation of mathematical Uncertainty

Bayesian definition

The conditional probability of a proposition, given particular evidence is a real number between 0 and 1, that represents an entity's belief in that proposition given the evidence.

$$P(h \mid e) = \text{probability of hypothesis given evidence e}$$

Axioms

i/ $0 \geq p(h \mid e) \geq 1$

ii/ $p(\text{true} \mid e) = 1$

iii/ $p(h \mid e) + p(\neg h \mid e) = 1$

iv/ $p(gh \mid e) = p(h \mid ge).p(g \mid e)$

Nomenclature (cont)

Certainty Factor Formulation

CF = Certainty factor
CF = (MB - MD) Where MB = Measure of belief and MD = Measure of disbelief
CF = -1 (Complete certainty that a proposition is false)
-1 < CF < 0 (Decrease in belief)
CF = 0 (No change in belief)
0 > CF < 1 (Increase in belief)
CF = 1 (Complete certainty that a proposition is true)

Epistemic probability (Dempster-Shafer theory of evidence)

Rule. If m_1 and m_2 are two bpa,s obtained from independent evidences, then the combined bpa is given by :

$$(m_1 \oplus m_2)(C) = \frac{\sum_{A \cap B = C} m_1(A)\, m_2(B)}{1 - \sum_{A \cap B = \emptyset} m_1(A)\, m_2(B)}$$

Abbreviations

CD = Closed Domain

CW = Closed World, cwa = closed world assumptions

bpa = Basic probability assignment

wff = well formulated formulae

iff = if and only if.

Chapter I

1.0 INTRODUCTION

"The only things that evolve by themselves in a project are, disorder, friction and malperformance culminating in total chaos"
P.Drucker[3]

1.1 Overview and Guide to the content of the PhD

1.1.1 Overview

In more recent years the business of managing major capital projects has become considerably more scientific, both in the approach and the execution. As with many areas of technology project management involves elements that readily lend themselves to the application of computer technology e.g. Resource Scheduling and programming, and other soft skill elements such as the management of conflict that do not.

In the majority of capital projects being undertaken in the Chemical, Petrochemical and Pharmaceutical industries the project management method is often dictated by the organisation responsible for delivering the project.

Most prescriptive project management procedures will afford some degree of freedom to the manager in order to accommodate individual management styles and preferences.

The Association of Project managers (APM) and their US counterparts The Project Management Institute (PMI) have each developed their respective "Body of Knowledge" pertaining to Project Management. Extracts of which, are included in Appendices A4 and A5.

The very nature of *project management* and *engineering design* requires that any research effort taking both an in depth and holistic view of the interactions of the two professions will, by definition, be wide ranging and broad based.

This dissertation describes a methodology that can be considered as being such a case.

1.1.2 Difficulties

One of the major difficulties facing the project manager is that of matching the needs of the project to the various statutory, organisational and contractual requirements within the resource and budget constraints of the projects. In developing a project execution strategy many project managers[1] will use their heuristic and experiential knowledge. This process can be risk laden as most projects are unique and there are many management theories from which to choose Ref. B8 and B9.

This submission introduces an **alternative** approach which considers how **knowledge-based (KB)** technology might be employed in a project management environment. The advantage of using a KB system is that the expertise of many project managers' can be employed in the decision making process. The concept presented in this submission is a method of identifying the *key factors* of the project, the *specific risks* and the *success criteria* to which knowledge rules may be applied in order to produce an interactive management system.

The concept also uses a three dimensional facility which allows the user to view the application and status of the engineering resources assigned over the life cycle of the engineering design and project management period.

1.1.3 Audience Identification

This thesis has primarily been written to meet the requirements of the Ph.D. in keeping with Cranfield University Regulations 35.

In fulfilling the academic requirements, the submission should be of value to other **researchers, knowledge engineers** and **students** undertaking investigations in the field of project management. Practising **project managers** should also find the approach of interest as will the **developers** of new project management **software.**

In summarising,

- *The thesis presents a new project management approach, based upon the author's experiences and the findings from industrial case based studies.*
- *It tackles issues directly affecting the probability of project management failure.*
- *It employs knowledge-based technology designed to provide decision making assistance to project managers.*
- *It offers a framework for identifying risks selecting and applying appropriate management system to meet the specific needs of the project being managed.*

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[1] The term project manager is meant to infer both genders

1.1.4 Content guide

This thesis consists of ten Chapters, Chapter I the Introductory chapter which provides an insight into the problems facing project managers and the limitations of commercially available software. The strategy employed in the preparation and compilation of this Ph.D. is described along with the contribution to knowledge.

Chapter II Introduces the reader to the business of managing major capital projects and the various project management theories available, including the types of knowledge employed by project managers and an analysis of the existing methods.

Chapter III Presents an analysis of the findings obtained from the industry based research. It also includes the observations and conclusions on the effectiveness of the project management methods studied.

Chapter IV Introduces the underlying theory behind the ConSERV concept, and KLICK, the KBS development process advocated by *Guida and Tasso*[4].

Chapter V Describes the development of the 'project management' element of the concept and the stages of project identification, risk and the effect on the design man-hours. This chapter also covers the selection of the KBS development environment used to develop Demonstrator 'A'.

Chapter VI Describes the development of the 'engineering design' part of the concept including the design risk issues and the design support provided by the technique.

Chapter VII Considers the engineering resource management aspects and the 3D visualisation of the design and information flow element of the concept.

Chapter VIII Presents the technical details of the system including the architecture, structure, processing requirements and the limitations of the two demonstrators.

Chapter IX Outlines the testing procedures and the evaluation of the demonstrators. The performance of the system is compared with the case studies in order to establish any real benefit afforded by the KB approach.

Chapter X The final chapter, summarises the content of this theses outlining the contributions to knowledge made in this submission. The Chapter contrasts the arguments and hypothesis with the research findings in order to draw a conclusion.

The chapter identifies prospective future market potential developments, and recommends areas of further research and development afforded by ConSERV.

1.2 Problems with current management techniques.

1.2.1 Project Failure

From the research work into project failure on major and epic projects, undertaken by *Morris & Hough*[5] it was apparent that a considerable proportion of project failure was attributed to the limitations of the project managers and the systems employed. The authors purported that:- "Despite the enormous attention project management and analysis have received over the years the track record of project management is fundamentally poor"

They went on to identify that overruns on project budgets were typically, **40-200 %.**

The background to this submission stems from the belief that most major multidisciplinary projects consistently fail to satisfy the three main requirements deemed necessary for project management success, namely **Cost Quality** and **Time.**

One of the main reasons why project success is difficult to measure, is that the *focus* of the project will inevitably change over the life of the project, vacillating between the previously mentioned criteria.

There appears to be no proven recipe for project and project management success, even in major organisations in which projects are managed in accordance with the most stringent project execution procedures, project failure still exists.

Newtown [6] undertook a research study into project failure, extracts of which are included in Appendix A3 (Fig 3).

Belassi & Tukel [7] provided a listing of success/failure criteria an extract of which is provided in Appendix A7.(Fig 6).

It may be argued that it is simply not possible to satisfy all of the various project stakeholders simultaneously, as each will have their own perception of what constitutes **project success** and how it is, or should be, measured.

The main stakeholders involved with major capital projects include :-

The Client/Project Owners, Accountants, Marketing Managers, Safety Officers, Environmentalists etc. Each will evaluate the project success from their own perspective and preference. The clients' requirements for example are for the **lowest cost, highest quality** and **shortest time,** anything else may be seen as 'failure'.

1.2.2 Field Research Work

Field research undertaken in 1992-93 identified that not only is human decision making in project management seriously flawed, but that many projects employ inappropriate software tools and management methods.

The main reasons for these conclusions are associated with the limitations of human information processing capabilities, coupled with the ever increasing demands imposed by organisational constraints and the time pressures.

Findings from the author's MSc. "Decision Analysis in Project Management"[8] (1992) left many questions unanswered, consequently this submission can be seen as being a continuation of the MSc. Research.

The background to this research is considered to be well founded as it includes both the author's personal experiences gained from many years of project management experience, and in depth interviews with over 100 project managers from various organisations. The standardisation, tabulation, documentation and analysis of this data is incorporated in Appendix B2-B7. (Figs 8-12)

1.2.3 Project success

The relationship between the success of **managing** a project and the success of '**the project**' was described by *Munns & Bjerirmi*[9] who recognise that :-

"The definition of a **project** suggests that there is an orientation towards a higher and long term goal". E.g. The transportation of passengers at supersonic speed (Concorde). "The definition of **project management** on the other hand suggests a shorter term and more specific context for success".

E.g. Delivering the project on time, within budget and to quality.

In the context of this submission it is important to recognise this distinction between successful 'project management' and 'a successful project'.

The ConSERV concept is being developed to assist in the *project management* and *engineering design* of capital projects, in an attempt to improve the performance of the project, and the efficiency of the project management system.

1.3 The need for a new approach

1.3.1 Existing Methods

The existing methods presently employed in managing major multidisciplinary capital projects are well established and have given good service to project managers over the years. The traditional management technique of employing experienced "*project managers*" empowered to drive the project has become somewhat outdated.

The 1990 style of project management has swung more towards the notion that a project needs a "*Project Champion*", rather than a "*Project Manager*".

The demands placed on the project manager may often exceed the individuals knowledge and information processing capability. This problem is exacerbated by the requirements placed on the project manager to make a succession of key decisions over the life cycle of the project management phase.

Project managers and planners are normally engineers qualified from at least one engineering discipline i.e. Mechanical, electrical, civil etc. As a result, project managers on multidisciplinary projects spend considerable time working outside their field of expertise. This phenomenon supports the case for a more **intelligent** comprehensive project management methodology.

1.3.2 Quality.

In major organisations company QA procedures place even more demands on the management teams employed on the project. In order to satisfy the organisational requirements and operate across all engineering disciplines the project manager needs to be able to recognise the specific needs and the focus of the project throughout the life cycle of the project management process. In their article, "Next generation PC-based project management systems "*Heindel and Kasten*[10] concluded that: "None of the currently available PC-based project management systems support the higher-level managerial concerns for managing the enterprise such as managing strategies, products, value chains and people."

Present tools do not provide the project manager with any knowledge about the project or the flow of information between various engineering functions within the project team.

1.3.3 Project Execution Plans

Execution plans are normally developed in the opening stages of the project after the necessary justification and evaluation procedures have been completed. The plan should identify precisely how the project is to be managed and the resources assigned. Planning is often fraught with difficulties due to the highly subjective nature of the process. In developing accurate project plans it is necessary to spend sufficient time in order to obtain an acceptable level of work breakdown detail.

Few of the existing planning tools provide the facility to 'weight' activities in terms of the value of the activity to the program as a whole. Existing packages employ probabilistic analysis and as such depend entirely on the human interpretation of 'progress'. Given the recent developments in AI and expert systems, it seems logical to assume that the development of future project management software tools, will utilise the more sophisticated software including **knowledge based systems**.

One common fault in the management of capital projects is the development of unworkable project execution procedures, PEP's. Project managers should recognise the importance of developing and applying project execution plans that meet the needs of the project being managed.

E.g. Using inappropriate mid range planning tools on a design intensive project being undertaken in the Nuclear industry.

Whilst in principle it is possible to use the tool at a level 1 WBS, the tool will be unable to identify the likely resource productivity factors or risk issues that may ensue over the life cycle of the project. Existing project management methods tend to be *static* rather than *dynamic*. This may not seem to be the case when one considers the updating facilities inherent in the top range and top range planning tools. On closer inspection however it is apparent that the act of updating programs can be highly subjective as the actual progress of an activity on the Gantt chart is usually measured as a percentage of its completion. In reality the progress of an activity is a far more intricate issue than it may appear on a simple bar chart.

One final limitation is that existing planning tools are activity oriented and take no account of the flow of **information** between the engineering disciplines or project team members.

1.3.4 Uniqueness

In order to illustrate the unique nature of industrial projects, consider as an example the following key elements of two major projects identified below :-

Project (i) is being undertaken in the ***chemical industry*** *based in* ***Europe*** *at the* ***Grimsby*** *plant. The project is a* ***new major*** *capital project being undertaken on behalf of the* ***Black section production Dept.*** *The project involves the* ***digestion*** *process and includes* ***a,b,c,d,e,*** *main plant items. The project is a new* ***greenfield*** *site location and involves* ***modifications*** *to existing plant. The project value is in* ***excess*** *of £ 3 M and will be undertaken in* ***14 months.*** *The project will follow* ***ICI company procedures*** *be* ***time*** *driven, and use* ***combined resources.***

Project (ii) is being undertaken in the ***Pharmaceutical industry*** *based in* ***Asia*** *in* ***Bangladesh.*** *The project is a* ***new major*** *capital project undertaken on behalf of* ***Square Pharmaceuticals Ltd.*** *The project involves* ***antibiotic manufacturing*** *processes and includes* ***a,b,c,d,e,f*** *main plant items. The project is a new* ***greenfield*** *site location and involves* ***no modifications*** *to existing plant. The project value is in* ***excess of £ 12 M*** *and will be undertaken in* ***24 months.*** *The project* ***procedures need to be established*** *The project will be* ***cost*** *driven, and will use* ***combined resources.***

By defining the specific issues associated with each project in a standard format it is possible to see how each project can be represented using a variety of unique **project specific** statements, such as those described above. It is also easy to see how each project will require totally different project specific management systems and strategies. Existing planning tools are unable to recognise any project specific requirements and are normally applied to projects irrespective of whether the systems are appropriate for the project being managed or not.

The ConSERV concept is intended to allow the project manager to identify the key dimensions of the project being managed, the risks that are likely to ensue, then develop an appropriate management system for that particular project.

Once implemented the system performance can be evaluated in light of the "developing project specific knowledge" and if necessary be modified to suit the external influences encountered over the life of the project.

1.4 The strategy and objectives of the research

1.4.1 The Research Strategy

The strategy adopted from the outset of this submission was that of employing a rigid highly structured methodology, in which the assumptions concerning the new technique were critically examined and evaluated. The strategy was to employ an industry based research approach in keeping with the recommendations of *Philips and Pugh* [2] (pp v) which combined the responses to **questionnaires and interviews** with the findings from **research data** obtained from the industrial case studies.

The results were then analysed in light of the **literary study data** in order to identify the most common project management failure mechanisms. Having established a need for the research effort, an *Opportunity Analysis* was undertaken to establish whether or not a KB solution was appropriate. Having confirmed the need for a KB approach the *Plausibility Study* was commissioned which provided the framework for the demonstrator 'A'. Ref. p72-75. The 'deliverables' associated with this submission were established early in the project execution plan, and include :-

i) A summary of the findings from the literary studies
ii) A summary of the results of the industrial cases studied.
iii) The Opportunity Analysis report (OA/001/96 Jan 1996)
iv) The Plausibility Study report (PS/001/96 Feb 1996)
v) The Demonstrator Report (DR/001/96 Jul 1996)
vi) Demonstrator software (March 1997)
vii) The ConSERV concept test results (July 1997)

The deliverables were all met on schedule.

1.4.2 The Procedure

The procedure for the development of the KBS is the KLIC system proposed by *Guida and Tasso*[4] schematically shown in Fig. 1 below.

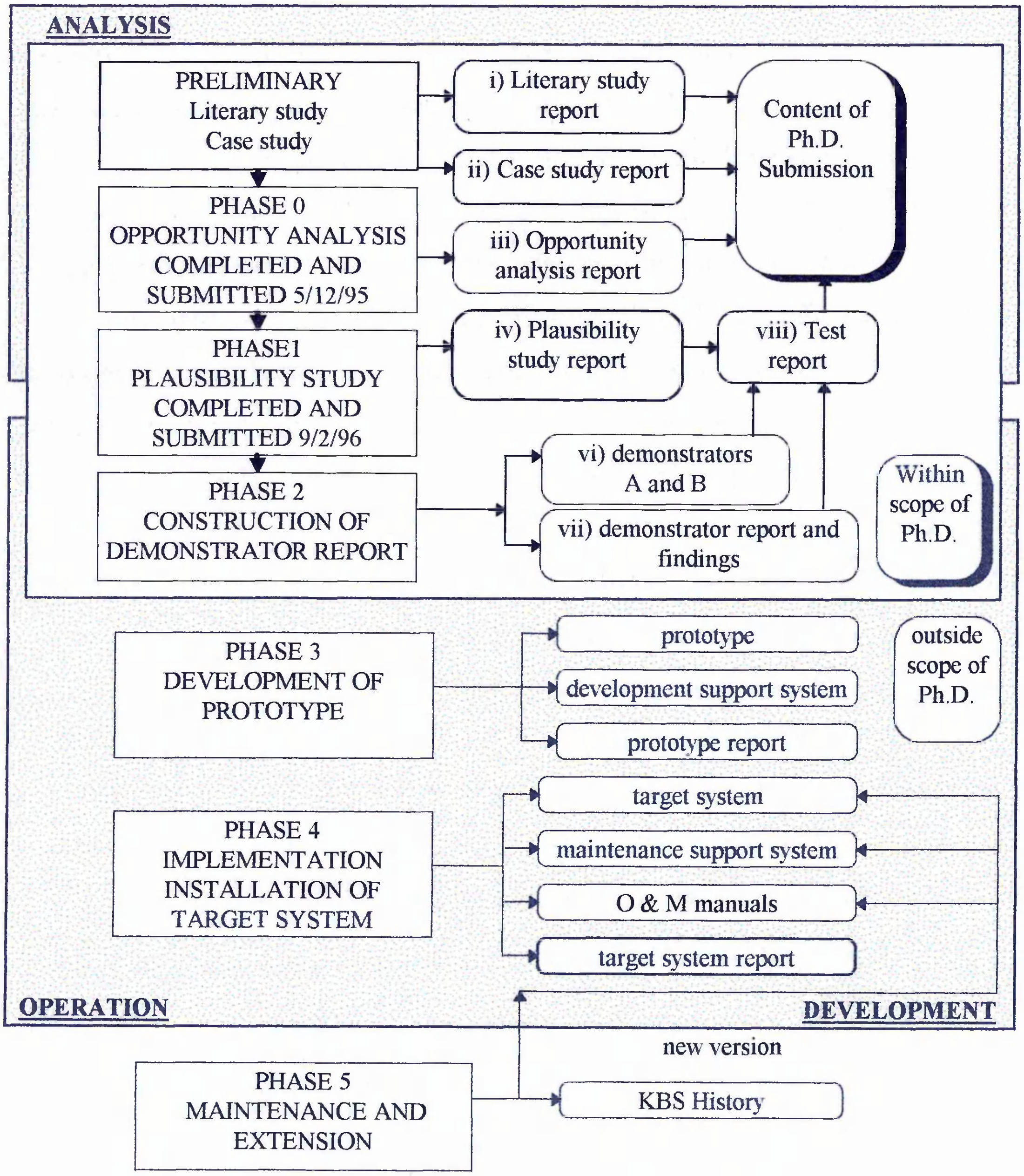


Fig 1 The KLIC life cycle as proposed by Guida and Tasso

1.4.3 The Main Research Objectives

Following the literary study, the main research objectives were identified as being:-

a) Project based Industrial case study research

i) To investigate project management techniques practiced in industry at present.

ii) To record day to day decision making processes and strategies employed over the life cycle of 'typical' major capital projects.

iii) To analyse the results of the project management techniques and methodologies employed in order to identify weaknesses and develop hypothesis and arguments.

iv) To identify from cause and effect analysis the impact and consequences of key management decisions made over the projects life.

v) To undertake an analysis of the multidisciplinary issues and the flow of critical information between engineering disciplines during design and construction periods.

vi) To investigate the effects of behavioural and organisational influences on the case study projects.

vii) To consolidate, standardise, tabulate and analyse the findings in order to identify specific project failure mechanisms.

b) Development of the ConSERV concept

i) To use the industrial research data to justify the need for a KBS. management approach able to pre-empt the identified failure mechanisms.

ii) To identify an appropriate management system and convert it into a model

iii) To identify key project specific risk issues and knowledge handling requirements.

iv) To develop the concept into an alternative risk driven management technique.

v) To apply a rigid and impartial KBS development approach from feasibility, through to plausibility and finally to demonstratability.

vi) To develop demonstrators capable of proving the management concept using a limited subset of the problems identified from the industrial research.

vii) To test the demonstrators against three industrial case studies in order to verify whether or not the principle of the concept is workable.

viii) To analyse the feedback and provide a sound basis for the subsequent development of future knowledge-based project management software.

1.5 Background and brief history

1.5.1 The Background

The background to this research effort stems from the notion that one of the main factors contributing to an ailing economy is that of mis-managing capital projects.

As agents of change project managers are directly responsible for the appropriation of £ billions every month in the UK economy alone. Project management is a relatively new branch of management sciences that does not readily lend itself to traditional or line management theories. The management of major capital projects presently being undertaken in the Chemical, Pharmaceutical and Petrochemical industries demands a unique blend of human expertise, organisational direction and the application of *appropriate* project management theories. A summary of the literary research is provided in Appendix D7 and D8.

1.5.2 Brief History

The history of project management is difficult to trace as many major projects have been "managed" since around 2000 B.C. i.e. The pyramids. The mobilisation of large labour forces is also not a new concept, armies have been marshalled and major campaigns undertaken since the time of the 12th dynasty of Egyptian civilisation.

The management techniques have of course developed extensively with the more familiar project management concepts being formalised around the turn of the century.

1.5.3 The Traditionalists view

The traditionalists view of project management is a rather simplistic one in which the role of the project manager is seen as being that of a middle management position operating within an organisational structure. Previous research findings *Conroy* [8] suggest that the project manager is likely to have risen to the position by demonstrating some level of intimate knowledge with the type of work associated with the project in question. i.e. familiarity, rather than proficiency.

1.5.4 The Professionals view

The professionals' view of the project manager is that of an individual able to demonstrate competence in a range of knowledge domains as identified by the APM and PMI's Body of Knowledge A4 and A5 (Fig 4 and 5).

1.6 Contribution to knowledge

1.6.1 The New Methodology

This section is intended to provide the reader with an outline of what to expect with regard to the *contribution to knowledge* made during the course of this submission.

The most useful contribution to knowledge this research has made is in taking the hitherto unspecified, heuristic based project management and engineering design knowledge into an area where it is able to be more readily applied to the management of design intensive projects. The technique assists users in identifying a set of risks that are unique to the project. Having identified the specific risks, the system can assign a risk management methodology employing experiential knowledge in order to offer alternative methods of controlling the 'project management' and 'design' risks.

It is the author's opinion that the main contribution this submission makes to knowledge is in "*Knowing why engineering design man-hours assigned at the outset of a multidisciplinary design intensive capital project will overrun.*"

Phillips and Pugh[2] suggested fifteen definitions by which a Ph.D. thesis might be determined as being original, six of which are considered applicable to this thesis.

i/ The setting down a major piece of new information *(failure mechanisms identified)*

ii/ Providing a single original technique *(The ConSERV concept)*

iii/ Having many original ideas *(Identifying risks and visualising the workflow in 3D)*

iv/ Bring new evidence to bear on an old issue. *(Resolving multidisciplinary conflicts)*

v/ Being cross disciplined and using different methodologies *(Integrating Project management and engineering design issues in one methodology)*

vi/ Addressing new areas that people in the discipline have overlooked *(Errors in human decision making processes in project management and engineering design)*

As contentious as the statement might be *Robson*[1] suggests that, "All scientific enquiry is a contribution to knowledge" albeit in the most part inadequate to satisfy the needs of a Ph.D.

1.6.2 The Focal theory

This research work provides a proposal on how projects can be better managed, by using a risk driven, knowledge based, design interactive, on line, project management methodology. The **Con**current **S**imultaneous **E**ngineering **R**esource **V**iew concept is essentially a Configuration Management technique that interacts directly with engineering and engineering design resources whilst recognising the need to operate within industrially acceptable management procedures.

The concept involves, a data acquisition process able to identify the key ***project specific*** requirements and the related ***engineering design*** risk issues which enable the user to assign engineering man-hours to manage the project specific issues identified. The technique allows the selection and development of a customised interactive project management system that can respond, and if necessary adjust itself to, the ever changing needs of the project as the focus shifts over the project management life cycle. The ***engineering design*** element of the concept, provides a method by which the project specific **engineering** requirements, and the interdisciplinary **engineering design** resources, can be viewed using a **dynamic 3 dimensional visualisation**.

This new technique enables the project manager to identify resource and activity difficulties in the context of the project as a whole.

The ConSERV concept also provides a **self audit** project facility by giving the project manager a direct interface with the key dimensions of the simulated project.

The system proposed may qualify as a 'Configuration' as defined in BS 6488[11]

Allan[12] submits "The end product of an effective CM system should be an awareness of the status of all components at any given time". The further contribution to knowledge this submission affords is in the failure mechanisms identified from the research and analysis from the application of existing organisation and management systems. Ref. Fig. 59 p 120. The research findings from both the MSc. and the Ph.D. have provided data that supports a number of hitherto un-proven assumptions concerning the decision making and behavioural aspects of project management.

Perhaps one of the most useful areas in which this dissertation provides a contribution to knowledge is in that gleaned from the evaluation and testing of the new technique. Ref. Figs. 100 and 101. p 173-174. Details of the Focal theory are provided on p 66.

1.7 Summary and References

1.7.1 Summary

This Chapter, and the relevant appendices, has given an account of what project management is, and what a project manager is expected to do. It has highlighted some of the known classical project management failure mechanisms and provided arguments justifying this research effort.

The need for a new approach to project management has been identified and a clear statement of the research objectives of the Ph.D. has been stated.

A brief comparison of two typical projects, and their respective differences has been alluded to in order to give the reader an insight into how the specific project needs differ widely between projects.

This Chapter has provided a clear indication of the strategy of the research and the methodologies applied in the development of a knowledge based approach to project management.

This submission is about real world projects that do not live up to 'expectation'.

For every project that 'fails' there is usually a team of project managers and engineers who might also be seen as failures. Many organisations are reluctant to concede that their systems and managers are unable to deliver successful projects. It is for these reasons that the subject matter is often treated as being taboo and, at times, is difficult to research.

Appendix A provides a more concise summary of the Project Management functions as applied in the industry. A listing of the case studies is provided along with a summary of the basic hypotheses and arguments forming the focal theory of this submission.

In Chapter II the author reviews in some detail the *science* and the *art* of project management, and attempts to identify what constitutes 'expertise' in project management.

1.7.2 References

1 Robson, C. (1993) *Enquiry in the real world.* Oxford Blackwell

2 Phillips, E.M. and Pugh, D.S. (1992) *How to get a Ph.D.* Open University Press.

3 Drucker, P. F. (1968) *The Practice of Management.* Pan Piper

4 Guida, G. and Tasso, C. (1994) *Design and Development of knowledge based systems.* J Wiley London.

5 Morris, P.W.G. and Hough, G.H. (1987) *The Anatomy of Major Projects.* J Wiley London.

6 Newtown. J de. (1994) 'Causes of Poor Project performance' Hawksmmere.

7 Belassi, W and Tukel O.I. (1996) 'A new framework for determining critical success/failure factors in projects' International Journal of Project Management vol. 14, no.3, 141-151.

8 Conroy, G. (1992) 'An investigation into Decision making processes in project management'. Huddersfield University MSc. Dissertation.

9 Munns, A.K. and Bjeirmi, B.F. (1996) 'The role of project management in achieving project success'. International Journal of Project Management vol.14, no.2, 81-87.

10 Heindel, L.E. and Kasten, V.A. (1996) 'Next generation PC-based project management systems'. International Journal of Project Management vol.14, no. 5, 307-309.

11 BS 6488;1984 *British Standard Code of Practice for Configuration Management of Computer-Based Systems*

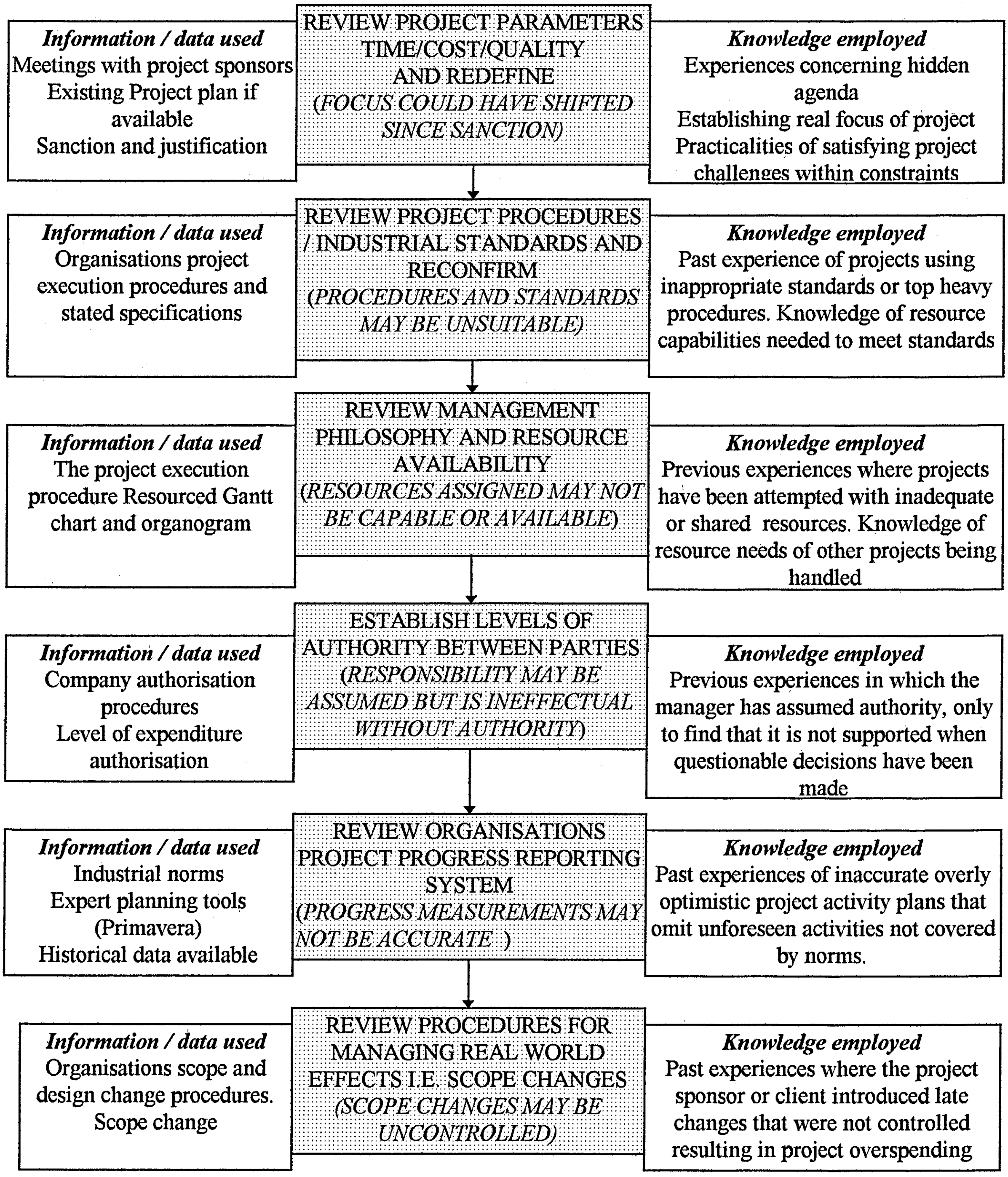
12 Allan, G (1997) 'Configuration management and its impact on businesses that use computer platforms' International Journal of Project Management vol.15, no. 5, 321-330.

APPENDIX A

ACTIVITIES OF THE PROJECT MANAGER
CAUSES OF POOR PROJECT PERFORMANCE
PRESCRIPTIVES FROM APM AND PMI BODY OF KNOWLEDGE
EXAMPLES OF KNOWLEDGE CLASSIFICATION
SUCCESS/FAILURE FRAMEWORK
SUMMARY OF CASE STUDIES
TABLE OF HYPOTHESES

APPENDIX A

The activities of the project manager are extensive, in determining whether a new management concept is necessary, it is important to recognise the full extent of the actions of the project manager, which are summarised in Fig. 2 below.



Information / data used
Meetings with project sponsors
Existing Project plan if available
Sanction and justification

REVIEW PROJECT PARAMETERS TIME/COST/QUALITY AND REDEFINE
(FOCUS COULD HAVE SHIFTED SINCE SANCTION)

Knowledge employed
Experiences concerning hidden agenda
Establishing real focus of project
Practicalities of satisfying project challenges within constraints

Information / data used
Organisations project execution procedures and stated specifications

REVIEW PROJECT PROCEDURES / INDUSTRIAL STANDARDS AND RECONFIRM
(PROCEDURES AND STANDARDS MAY BE UNSUITABLE)

Knowledge employed
Past experience of projects using inappropriate standards or top heavy procedures. Knowledge of resource capabilities needed to meet standards

Information / data used
The project execution procedure Resourced Gantt chart and organogram

REVIEW MANAGEMENT PHILOSOPHY AND RESOURCE AVAILABILITY
(RESOURCES ASSIGNED MAY NOT BE CAPABLE OR AVAILABLE)

Knowledge employed
Previous experiences where projects have been attempted with inadequate or shared resources. Knowledge of resource needs of other projects being handled

Information / data used
Company authorisation procedures
Level of expenditure authorisation

ESTABLISH LEVELS OF AUTHORITY BETWEEN PARTIES
(RESPONSIBILITY MAY BE ASSUMED BUT IS INEFFECTUAL WITHOUT AUTHORITY)

Knowledge employed
Previous experiences in which the manager has assumed authority, only to find that it is not supported when questionable decisions have been made

Information / data used
Industrial norms
Expert planning tools (Primavera)
Historical data available

REVIEW ORGANISATIONS PROJECT PROGRESS REPORTING SYSTEM
(PROGRESS MEASUREMENTS MAY NOT BE ACCURATE)

Knowledge employed
Past experiences of inaccurate overly optimistic project activity plans that omit unforeseen activities not covered by norms.

Information / data used
Organisations scope and design change procedures.
Scope change

REVIEW PROCEDURES FOR MANAGING REAL WORLD EFFECTS I.E. SCOPE CHANGES
(SCOPE CHANGES MAY BE UNCONTROLLED)

Knowledge employed
Past experiences where the project sponsor or client introduced late changes that were not controlled resulting in project overspending

Fig. 2 Typical actions and activities of the project manager

APPENDIX A

CAUSES OF POOR PROJECT PERFORMANCE

(Extracts from J de Newtown 1994 survey)

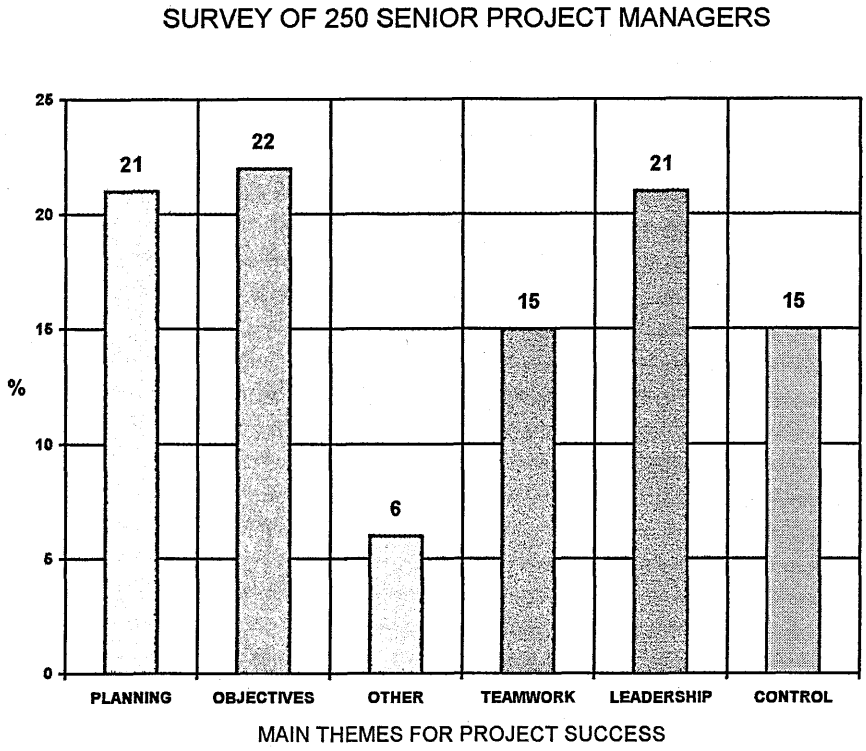


Fig 3 Causes of poor project performance

APPENDIX A

The following is an extract from the 1995 APM Body of Knowledge. (BOK)
NB extracts from the BOK are with the kind permission of the APM

PROJECT MANAGEMENT

1.1 SYSTEMS MANAGEMENT
1.2 PROGRAMME MANAGEMENT
1.3 PROJECT MANAGEMENT
1.4 PROJECT LIFE CYCLE
1.5 PROJECT ENVIRONMENT
1.6 PROJECT STRATEGY
1.7 PROJECT APPRAISAL
1.8 PROJECT SUCCESS/FAILURE CRITERIA
1.9 INTEGRATION
1.10 SYSTEMS AND PROCEDURES
1.11 CLOSE-OUT
1.12 POST PROJECT APPRAISAL

2. ORGANISATION AND PEOPLE

2.1 ORGANISATION DESIGN
2.2. CONTROL & CO-ORDINATION
2.3 COMMUNICATION
2.4 LEADERSHIP
2.5 DELEGATION
2.6 TEAM BUILDING
2.7 CONFLICT MANAGEMENT
2.8 NEGOTIATION
2.9 MANAGEMENT DEVELOPMENT

3. PROCESSES AND PROCEDURES

3.1 WORK DEFINITION
3.2 PLANNING
3.3 SCHEDULING
3.4 ESTIMATING
3.5 COST CONTROL
3.6 PERFORMANCE MEASUREMENT
3.7 RISK ANALYSIS AND MANAGEMENT
3.8 VALUE MANAGEMENT
3.9 CHANGE CONTROL
3.10 MOBILISATION

4. GENERAL MANAGEMENT

4.1 OPERATIONS/TECHNICAL MANAGEMENT
4.2 MARKETING AND SALES
4.3 FINANCE
4.4 INFORMATION TECHNOLOGY
4.5 LAW
4.6 PROCUREMENT
4.7 QUALITY
4.8 SAFETY
4.9 INDUSTRIAL RELATIONS

Fig 4 Extracts from APM Body of Knowledge Courtesy APM

APPENDIX A

The PMI BoK (Body of Knowledge) affords a similar set of definitions shown diagramatically. Overview of Project management Knowledge areas and project management processes.

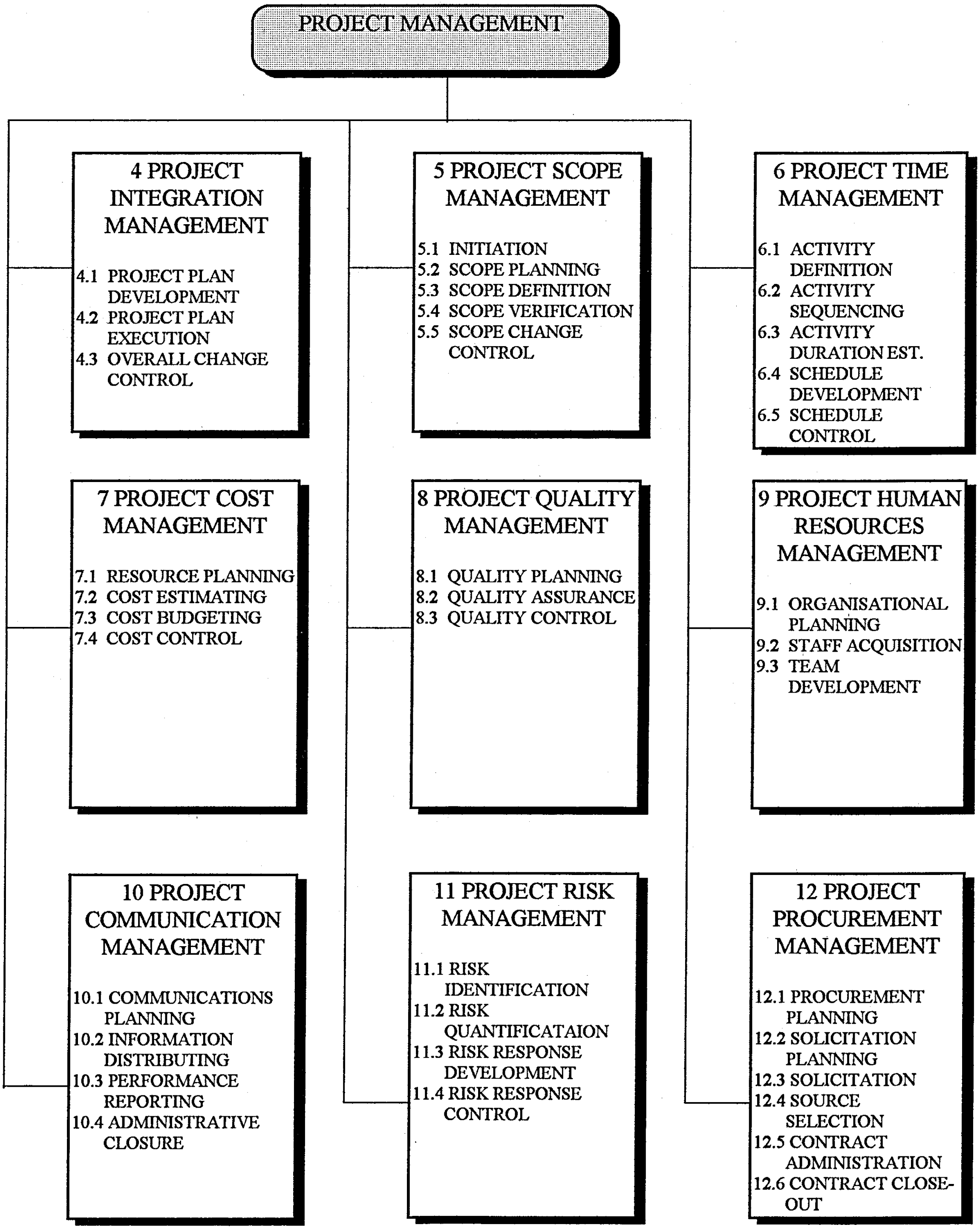


Fig 5 Extract from PMI BoK

APPENDIX A

Typical examples of knowledge classification used in Project management

Function Name	Description of activity / discipline	Organisation category	Corresponding Knowledge	Characterisation of type of knowledge
Project management 1.0	General management theory	Project Group Level 1 (Executive)	Organisational procedures and knowledge from experiences	declarative, symbolic, incomplete
Project management 2.0	General project management theory (Ref APM body of knowledge)	Project Group Level 2 (Senior Management)	Ref. Association of Project Managers Body of Knowledge	uncertain, imprecise, subjective
Project management 3.0	General project management practice	Project Group Level 2 (Senior management)	Past project audits performance and results, experiential	fragmentary, subjective.
Project management 4.0	Project Costing and Accounting	Project Group Level 2/3 Project manager	Organisational procedures. Accounting procedures	procedural structured objective
Project management 5.0	Appreciation of type of Industry and culture.	Project Group Level 2/3 Project manager	International Standards codes of practice	subjective interpretation
Project management 6.0	Applicable fields of Engineering. (Multidiscipline)	Project Group Engineering, maintenance development	International / Other company standards	qualitative, procedural
Project management 7.0	Relevant Contractual elements	Project Group Senior management level	Contract Law and past projects, experiential	subjective, fragmentary declarative
Project management 8.0	Risk theory and risk management	External consultants	Probability theory own experiences	uncertain, incomplete declarative
Project management 9.0	Principles of engineering design	Organisations design methods and company standards	Alternative design facilities and appropriate software tools	incomplete conflictory during conceptual stages of design
Project management 10.0	Man management and discipline	Project Group senior management consultants	Organisational guidelines, behavioural psychologists	declarative, subjective contradictory conflict
Project management 11.0	Project management research, IT and computer technology	Research Institutes and Universities	Research findings from industry and Government	imprecise, empirical, declarative

Table 1 Extract from Plausibility study knowledge classification

APPENDIX A

Project Success / Failure framework identified by *Belassi and Tukel*

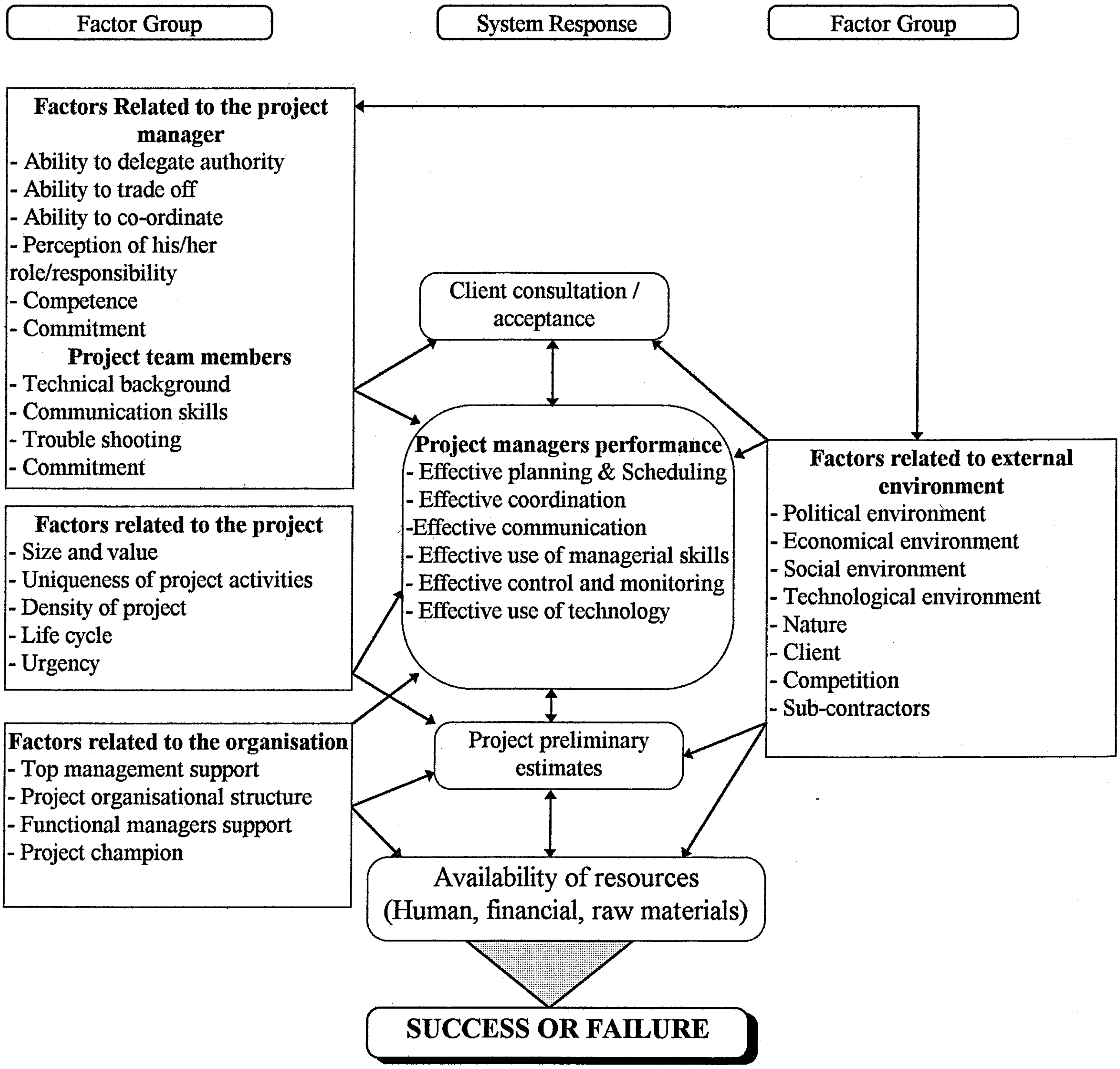


Fig 6 Project management success/failure framework

APPENDIX A

Summary of Industrial Case study Projects referenced in the submission.

Case Study 1 (1993-1994) Gas Cleaning project	PLANNING	COST CONTROL	DESIGN / QA	COMMUNICATION
Organisational procedures	Existing ICI procedures	Existing ICI procedures	Established ICI procedures & Stds	Determined by project manager
Software chosen	Microsoft Project V3	Organisations purchasing Dept	ACAD 12	None
Project Outcome	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Auditable	Yes	Yes	Yes	Yes

Case Study 2 (1995-1996) New Digester Project	PLANNING	COST CONTROL	DESIGN / QA	COMMUNICATION
Organisational procedures	Existing ICI procedures	Existing ICI procedures	Established ICI procedures & Stds	Established ICI procedures
Software chosen	Microsoft Project V4 Primavera P3	Microsoft Excel spreadsheets	ACAD 12 / 13	Cyco Workflow
Project Outcome	Satisfactory	Satisfactory	Unsatisfactory	Satisfactory
Auditable	Yes	Yes	No	Yes

Cephalosporins Project 3 (1996 - 1997)	PLANNING	COST CONTROL	DESIGN / QA	COMMUNICATION
Organisational procedures	No Existing procedures	Client purchasing system	Procedures for UK design exist	To be determined
Software options	Microsoft Project V4	Microsoft Excel or Macris ?	ACAD 12 / 13	Visio, Modem system Reachout ?
Project outcome	Unknown	Unknown	Unknown	Unknown
Auditable	To be determined	To be determined	To be determined	To be determined

New Sulphuric acid project 4 (1997-1998)	PLANNING	COST CONTROL	DESIGN / QA	COMMUNICATION
Organisational procedures	Organisation procedures (limited)	Project group company procedures	European Stds Procedures for UK design exist	Client - Contractor HQ - Contractor Site.
Software options	Microsoft Project V4	Microsoft Excel or Macris	ACAD 13 2 D and 3D Autoplant	Visio, Modem system
Project outcome	Unknown	Unknown	Unknown	Unknown
Auditable	To be determined	To be determined	To be determined	To be determined

Zimbabwe Sinter Plant Project 5 (1992-1997)	PLANNING	COST CONTROL	DESIGN / QA	COMMUNICATION
Organisational procedures	Organisation procedures	Project group company procedures	European Stds. Procedures for UK design exist	Overseas Client - Contractor HQ - Contractor Site.
Software options	Limited	Company systems	Generic System	None
Project outcome	Successful despite 2year mothballing	Successful	Satisfactory	communicating with African countries unsatisfactory
Auditable	Yes	Yes	Yes	No

Fig 7 Summary of Industrial case studies referenced in submission

APPENDIX A

Table of Hypothesis / Arguments and premises forming the basis for the Ph.D.

Item	Description of Hypothesis / Argument	Basis of the assumption
1	That the majority of capital projects being managed in the Process industry today employ traditional project management and engineering design techniques	Experience, Industrial and Literary research
2	That the techniques employed include an assortment of commercially available and bespoke planning, scheduling and costing software tools as combined with organisational procedures and human expertise	Experience, Industrial research and investigative studies
3	That project management, engineering design and risk management theories are generalised and broad based and therefore difficult to apply to any specific cases	Literary research and investigative studies
4	That traditional project management and engineering design techniques do not readily integrate with the organisational procedures in which they operate.	Experience, Industrial research and case studies
5	That traditional project management and engineering design techniques fail to identify project sensitivities	Experience, Industrial research and investigative studies
6	That traditional project management and engineering design techniques fail to capture the reasons for, and the knowledge and lessons learned from, 'unsuccessful' projects.	Literary research Journals and Industrial studies
7	That traditional project management and engineering design techniques are heavily dependent upon the skills and expertise of the individual, and therefore prone to project failure through human error.	Investigative studies and Industrial research
8	That traditional project management and engineering design techniques fail to differentiate between project failure and project management failure.	Literary research and experience
9	That traditional project management methods do not necessarily improve the likelihood of project success	Experience, Literary research and assumption
10	That traditional project management and engineering design techniques do not interact in a multi disciplinary environment	Experience

Table 2 Table of Hypothesis and arguments as basis for the Ph.D. research

Chapter II

2.0 THE ART AND SCIENCE OF MANAGING PROJECTS

"Project management, an occupation not for the faint hearted. Project management is now viewed more in terms of managing a 'risky' business".
Conroy [1].

2.1 Project management, an art or a science

2.1.1 Introduction

Chapter I provided an insight into the business of managing capital projects in the Chemical, Pharmaceutical and Petrochemical industries. It also highlighted a number of problems associated with current project management techniques and the available software used in managing multidisciplinary design projects.

This chapter reviews some of the history of project management and contrasts the hard and soft skill issues of project management.

2.1.2 The science of project management

The science of project management includes many well researched management theories that can be applied to the management of capital projects

E.g. The capitalistic ethic, socio cultural values, business ideologies, national industrial policies etc. **The scientific management** theory emerged under the driving force of *Taylor* [2] who's views were strongly influenced by the Protestant ethic of the time, that of hard work, economic rationality, individualism and the idea that each person had a role to play in society.

Scientific management required that managers plan, organise and control task performance. It demanded a new, and more systematic approach to the process of management, which brought about the introduction of personnel and quality control functions. Despite considerable opposition Taylorism spread widely throughout the USA industries and the scientific approach to management grew into an organisation theory. In 1916 a French industrialist *Fayol* [3] published a comprehensive list of management principles "*Administration Industrielle et Generale*".

Fayol's theory involved five primary elements :- Planning, organizing, command, coordination and control. These elements were subdivided into: 1 Division of work, 2 Authority and responsibility, 3 Discipline, 4 Unity of command, 5 Unity of Direction, 6 Subordination, 7 Remuneration, 8 Centralisation, 9 Scalar chain (organogram), 10 Order, 11 Equity, 12 Stability of tenure, 13 Initiative and 14 Esprit de Corps (Team work)

Fayol's principles employed many of the basic tenets found in today's project management theories. The third major pillar in the development of the classical organisational concepts was provided by *Weber's* bureaucratic model. *Weber*[3] was one of the founders of modern sociology and was a significant contributor to economic, social and administrative thought. The bureaucratic model is most appropriate for the routine organisational activities in which productivity is seen as the major objective.

Economic theory has its emphasis on rationality, strongly influenced managerial thought and subsequent actions that provide a rationale for the operation of the business.

Economic theory provides for the adaptation of market forces and is more applicable to the highly competitive types of business operations.

Other management theories such as **public administration** and **administrative management theory** combine to form what is commonly known as **traditional management theory.**

The basic premise of a rational economic man (complete knowledge and maximising behaviour) was integrated by the classical management writers into their views of the organisation. The classical management theories thus evolved into the development of concepts such as pyramid structure, unity of command, span of control, management by exception, specialisation by function, line staff dichotomy and other generalised *principles of management* that *seemed* appropriate for use in **all** organisations.

The major criticism of the classical management theory was that it employed unrealistic closed-system assumptions about organisations. It was a model that failed to consider many of the environmental influences on the organisation as well as many important internal aspects.

More than half a century has past since the development of these traditional management theories and as a consequence there has been a dramatic change in the methods of application. These changes have come about due to the fact that people are more educated, they have a higher level of skill, and they have more complex aspirations. The technologies applied in every day management scenarios are more sophisticated and demand greater participant awareness. The global issues involved in project management are now more influential, with more recognised risk mechanisms, and there is a far greater awareness of the environmental issues associated with managing **change.**

In his preface *Lock* [5] suggests that "Project management is both a specialist and a non-specialist skill" he argued that it is specialist because it uses a family of highly developed techniques for planning and control purposes, but it is non-specialist because the project manager must have a very broad appreciation of the working methods used by the respective parties involved.

Lock purports that "Projects have been a part of the human scene since civilisation started, yet the practice of project management is, on the historical time-scale almost brand new". Even in the ten years since *Lock* published his "Project management Handbook" there have been a number of significant changes as was confirmed by the research findings Ref. p32.

The scientific approach to project management is in the main a well founded and well established science. However, with the staggering amount of recent technological development there is a real risk that applying a totally scientific based management methodology could place demands on project managers that are beyond their mental processing skills. Humans process at around 10^{15} MIPS whilst machines are now approaching 10 MIPS. The skills needed to work effectively in a *virtual project* environment will be those of time management, self reliability, IT and self motivation.

Being on the asymptote of the technological curve may well result in upsetting the delicate balance between the hard, science based skills, and the soft, humanistic management skills, traditionally considered necessary in order to manage major capital projects. Ref. Appendix B8 and B9 (Tables 8 and 9)

2.1.3 The ***artistry*** of project management

It may well be that the art of managing projects is a function of the way in which the manager employs the available tools and resources at his/her disposal.

The conductor of an orchestra for example, may act as the catalyst for a virtuoso performance, or may be the cause of a mediocre performance.

In a totally technical environment, such as engineering design, there may not appear to be much room for freedom of thought or self expression, especially if the designs involve highly technical risks such as those encountered in the Nuclear industry.

An appreciation of art is however embodied within the engineering communities, consider for a moment the grace of Concorde or the elegance of an Aston Martin.

The appreciation of art is not restricted to the artifact, in much the same way that the mastery of the conductor is remembered for a virtuoso performance, a project can be remembered for the mastery of the project manager. In order for the conductor to conduct an orchestra he/she requires an in depth understanding of all the elements necessary to give an outstanding performance.

The exuberance and confidence of the conductor may reinforce self belief within the team, this leadership quality is comparable to the **artistry** of project management.

The professional project manager will exude similar characteristics albeit in a far less flamboyant manner than that of a symphony orchestra conductor.

Art is concerned with creativity and innovation, many experienced project managers will readily identify with these concepts. During the life of a major capital project the project manager will invariably resort to many techniques in order to achieve a desired result.

Virtually all of the soft skills involved in the business of managing projects can be considered as being more of an art form than a true science.

E.g. The art of communication, the art of negotiation, the art of resolving conflict, the art of listening, the art of exercising control, the art of exercising power, the art of diplomacy, the art of managing human resources.

It could be argued that converting scientific principles, organisational procedures a budget and a number of human resources into a successful project is in fact an art in its own right, i.e. the art of project management.

The artistry of project management within the context of this dissertation is worthy of reference, especially, if the ConSERV knowledge based management selection process is to go beyond the application of scientific rules. The hard and soft skills applied by the project manager consist of a **combination** of the individuals background, training, beliefs and values.

In order to imitate the more humanistic nature of project management, i.e. the artistry, the KBS has to periodically check that those soft skill elements that influence project success are continually monitored and addressed. i.e.

i/ That the individuals assigned to the project have all been correctly briefed and that they possess the necessary skills.

ii/ That any weaknesses in the team have been identified and a corrective strategy agreed and employed.

iii/ That individuals views are expressed and recognised.

In short, that synergy exists between the key parties involved in the project, and the systems User Interface.

In order for the system to be accepted by the project team it must be able to interact with individuals of different disciplines and with mixed skill levels.

It seems that project management is a profession quite unlike any other as it places demands on the individual that require the continual use of both charismatic power and scientific skills.

The **art** and **science** of managing projects are complimentary demands often overlapping each other. The intricacy by which they are woven into the every day business of project management and their relative dependencies must not be underestimated.

It might be argued that the art of managing projects in the next Millennium will be in appreciating and working with the interactive capabilities of the next generation PC's and the future IT sciences.

2.2 Project management expertise and knowledge

2.2.1 Expertise and knowledge domains

Guida and Tasso [6], define "An **area** within a given organisation as a sub part of the organisation, including one or more structures which has a specific role for the execution of a set of processes. E.g. The Design Department, or the checker in a design department.

An **application domain** within a given organisation is a set of strictly interrelated processes which pursue a common goal, E.g. The maintenance department, the quality control department.

A domain is characterised by a specific and well identified set of knowledge called the **knowledge set** of the domain.

The knowledge set is neither homogenous nor unitary and may include several knowledge classes.

Areas and domains are generally independent of each other, the main distinction being that areas are static whilst domains are dynamic.

The organisations studied in the industrial based research had the following project management and engineering design areas :-

- Executive Management

SUBSTANTIATE NEED FOR PROJECT
SANCTION FRONT END ENGINEERING COSTS
AUDIT PROJECT

Functions :
Project screening, justification and approval
Appropriation of monies and human resources.
Audit of projects/guidance and direction for capital projects
Authorisation of procedural changes

- Project group management

DEVELOP +/- 10% PROJECT BUDGET
ESTABLISH PROJECT FEASIBILITY
ASSIGN PROJECT MANAGER

Functions :
Liaise with works management
Prioritise and schedule all projects
Allocate group resources
Report project progress to Executive Management
Authorise purchase requests
Approval of invoices

- Project manager

DEVELOP PROJECT EXECUTION PLAN
ESTABLISH ORGANOGRAM AND QA SYSTEM
SUPERVISE DESIGN EFFORT AND SCOPE
IMPLEMENT PROJECT MANAGEMENT PROCEDURES

Functions :
Develop project requirements and justification for Capex (Capital expenditure)
Assign personnel to project tasks
Develop organogram
Develop project execution plan
Raise orders and procure project plant items
Manage project activities including engineering and construction

- Discipline engineers

REVIEW FEE STUDY AND DEVELOP +/- 10% BUDGET
MAKE ENGINEERING DESIGN DECISIONS
SPECIFY DISCIPLINE REQUIREMENTS
COMMISSION DISCIPLINE SPECIFIC ELEMENTS

Function :
Develop engineering design associated with own discipline area (GA's P&ID's)
Undertake discipline specific calculations
Specify discipline specific engineering requirements
Integrate discipline activities
Place orders, inspect and supervise installation
Commission plant and handover

- Quality Management

REVIEW FEE STUDY AND DEVELOP +/- 10% BUDGET
DEVELOP QA PROCEDURES
IMPLEMENT AND MANAGE QA PROCEDURES
MAINTAIN QA DOCUMENTATION

Functions :
Provide input into FEE Study
Advise on QA requirements and cost
Develop QA Plan
Maintain QA documentation

- Design Management

REVIEW FEE STUDY AND DEVELOP +/- 10% BUDGET
DEVELOP DRAWING AND DOCUMENT CONTROLS
DEVELOP DISCIPLINE ENGINEERS DESIGNS
OBTAIN APPROVALS AND DETAIL
COMPLETE AS BUILTS, RECORD AND FILE DRGS

Functions :
Provide input into FEE Study
Advise on Design man-hours
Develop QA plan and organogram
Report man-hours expended
Check all designs for compliance.

- Purchasing/Procurement

ESTABLISH PROJECT COST CONTROLS
PROVIDE PROCUREMENT SERVICES
PROVIDE ENQUIRY SERVICES
PROVIDE COMMERCIAL AND CONTRACTUAL SERVICES

Functions :
To provide commercial assistance
Develop contract basis.

2.2.2 Domains

Are characterised by the *Guida and Tasso* methodology by focusing on the **knowledge** required to perform specific functions in each of the identified areas.

For each domain, the relevant **knowledge set** is defined and the main knowledge classes are identified.

Each domain is considered again and carefully checked in order to determine whether it is **knowledge intensive** or not.

A **knowledge - intensive** domain is an application domain in which:

The knowledge set of the domain is extensive, when:

i/ It involves a large amount of highly structured knowledge,

ii/ It includes several inter related knowledge classes.

iii/ It involves a significant part of non-procedural knowledge, i.e. knowledge which cannot easily be organised into an algorithmic, or procedurally structured form.

iv/ It contains knowledge relevant to a large class of problems in the domain.

v/ The solution requires complex knowledge processing activities involving the exploitation of general problem solving methods and specific heuristic strategies.

In order to determine whether or not a domain is knowledge intensive, it is necessary to undertake knowledge acquisition techniques.

Knowledge Intensive Domains. (KID's) are obtained by discarding all the domains which turn out not to be knowledge intensive, and completing the remaining ones with indications of the relevant knowledge set together with main knowledge classes, and a list of the reasons that make the domain knowledge intensive.

The storage and distribution of knowledge within each organisation will vary widely depending upon the nature of the business, the security and confidentiality of the knowledge.

The knowledge used in project management is highly transportable knowledge, consisting of a **combination** of proceduralised (science based) knowledge and experiential (heuristic) knowledge.

2.2.3 Knowledge distribution

The distribution of knowledge within the organisations studied included :-

i/ A readily accessible central repository of fundamental knowledge peculiar to the business (The Technical information Centre) and,

ii/ Temporal knowledge held by transient and contracted staff operating within the organisation.

iii/ Historical knowledge in the form of project records and archives.

iv/ Current knowledge in the form of management training and development programs.

v/ Emerging knowledge in the form of developmental research and experimentation.

2.2.4 Future knowledge structures

In his paper presented to the IEE Colloqium in 1995 *Drabble* [7] showed how intelligent planning techniques could be used to create an environment in which existing project planning and scheduling tools could be used to handle projects.

The paper concentrates on the planning issues of project management, and how the plan can be used within a workflow environment.

Shane and Schumaker [8] proposed a knowledge based system for managing projects at the 1993 Hawaii International Conference on Systems Science. The KBS is a hypertext intelligent system called 'Skillset' that provides advice and suggests a range of management tools appropriate for solving a number of project management problems. The suggestions are drawn from a data base of some 230 managerial tools.

Toth [9] proposed a method for identifying and prioritising project risk factors. A tool called 'Software Technology Risk Advisor' is described in the paper which transforms qualitative inputs into quantitative risk factors used to rank and compare the risks.

The various techniques identified above, along with those listed in the literary research summary indicate a strong trend towards a new IT based style of project management.

The ConSERV concept is in many ways a combination of the processes described above albeit with the additional feature to visualise the application and interaction of the multidisciplinary engineering resources committed to the project effort.

2.3 Definitions of project management systems

2.3.1 The project management system (PMS)

Is defined as being *"the collection of management techniques, tools and methodologies employed over the project life cycle, deemed necessary in order to satisfy the specific project requirements"*. The specific project requirements will normally consist of a combination of project management activities identified in Appendices A3,A4 and A5.

2.3.2 The Project

The definition of the project in the context of this Ph.D. thesis is:

"Any specific piece of work with a defined end point that requires people to work together and commit resources across organisational boundaries"

Projects frequently involve working with a range of individuals from both within and outside of the organisation. Individuals will be from various nationalities, and will have various levels of expertise, knowledge and seniority.

2.3.3 The Sponsors

The sponsor of a project is one who is seen to *"visibly support and encourage the project, in its completion and delivery"*.

Sponsors are key to the success of a project and will be held accountable for ensuring that the project is afforded sufficient resources and that any cross-team issues are resolved.

2.3.4 The Project Manager

The role is of course pivotal to the success of the project management , the project manager not only has to lead the team and deliver the project but must also keep the project sponsor informed and enthusiastic about the project. The selection of the management model, or system is not an easy process as it requires strategic decision making and agreement by the main parties identified. In their recent (1996) Handbook Zeneca Pharmaceuticals identified the core competencies and attributes of a good project manager, suggesting that: "Each person who is chosen to lead a capital project will be recognised as an **experienced manager** with **technical credibility** and a sound understanding of **business strategy and processes**".

Zeneca Pharmaceuticals identified core competencies and attributes as:

i) An ability to balance and integrate the **needs** of different stakeholders and know when high level resolution is needed.

ii) To be driven by objectives, results and priorities, to be **achievement oriented**.

iii) To **enthuse and motivate** the team by building on positive attributes of the team.

iv) To accept, understand and **appreciate** cultural differences within the organisation.

v) To show **consideration** for and respond to the feelings of all parties involved.

vi) To act in a **proactive manner** to preserve long term work relations

vii) To work with **informal** as well as **formal** systems to influence situations.

viii) To be **guided by a range of considerations** in deciding the best course of action in influencing people.

ix) To **match** the **organisational needs** with those of the individuals.

x) To **decide courses of action** that take account of different environments and cultures.

These competencies identified in the Pharmaceutical industry are not necessarily transportable into other industries such as the Petrochemical or Nuclear industry.

E.g. It is unlikely that the Petrochemical organisations would advocate that project managers work with "informal systems" or that they should "match the organisational needs to those of the individual" as this approach would be viewed as irresponsible.

In Chapter I the unique nature of each project was identified. In Chapter II it has been established that each industry management system is, to some extent, also unique.

2.3.5 The Sponsor's role

i) To understand and support the project system.

ii) Ensure alignment of the project with the needs of the business

iii) Agree the format of the project sponsorship, i.e. its priority and profile.

iv) Identify and appoint experienced persons, provide coaching in project and team management skills

v) Act as the interface between the business through the project manager

vi) Determine whether or not a project steering group is required and suggest enhancements to the project system where applicable.

2.3.6 The PMS factors

In choosing a project management system several issues need to be considered :-

i/ The system capability - data handling and processing.

ii/ The system flexibility - ability to adapt to project circumstances.

iii/ The system response - ability to provide meaningful results.

iv/ The system intelligence - ability to handle structured reasoning, problem solving

v/ The system storage - ability to store and handle project specific information.

The project management systems investigated were all found to be very similar in structure, i.e. That they comprised of a declarative form whereby the organisations quality policy incorporated 'statements of intent' with regard to the management of projects. The organisations' 'project execution procedures' were written in generic form to try and cover all possible events. In so doing the procedures were not in any way project specific, and some were found to be not applicable to specific needs of the project in question. The management systems reviewed were well proven, systematic and highly proceduralised, as a consequence they were also open to subjective interpretation. The project management systems and techniques investigated in this research were those developed by,

1.0 The Pharmaceutical Industry

Smithkline Beecham Worthing (Design consultants = Freeman Process Systems)

Zeneca Pharmaceuticals Manchester/Huddersfield (Design consultants = Tanvec)

2.0 The Chemical Industry

Holliday Dyes and Chemicals Huddersfield (Design Consultants = Jacob Int.)

Tioxide ICI Grimsby (Design Consultants = On-Line, Westbourne)

Hays Chemicals Ltd. Sandbach (Design Consultants = Lurgi UK)

Zimbabwe Iron and Steel ZISCO (Design Consultants = Lurgi UK)

3.0 The Petrochemical Industry

ARAMCO Saudi Arabia (Design consultants = Eagleton Saudi)

SAMAREC Saudi Arabia (Design consultants = Lummus Ali Reza)

2.3.7 Philosophical differences

The two tables below indicate the perceived[1] differences in the philosophy of each industry concerning the choice of management system.

Industry	Type of Organisational structure	Established Project Management systems	Empowerment of contracted project manager	In house project management expertise
Pharmaceutical Smithkline Beecham	Matrix	Yes	Limited	Strong
Pharmaceutical Zeneca Pharmaceuticals	Matrix	Yes	limited	Strong
Chemical Tioxide ICI Grimsby	Customised to suit project needs	Yes	Yes	Limited
Chemical Holliday Dyes and Chemicals	Contracted to suit project needs	No	Limited	Limited
Petrochemical ARAMCO Saudi Arabia	Matrix	Yes	No	Yes
Petrochemical SAMAREC Saudi Arabia	Matrix customised to suit project needs	Yes	No	Limited

Table 3.0 Philosophical differences between organisations

Industry	International Dimension	Market position	Research oriented	Driving force
Pharmaceutical Smithkline Beecham	Global	Leader	Strongly	Technology
Pharmaceutical Zeneca Pharmaceuticals	Global	Leader	Strongly	Technology
Chemical Tioxide ICI Grimsby	Global	Established	not	Profit
Chemical Holliday Dyes and Chemicals	National	Medium	not	Profit
Petrochemical ARAMCO Saudi Arabia	Global	Leader	not	Markets
Petrochemical SAMAREC Saudi Arabia	National	Medium	not	Markets

Table 4.0 Philosophical differences between organisations

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[1] Authors own view

2.4 Analysis of the Project management survey

2.4.1. Data Analysis

The analysis of data from a series of interviews taken with project managers between 1992 and 1995 provided some interesting facts regarding the actual management systems employed by a number of major companies.

The objectives of the investigation were to address a number of key factors concerning the role and the behaviour of the **project manager,** in order to better understand how scientific and non-scientific **knowledge** is applied in project management. An example of the questionnaire is included in Appendix B2.

The original interviews were undertaken in 1992 during the authors MSc. course:

" An investigation into decision making processes in Project management"

A number of those interviewed have been revisited as part of the Ph.D. thesis to reconfirm the findings and add to the information gained during the MSc. course.

2.4.2 Career and Job satisfaction

a) How and Why do people become Project Managers ?

There would seem to be a variety of ways that individuals become project managers, the most common route identified by seven of the twenty respondents was that of a structured career route,

Of the under 35's interviewed almost 50% were embarking upon the project management route via an organised and defined career path, in which the more able engineers are given management training and are effectively channeled into project oriented work.

In contrast only two of the over 35's interviewed were in the job as a result of 'natural progression', where the vacancy arises as a result of the retirement of ones superior.

It would appear that the main reasons people enter into project management are those associated with the perceived job satisfaction.

b) Are project managers satisfied with their job ?

Question 1b on the questionnaire was designed to determine the level of job satisfaction perceived by the project managers.

The two sets of results were tabulated and the means estimated. It would seem that the majority of those interviewed do in fact find the job highly satisfying.

2.4.3 The Role

c) How do Project managers perceive their role ?

The over 35 group see the project managers' role more in terms of a driving force, taking on a leadership type activity, whilst the under 35's perceive the role in terms of co-ordination and responsibility. The dominant theme expressed by the over 35 group would seem to be one of leadership. The view that most project managers have concerning the role of the project manager, is that of a person exhibiting a number of overt characteristics which produce the image of an individual who is in control.

c) How the role has changed

It was found that fifteen of the twenty interviewees considered that the role had indeed changed over the past forty years, two felt it hadn't and three had no opinion. Nine of the ten over 35's felt that the role had changed, whilst only six of the under 35's were of the same opinion. The most common view expressed by half of those interviewed, related to the distinct advantages afforded by today's technology, and the use of the computer. One interviewee asked whether or not the role had changed over the past 40 years responded, " *Not so much over the past 40, more so over the past 10 to 15 years !. Now the project manager is expected to do it all, whereas before each person had his own part of the project to look after*".

2.4.4 Project Management Systems

d) Whether or not project management differs between companies

Responses to Q14 "Does company policy change from project to project ?",
Q15 "Does project management philosophy change from company to company ?",
Q16 "Is project success assured by giving them to the major contractors ?"
and Q17 "Do the major contractors give value for money ?" were most interesting. Only two of the twenty respondents felt that company policy does not change from project to project, both were in the under 35 group. Two over 35's expressed the opinion that policy should not change, but felt that in practice it did. This seems to be inconsistent with the view of *Morris & Hough* [10] concerning the fact that organisational structure should be dynamic, changing as the needs of the project change. As we have seen earlier rigid policy is in fact a potential problem for project managers.

2.4.5 Decision Making Processes

e) The balance between engineering/scientific decision making and behavioural decision making.

The response to Q5 "What percentage of your normal working day is spent on engineering matters ?" and Q21 "Which decision making process do you tend to use the most, Scientific or Behavioural ?" was summarised as follows :

With the exception of one under 35 respondent, all of those interviewed felt they spent one third, or less, of their time engaged on technical matters, with the average for the total population being 23.9%. The results indicated some difference between the averages of the two groups with the over 35's scoring lower than the under 35's.

This would seem to suggest that the more senior the position, the less the time spent on technical issues. Whilst the graph in Appendix B5 demonstrates that the under 35 age group perceive that, on average, they spend more time on technical matters than the over 35 age group, it was necessary to ascertain whether or not there was any significant difference. This was done by applying a "t" test to the two sets of data.

The test revealed that at 5% confidence level there was no significant difference between the populations.

It could well be argued that the higher average score for the under 35 population could well be attributed to the fact that many under 35's would in practice spend slightly less time dealing with non technical issues. Item (e) was considered to be an important project success factor in designing the KBS.

2.4.6 Influence

f) Do project managers relate project success or failure to an individuals character or personality ?(Risk seeking or risk averse)

The four sets of questions i.e. Q7 "Can project success or failure be influenced by the type of project manager ?", Q8 "Can you provide any examples ?, Q9 "Do project managers need formal engineering qualifications ?" and Q18 "To what extent is the project dependent upon the skill of the project manager ?" provided the information concerning whether project success or failure could be directly attributed to individual skills. The analysis showed project managers were unanimous that the success or failure of a project **can** be influenced by the type of project manager employed.

2.4.7 Types of Decisions that need to be made.

g) What types of decisions that project managers find most difficult to make. ?

Q20 Was developed from the analysis of the most common types of decisions facing the project manager. The research indicated that virtually all project management decisions could be broken down into five categories.

i/ Technical ii/ Commercial iii/ Interpersonal iv/ Disciplinary and v/ Strategic

The respondents were asked to rate the five types in order of perceived difficulty. In this question the respondents were merely asked to place the five topics in order, and not to make any subjective assessment of degree of difficulty. Scores of 5 for the first choice 4 for the second and so forth were applied and the results tabulated. Extracts of the table are provided in Appendix B3.

It was thought that if project managers are technically minded people, they will tend to use decision making processes favouring the **scientific paradigm** in preference to the **behavioural type of decision process,** if this assumption is true then the results from the questionnaire should reflect this.

DECISION TYPE	TECHNICAL	COMMERCIAL	INTERPERSONAL	DISCIPLINARY	STRATEGIC
UNDER 35	13	31	25	48	33
OVER 35	22	24	28	48	28
GROUP	SCIENTIFIC 13+31+22+24 = 90		BEHAVIOURAL 25+48+28+48 + 149		BOTH

Table 5 Categorisation of types of decisions facing project managers

The maximum possible score for each element is 5 x 10, the maximum for the scientific / behavioural groupings is 5 x 10 x 4 = 200.

Across the total population the scientific group scored 90 whilst behavioural group scored 149. In comparing the mean scores of each group as shown above it is possible to make a number of observations, the most significant being that both groups considered decisions involving **Disciplinary** matters to be the most **difficult** type of decision they had to make.

h)The major factors that influence project managers decision making processes.

The two questions, Q12 and Q19 were both intended to obtain data concerning the most important and influential factors governing the decisions that would normally be made by project managers.Q12 consisted of 10 subsets of questions, the levels of importance for each specific element were rated by the respondents on a 1-10 scale.

In comparing the results of the ten elements Q 12v the importance of site safety scored highest on both groups, the influence of safety elements in Q 19 provided the second highest score suggesting that both groups recognise safety aspects as being the most important and influential factor in decision making. the results are shown in Appendix B6.

2.4.8 Improvements

j) What do project managers feel they need in order to make better decisions

UNDER 35	IMPROVE BY
BERNARD	LISTENING HARDER
ROBERT	MORE TIME ACCURATE INFORMATION
ALISTAIR	DECISION AID/TREE AND MORE TIME
HUGH	USING PROCEDURES AND ROUTINES
ALAN	RELIABLE ACCURATE INFORMATION
PAUL	UNDERTAKING A COURSE OF STUDY
DAVE	TRAINING IN DECISION MAKING
SIMON	INTRODUCING USEFUL DECISION AIDS
STEVE	LIMITING CHOICE OF OPTIONS
JONATHON	DECISION MAKERS TO HAVE NO VESTED INTEREST
OVER 35	**IMPROVE BY**
GORDON	BEING MORE INVOLVED IN DECISION MAKING
KEITH	BEING DECISIVE
JIM	ADHERING TO SYSTEMS
GRAHAM	GIVING THE DECISION MAKER AUTHORITY
JIM M	BEING GIVEN AUTHORITY AND TRAINING
ALLEN	BEING GIVEN TIME AND SPECIFYING PRIORITIES
RICHARD	UNDERTAKING A DECISION MAKING COURSE
TREVOR	USING STATISTICAL DATA WHERE POSSIBLE
EDDIE	USING APPROPRIATE SOFTWARE PACKAGES
GEORGE	USING ONLY ACCURATE INFORMATION

Table 6 Listing of items identified to improve decision making

Some 25 comments were recorded in response to Q13, asking the interviewees how they thought decision making might be improved. In analyzing the results it was possible to identify three specific areas:

i/ The use of decision aids, not necessarily knowledge based.

ii/ Being given more time in which to make the decision.

iii/ Being given accurate and reliable information.

The practicality of employing decision aids in project management would need to be addressed, as normative decision aids would almost certainly be useful for scientific problems but would have limited application to behavioural situations.

2.4.9 Analysis

The method of *analysis* employed on the data obtained from the investigation was two fold.

a/ Using *statistical analysis* methods employing probability theory,
Correlation and 't' tests.

b/ Using *content analysis* techniques. As suggested by *C Robson* [11]

Given that a **theory** is a general statement that summarizes and organizes knowledge by proposing a general relationship between events, and that a **hypothesis** is a testable proposition about the relationship between two or more events, this section of the submission is purely a report on an **investigative** study which is intended to provide no more than a presupposition concerning possible causes of judgmental error in project management decision making. The analysis also provided a guide concerning the significance of the soft skill, artistic project management issues and their influence on decision making.

The method of analysis has essentially been one of interpreting the responses to the questionnaire, rather than providing experimentally controlled statistical data.

Where opinion between the two age groups varied, the data was analysed using 't' tests to determine whether or not the variance was significant.

A summary of the data analysis is presented in Appendices B4 and B5 (Figs 9, 10, 11)

2.5 Conclusions and References

2.5.1 Conclusions

In order to develop any hypothesis concerning the degree to which these findings are representative of the industry as a whole, further research is necessary in which a formal hypothesis can be developed and tested in a controlled manner against a much greater population sample.

The main features of the results suggest that there are indeed some **inconsistencies** concerning the decision making processes and the **application of management systems** associated with the project management profession.

Decisions made by design engineers and project managers can broadly be categorised into two distinct groups, **scientific** and **behavioural.**

It is submitted that the traditionalists perception of the role of the project manager is incomplete as it takes little or no account of the behavioural element effect on decision making in project management. It is argued that the human decision making strategies employed by traditionally qualified project managers may be inappropriate for handling both **cross discipline** scientific problems and **behavioural** situations.

It is also argued that the soft skill elements of project management are especially difficult for those project managers from an engineering background to manage effectively. The results obtained from the study support the notion that :-

a/ Project managers do spend considerably more time dealing with behavioural type decisions than the scientific type.

b/ Project managers do recognise that behavioural type decisions are far more difficult to handle than the scientific type.

c/ Project managers do feel that project success or failure can be affected by the skill of the individual.

d/ There is little evidence to suggest that the judgment of less experienced project managers is less reliable than that of those more experienced.

e/ Project managers of both age groups identified the most influential factors in decision making as being safety related issues.

It appears that project management is a **combination** of experiences and skills, executed both **scientifically,** in an overt manner, and **artistically,** in a covert manner. Whilst the majority of skills have been identified by the Association of Project Managers (APM) and the Project Management Institute (PMI) , it would seem that a continuing dilemma exists, in determining **which** combination of skills to employ for any given project, and whether they are **effective and appropriate**.

Standard organisational procedures are seldom equally applicable to all projects, they can be top heavy and may be open to subjective interpretation.

Over 80% of the project managers interviewed , indicated that a real need exists for a more **comprehensive project management system** that can handle the **scientific elements** of project management **whilst also** providing guidance on the behavioural soft skill issues sensitive to the specific requirements of a given project.

Reiss [12] recognised that "Success in projects is not proportional to success in project management" the issues concerning what constitutes real project success are very difficult to isolate from the every day complexities of managing capital projects.

Clearly project success is about having the right people working with the right experience working with the right systems.

In practice obtaining this combination is far more difficult than applying a set of theoretical ideals.

Williams [13] recognised that most individuals work reasonably well when they are empowered and there is structure applied to the work environment, but warned that empowerment competes with risk management. The whole issue of empowerment, risk management and teamwork is central to the management technique being presented in this submission. One of the major problems facing project teams in industry today is integrating the combined skills and talents of the individuals within the team.

Gone are the days of reverence for the white top project management Gurus able to 'work' the organisational structure, secure in their field of expertise. Organisations are now far more accountable and transparent in their approach to project management.

The information technology that is applied in the industry today is a great leveler of individual abilities, allowing apparently inexperienced project team members to access, manage and administer vast amounts of data with incredible speed and efficiency. Albeit on occasion without fully appreciating the consequences and implications of their actions and decisions.

Parkin [14] addressed the issues surrounding the whole purpose of what project managers do, and how they appear to do it. It is clear that decision making takes up a major part of the project managers time, but that the quality of the decisions made is less than satisfactory.

This Chapter has provided an insight into the business of managing capital projects and has presented the views of many practicing project managers in the Process Industry.

Chapter III addresses the industrial case studies in some detail and traces the flow of information between the respective engineering disciplines. The Chapter looks at how key decisions over the design life cycle of a major project were made and what impact they had on the outcome.

2.5.2 References

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APPENDIX B

APPENDIX B

QUESTIONNAIRES
FINDINGS FROM INVESTIGATIVE RESEARCH
EXTRACTS FROM DATA ANALYSIS
BIBLIOGRAPHY OF HARD/SOFT SKILL METHODOLOGIES
EXAMPLES OF PROJECT MANAGEMENT SOFTWARE
DOMAIN KNOWLEDGE

APPENDIX B

INTERVIEW QUESTIONNAIRE TYPE 1.0 IN DEPTH

INTERVIEWEE DETAILS :
NAME AND SEX :
DATE OF INTERVIEW :
LOCATION :
INTRODUCTION (TAPED)
POSITION :
ORGANISATION :
AGE GROUP :
STAFF OR CONTRACT :
Q 1 a WHAT DREW YOU INTO THE FIELD OF PROJECT MANAGEMENT ?
Q 1 b HOW WOULD YOU RATE THE EXTENT TO WHICH THE JOB HAS LIVED UP TO YOUR EXPECTATIONS ?
Q2 COULD YOU ELABORATE ON HOW YOU SEE THE ROLE OF THE PROJECT MANAGER ?
Q3 HOW DO YOU THINK THE ROLE HAS CHANGED OVER THE PAST 40 YEARS ?
Q4 DO YOU THINK THAT TODAYS PROJECT MANAGERS ARE IN ANY WAY BETTER EQUIPPED TO MANAGE PROJECTS ? IF SO HOW?
Q5 HOW MUCH OF YOUR NORMAL WORKING DAY WOULD YOU SAY IS SPENT ON ENGINEERING MATTERS ?
Q6 WHAT WOULD YOU SAY ARE THE MOST IMPORTANT QUALITIES THAT A PROJECT MANAGER NEEDS ?
Q7 FROM YOUR EXPERIENCE WOULD YOU SAY THAT THE SUCCESS OR FAILURE OF A PROJECT CAN BE INFLUENCED BY THE TYPE OF PROJECT MANAGER EMPLOYED ?
Q8 CAN YOU RECOLLECT ANY EXAMPLES OF WHERE A PROJECT HAS BEEN INFLUENCED BY THE PERSONALITY OR MANNER OF THE PROJECT MANAGER ?
Q9 DO YOU THINK THAT AN INDIVIDUAL WITH NO FORMAL ENGINEERING QUALIFICATION COULD MAKE A SUCCESSFUL PROJECT MANAGER ?
Q 10 AS A PROJECT MANAGER ARE YOU COMFORTABLE WITH YOUR DECISION MAKING PROCESSES, OR COULD THEY BE IMPROVED ?
Q 12 GIVEN THAT ALL PROJECTS DO HAVE A START AND END DATE, A FINITE SCOPE AND A BUDGET, CAN YOU PLEASE ASSIGN A VALUE OF BETWEEN 1 AND 10 TO THE FOLLOWING IN TERMS OF IMPORTANCE.
i/ IMPORTANCE OF MEETING END DATE
ii/ IMPORTANCE OF SATISFYING CLIENT
iii/ IMPORTANCE OF STAYING WITHIN BUDGET
iv/ IMPORTANCE OF DEFINING PROJECT SCOPE
v/ IMPORTANCE OF SITE SAFETY
vi/ IMPORTANCE OF ACCURATE INFORMATION
vii/ IMPORTANCE OF PERSONALITIES/RELATIONS
viii/ IMPORTANCE OF SITE CONSTRUCTION MANAGEMENT
ix/ IMPORTANCE OF MANAGEMENT SKILLS
x/ IMPORTANCE OF NEGOTIATION SKILLS
Q 13 FROM YOUR EXPERIENCES COULD YOU SUGGEST ANY WAY IN WHICH THE ROLE OF THE PROJECT MANAGER COULD BE IMPROVED WITH REGARD TO DECISION MAKING ABILITY
Q 14 DOES COMPANY POLICY TOWARDS PROJECT MANAGEMENT CHANGE FROM PROJECT TO PROJECT. I.E. IS THE MANAGEMENT OF A PROJECT DICTATED BY ITS SIZE, COMPLEXITY ETC.
Q 15 FROM YOUR EXPERIENCE DOES PROJECT MANAGEMENT PHILOSOPHY DIFFER FROM ONE COMPANY TO ANOTHER ?
Q 16 ARE SUCCESSFUL PROJECTS ALWAYS ASSURED BY EMPLOYING THE MAJOR CONTRACTING ORGANISATIONS ?
Q 17 DO YOU FEEL THAT THE MAJOR CONTRACTING COMPANIES GIVE VALUE FOR MONEY ?
Q 18 TO WHAT EXTENT DO YOU FEEL THAT THE SUCCESS OR FAILURE OF A PROJECT IS DEPENDANT UPON THE INDIVIDUAL SKILL OF THE PROJECT MANAGER. ?
1 2 3 4 5 6 7 8 9 10
Q 19 ON A SCALE OF 1 TO 10 PLEASE RATE THE DEGREE OF INFLUENCE THAT EACH OF THE FOLLOWING ELEMENTS HAS ON YOUR DAY TO DAY JUDGEMENT DECISION MAKING
i/ THE PROJECT TECHNICAL DEMANDS
ii/ THE PROJECT FINANCIAL DEMANDS
iii/ THE ELEMENTS OF SAFETY
iv/ THE ENVIRONMENTAL ISSUES
v/ THE PRESSURE
vI/ THE TIME CONSTRAINTS
vii/ THE DEGREE OF UNCERTAINTY
viii/ THE POLITICAL FACTORS
ix/ THE INTERPERSONAL RELATIONS
x/ PERSONAL INVOLVEMENT
xi/ CORPORATE STRATEGY
Q 20 AS A PROJECT MANAGER WHAT DO YOU CONSIDER TO BE THE MOST DIFFICULT TYPES OF DECISIONS TO MAKE ?
PLEASE RATE IN ORDER OF DIFFICULTY
i/ TECHNICAL
ii/ COMMERCIAL
iii/ INTERPERSONAL
iv/ DISCIPLINARY
v/ STRATEGIC
WHICH DECISION MAKING PROCESS YOU BELIEVE THAT YOU USE MOST OF THE TIME ?
I.E. SCIENTIFIC BASED OR BEHAVIOURAL

Fig 8 Questionnaire type 1

APPENDIX B

Tabulated findings from Q1

UNDER 35	TECHNICAL	COMMERCIAL	INTERPERSONAL	DISCIPLINARY	STRATEGIC
BERNARD	1	4	2	5	3
ROBERT	4	3	1	5	2
ALISTAIR	1	3	2	4	5
HUGH	1	2	3	5	4
ALAN	1	2	3	5	4
PAUL	1	4	2	5	3
DAVE	1	4	2	5	3
SIMON	1	4	3	5	2
STEVE	1	3	2	5	4
JONATHAN	1	2	5	4	3
	13	**31**	**25**	**48**	**33**
OVER 35	TECHNICAL	COMMERCIAL	INTERPERSONAL	DISCIPLINARY	STRATEGIC
GORDON	1	4	2	5	3
KEITH	3	5	1	4	2
JIM	4	3	1	5	2
GRAHAM	1	4	2	5	3
JIM M	3	2	4	5	1
ALLEN	1	2	3	5	4
RICHARD	3	1	4	5	2
TREVOR	2	1	3	5	4
EDDIE	2	1	5	4	3
GEORGE	2	1	3	5	4
	22	**24**	**28**	**48**	**28**

Table 7 Summary of Findings from investigative studies

APPENDIX B

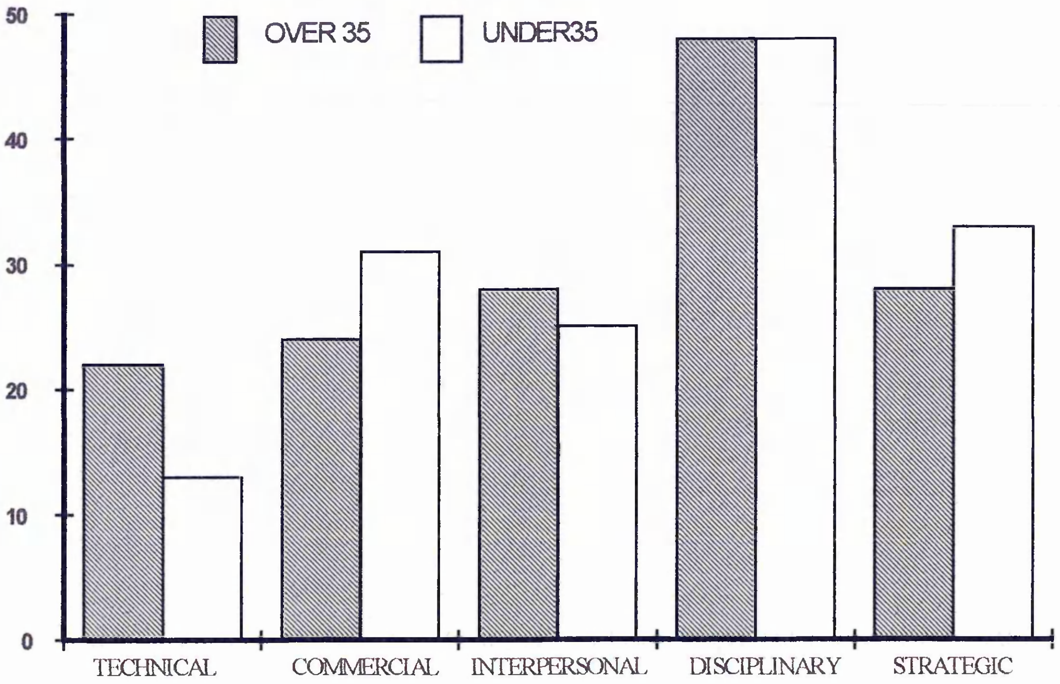


Fig 9 Graph showing response to Q20

APPENDIX B

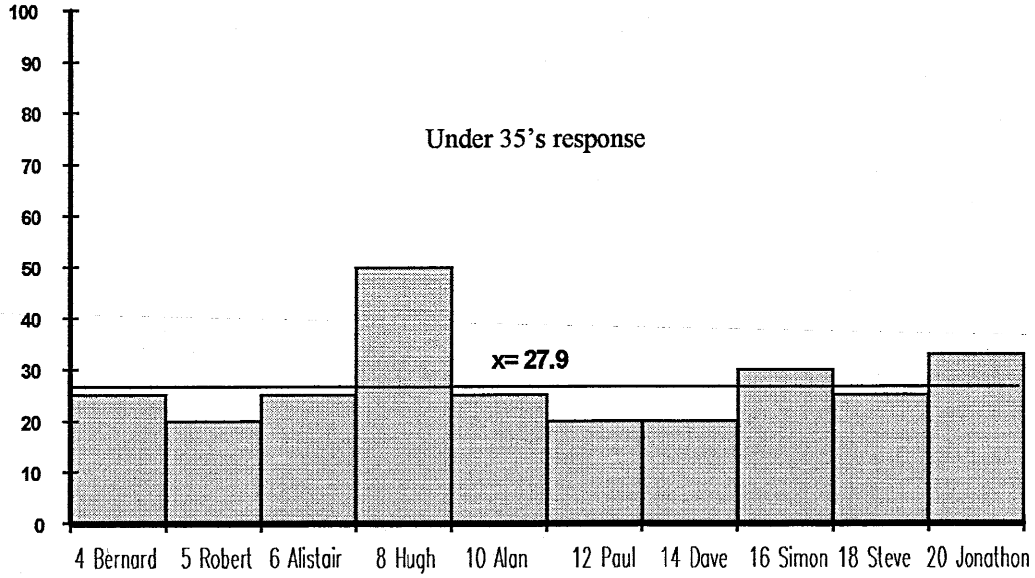


Fig 10 Graph showing response to Q5

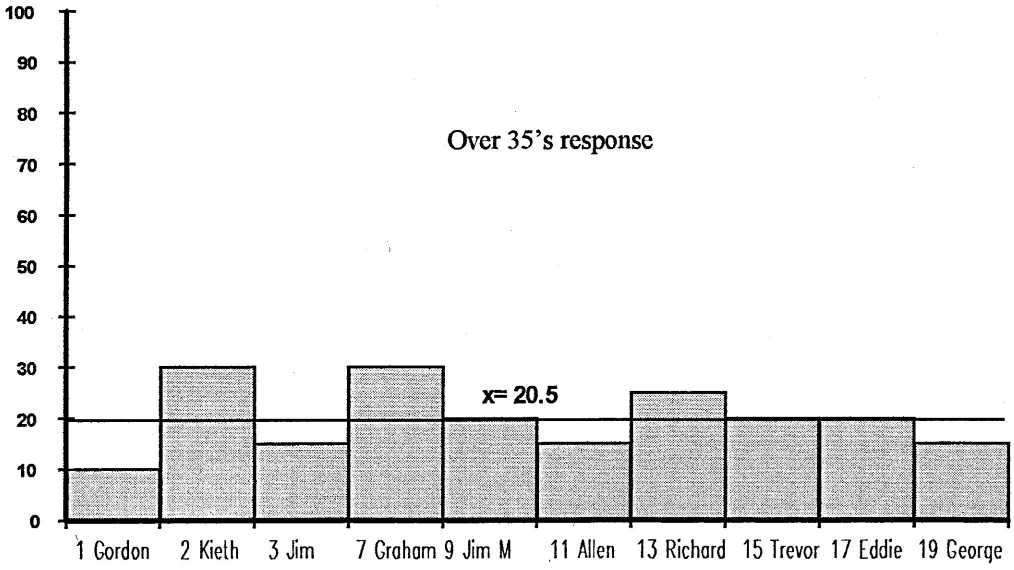


Fig 11 Graph showing response to Q5

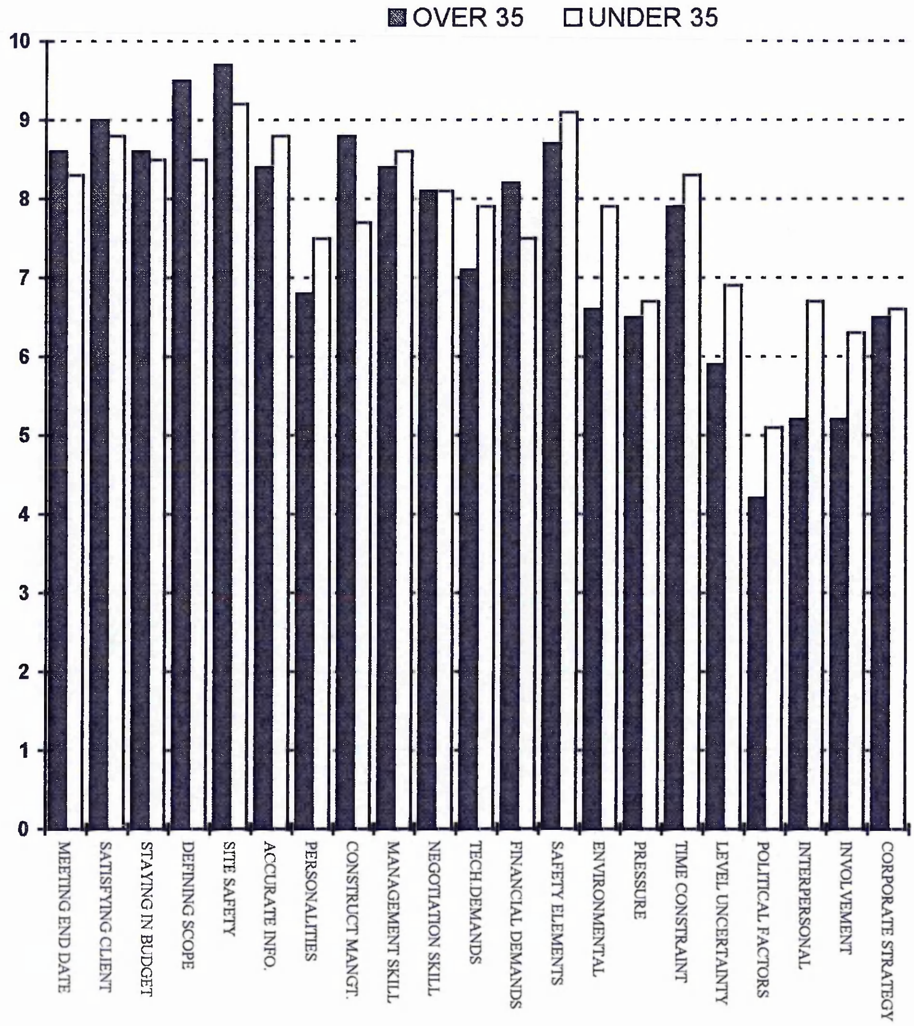


Fig 12 Graph showing combined response to Q12

APPENDIX B

QUESTIONNAIRE TYPE 2 DESIGNED TO ESTABLISH THE NEED FOR A MULTIDISCIPLINARY ENGINEERING PROJECT MANAGEMENT CONCEPT

This questionnaire has been designed in order to establish whether or not a real need exists for a software package that is able to assist in the day to day management of projects involving **multidisciplinary** engineering functions, your co-operation is greatly appreciated, please complete and return using self addressed envelope.

1.0 Please advise of your organisations main business a/ Consultative b/ Design only e/ Turnkey f/ Contractor

2.0 Does your organisation undertake projects involving more than one discipline ? yes ☐ no ☐

3.0 Size of organisation : a/ 0-10 b/10-20 c/ 20-50 d/ over 50

4.0 Is your organisation QA accredited ? yes ☐ no ☐

5.0 Approx. spread of disciplines please add any not listed :

Discipline	approx. No of people	0%	10	20	30	40	50	60	70	80	90	100
Mechanical												
Electrical												
Civil												
Structural												
Process												
Instrumentation												
Quality												
Planning												

6.0 Present method of communicating project information between discipline engineers again please add :

Method	approx. No of people	0%	10	20	30	40	50	60	70	80	90	100
Formal meetings												
Informal meetings												
Electronic mail												
Memo												
Formal letter												
Formal verbal												
Informal verbal												
Notes												
One-on-one												
open forum												

7.0 Who handles communications with clients ? Title..

If an engineer, what discipline ? ....

Does the individual inform other discipline engineers of client meetings and discussions yes ☐ no ☐

If yes by what method is information communicated ?

....

8.0 Does your organisation employ project management tools. ? yes ☐ no ☐

9.0 Do they provide any facility for multidisciplinary project management? yes ☐ no ☐

10.0 On a scale of 0 to 100 how important do you value communication between interdisciplinary engineers ?

0%	10	20	30	40	50	60	70	80	90	100

11.0 Do you or your organisation believe that a purpose built project management tool is needed to handle multidisciplinary projects ? yes ☐ no ☐

12.0 On a scale of 0 to 100 how important do you value communication between discipline engineers in terms of project success ?

0%	10	20	30	40	50	60	70	80	90	100

Fig 13 Questionnaire type 2

APPENDIX B

BIBLIOGRAPHY OF HARD SKILL PROJECT MANAGEMENT THEORIES AND METHODOLOGIES

Methodology	Abbreviation	Summary	Reference
Analytical Hierarchy Process (*Prasanta Dey* etal)	AHP	A multi attribute decision making technique	IJPM Vol.12 No 1 pp23-33 1994
Back-Forward uncetainty estimate *(Gong and Rowings)*	BFUE	A time disturbance analysis technique for calculating 'safe' float	IJPM Vol. 13 No 3 pp 187- 194 1995
Boardman Soft system Methodology *(Sherman et al)*	BSSM	A technique of using systemigrams to provide enlightened understanding of engineering process dynamics	IJPM Vol. 14 No 1 pp23 - 36 1996
Computer aided software engineering *(Aggarawal and Rezaee)*	CASE	The application of TQM in project management systems development	IJPM Vol. 14 No 2 pp115-120 1994
Computer sequencing using activity on arc networks *(Nkasu)*	COMSARS	A computer sequencing approach to multiresource constrained scheduling	IJPM Vol. 12 No 3 pp183 -192 1994
Concurrent Simultaneous Resource View A methodology for managing multidisicplinary design projects ***(Conroy and Soltan)***	**CONSERV**	A new project management concept that provides users with a system selection & 3 D visualisation of the project status	**IJPM Vol. 15 No 2** **pp 121-132 1997**
Concurrent Simultaneous Resource View A continual audit concept ***(Conroy and Soltan)***	**CONSERV**	A new management technique that enables projects to be continually audited	**IJPM Vol. 16 No 3** **pp 185-197 1997**
Concurrent Simultaneous Resource View A risk management approach ***(Conroy and Soltan)***	**CONSERV**	A new management technique that allows the user to identify project risks	**Approved for publication**
Computer supported co-operative work *(Kurbel)*	CSCW	A task management technique using groupware.	IJPM Vol. 12 No 4 pp 222 - 229 1994
Communication - Process - Responsibility (Kartam and Ibbs)	CPR	An integrated systematic approach to planning	IJPM Vol. 14 No 6 pp 359 - 365 1996
Cost time trade off *(Sunde and Lichtenberg)*	CTTO	A technique to balance cost-time and resources	IJPM Vol. 13 No 1 pp 45 - 49 1995
Configuration Management *(Fowler)*	CM	To clarify, document and maintain design intent.	IJPM Vol. 14 No 4 pp 221 - 230 1996
Integrated Project Development Teams *(Flemming and Koppelman)*	IPDT	A team approach to project management	IJPM Vol. 14 No 3 pp 163 - 168 1996
Management of the Requiremement capture stage *(Chatzoglou and Macaulay)*	MARCS	A rule based planning model	IJPM Vol. 14 No 3 pp 173 - 183 1996
Project Evaluation and Review Techniques Expanded PERT *(Kuklan et al)*	PERT EX-PERT	A planning and control technique	IJPM Vol. 11 No 2 pp 87-91 1993
Project Evaluation and Review Techniques - Path network. *(Mummolo)*	PPNT	A planning refinement technique	IJPM Vol. 12 No 2 pp 89 - 99 1994
Time and Priority allocation scheduling *(Jaafari)*	TAPAS	An advanced scheduling technique	IJPM Vol. 14 No 5 pp 289 - 299 1996
Total ethical risk analysis method *(Nicolo)*	TERA	A risk management technique	IJPM Vol. 14 No 3 pp 153 - 162 1996
Professional Intelligent Project Planning Assistant *(Winstanley and Kellet)*	PIPPA	Configuration and planning technique using Rule based Frame systems	IJPM Vol. 11 No 6 pp 367 - 371 1996
Structured Analysis and Design Technique *(Yousef and Smith)*	SADT	An integrated design and build software development system.	IJPM Vol. 14 No 5 pp 289 - 299 1996
Risk Analysis *(Semister)*	PRAM	A risk management technique	IJPM Vol. 12 No 1 pp 5 - 8 1994
Productivity Initiative Programme *(Jaafari)*	PIP	Leadership based education	IJPM Vol. 14 No 6 pp395 - 403 1996
Quality Function Deployment *(Sarkis and Liles)*	QFD	A decision support methodology for providing a 'business case'	IJPM Vol. 13 No 3 pp187 - 195 1995
Simple Multiattribute rating technique *(Green)*	SMART	A design based value engineering technique	IJPM Vol. 12 No 1 pp 49 - 55 1994

Table 8 Listing of various hard skill project management methodologies

APPENDIX B

BIBLIOGRAPHY OF SOFT SKILL PROJECT MANAGEMENT THEORIES AND METHODOLOGIES

Methodology	Abbreviation	Summary	Reference
Thinking styles of managers of Multiprojects *(Tullet)*		A paper that argues in favour of project managers employing innovative styles	IJPM Vol. 14 No 5 pp 281 - 287 1996
Self organising and Meta rules for large scale projects *(Jolivet and Navarre)*		A new approach to large scale project management to assist in finding right form of approach	IJPM Vol. 14 No 5 pp 265 - 271 1996
Organizational decision making and the project manager *(Parkin)*	Actor - Network Theory	A Coherent explanation of the deep forces moulding the decision making processes	IJPM Vol. 14 No 5 pp257 - 263 1996
The importance of recognising alternative perspectives *(Kirby)*		An analysis of the life cycle of an information system project	IJPM Vol. 14 No 4 pp 209 -211 1996
Simultaneous management the key to excellence in capital projects *(Laufer et al)*	Simultaneous management	An alternative management style that shifts away from accepted practices and routines, by orchestrating between demands.	IJPM Vol. 14 No 4 pp189-199 1996
Integrated Project Development Teams *(Flemming and Koppelman)*	IPDT	A team approach to project management	IJPM Vol. 14 No 3 pp 163 - 168 1996
A new framework for determining critical success/failure factors in projects *(Belassi and Tukel)*		A paper that summarises critical success criteria using a literary approach	IJPM Vol. 14 No 3 pp 141 - 151 1996
Professional project management a shift towards learning and knowledge creating. *(Ayas)*		A paper that presents learning as the key strategic variable for project management	IJPM Vol. 14 No 3 pp 131 - 136 1995
Low cost engineering centres *(Lawson)*		An investigation into the growing trend to utilise labour and resources from "Low cost engineering centres"	IJPM Vol. 14 No 2 pp 111 - 114 1996
The role of the project manager in achieving project success *(Munns and Bjeirmi)*		A paper that identifies the overlap between definition of the project and management of the project	IJPM Vol. 14 No 2 pp 81 - 87 1996
Machiavellian project managers, do they perform better ? *(Graham)*		A paper that looks at the value of political skill in the field of project management	IJPM Vol. 14 No 2 pp 67 - 74 1996
Meaning and action in a multi project environment *(Eskerod)*		A paper that questions traditional project management and the understanding of the environment by means of metaphors	IJPM Vol. 14 No 2 pp 61-65 1996
Assisting cultural reform in a projects based company using systemigrams *(Sherman et al)*	Systemigrams	A new technique to create diagrams that describe company values such that they become shared values	IJPM Vol. 14 No 1 pp 23 - 30 1996
The project management of organisational change *(Partington)*		A paper that recognises the need to abandon beurocratic forms of organisations in favour of flexible project based.	IJPM Vol. 14 No 1 pp 13 - 21 1996
How generic and how industry specific is the project management profession ? *(Wirth)*		A paper that analyses 41 projects across 5 industries and finds in favour of transferability	IJPM Vol. 14 No 1 pp 7 - 11 1996
Impact of human relations on the safety of construction workers *(Jannadi)*		A paper that reviews safety issues on pipeline construction workers in Saudi Arabia	IJPM Vol. 11 No 6 pp 367 - 371 1996
Lao Tzu's Tao Te Ching and its relevance to project leadership in construction *(Pheng)*		A paper that compares an established Chinese philosophy with modern day construction management	IJPM Vol. 13 No 5 pp 295-302 1995
Application of systems thinking to the identification, avoidance and risk prevention *(Stewart and Fortune)*		A paper that advocates the application of a systems thinking approach to project management in order to limit risk	IJPM Vol. 13 No pp 279 - 286 1996
Building the culture of organisational networking *(Hastings)*		A paper that considers the changing roles that organisations will face in the near future	IJPM Vol. 12 No 1 pp 5 - 8 1994
Anatomy of decision making in project planning teams *(Shapira et al)*		An investigation into the decision making of key parties involved in project planning	IJPM Vol. 12 No 3 pp 172 - 182 1994
Management of conflict *(Al-Sedairy)*		An examination of the effect of conflict in public sector construction industry	IJPM Vol. 12 No 3 pp 143 - 151 1994
Managing the behaviour of people working in teams *(Johns)*		A paper that describes the project-management method for managing behaviour needed by team members	IJPM Vol. 13 No 1 pp 33 - 38 1995
Organisation of public-private partnerships *(Reijniers)*	PPP	An investigation into the pitfalls of PPP projects using cause / effect analysis	IJPM Vol. 12 No 3 pp 172 - 182 1994

Table 9 Listing of various soft skill project management methodologies

APPENDIX B

Typical example of commercially available Project management tools and their respective functional elements.

GROUP	**PRODUCT**		
PLANNING	PRIMAVERA P3 ARTEMIS PRINCE V2 PERTMASTER PRINCE O PLAN MICRO-PLANNER X PERT	MICROSOFT PROJECT V4 SURETRACK 1.5 CA SUPERPROJECT V3 MULTIPROJECT FINEST HOUR PM WORKBENCH PLANTRAC - OUTLOOK	TIME LINE 6 ON TARGET SKYPROJECT TOTAL PROJECT MANAGER HARVARD PM V3 MICROPLANNER
SCHEDULING	PROJECT INCEPTOR MICROPLANNER PROFESSIONAL PRINCE	SCHEDULE EXPRESS FAST TRACK SCITOR SCHEDULER 6 BEST SCHEDULE	ON TARGET QUICK SCHEDULE PROCUBE
COSTING	MACRIS COSPAC	APACHE SOFTCOST	TIMESHEET V4
ESTIMATING	BSO PLANNER BRIDGE COCOMO CODEC ESTIMATE	QUESTIMATE BUTTRESS ESTIMACS LOOK BEFORE U LEAP	ESTIMACS
FORECASTING	MONTE CARLO FORESIGHT ULTRA PLANNER	AUTOPROJECT VALUE 7000 FORECAST	4C Q-GERT
DECISION MAKING	MAUD CHEOPS	SKYDESIGN UDECIDE	
ENGINEERING	ADEPT EPEE SCHEMEBUILDER	CDEX PROCEDE AMTECH CABLE MASTER	SUPPLIERS SOFTWARE
DESIGN	ADEPT 3D STUDIO ACAD V12/13 PDMS MEDUSA	KBDS XCAD PRO-PLANT AUTO - PLANT	AUTOSKETCH AUTOCAD LT CADSI
COMMUNICATION FLOW CHARTING	NOVEL WORKFLOW WORKMANAGER	DOMS PROCUBE CATS	DATAPRO VISIO ABC/ORG PLUS
RISK	ACCESS 7000 RISK 2000 / 7000 @RISK MONTE CARLO RISK PRINCE	PREDICT PROJECT RISK BRISK SSDAM RISKMAN	DISASTER PLAN 80 DYNRISK OPERA CASPAR RISK +

Table 10 Listing of various project management packages

APPENDIX B

The **Knowledge domains** associated with the project management function identified from the case studies were :-

Executive Management (Knowledge - Intensive)

Engineering Contract Management Business acting on behalf of Production Group

Knowledge set is extensive

A significant part is non procedural

Contains knowledge relevant to a large class of problems

Solution requires complex knowledge processing activities.

Includes in depth knowledge of the business and market

Project Group Management (Knowledge - Intensive)

Engineering Contract Management Business (Man Management)

Knowledge set is extensive

Significant part is non procedural

Contains knowledge relevant to a large class of problems

Solution requires complex knowledge processing activities.

Single Discipline Project Management (Knowledge - Intensive)

Engineering Management Business

Knowledge set is more limited but extensive within discipline

Significant part is procedural, but occasionally new designs extend knowledge.

Contains knowledge relevant to a large class of problems

Solutions require complex knowledge processing activities.

Multi Discipline Project Management (Knowledge - Intensive)

Engineering Management Business

Knowledge set is extensive i.e. Multidisciplinary Project Management

Significant part is non procedural sometimes reactionary.

Contains knowledge relevant to a large class of problems outside of single discipline.

Solutions require complex knowledge processing activities.

APPENDIX B

Discipline Engineers not necessarily Knowledge - Intensive

Engineering Management Business

Whilst knowledge is extensive it is limited to a single discipline. Mech. Elect. Struct. etc.

Significant part is procedural.

Contains knowledge related to a large class of problems

Only unique solutions require complex knowledge processing activities involving complex search and problem solving methods / heuristics.

Quality Management (not knowledge-intensive)

Engineering Management Business

Knowledge is extensive

Significant part is procedural

Contains knowledge related to a limited class of problems

Solutions do not usually require complex knowledge processing

Design Management is (Knowledge - Intensive).

Engineering Management Business

Knowledge is extensive and multidisciplinary

Significant part is non procedural.

Knowledge is related to a large class of unique problems.

Solutions usually require complex knowledge processing methods.

Knowledge of international standards and organisation culture is required.

Chapter III

3.0 THE INDUSTRIAL CASE STUDIES

"Scientific knowledge is proven knowledge. Scientific theories are derived in some rigorous way from the facts of experience acquired by observation and experiment"
Chalmers[1]

3.1 Introduction, strategy and prerequisites

3.1.1 Introduction

Chapter II offered an insight into the two faces of project management, the hard scientific skills and the soft humanistic skills. The findings of earlier research work were discussed and the results of the project manager survey were summarised.

The main purpose of this Ph.D. is to provide a practical approach to the application of knowledge based systems in project management. This chapter is intended to focus on the practical difficulties of managing major projects in large organisations, it also presents the observations and findings obtained from the industrial case studies researched.

3.1.2 Research strategy and pre requisites.

Having interviewed a number of practicing project managers and obtained a variety of opinions, it was necessary to establish precisely how projects being undertaken in industry fared against the subjective views expressed by the interviewees.

The strategy included a comparison of the case study findings with the research work undertaken by *Belassi & Tukel*[2] into project success/failure factors.

The business of managing capital projects in the Chemical, Pharmaceutical and Petrochemical industries invariably takes place at both the **design level** and at the **construction level.** As the locations of these activities are mainly at the design offices and the construction sites, it was decided that the collated data should also be split between the two functions. A major element in this research was to investigate in some detail the transfer of information between the respective project team members and the discipline design engineers.

3.1.3 Validity of the Studies

It was considered essential to study only those projects that exhibited **all** of the key aspects of project management, including :-

i/ Sufficient technical complexity (new technology, proven technology or R&D)

ii/ Sufficient budget management complexities (over £3M)

iii/ Sufficient project duration (<12 month life cycle)

iv/ Sufficient interpersonal exchanges (< 12 team members and outsourced services)

v/ Sufficient external influences (National/International dimension)

vi/ Sufficient project auditability (recognised QA and CDM requirements)

During the period September 1993 to April 1996 it so happened that the author was directly involved in the management of two major capital projects, undertaken on behalf of a blue chip international chemical company based on the East coast.(UK)

The first project, *The Calciner Gas Cleaning Project* (Project 1) which ran from Sept. 1993 to Dec. 1994 and the second project, *The New Digester Project* (Project 2) which ran from Jan. 1995 to April 1996. Ref. P10 Appendix C12.

Project 1 was actually started prior to the Ph.D. registration, being an auditable project however, the case study data was considered to be admissible for the purposes of this reseasrch.. The research methodology used on Project 2 was specifically designed for the purposes of the Ph.D. research.

The research strategy selected for the industrial case study is really a hybrid of the three traditional research methodologies *'experiment'*, *'survey'* and *'case study'*, recommended by *Robson* [3], with a greater emphasis on the **survey** and **case study** techniques.

References to *The Bangladesh* Project and *The Hays* Project (Projects 3 and 4) are included in the body of the submission as they were both front end studies on major capital projects.

Project 5 was also considered to be worth including in the findings as it was a good example of the problems encountered at the back end of the project, the close out period. Projects 3 and 5 were particularly useful to demonstrate the international dimension and diverse nature of projects.

3.1.4 The purpose of the Case Studies

The purpose of the industry based research study was to provide a greater insight into the various project failure mechanisms, and assist in the development of the knowledge based alternative. It was intended that the research data obtained would be used to populate the KBS and test the validity of the concept in an industrial environment. The data can be described as being both *explanatory* and *descriptive*.

Explanatory in that the research attempted to explain the various mechanisms by which major capital projects are actually managed.

Descriptive in that the existing management techniques do not always provide satisfactory results despite following exacting procedures.

This research is primarily intended to portray an accurate profile of the events over the life cycle of two projects being undertaken in the Chemical industry, each exhibiting classical potential failure mechanisms.

The findings from three other associated projects is also alluded to.

The study was also designed to compare whether or not the projects being managed by traditional methods exhibited any of the success/failure factors identified by *Belassi & Tukel's* new deterministic framework theory shown in Appendix A7 (Fig 6).

According to *Robson,* "Descriptive research requires extensive previous knowledge of the subject being researched or described". Being directly involved in all five projects this type of research was considered wholly appropriate in the context of this submission. The research study was also designed to consider how information is transferred between engineers in the design environment, especially risk issues. As *Taylor*[4] purports "During plant design, generic failure rate data is all that is available" and only 'single event failure rates' are normally provided. By following the flow and transfer of design critical data it was hoped that the study would show how potential design risks were actually identified and managed in practice.

3.2 Case Study 1

3.2.1 Project 1 Introduction and background

The Calciner Gas cleaning project was a major capital project undertaken in accordance with established project execution procedures on behalf of a blue chip international chemical company operating on the East coast. Ref. Appendix C2-C3.

The project was sanctioned at a total project value of £ 4.5 M in 1992 and was initiated as part of a European Commission Environmental Directive concerning gaseous emissions. The project sponsors were the company's project management group based at the works site.

The project manager was appointed on a fixed term contract specifically for the duration of the project which ran from September 1993 through to completion December 1994.

The project involved the purchase, installation and commissioning of a new Waste Gas treatment plant "The Sulfacid process" a well proven technology developed and marketed by a major German company. The work involved the demolition of existing redundant plant to provide real estate for the new process, and the enabling civil works to support the 5 GRP vessels and new fan. The project justification was based on being able to reduce the levels of Sulphuric acid emissions to within the newly imposed HMIP consent limits within the time deadline demanded by the EC.

The project manager was contracted from outside of the organisation and given the full project management remit in accordance with the company procedures.

In order to perform the role of project manager the individual was empowered by providing an electronic PIN / ID No. with a spending authorisation limit. The ID provided access to the necessary data files required to manage the project.

The main plant items associated with the project were supplied by means of an MF1 contract, in which the title "The Engineer" was assigned to the project manager in order that he could negotiate the contractual elements of the project with "The Contractor" on behalf of the company.

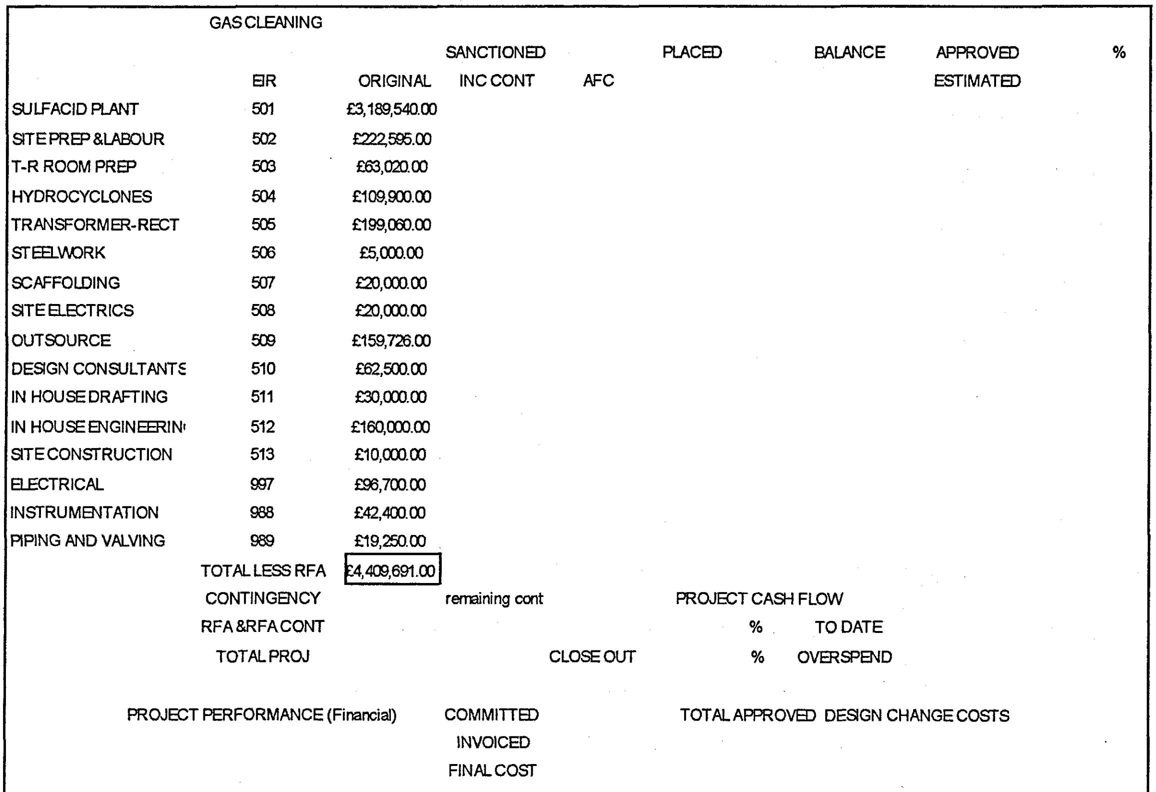
3.2.2 Site Based Activity

Site based activity work and progress was monitored by means of the site activity day diary system. An example of a blank single day diary sheet for a single contractor is shown in Appendix C7.

3.2.3 Cost Controls

The systems employed on the Calciner gas cleaning project was a combination of "The organisations cost controls" and the project "Cost controls".

All orders were raised by the project manager and logged onto the project cost control system. The main cost elements were allocated their own budget cost centres and were incorporated into the overall spreadsheet as shown below.



GAS CLEANING

	EIR	ORIGINAL	SANCTIONED INC CONT	AFC	PLACED	BALANCE	APPROVED ESTIMATED	%
SULFACID PLANT	501	£3,189,540.00						
SITE PREP &LABOUR	502	£222,595.00						
T-R ROOM PREP	503	£63,020.00						
HYDROCYCLONES	504	£109,900.00						
TRANSFORMER-RECT	505	£199,060.00						
STEELWORK	506	£5,000.00						
SCAFFOLDING	507	£20,000.00						
SITE ELECTRICS	508	£20,000.00						
OUTSOURCE	509	£159,726.00						
DESIGN CONSULTANTS	510	£62,500.00						
IN HOUSE DRAFTING	511	£30,000.00						
IN HOUSE ENGINEERIN	512	£160,000.00						
SITE CONSTRUCTION	513	£10,000.00						
ELECTRICAL	997	£96,700.00						
INSTRUMENTATION	988	£42,400.00						
PIPING AND VALVING	989	£19,250.00						
	TOTAL LESS RFA	£4,409,691.00						
	CONTINGENCY		remaining cont		PROJECT CASH FLOW			
	RFA &RFA CONT				%	TO DATE		
	TOTAL PROJ			CLOSE OUT	%	OVERSPEND		
PROJECT PERFORMANCE (Financial)			COMMITTED		TOTAL APPROVED DESIGN CHANGE COSTS			
			INVOICED					
			FINAL COST					

Fig 14 Example of spreadsheet used on Project 1

The method of analysis employed on project 1 was to use the minutes of meetings and general correspondence files along with the case history of the project captured on the site activity day diary sheets. The findings from the historical data were then compared with the **audit reports** in order to provide global analysis of the main factors that influenced the project outcome.

3.3 Case Study 2

3.3.1 Project 2 Introduction and background

The New Digester Project was a second major capital project undertaken in accordance with the same procedures as those on project 1.

The project was sanctioned at a total project value of £ 2.997 M in 1994 and was initiated as part of the company's expansion programme. The project sponsors were the company's project management group based at the works site.

The project manager was appointed on a fixed term contract specifically for the duration of the project which ran from January 1995 through to completion April 1996

The project involved the design, construction, installation and commissioning of two new, 100 m^3 capacity digesters fabricated from Carbon steel shells incorporating lead and brick lining. The work involved the recovery of greenfield real estate and connection into an existing production facility. The project justification was based on an increased production capability, coupled with the limited life of the existing digesters.

The project was considered highly suited for the second case study as it was also a fully auditable project involving the element of a typical multidisciplinary project.

The management system employed on the project was principally the same as that used on project 1.

The project manager was contracted from outside of the organisation and given the full project management remit in accordance with the company procedures.

It is worth noting that on the second project the manager had established credentials and was more aware of the organisational politics.

The same level of empowerment was afforded to the project manager employing the same electronic PIN / ID No with the same spending authorisation limit.

By the time the second project was in progress the new project management system had been introduced, requiring training in order to access the necessary data files required to manage the project.

The main plant items associated with the project did not necessitate the use of an MF1 contract as the items concerned were essentially an “in house” vessel design customised to suit the specific needs of the process. Ref. Appendix C4-C5

As with the first of the two case studies the company procedures required that a full audit trail was in place and that project audits were undertaken at 30% 60% and 100%.

3.3.2 Cost Controls

The system employed on the New digester project was again a combination of “The organisations cost controls” and the project “Cost controls”.

All orders were raised by the project manager and logged onto the project cost control system.

	NEWDIGESTERS								
			SANCTIONED		PLACED	BALANCE	APPROVED		%
	EIR	ORIGINAL	INC CONT	AFC			ESTIMATED		
Grimsby works costs	0001 (510)	16500	16500	16500	16500	0	16500	1	0.006
Main plant Items	0002 (501)	804610	996660	996660	951625.21	711.79	980000	0.98	0.356
Civil works	0003 (502)	153200	153200	187024.51	187024.51	175.49	180000	0	0.07
Steelworks	0004 (503)	250000	285000	285000	281712.37	3287.63	281712.37	0.99	0.105
External Design	0005 (504)	103000	103000	103000	102162.79	4337.21	98000	0.95	0.038
In house design	0006 (505)	64000	129000	129000	124182	4818	124182	0.96	0.046
In house Engineering	0007 (506)	122000	225000	225000	220333	4667	220333	0.98	0.082
Construction & painting	0008 (507)	281500	281500	316500	316389.46	110.54	280000	0	0.118
Spares	0009 (508)	85813	85813	40813	38990.51	1822.49	34000	0	0.015
Electrical	0012 (988)	157000	91500	91500	82025.51	5559.49	100735	1.1	0.031
Pipework and valves	0013 (990)	388300	578350	578350	575465.7	2884.3	550000	0.95	0.215
Instrumentation	0014 (997)	218905	294480	294480	282972.4	11507.6	280000	0.95	0.106
East Site costs	E/SITE (509)	30000	30000	30000	30000	0	28000	0.93	0.011
RFA & Cont	RFA	52250	52250	52250	51574.51	675.49	51574.51	0.99	0.017
	TOTAL LESS RFA	2674828	3270003	3293827.5	3209383.5	40557.03	3225036.88		1.217
	CONTINGENCY	269922	remaining cont	-349077.5	PROJECT CASH FLOW		-15653.42		
	RFA &RFA CONT	52250				% TO DATE	121.71		
	TOTAL PROJ	2997000		CLOSE OUT	3293827.5	% OVERSPEND	9.9		
PROJECT PERFORMANCE (Financial)			COMMITTED	3209383.5	TOTAL APPROVED DESIGN CHANGE COSTS				
	97.67		INVOICED	3225036.9		292538.75			
			FINAL COST	3293827.5					

Fig 15 Example of cost control spreadsheet on project 2

The LAN allowed the simultaneous use of spreadsheet updates providing an immediate project costing update. The project department cost control system enabled the project manager to restrict spending against over committed budgets by withholding contingency monies.

3.4 Data tabulation and Findings (Project 1)

3.4.1 Research Techniques

The main data acquisition techniques employed on project 1 was a combination of in depth interviews and fact finding studies obtained by inspection of the project correspondence files and site activity day diary sheets Ref. Appendix C7.(Fig 20)

The one on one interviews were kept informal and personal, and were restricted to only those parties directly involved with the project.

The interviews were conducted at time intervals over the project life in order to establish whether there was any perceivable shift in the project focus or project priority.

The users group including :-

i) The organisations operations manager
ii) The organisations works engineer
iii) The organisations production manager

The project group including :-

i) The organisations executive management
ii) The site based project group management
iii) The discipline engineers

The main contractors and sub contractor group including :-

i) The contractors senior management
ii) The contractors project manager
iii) The contractors commercial manager

The results of the interviews were analysed using Content analysis. A technique whereby the responses are standardised and the frequency of use of specific words is analysed using a key word coding system.

3.4.2 Project Execution Strategy

The management system applied to project 1 was essentially in keeping with the organisations PEP. The MF1 form of contract was introduced into the PEP largely due to the senior management concerns regarding the contractual risks.

The day to day management systems required by the organisations Project execution procedures were reviewed by the project manager and found to be lacking for a major capital project.

The main areas in which the management system were seen as being weak were in cost monitoring and controls, as these were normally handled by the company's purchasing department located some distance from the site.

The project manager decided to enhance the existing PEP by introducing an "in house" cost control system to run in conjunction with the existing cost monitoring system.

The strategy of using the project correspondence files required that all information and data transfer between the organisations project manager and the contractors project manager was well documented.

Minutes of all meetings were recorded and approved by both parties before being admitted onto the project file.

Weekly team meetings were held and were chaired by the project manager, all weekly meetings had the same format and agenda list example shown below

PROJECT GROUP
CALCINER GAS CLEANING
WEEKLY AGENDA/REPORT
DAY / MONTH / YEAR
Week No.

1.0 SAFETY
2.0 PROGRESS TO DATE
3.0 WORK IN PROGRESS (WIP)
4.0 WORK PLANNED (WP)
5.0 UNPLANNED ACTIVITIES (UA)
6.0 CONCERNS
7.0 OTHER MATTERS

3.4.3 Project 1 Interviews

A) User Group responses

The first responses obtained from the user group were those minuted as part of the project coordination meeting.

In general the comments were surprisingly very positive, despite the fact that the new process would be critical to the site operation and would require additional resources and training[1].

The works maintenance response was less positive, influenced by the fact that the additional plant would put greater demands on the already depleted maintenance resources.

The operations manager expressed the view that the new plant was a necessary facility to meet environmental pressures, but that it did little to improve the factory output.

This view changed considerably later in the project when the HMIP advised of the legal consequences of failing to meet the directive.

The works engineer was primarily concerned with ensuring that the new facility would be as maintenance free as possible and that the project should absorb all costs associated with spares. This view proved to be the most difficult one to satisfy as considerable subjectivity and preferential engineering was introduced into the project which led to a protracted hand over phase .

The production manager emphasised the point that the whole operation of demolition, building, installing and commissioning the new facility should be undertaken with the absolute minimum interference to the existing production capability. This position also created problems over the life of the project especially during the inevitable stack outage and commissioning period.

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[1] Recognising the economic climate at the time.

B) Project Group responses

The first feedback from the discipline engineers assigned to the project were informal and were obtained as part of the introductory phase.

The question posed being :- "How comfortable are you with the assignment ?"

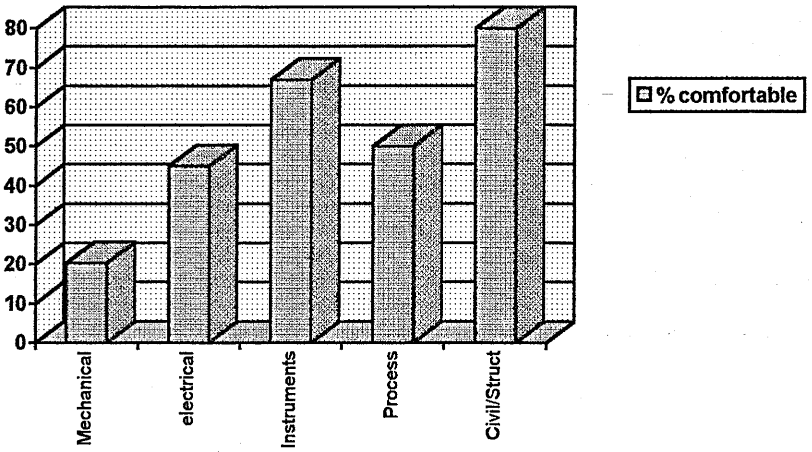


Fig 16 Tabulated responses from project team

The response indicated that the "In house" resources were far less comfortable with the assignment than the "outsourced" design resources.

The reasons were identified as being :-

i) That the individual discipline engineers had not been directly involved in scoping the work or developing their own discipline budgets.

ii) That the individuals assigned to the project were not dedicated to the project, i.e. they were sharing their time between project 1 and other projects.

iii) The individuals were unfamiliar with the new technology.

iv) The individuals had not yet gained any confidence in the project manager.

The outsourced contractors on the other hand were more comfortable with their part of the project having bid the work against a defined and quantifiable work scope.

C) Main contractor group responses

The initial response from the main contractors team was overly optimistic, this exuberance was bolstered by having recently won two other major contracts.

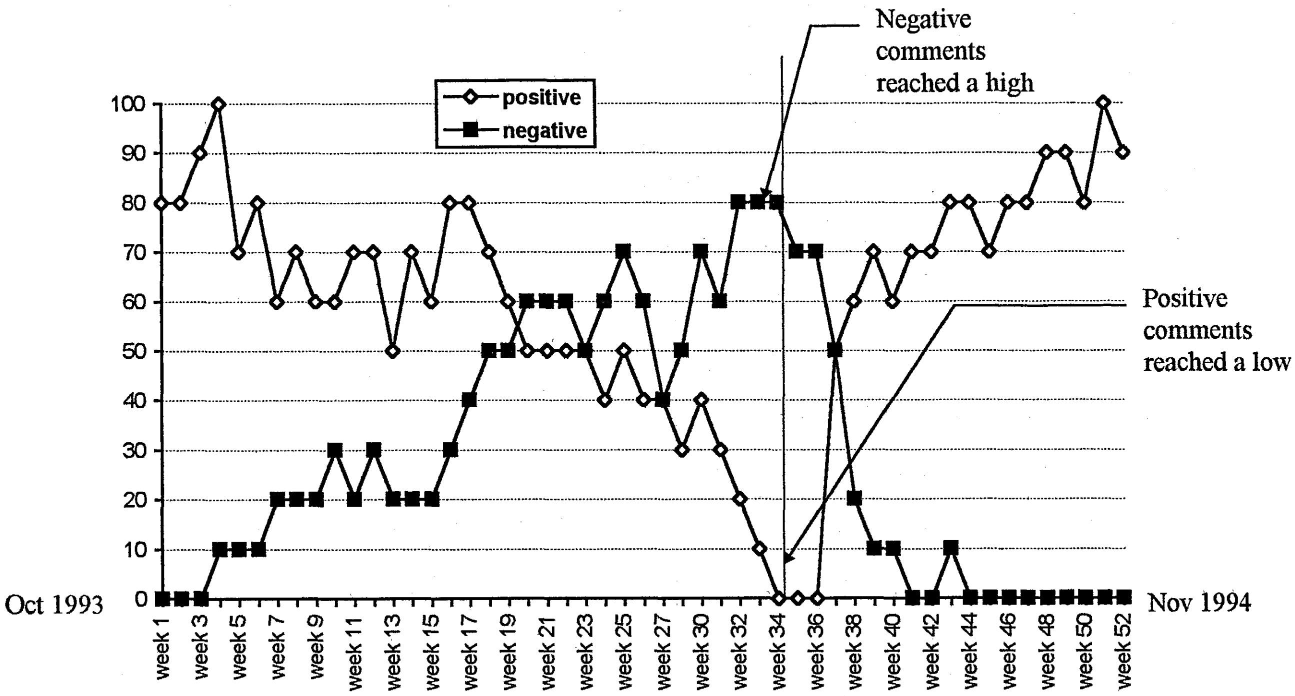
This optimism was a cause of concern for the project manager and the project team aggravated by the absence of any detailed project plan or Gantt chart.

The situation was further inflamed by the appointment of the main contractors project manager who adopted a somewhat arrogant and unhelpful position.

In researching this area of the project, the technique employed was to review the correspondence file and compare the outgoing and incoming T Q's and responses.

A key word content analysis was applied to the correspondence data which identified how the relationship between the respective parties developed.

These findings were tabulated graphically as shown below, as can be seen the worse period for the relationship was around week 34 in which there were a considerable number of **negative** references with very few **positives.**



Negative comments reached a high

Positive comments reached a low

Oct 1993

Nov 1994

Fig 17 Graphical representation of relationship between parties

3.5 Data tabulation and Findings (Project 2)

3.5.1 Research Technique

A complete project case history dossier was established from the outset on project 2 which involved dissecting the project into its constituent shared task elements, 12 in the design phase and 12 in the build phase.

From the analysis of the findings a summary of the **types** of problems encountered for each of the major tasks was identified and is shown below.

Design Phase

Problem **Task**	Human Resources not available	Unforeseen technical difficulties	Space conflicts (clashes)	Quality of document (errors)	Lack of client approvals	Incorporate outsourced design data	Lack of in house design expertise
1 Vessels		x		x	x	x	x
2 Lids						x	x
3 RC Slab	x	x	x			x	x
4 Steelwork							
5 Acid line	x	x	x	x	x		x
6 Ferrous pipe	x		x	x			
7 On plot acid	x	x	x	x			x
8 Plastic pipe	x		x	x			
9 Mech handling		x				x	x
10 Ductwork		x	x			x	x
11 Instruments	x	x			x		
12 Brick/tiling							x

Table 11 Tabulated response of problems identified during design phase of Project 2

Of the 40 problems encountered during the design phase, the design of the acid line, the slab and the vessel provided the most difficulties.

The history of information flow and decision making logic for task 1.0

The mechanical design fabrication and installation of the 2 new digesters

is shown as an historical record in Appendix C8 (Fig 21). The research technique employed was to map the historical data obtained from the investigations onto an 'S' curve for the specific task being undertaken Appendix D5 (Fig 31). The inter related activities and sub elements of the task were then identified and their impact on the task in question was recorded as shown in Appendix C9 (Fig 22).

3.5.1 Project 2 Research Technique (Cont)

The construction phase of the project was analysed in much the same way as the design phase, with 32 major problem issues being identified, these are shown below in Table 12. The late delivery of the vessel ring is shown in photo P06 Appendix C5.

Construction Phase

Problem **Task**	Site construction safety issues	Site technical difficulties and workmanship	Space conflicts (clashes)	Quality of construction documents	Adverse weather	Restricted access to construction site	Late supply of critical plant items
1 Vessels		x	x	x			
2 Lids		x			x		
3 RC Slab	x	x					
4 Steelwork			x				
5 Acid line		x	x	x		x	
6 Ferrous pipe		x	x	x		x	
7 On plot acid		x	x	x		x	
8 Plastic pipe							
9 Mech handling			x	x		x	
10 Ductwork					x	x	
11 Instruments							
12 Brick/tiling	x	x	x		x	x	x

Table 12 Tabulated list of construction related tasks

Each of the 24 **design and construction** tasks were studied in the same manner, i.e. The daily issues occuring over the project life were recorded on the "*History of information flow and Decision making logic sheets*", and *Site Activity Day Diaries.* The inter disciplinary relationships were identified and recorded along with the *effects* that the problems had on the project as a whole. Ref. Appendix C9 (Fig 22).
i.e. additional man-hours, impact on time, impact on quality and impact on cost.
The major problem issues, those likely to have a significant effect on Cost Quality and Time were identified and tabulated as shown in Tables 11 and 12 above.

3.5.2 Project Execution Strategy

The management system applied to project 2 was also in keeping with the organisations PEP. There was no MF1 form of contract however the project was still deemed as being auditable and therefore required traceability and accountability.

The day to day management systems required by the organisations project execution procedures PEP were similar to those employed on Project 1 with the addition of a man-hour data base system. The project was reviewed by the project manager and was deemed as being undervalued.

Internal political pressure was applied to the project group based on the ROI for the project and senior management expectation was to deliver the project at the sanction value of £ 2.997 M.

A risk assessment was undertaken by the project manager using a risk analysis technique alien to the organisation.

The cost impact of the risk analysis identified that the risk contingency would need to be in the order of 8 % of the total project value.

It was decided by senior management that having obtained project sanction, the project should proceed with the original estimates, contrary to the recommendations of the project manager.

The main areas of concern expressed by the project manager were :-

1.0 The design basis for the vessels had not been established, i.e. The need to use pressure vessel codes.

2.0 The vessels were lead and brick lined with exotic alloy lids, the lid fixing detail had not been finalised.

3.0 The two new vessels had to be tied into an existing bank of digesters making access particularly difficult.

4.0 The two new vessels were to be "automated" using new unproven technology.

Senior management viewed the issues as being problems that could be addressed during the life cycle of the project.

3.5.3 Project 2 Interviews

A) User Group responses

Responses from the user group were obtained from informal interviews in order that the research itself did not influence the outcome of the project.

The initial response from the works maintenance team was favourable given that a recent organisational reshuffle had taken place following the appointment of the new managing director.

Digester vessels were seen as special plant items able to give 20 years of service, and were therefore not considered to be a major issue. The remaining plant items were seen as being a significant maintenance problem, specifically the 96% acid line and the associated plant.

The Operations manager was enlisted onto the project team to ease the interface between project engineering personnel and the key process personnel, i.e. Shift supervisors.

Production personnel were aware of the need for the new plant and recognised that the investment in the project was seen as continued support to the manufacturing base, even so the production demands were number one priority and plant outages were to be minimised. The production manager agreed to give the project his full support, this was seen as a major contribution to the likelihood of project success.

In the event the commitment afforded at the outset of the project was not sustained and interface issues did become a problem.

One benefit of the risk analysis was that it focused the minds of the project group senior management, such that whilst no additional resources were afforded to the project, the project was given a priority rating.

The project manager was also given freedom to outsource the civil, structural and vessel design work.

This was considered a major benefit as the project manager had recognised the in house design limitation from Project 1.

B) Project 2 Group responses

Feedback from the discipline engineers assigned to the project was informal and obtained as part of the introductory phase.

The same question posed being :- “How comfortable are you with this assignment ?”

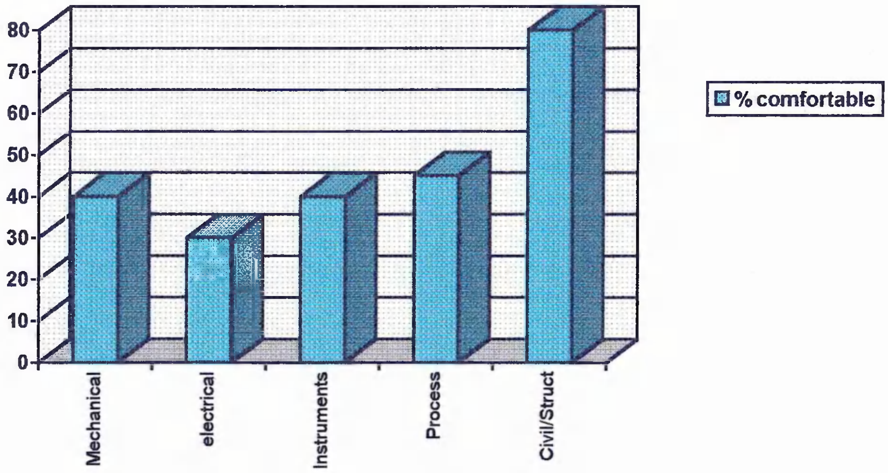


Fig 18 Tabulated responses from Project 2 in house discipline engineers

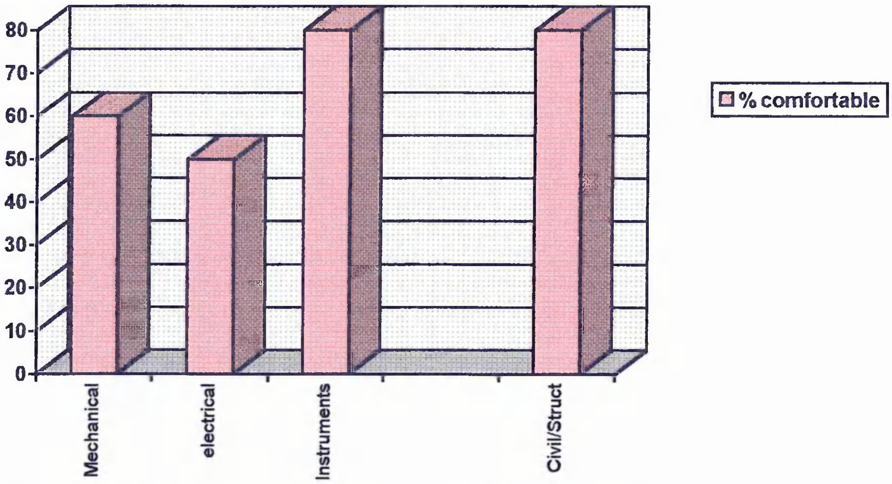


Fig 19 Tabulated responses from Project 2 outsourced discipline engineers

The response indicated that in the second project the `in house` resources were also less comfortable with the assignment than the `outsourced` design resources even though the `outsourced` design content of the project was greater and the risks higher than those in project 1.

The reasons were identified as being:

i) That the design offices were overly optimistic, again this assumption was based on the earlier experiences gained during project 1.

ii) That the individual discipline engineers assigned to the project were not familiar with the new technology and shared the same concerns of project funding.

iii) The individuals were not dedicated to the project despite the prioritisation.

The confidence level in the outcome of the project at this time was :-

Cost - A very low confidence level in meeting the £ 2.997 ± 10% given the risk analysis prediction.

Time - Jan 1995 to April 1996 15 month programme was considered as being extremely tight. No established norms available therefore confidence of meeting 15 month programme was low.

Quality - Given the status of the design, the budget limitations, the programme pressure and the new technology the confidence in being able to satisfy the client in terms of quality was considered to be very low.

C) Project 2 main contractor group responses

The main contractors engaged on project 2 were initially very positive even after reviewing the ITB's and visiting the works. The local mechanical contractors requested that they be allowed to bid the vessels as well as the piping. The project management view at the time was that as the company had no pressure vessel fabrication experience, and should therefore be excluded from the list of preferred contractors for this work.

The senior management were approached directly by the managing director of the contractor concerned and his company was subsequently included on the inquiry list. This decision proved to be critical to the success of the project.

As a result of third party inspectors nominated by the sub contractor failing to recognising the need to pre heat the vessel rings prior to welding, the peripheral weld on the first ring **cracked** in the fabricators workshop.

The history of events was recorded on the relevant sheet. Ref. Appendix C8 (Fig 21).

3.6 Analysis and Observations

3.6.1 Analysis

The focus of this element of the research was to obtain "real world" information concerning the **traditional method** of managing major capital projects in the Chemical industry, and to confirm whether or not the views of the project managers interviewed in earlier research could be substantiated.

The case studies were also intended to provide a basis against which the new **knowledge based** project management concept being developed by the author, might be compared.

Investigative techniques were employed during the design phase of the two projects in which the views of the individual designers, both 'in house' and 'outsourced' were solicited and recorded. In analysing the data obtained it was necessary to recognise the sensitivity of those design issues resulting from designer error.

Of the 40 problems encountered the main three problem areas identified were ;-

i/ Lack of 'in-house' expertise (8 counts)
ii/ Unforeseen technical difficulties (7 counts)
iii/ Human resources not available (6 counts)

These results supported the early concerns of the project manager with regard to risk.

Of the 32 major problems identified during the construction phase, two dominated :-

i/ Site technical difficulties and workmanship (7 counts)
ii/ Space conflict (clashes) (7 counts)

The results reinforce the view that by starving the project of key resources at critical design periods the consequences manifest themselves in the construction phase.

E.g. lack of design expertise in the design phase results in inadequate error laden documentation and subsequently the inevitable construction difficulties.

A substantial amount of data and information was obtained over the life cycles of the two capital projects investigated. The bulk of the data was in the form of
Diary entries, Reports from meetings, Progress reports, informal interviews etc.

Qualitative analysis techniques were used for non numerical data whilst quantitative analysis was used on the numerical data obtained from the case studies.

Statistical analysis of the numerical data included :-

i/ Determining the significance rating of an identified problem to include it in the table.

ii/ Correlation of data against other researchers success/failure criteria.

iii/ Assigning weighting values and criticality to identified problems.

Content analysis of the non numerical data included :-

i/ Frequency of use of key words in identifying and developing problem areas.

ii/ Error analysis, to compare consistency of belief between respective parties.

E.g. Having identified a potential problem, such as a report from the instrument engineer that an instrument specified in the inquiry needs to be changed for a new model, then the **effect** on the project as a whole had to be established.

The effect will largely depend on the status of the project life cycle at the time the problem is identified, and will be measured in terms of Cost, Quality and Time.

The example in appendix C9 (Fig 22) shows diagramatically the effect of the weld failure and its impact on the specific task in terms of additional man-hours and time. The quality impact was measured in terms of possible relaxation of standards and specifications. Problem cost impact $pc_i = \Sigma$ corrective measures $(m + h + t + q + p)$

m_1 = increase cost due to extra materials needed to correct problem.
h_1 = increase cost due to additional man-hours needed to correct problem.
t_1 = increase in cost due to extra time added to project duration.
q_1 = cost difference between required standard and accepted standard.
p_1 = cost due to programme changes.

For the purposes of this research the pc_i for any given task was evaluated in isolation, i.e. It was assumed that the problem cost was not cumulative. The author recognises that in practice there would be a project termination value, however as the data was analysed at the end of the project it was assumed that the accumulative pc_i costs were less than the ROI cut off as recognised in the Model formulation proposed by *Shtub et al*[5] The design phase pc_i's were considered significant if they were < 8% of total design budget, whilst the construction pc_i's were significant if they were < 2% of the total project budget. NB For those projects with LD's this assessment would not be valid.

3.6.2 Observations

The major observations resulting from the case studies were :-

i/ That whilst organisational procedures were followed during the execution of the two projects a number of problems still arose during both the design phase of the project and the construction phase.

ii/ That the cost impact of the major problems were potentially non trivial.

iii/ That many of the problems that arose were foreseeable and predictable.

iv/ That stakeholders declared interests were not consistent with their commitment.

v/ That senior management were influenced by political gain rather than the interests of the project.

vi/ That project managers were often perceived as being responsible for the project outcome, even when required resources were denied.

vii/ That decisions to over rule the project manager were often unsound and based on hidden agenda issues. (Politics and Personalities)

viii/ That outsourced design staff need to be fully integrated into the project team.

It is important to recognise that the observations made over a 12 month project life cycle period, may not always be consistent with the overall scheme of things as identified on p22 of this submission. Executive management is a dynamic business and 12 months is a long period for a company trying to hold on to its market share.

In general terms it would appear that the analysis findings from the two case studies is reasonably consistent with the views of the project managers interviewed, as summarised on p37.

Both projects involved a combination of hard and soft management skills.

The success/failure deterministic framework criteria proposed by *Belassi and Tukel* correlated well with the research findings.

The two projects were both considered successful, even though project 2 was delivered over the original budget.

In terms of the individual skill of the project manager affecting success, as there is no specific data concerning this claim it is not possible to comment.

3.7 Summary, conclusions and references

3.7.1 Summary

In summarising it is appropriate to revert to the objectives identified at the outset of this Chapter, namely to identify how project management and engineering design knowledge is applied in the real world. The two case studies provided a considerable amount of data which, after analysis, appeared to support the views of the project managers interviewed in the survey. The case studies were useful in providing an insight into how the project management systems were selected and applied over the life of two typical projects. A further benefit derived from the case studies was that the *Belassi and Tukel* theory could be compared against the findings in order to evaluate whether or not the deterministic framework could be used in the KBS.

The industrial case based research was designed to provide information into how projects are managed by one particular organisation, and to establish whether or not the projects analysed are typical of those undertaken in the industry as a whole.

The case studies were also intended to provide facts concerning project success/failure mechanisms for comparison with other research findings to determine whether or not the knowledge obtained can be incorporated into a decision support tool. *Wateridge* [6] recognised that "An unsuccessful project does not always indicate an unsuccessful project manager" He also conceded that, "Many project managers are still employing the same ideas they learned from their superiors" and concluded that, "The main method for managers to learn aspects of project management in the past is through experiential learning", and "Project managers must continuously develop their skills and competences throughout their career". If these points are correct one has to ask at what point, if ever, do project managers become 'experienced'. ?

Hackney [7] suggests that, "The list of qualifications for successfully performing these (Project management) duties would be very long, it would read like a text book description of the perfect business leader....but it would also include contradictory qualifications and combinations of qualifications seldom found in a single individual".

3.7.2 Conclusions

The conclusions formed from the research studies were that there is at present no panacea that will guarantee the success of a given set of project conditions.

There are however a number of well established management techniques that do afford guidance when developing project execution strategies and selecting management systems.

The cost risk analysis undertaken on project 2 Ref. Appendix E4 Fig 42 confirmed that the project was underfunded. The organisational procedures included no mechanism for incorporating the recent experiences gained from managing project 1 which contained information concerning the commitment of certain project team. members

These concerns were identified at the outset of the project but were not *shared* concerns and as such no contingency strategy was adopted.

Project 2 case study provided a good example of how projects can suddenly switch between apparent success and almost inevitable failure within the space of a day or so. E.g. The weld failure on the Digester ring.

The case studies provided a better understanding as to how the hard and soft skills identified in chapter II of this submission can directly influence project success.

The conclusion then, is that whilst project success is influenced by the systems applied it is more strongly related to the appointment of a professional and suitably experienced project manager, equipped with considerable experiential knowledge.

The projects analysed closely correlate with the new framework approach suggested by *Belassi and Tukel,* who also found "A strong statistical relationship between the managers **technical background** and his/her **competence** on the job".

The views of the interviewees also closely correlate with the case study findings and are therefore considered to be valid for the purposes of this research.

Chapter III has hopefully provided a more 'in depth' appreciation and understanding of the complexities of the design and build issues found in the construction industry.

Chapter IV reviews the justification, background and basic principles of the "Conserv concept" which is based largely on the results of the investigative and industrial research findings described earlier.

3.7.3 References

1 Chalmers, A. (1997) *Managing Projects: How to plan, implement and achieve specific objectives* How to Books.

2 Belassi, W. and Tukel O.I. (1996) 'A new framework for determining critical success/failure factors in projects'
International Journal of Project Management vol. 14, no.3, 141-151.

3 Robson, C. (1993) *Enquiry in the real world.* Oxford Blackwell

4 Taylor, J.R. (1994) *Risk Analysis for Process Plant, Pipelines and Transport.* E&FN SPON

5 Shtub, A Bard, J.F. and Globerson, S. (1994) *Project Management Engineering Technology and Implementation.* Prentice-Hall International.

6 Wateridge, J (1997) 'Training for IS/IT project managers: a way foreward'
International Journal of Project Management vol. 15, no.5, 283-288.

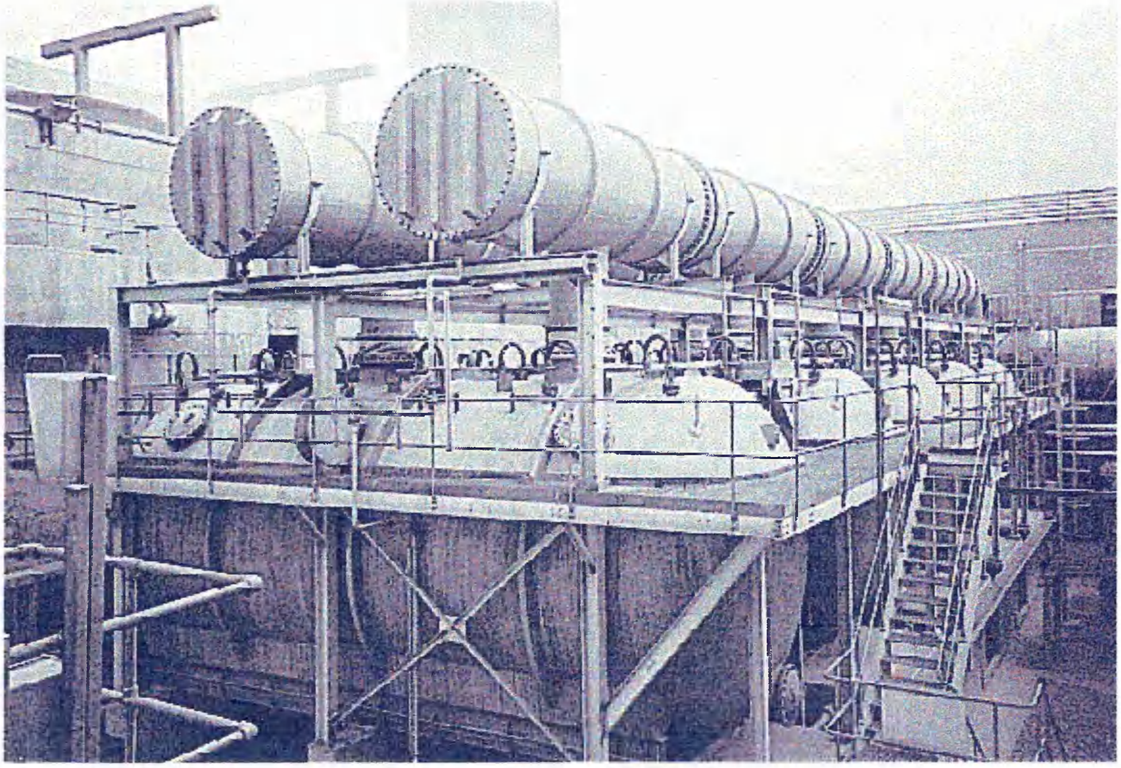
7 Hackney, J.W. (1992) *Control and Management of Capital Projects* (2nd Ed.)
American Association of Cost Engineers McGraw Hill

APPENDIX C

APPENDIX C

CASE STUDY PHOTOGRAPHIC RECORDS
TASK SHEETS
S CURVES
SITE ACTIVITY SHEETS
AUDIT REPORTS

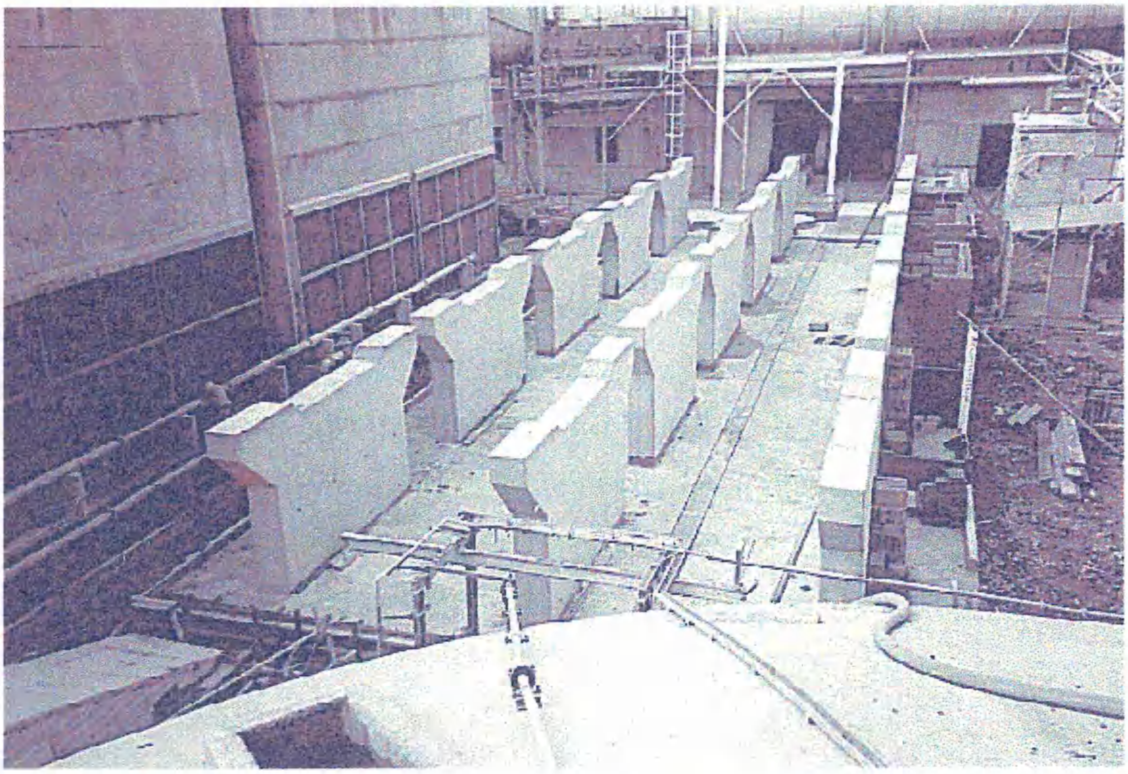
APPENDIX C



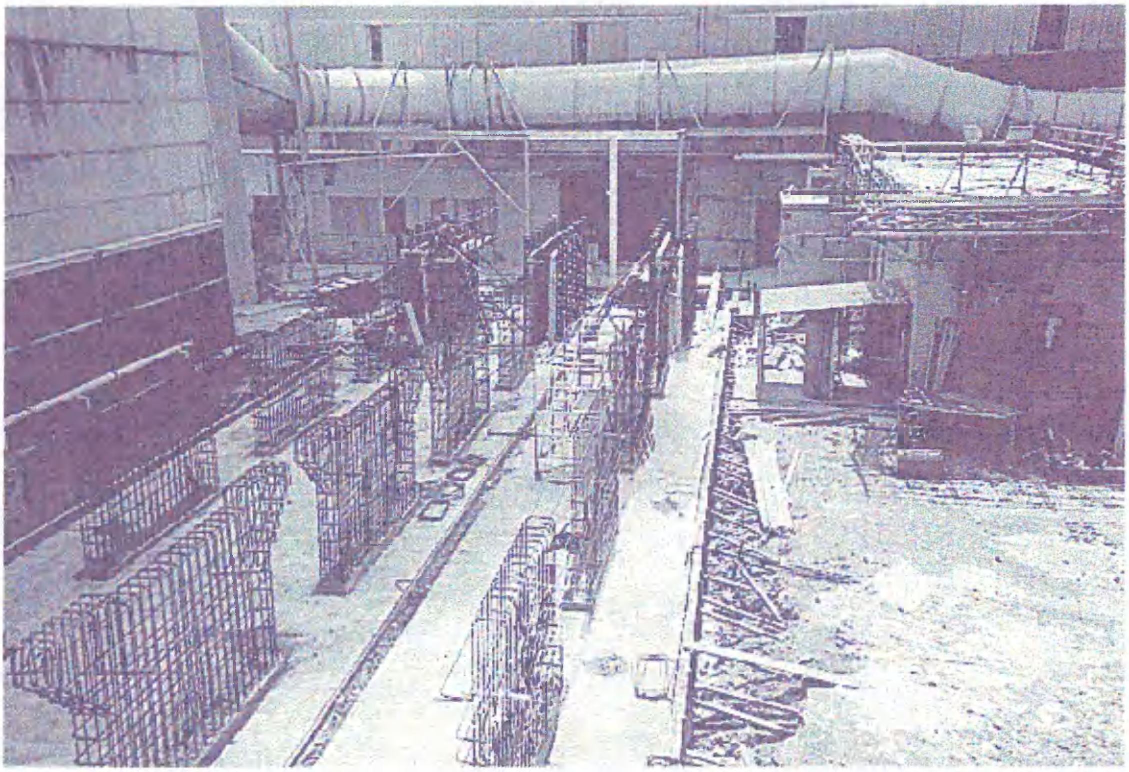
P 01 Photograph of Calciner Gas project (Project 1)

P02 Photograph of Calciner Gas project (project 1)

APPENDIX C



P03 Photograph of civil plinths under construction (Project 1)

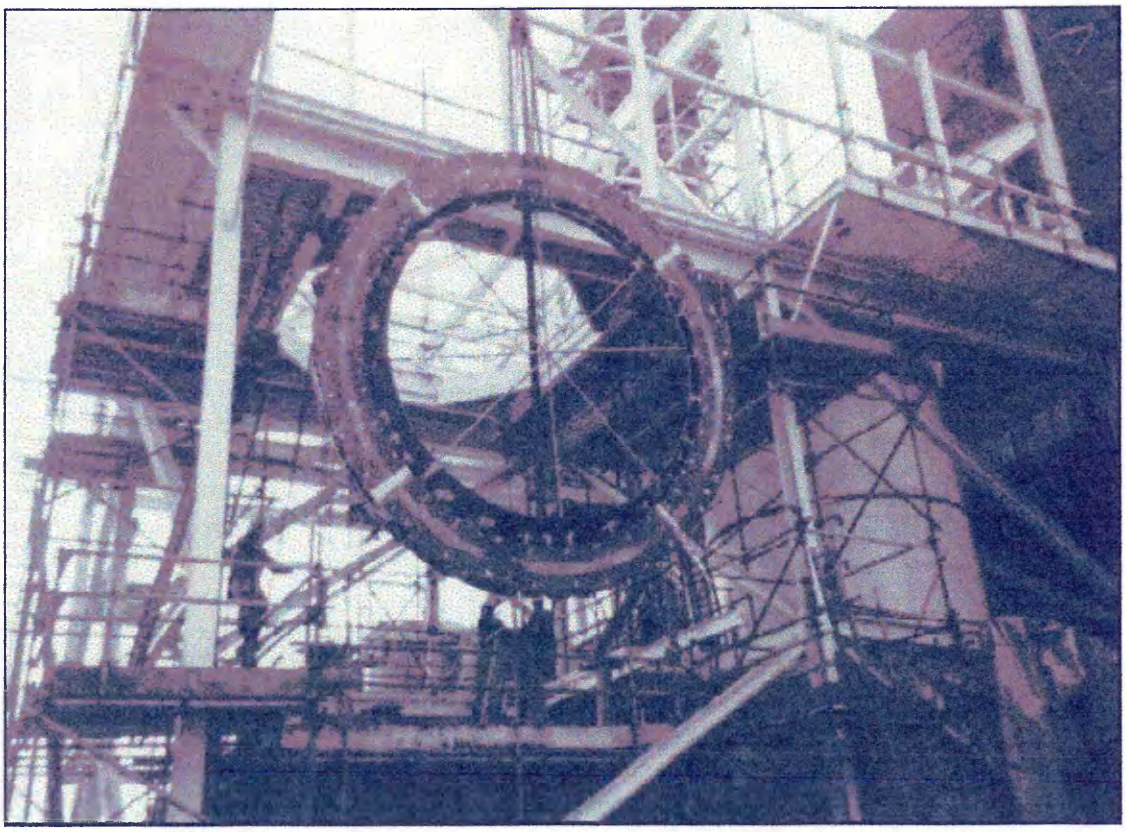


P04 Photograph of civil plinths under construction (Project 1)

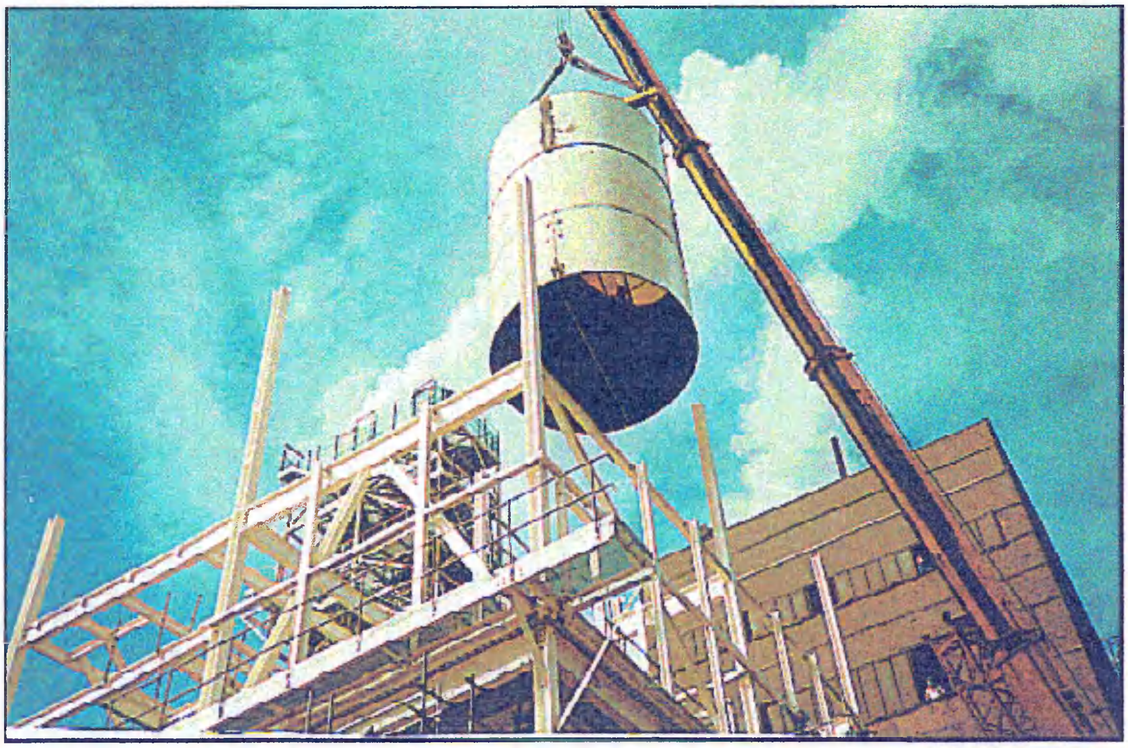
APPENDIX C

P 05 Photograph of New Digester project (Project 2)

APPENDIX C

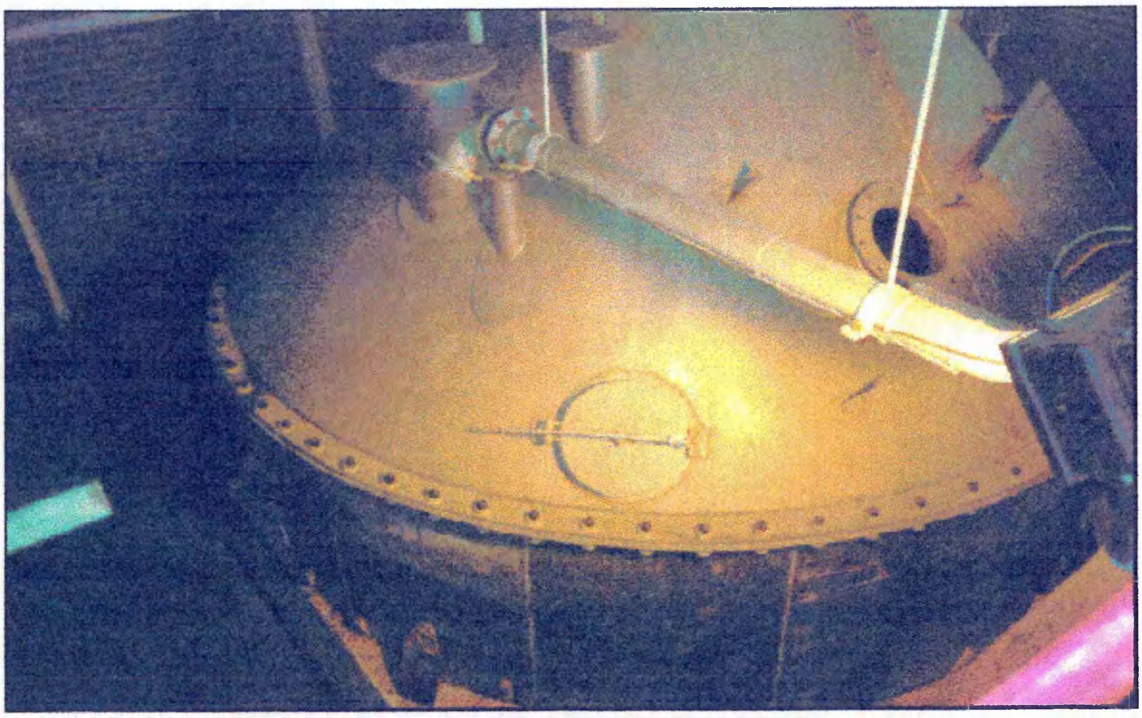


P06 Photograph of vessel ring New Digester project (Project 2)

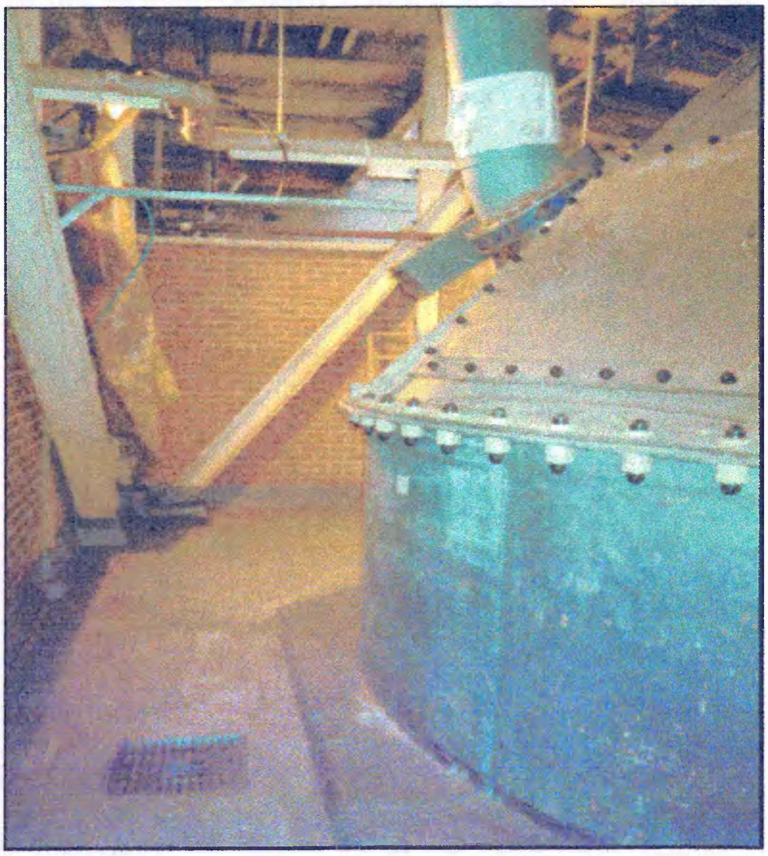


P07 Photograph of vessel shell being lifted New Digester project (Project 2)

APPENDIX C



P08 Photograph of vessel lid in position New Digester project (project 2)



P09 Photograph of lid fixing detail New Digester project (Project 2)

APPENDIX C

TIOXIDE EUROPE SITE ACTIVITY DAY DIARY SHEET
CALCINER GAS CLEANING PROJECT 0974

Site Contact : Mr. . Tomlinson Ext : 4314

Date :	**Sheet No. of**	**Disc : Mech/Elect/Inst/Civil**

To be completed by Contractors Representative

Contractor Sitework Activity for Day

....

....

....

Time **On Site**.................................... **Off Site**.. **Contractor**..............................

No. On Site................................... **Other Contractors on site** .......Y.........N.........

Name of Contractor..

Supervisor..

This signature confirms that all personnel working on behalf of the contractor are familiar with Tioxide Safety Rules TGY/STY/PLY/5,6,9 & 10 evacuation procedures and site is safe to commence work

Permit Requested/Issue... **Permit No**..................................

Hot Work Excavation/Demolition Isolation Vessel Entry

Permission Requested/Granted

Site Removal Plant Outage Stores Items Lifting Equipment Scafftags

Method Statement and Job Working Practices Required Yes/No ....

If Sitework Activity has known Hazards associated then a MS or JSWP is required. If in doubt consult Tioxide Plant Safety Department

Presite Work Safety Check (Attire)

OVERALLS, SAFETY SHOES/BOOTS, HELMETS TO BS.5240, SPECTACLES TO BS.2092

Presite Work Safety Check (Equipment)

Report of any Incident

....

....

Weather Conditions

Fine Rain High Winds Sub Zero

Site Work Stopped

Reason...Time..........................

..............By.................................Position..

Site Inspection/Safety Audit By ....Date.......................................

Inspected for : Cleanliness/Attire/Safe Working Conditions/JSWP/MS/Equipment

Comments:

....

....

Fig 20 Example of blank Site Activity day diary sheet

APPENDIX C

History of Information Flow and Decision Making Logic Task 1.0

THE MECHANICAL DESIGN FABRICATION AND INSTALLATION OF THE 2 NEW DIGESTERS

Undertaken by: Tioxide/LES/Robert James/National Vulcan

1.1 Data and information required to build vessels
i) Process Data Sheet
ii) Preliminary vessel design (using Calais technology) dimensions etc.
iii) Preliminary support legs design data
iv) Static design conditions
v) Dynamic design conditions
vi) Scope of work for the designer
vii) Quality plan for the design and building of the vessels
viii) Shop fabrication works
ix) Site fabrication works
x) Slab design to accommodate vessel foot print
xi) Confirmation of slab as built condition
xii) Organisations design and construct codes and procedures

1.2 Task 1.0 is again a typical design problem facing mechanical/vessel design engineers and shop fabricators. In the case study the vessels were designed by outsourced design offices Robert James under Tioxide engineers ITB and BS.5500 Cat II codes.
A quality plan was generated in which the third party inspection (National Vulcan) requirements were identified.
The basis of the design was the process data sheet, previous design technology and client comment.

1.3 Having determined the location, geometry and basic design requirements for the lead and brick lined vessels, the **preliminary** vessel arrangement drawing was generated using in-house designers (mechanical).The orientation and elevation levels for nozzle access were also determined in conjunction with the process engineer and instrument engineer. The vessel design codes were determined by the mechanical engineering department based on process data supplied by the process engineer.

1.4 Once the overall design had been determined the scope of works was drawn up and the enquiry tendered for design and fabrication (ITB Ref: E/M/002) Contractors approached (LES/Wefco/Newell Dunford/Ardeth/McTay).

14/3/95

1.5 Order placement. Promised delivery 24 weeks (actual delivery 31 weeks) Leg design information obtained from designers 3 weeks from order placement. Shell design calculations suggest 16mm cone 14mm strakes (only 12mm or 16mm thickness available).

1.04.95

1.6 Modification following lid fixing change required vessel rim to be in stainless steel and drilled rather than clamped.
1.7 LES failed to issue drawings for construction.

15.05.95 **Problem identified (Hard/soft skill)**

1.8 Site Supervisor noted leg changes from earlier drawing - work put on hold pending clarification
Hold removed following confirmation of revisions and third party inspection acceptance of design.

03.07.95 **Problem identified (Hard skill)**

1.9 Late delivery of materials to site - 5 weeks. Window created for LES to construct legs on site.

20.07.95 **Problem identified (Soft skills)**

1.10 Unscheduled holidays taken by sub contract designers.

12.07.95 **Major Problem (Hard/soft skills)**

1st cone weld failure during fabrication. Report required to ascertain reason.
Need for pre heating identified despite obtaining welding approvals from National Vulcan
1.11 Revised weld procedure submitted for cone fabrication
1.12 Revised programme shows first ring section now due *30/08/95*
1.13 Revised cone installation procedure requires structural modifications to enable cone to be installed .
1.14 Protracted delays necessitate revision to overall programme .Change to installation method approved.

29.08.95 **Major Problem (soft skills)**

1.15 Contractor submitted significant claim for costs due to additional material requirements 25 - 60 mm and 40 - 60mm
1.16 Costs rejected by Tioxide.*3/9/95*
Threat of demobilisation by contractor, negotiated agreement being that “consideration” will be given when 1st vessel is complete.
1.17 Renewed effort on site - LES construction manager appointed *01.09.95** key point. 1st vessel ring and cone assembled on site.
05.09.95 Tioxide agree to providing site pre-heating requirement to assist with progressing work.
1.18 Revised programme shows 1st vessel fabricated *29.09.95* and second vessel *20.10.95.* Programme revised *07.09.95* to accommodate the changes.

11.09.95

1.19 Weather conditions changes *04.09.95* site fabrication requires weather protection .LES claims for standing time agreed

12.09.95

1.20 Main lift went off well,1st vessel strakes and second vessel ring installed.

15.09.95

1.21 Inspection of part fabricated vessel reveals that nozzles have raised face flanges and 90 degree welds needed to be changed to facilitate lead lining

06.10.95 **Problem Identified (Hard skills)**

1.22 Contractor unable to lift second vessel shell due to high wind loads.

08.10.95

1.23 Second vessel shell installed Sunday 2 pump out tank lids installed project re scheduled date still holding.

13.10.95 **Problem Identified (Hard skills)**

1.24 Lids positioned on wrong pump out tanks.

15.10.95

1.25 Final radiographic clearance of welds.

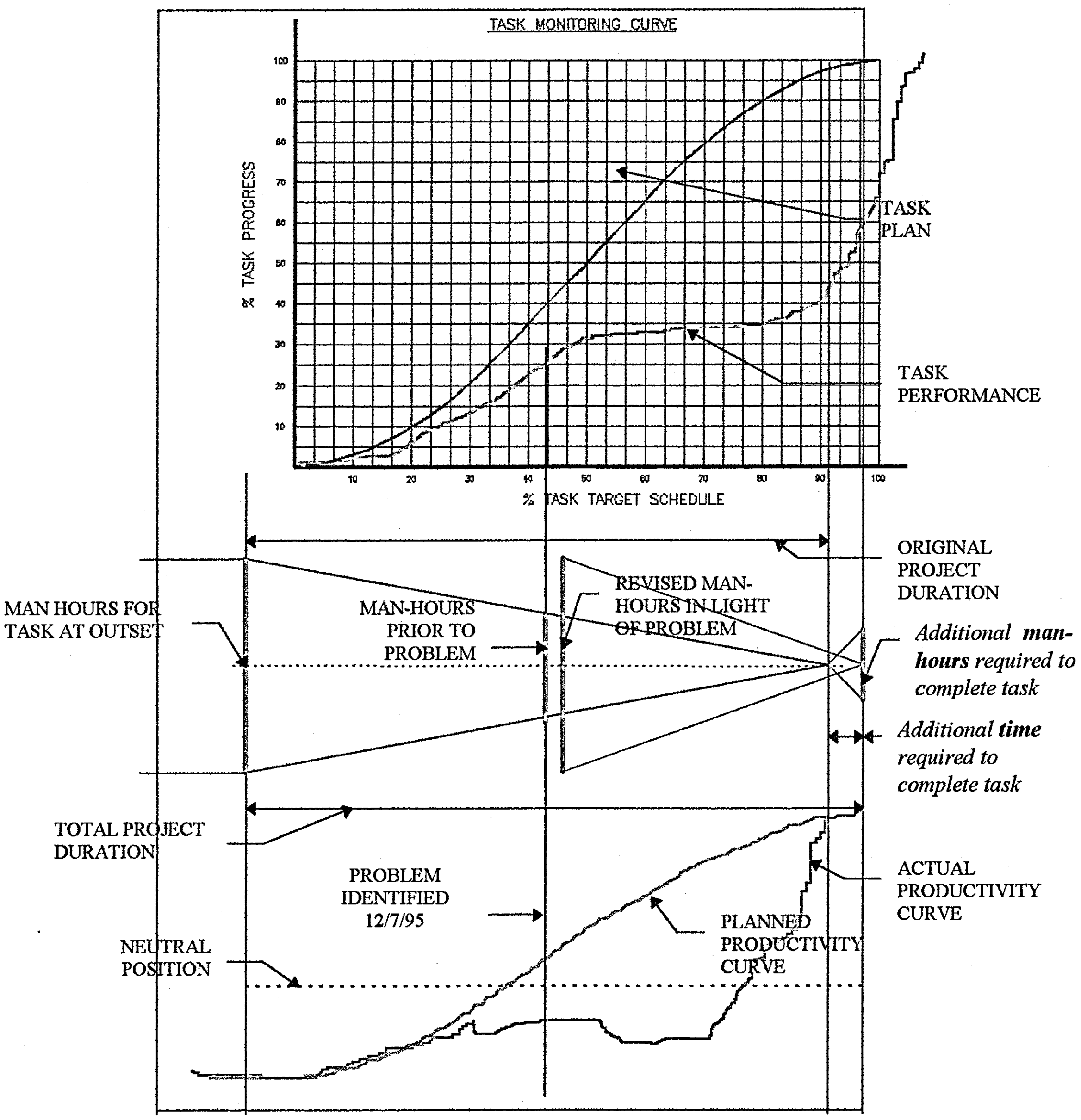
22.10.95

1.26 Completed welding of second vessel and leak test Sunday 22/10/95

Fig 21 Example of history of information flow and decision making criteria

APPENDIX C

PROGRESS SHEET TASK 1.0 MECHANICAL DESIGN FABRICATION AND INSTALLATION OF THE NEW DIGESTERS



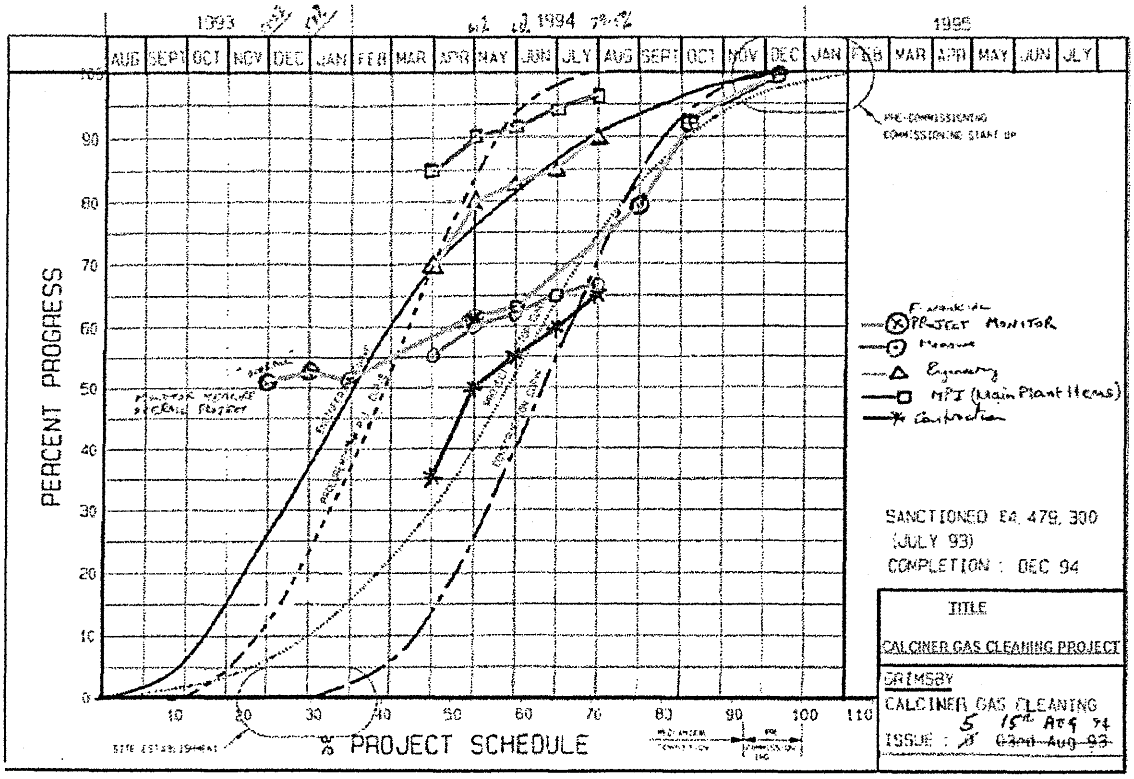
CRITICAL	MEMBER	DISCIPLINE	SOURCE	INFORMATION AVAILABLE as at 30/7/95	INFORMATION REQUIRED
Y	*FB/AL*	*CIVIL*	*Outsource*	*Shear loads and turning moments for holding down bolts*	*NONE*
Y	*FB/AL*	*STRUCTURAL*	*Outsource*	*Revised site construction programme*	*Deflection measurements with vessels full of water*
N	*AL/GC*	*MECHANICAL*	*In house*	*Report on cause of weld failure and remedial actions*	
N	*GW*	*ELECTRICAL*	*In house*	*N/A*	*N/A*
N	*IS/RR*	*INSTRUMENTATION*	*In house*	*Change to R1 and R2 orientation*	*NONE*
Y	*SD/GC*	*PROCESS*	*In house*	*Revisions to Quality plan*	*Weld test sheets*
N	*PG*	*PLANT SAFETY*	*In house*	*Revised crane lifting study to facilitate 2 part construct.*	*Vessel access*
Y	*RG/GC*	*QUALITY MNGT*	*In house*	*Weld procedure report on* ***weld failure***	*Full quality documentation package*
Y	*GC*	*PROJECT MNGT*	*In house*	***Deatails of claim***	
N	*Sk/JH*	*CLIENT*	*In house*	*Revised programme*	
N	*DL/RK*	*PURCHASING*	*In house*	*Extras claim details*	
		OTHERS			

Fig 22 Example of progress data sheet for a specific task

APPENDIX C

Project audit reports

'S' curves for projects 1 & 2 (scanned image of original 'S' curves produced during final audit)



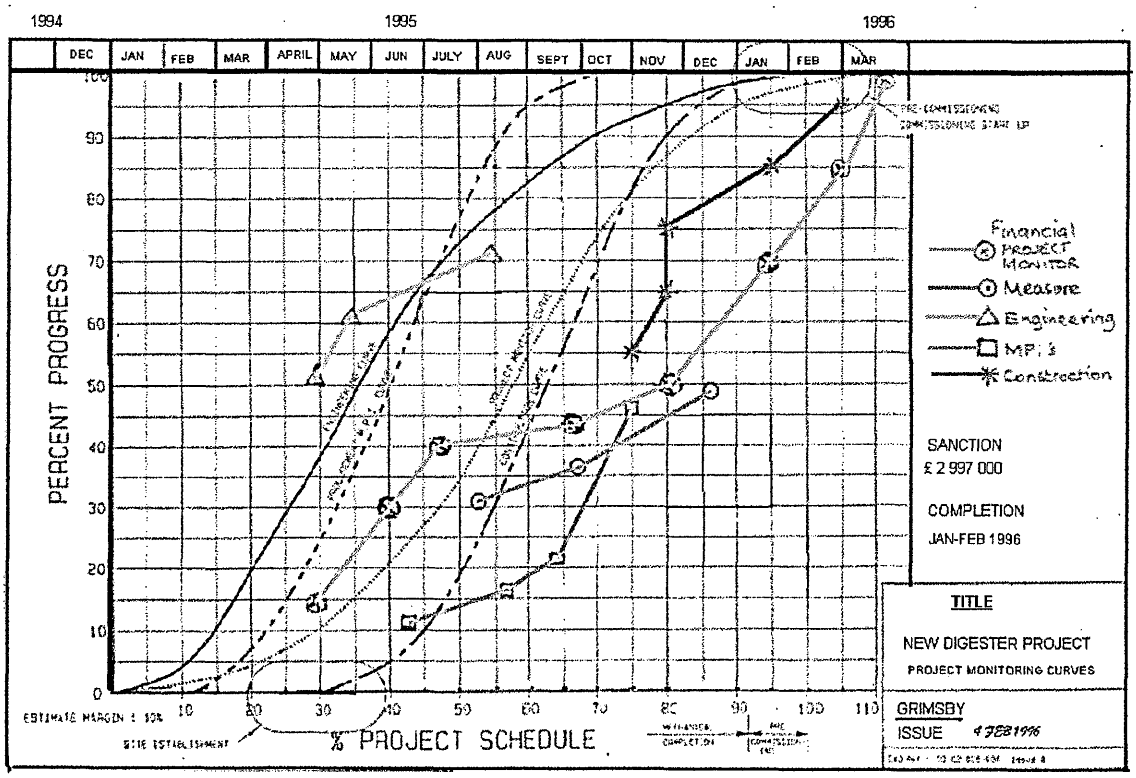


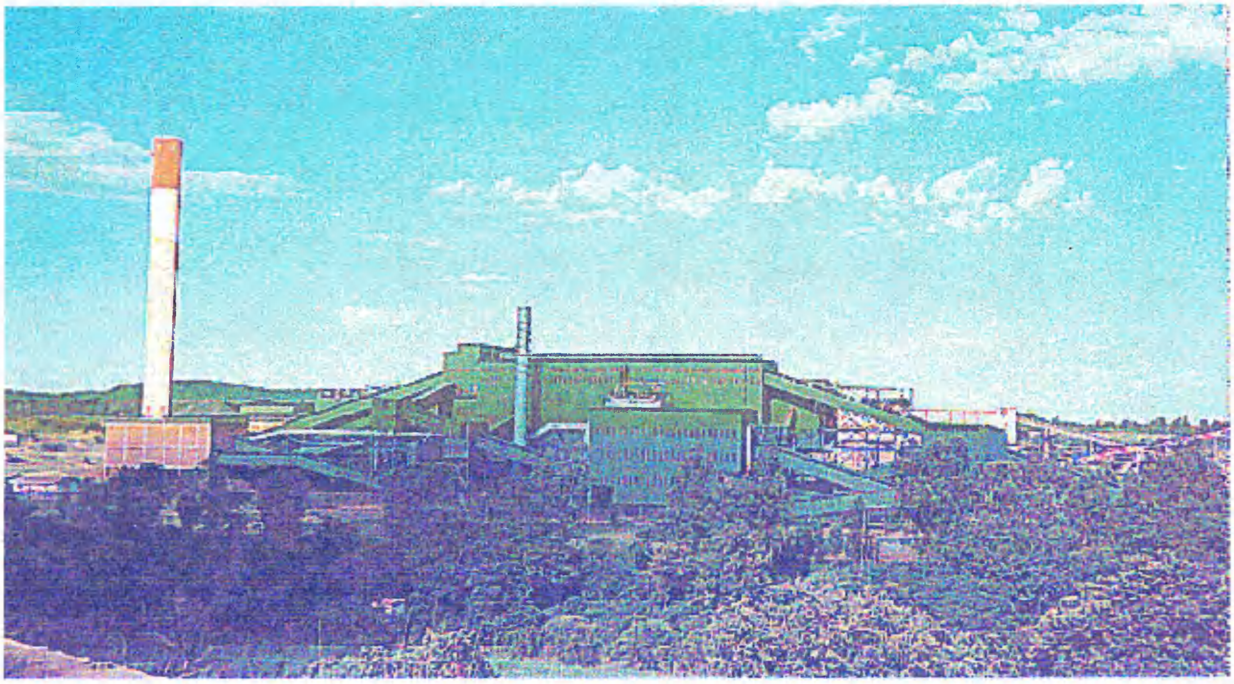
Fig 23 Project Audit reports for projects 1&2

Success and Failure factors identified during project management life cycle of projects 1 & 2

Success Factors	Project 1	Project 2
Factors related to external environment		
- Political environment	Not an issue project focus clear	A problem due to temporary posting.
- Economical environment	Not a problem project justification sound	A problem due to intransigence
- Social environment	Not a problem	Not a problem good teamwork
- Technological environment	Caused some concern due to new technology	Caused some concern due to new technology
- Nature	Usual weather problems	Usual weather problems
- Client	Some difficulties accepting care of plant	Difficulties accepting plant and interference
- Competition	Not applicable	Not applicable
- Sub-contractors	Main issues avoided through negotiation	Serious conflict avoided by negotiation
Factors Related to the project manager		
- Ability to delegate authority	Problem with availability of resources	Problem with performance of resources
- Ability to trade off	Not applicable	Essential to completing project
- Ability to co-ordinate	Important aspect due to project deadline	Not a significant issue
- Perception of his/her role/responsibility	Contracted professional services dedicated	Contracted professional services
- Competence	Fellow of Association of Project Managers	Fellow of Association of Project Managers
- Commitment	Dedicated to project for duration	Dedicated to project for duration
Project team members		
- Technical background	Professional Chartered engineers	Professional chartered engineers
- Communication skills	Good most attended pm courses	Good most attended pm courses
- Trouble shooting	Good able	Very good
- Commitment	Overall reasonable	Overall fair
Factors related to the project		
- Size and value	< 750 Activities (£4.5 M sanction value)	< 750 Activities (£ 2.9 M sanction value)
- Uniqueness of project activities	Stack outage activities critical	Vessel design and manufacture activities
- Density of project network No of CA's	< 30 CA's (Concurrent activities)	< 30 CA's (Concurrent activities)
- Life cycle	< 12 month duration	< 12 month duration
- Urgency	Paramount to staying in business	Production driven by ROI
Factors related to the organisation		
- Top management support	Excellent	Fair
- Project organisational structure	Good with specific organisational procedures	Good with specific organisational procedures
- Project champion	Project manager by default	Project manager and Production manager
- Functional managers support	Fair	Good

Table 13 Comparison with Belassi Turkel success/failure criteria

P10 Scanned aerial photograph of Tioxide Grimsby site



P11 Scanned photograph of Zimbabwe project (Project 5)

APPENDIX C

P 12 Scanned aerial photograph of HDC Ltd Huddersfield

Chapter IV

4.0 DESCRIPTION OF THE CONSERV KBS CONCEPT

"In the relatively short time in which integrated systems have been available the whole approach to project management has been transformed "
Lock[1] *(1987)*

4.1 Introduction background and theory

4.1.1 Introduction

Chapter II provided an insight into the way project managers view the business of managing projects, and introduced a bibliography of the alternative project management methodologies being advocated by various researchers.

Ref. Appendix B8 and B9 (Table 8 and Table 9)

The Chapter also identified some of the 250 software packages now available.

Ref. Appendix B10 (Table 10)

It was suggested that many of the methodologies and software tools are not universally applicable to all projects and in some cases may even conflict with the organisation and industrial basic requirements.

Chapter III outlined the findings obtained from the industrial case studies undertaken between 1993 and 1996 which employed the *traditional project management* techniques predominant in the industry today.

From the studies several project management and engineering design *failure mechanisms* were identified, tabulated and subsequently compared with the observations of other researchers. i.e. *Belassi & Tukel*[2], *Munns & Bjeirmi*[3]

This Chapter introduces the ConSERV concept as it applies to the field of project management and engineering design currently being undertaken in the Chemical, Petrochemical and Pharmaceutical industries.

The Chapter also provides a summary of the studies undertaken to justify whether or not the candidate concept is suitable for development as a knowledge based system.

4.1.2 Background

The field of study associated with this thesis is that of project management and engineering design. The recent developments in both areas of technology have been nothing short of staggering. The effects of computer technology have been more profound in the engineering domain than they have in the Project management elements. CAD and CAE technology has been cultivated through the emergence of the six Engineering Design Centres at Belfast, Bath, Cambridge, Lancaster, Newcastle and Plymouth. The centres emanated from the Feilden report which recommended that a number of centres of engineering design excellence should be funded, and based on appropriate University sites. The research work being undertaken in the project management domain has been driven more by industrial than the academic needs.

The areas of research being undertaken by the various institutions are wide and varied, a summary of the research being undertaken is provided in the literary research summary Appendices D7-D8.

Cognisant of the recent developments, many project managers are nervous that any software technology purchased is unlikely to remain *'state of the art'* over the life cycle of major and epic projects of typically 2-3 years duration.

Matching the project demands to the commercially available engineering design and project management software presents very real problems for managers of capital projects, not only by the sheer volume of the packages and tools available but also the time needed to evaluate and apply them. Ref. Appendix E17 (Fig 55).

The majority of decision support systems presently available for project management tend to focus on single elements of project management such as *Risk* or *Planning,* as such they are difficult to integrate into the body of the project as a whole.

Bespoke software is also of limited value to the needs of any given project as it is unlikely that the project budget will afford any software development costs.

The need and justification for a new concept is supported from the investigative research, the literary research and the industrial research described in the earlier chapters of this submission. It is also endorsed by the feed back obtained from the test results provided in Chapter IX.

4.1.3 The Underlying Theory

The underlying theory behind the concept is that the successful management of a project is largely influenced by, the project manager's style, experiential knowledge, and the choice and efficacy of management system employed. The project success on the other hand is strongly influenced by the engineering and design issues.

Tullet[4] suggests that "thinking style is a component of cognition which influences the way in which a person acquires, organises and uses information", concluding that "a typical manager of multiple projects has an *innovative* thinking style".

Tullet makes reference to the theory of adaptive-innovative (A-I) thinking style developed by Kirton after observing the way in which individuals and teams made (or avoided) decisions, solved (or ignored) problems and implemented (or failed to implement) change. The Kirton Adaption-Innovation inventory (KAI) is a psychometric instrument for measuring A-I thinking styles.

Whilst the research work of cognitive psychologists is of enormous interest one of the fundamental difficulties facing the project manager is that of **inconsistency** in human behaviour. Experienced project managers may be able to predict certain risk issues and thereby apply a proactive management technique that may reduce or mitigate the occurrence of the risks.

4.1.4 The Focal Theory

The focal theory of this submission is to improve the chances of project success by providing less experienced users with the experiential knowledge of experienced project managers and engineering designers through the application of a KBS.

Project management is spoilt for choice when it comes to applying theories, a list of the more common theories is provided. Ref. Appendices B8 and B9 (Tables 8 and 9)

The business of managing major multidisciplinary capital projects that include considerable engineering design effort is very unforgiving and the demands on the project manager can often be overwhelming

The ConSERV concept is being developed as a management system that provides decision support and decision reinforcement by using expertise and historical data obtained from past, closely related, project audits.

4.1.5 The Approach

A fully developed version of the concept should be seen more as a comprehensive management system in which the numerous software packages can be strategically managed and administered.

The concept is being designed to simulate knowledge that is relevant to the project by using an intelligent approach in which the user interacts with the knowledge base to perform a limited number of *"what if "* scenarios on the available choice options presented. Correctly structured, the *resident knowledge* can be used to challenge the current *knowledge* of the user and possibly formulate new rules specific to the project being managed.

E.g. *What if* I agree to accepting a change to scope requested by the client ?

In this case the *project management system*[1] (p.m.s.) may need to be revised to take account of the new risk issues that have been generated as a result of the request.

The system should be able to identify that a serious scope change has been introduced by comparing variations made to the Gantt chart over a finite period.

In such an event ConSERV will advise the user that the project identification process should be revisited in order to ensure that the current management system remains valid.

Traditionally scope changes are incorporated into the project within the framework of the established management system. Very few traditional systems recognise the full extent of the scope changes especially the effects of having to ***undo*** and ***redo*** work.

The ConSERV 3D visualisation element is able to recount the effect of the change by regressing the project back to the last point of engineering design concurrence (synchronisation in CE terms).

In so doing the project manager is able to advise the client of the true cost of the proposed change and the likely consequences.

The *'what if'* scenarios will provide the project manager with an alternative perspective. Ref. Appendix C9 (Fig. 22)

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[1] Definition of the Project Management system P 27

The ConSERV concept is still very much in its embryonic stage and is being developed to provide project managers with a new, more visual, management technique. The concept is intended to be used as a **decision support** tool able to provide the user with additional **expertise** in tailoring the management system to the needs of the project. In the first part of the technique shown in Fig. 24, the user is taken through a question and answer routine aimed at extracting **project specific** information sufficient to establish the key dimensions and thereby the *identity* of the project being managed. An example of the identity of two projects is shown on p 8. The information obtained during this phase is then used to assist the project manager in identifying the *apparent* (overt) risks. Ref. Appendix E2 and E3 (Figs 40 and 41) By applying a limited set of knowledge based rules, a number of *latent* (covert) project specific risks are also identified by the expert system which may lead to issues of conflict. The technique recognises the possibility of disagreement between the system and the user. Ref. Appendix F4 to F7 (Figs 64-68)

The engineering man-hours are developed using the project specific data obtained by completing the processes A1 to A4 illustrated in Fig. 24.

The second part of the concept is essentially a three dimensional representation of the collective effort of the engineering design team. Ref. Appendices D6 and G3 (Fig 78 and 79) The model illustrated in this research is intended to provide the user with a visualisation of the status of the design issues involved in the project at any one moment.

The 3 dimensional graphic representation is effectively the **Con**current, **S**imultaneous, **E**ngineering, **R**esource **V**iew (ConSERV). The mechanics and dynamics of the concept are described in section 4.5 of this chapter.

Ref. Appendix G3 Figs 79 and 80.

4.1.6 Justification of a KBS Solution

The findings and conclusions of the two previous Chapters identified the need for a more comprehensive project management system. Justifying the use of a KBS to satisfy the need has to be undertaken with caution. The main justification to employ a **knowledge based** approach was made on the strength of the 3 earlier studies submitted to the school between Jan-July 1996. The Opportunity Analysis, the Plausibility Study and the Demonstrator Report.

The main source of data used in developing the reports was obtained from the two Industrial case studies; "Calciner Gas Cleaning" and "New Digesters"

The underlying requirements of the new comprehensive management system were perceived as being :-

i/ Obtaining an understanding of the *type* of project being managed. i.e. Developing project specific data.

ii/ Incorporating the requirements of the *organisation* undertaking the project.

iii/ Developing the *organisational knowledge* base.

iv/ Selection of the most appropriate *project management system.*

v/ Evaluation of the efficacy of the selected system and to identify shifts in the *focus* of the project.

vi/ The ability to provide on line *decision support* for both management and engineering design issues.

vii/ The ability to *accept, challenge* and *distribute* critical design data and project management information within the project team environment.

viii/ The ability to display the *status* of the combined multi disciplinary engineering design resources on a single three dimensional representation.

ix/ The ability to accept and evaluate the effect of *external factors* facilitating a number of "*What if*" scenarios.

x/ The ability to retain *historical records* of the key *decision making* events over the life of the project.

xi/ The ability to incorporate *knowledge* obtained from *audit data* of previous projects and thereby improve user decision support.

4.2 Summary of the Opportunity Analysis

4.2.1 The Opportunity Analysis (OA/001/96 submitted Jan 1996)

The methodology and procedure for the design and development of Knowledge Based Systems has been described in some detail by *Guida and Tasso*[5]

The concept proposed by *Guida and Tasso,* is KLIC, a KBS Life Cycle technique which comprises of three macro phases and six global phases, each phase is defined in terms of tasks and steps.

The KLIC life cycle is the result of extensive professional experience and critical analysis of the various alternative KBS development methodologies.

The first phase, *The Opportunity Analysis*[6], is an important element for the successful development of any KBS.

This phase of the development of a KBS identifies within a given organisation the application areas which could benefit from the development of KBS projects, and rank them according to their strategic value, importance, expected benefits, technical complexity, suitability and readiness for a KBS application.

The author recognises that the Opportunity Analysis is usually carried out by independent consultants in close co-operation with the organisation concerned. The analysis undertaken as part of this Ph.D. has been compiled in consultation with. senior management personnel from the Chemical industry. An example of the management indications document (the brief) is provided in Appendix D2.

The Opportunity Analysis formed the basis for the justification of using knowledge based technology. The main purpose of the analysis was to identify the opportunity provided by ConSERV then characterise and evaluate it in terms of its technical appropriateness and use.

Generic tasks offer a very useful aid to evaluating the appropriateness of a potential KBS application. The task based analysis proposed by *Guida and Tasso* is founded on the assumption that:

"If the global function that a KBS application is to perform is an instance of one or more of the generic tasks identified, then there is sufficient evidence that the application considered may be appropriate for knowledge based technology."

4.2.2 The Analysis

In the context of this Chapter an '*opportunity*' is a potential KBS application in a given domain, for which concrete evidence exists of its appropriateness[1] and usefulness[1].

An analytical assessment and a task based analysis are recommended for determining whether or not a candidate 'opportunity' is suitable for KBS technology.

The analysis undertaken confirmed the suitability of the ConSERV concept as a candidate for the application of a KBS on the grounds that the project management of both *single discipline* and *multi disciplinary projects* is **knowledge intensive**.

Ref. pp 25 -26

The analysis also established that the pre-conditions of *technical appropriateness*[1] and *organisation usefulness*[1] were also satisfied, namely that :-

i/ Domain Experts are available. (Project managers, project and discipline engineers)
ii/ Knowledge problems are considered too difficult to solve using other approaches.
iii/ The knowledge domains are likely to be large.
iv/ There are organisational systems that should closely interact with the KBS
v/ Preconditions and support will be necessary.
vi/ The KBS will fit into the strategic plans of the organisation.
vii/ The KBS will be expected to solve existing and persistent knowledge problems.
viii/ The problems addressed by the KBS are considered important by the users.
ix/ The KBS role, purpose and expected benefits were identified at the outset.
x/ There are other potential user sites where versions of the KBS may be used.

The task based analysis considered the *analytical tasks*, which are aimed at identifying the unknown properties of a system described through a given set of 'knowledge' criteria concerning its structure, behaviour, function and purpose. The analysis also considered the *synthetic tasks*, which are aimed at determining a structured description of a system at the desired level of abstraction and granularity, starting from a given set of basic constitutive elements and from a set of desired properties.

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[1] Guida and Tasso terms not the authors (Design and Development of KBS (1994) pp 75 - 77

4.3 Summary of the Plausibility Study

4.3.1 The Plausibility Study (PS/001/96 submitted Feb 1996)

The main purpose of *The Plausibility Study*[7] was to evaluate whether the conditions exist to make a potential KBS project possible, and to help make the first set of basic technical and organisational choices. The *PS* is a mandatory phase of the life cycle as described by *Guida and Tasso.* The need for this phase is driven by the following:

i) The novelty of knowledge-based technology can easily lead to wrong unrealistic expectations of a KBS as identified by *Casey*[8] (1989)

ii) The development demands of any KBS are very high, therefore the conditions that make them feasible must be analysed in depth.

iii) The impact on the operatives of the KBS can be substantial. i.e. job security.

iv) Considerable risk is involved with any KBS project therefore the decision to proceed should be made on a thorough assessment of the critical factors.

4.3.2 The goals of the Plausibility Study

i) To determine whether the application domain and potential KBS application is globally appropriate, technically suitable and commercially viable

ii) To analyse the requirements of the KBS and define the overall goals.

iii) To define the specification of the KBS and the acceptance criteria.

iv) To evaluate the technical feasibility, organisational impact, practical reliability, economic suitability and the opportunities and risks of the KBS proposal.

v) To develop a draft technical design, a draft organisational design and a global project plan. Ref. Fig 1p8.

The inputs to the plausibility study include the *Management Indications,* which defines the application domain and potential KBS application, and the *Opportunity Analysis*

The product of the ***Plausibility Study*** is a report which contains a combination of the activities carried out and a detailed illustration of the results achieved including :-

* The definition of the functional operational and technical specifications.

* The draft technical design and draft organisational design.

* The global project plan.

4.3.2 Goals of the Plausibility Study (cont)

Name of Goal	**Type of Goal**	**Temporal characterisation**	**Importance factor**
To provide intelligent decision making assistance to the engineering management of projects	Functional	*appropriate*	*high*
To facilitate the immediate transfer of critical project data between engineering disciplines	Functional	*appropriate*	*high*
To maintain electronic records of data transfer	Functional	*useful*	*medium*
To interface with existing project management tools	Functional	*appropriate*	*high*
To facilitate remote data input from external site located database, ***project specific data***	Functional	*appropriate*	*high*
To store and retrieve ***organisational*** data	Functional	*appropriate*	*high*
To store and retrieve ***project management*** data	Functional	*appropriate*	*high*
To provide crucial information at key points during the project life cycle	Functional and strategic	*appropriate*	*high*
To enable structured communication across all engineering disciplines using existing technology	Functional and strategic	*appropriate*	*high*
To facilitate conflict resolution between engineers	Functional	*appropriate*	*high*
To provide "What if" possibilities	Strategic	*useful*	*medium*
To evaluate risk using probabilistic and heuristic decision making methodologies.	Functional and strategic	*appropriate*	*high*
To provide a 3 dimensional visualisation of the status of a project at any one time	Functional and strategic	*appropriate*	*high*
To provide a continual audit facility using organisational procedures	Functional and strategic	*appropriate*	*high*
To facilitate the update of organisational data	Strategic	*useful*	*medium*
To challenge and justify the validity of data entered	Functional	*appropriate*	*high*
Able to be used by all levels of Project managers	Functional	*appropriate*	*high*

Table 14 Listing of project goals

4.3.3 Evaluation of the candidate KBS

The types of **domain knowledge** involved in project management are appropriate for knowledge based processing as they are mainly declarative, usually incomplete and often uncertain. Ref. Appendix A5 (Table 1)

The **reasoning methods** involved are also appropriate for KB processing as they tend to be mainly non procedural, non monotonic and complex.

Domain knowledge is reasonably **well defined** albeit extensive and expansive.

Ref. Appendices A3 and A4 (Fig 4 and 5)

The knowledge is however confined and constrained by the project at hand.

The **problem solving strategies** utilised by experts are reasonably identifiable and explicable. The problem solving strategies will involve **large search space** and will probably involve multiple lines of reasoning, including **conflict resolution.**

Domain experts (project managers) do generally agree on the problem solving strategies they employ but not necessarily on the correctness or accuracy.

4.3.3 Evaluation (cont)

The KBS task (the management of multidisciplinary major capital projects) is **complex** and will involve more than one knowledge base.

The KBS task is **judged** by project managers as being complex and will extend over the life cycle of the project. (months, possibly years)

The KBS will be of enormous value even if only **partial solutions** are produced.

The minimum **acceptable performance** of the KBS can be reasonably well defined and measured.

The task requires a number of capabilities within the **current possibilities** of KB technology, but also includes new theories on project management. i.e. ConSERV

Incremental development of the KBS is possible and highly desirable.

The KBS task at hand seems unable to be answered by means of other approaches despite a number of attempts. including Pro-Cube, Admit and Adept.

Project management is a unique science involving extensive knowledge domains.

The investigative research identified that existing tools were often unsatisfactory, and in their present form unlikely to meet the full needs of the project manager.

The **nature** of projects makes the management of them unsuited for being streamlined or upgraded, even a repeat project will involve a different team and will be undertaken at a different time.

The project management group identified in the case study have used the services of management consultants such as *Hawksmere Ltd.* and have sent staff on **training** courses. These actions appeared to have little effect on project success.

The **stability** of the KBS being considered in this research is good, projects are a never ending process and are an integral part of any major organisation keeping abreast of technology, the environment and the business demands.

There will be a need to **maintain** the KBS as organisation standards are continually under revision in order to comply with industrial standards and legislation.

4.3.4 Assessment of knowledge applications.

The knowledge and reasoning mechanisms used in addressing the 5 KBS domain tasks shown below has been tabulated in Table 15

Task 1 = The identification of the project
Task 2 = The determination of the project risk
Task 3 = The selection of a traditional project management system
Task 4 = The establishment of the project team and execution plan
Task 5 = The project interface management mechanism

1 Procedural	2 Data driven deduction	3 Goal driven deduction	4 Abduction	5 Non Monotonic reasoning	6 Analogical reasoning	7 Model based reasoning
Task 1	Task 1		Task 1		Task 1	Task 1
Task 2	Task 2				Task 2	Task 2
Task 3	Task 3	Task 3			Task 3	Task 3
	Task 4	Task 4	Task 4	Task 4	Task 4	Task 4
		Task 5		Task 5	Task 5	Task 5
8 Generalisation	9 Specialisation	10 Hypothetical reasoning	11 Reasoning by refutation	12 Temporal reasoning	13 Spacial reasoning	14 Heuristics
Task 1	Task 1	Task 1	Task 1	Task 1	Task 1	Task 1
Task 2	Task 2	Task 2	Task 2	Task 2	Task 2	Task 2
Task 3	Task 3	Task 3	Task 3	Task 3	Task 3	Task 3
Task 4	Task 4	Task 4	Task 4	Task 4	Task 4	Task 4
Task 5	Task 5	Task 5	Task 5	Task 5	Task 5	Task 5

Table 15 Table of reasoning functions employed by the project

The APM (Association of Project Managers) Classification of knowledge[1] is shown in Table 16 and to be read in conjunction with Appendix A5. Table 1

Project Management	Organisation & people	Process & procedures	General management
System Mngt.	Organisation design	Work definition	Operational Mngt
Programme Mngt.	Controls co-ordination	Planning	Technical Mngt
Project Mngt	Communication	Scheduling	Marketing
Project Life Cycle	Leadership	Estimating	Sales
Project Environment	Delegation	Cost control	Finance
Project Strategy	Team building	Performance measure	Information Technology
Project Appraisal	Conflict Mngt	Design Mngt	Contract Law
Project measurements	Negotiation	Risk Mngt	Industrial Relations
Integration	Management Develop.	Value Engineering	Environmental legislation
Systems / Procedures	Information exchange	Change controls	Arbitration procedures
Quality	Client Liaison	Procurement	International Law
Safety		Mobilisation	
Audit procedures		Close out	

Table 16 Listing of knowledge classes identified from APM BoK

[1] The depth of knowledge for each element can be determined from the APM BoK which affords a self evaluation system using a theoretical and practical measurement technique. (Disc appended)

4.4 Summary of the Demonstrator Report

4.4.1 The Demonstrator Report (DR/001/96 submitted July 1996)

The purpose of *The demonstrator report*[9] is to develop a running system, namely the *demonstrator* that will anticipate a subset of the function of the final KBS.

The justification to develop a demonstrator is that :-

i) Some aspect of the problem to be tackled by the KBS may not be as well understood or sufficiently well specified despite undertaking the plausibility study.

ii) The technical difficulties associated with providing an acceptable system may not be fully appreciated, or may not be apparent.

iii) The risks associated with the developmental costs may not be fully quantified.

According to *Guida and Tasso* several *types* of demonstrators may be used ;

i) Promotional demonstrators, which promote the acceptance of KBS technology
ii) Commercial demonstrators, which provide support for management acceptance
iii) Involvement demonstrators, which encourage the involvement of management
iv) Exploratory demonstrators, which refine and develop the KBS specification
v) Experimentation demonstrators, which validate and possibly refine the KBS
vi) Organisational demonstrators, which improve understanding of what KBS do and
vii) Planning demonstrators, which validate and correct the critical aspects of the KBS

Each demonstrator type has its own features as categorised in Table 17 below :-

	Promotional	commercial	involvement	exploration	**planning**	organisational	experimentational
Throw away	yes	yes	yes	yes	no		no
Near to product					yes	yes	possible
Software re use	no	no	no	no	possible		yes
Knowledge re use	possible	possible			yes	possible	possible
Time constraints	rapid	very rapid					
Cost constraints	low	low					
Technical complexity	low	low	medium		medium	medium	high
development time	short	short	long			long	long

Table 17 Typical features of the different types of demonstrators

The best description for the demonstrators required to demonstrate the ConSERV concept are the *Promotional* and *Planning* types of demonstrators.

4.5 Explanation of the mechanics of the Concept

4.5.1 The data acquisition and risk agreement phases A1-A3

In justifying the need for a new technique it is important to appreciate what the proposed system will do for projects that existing systems fail to do. *Chapman* [10] suggests that "All RMP's (Risk Management Process) methods emphasize the need to identify sources of risk at the outset of the process" *Chapman* also recognises that "Identifying risks and responses involves two specific tasks;

i/ *Search* for sources of risks and responses, and ii/ *Classify*, to provide a suitable structure for defining risks and responses". The mechanics of the ConSERV concept are best described graphically Ref. Fig 24 and 26.

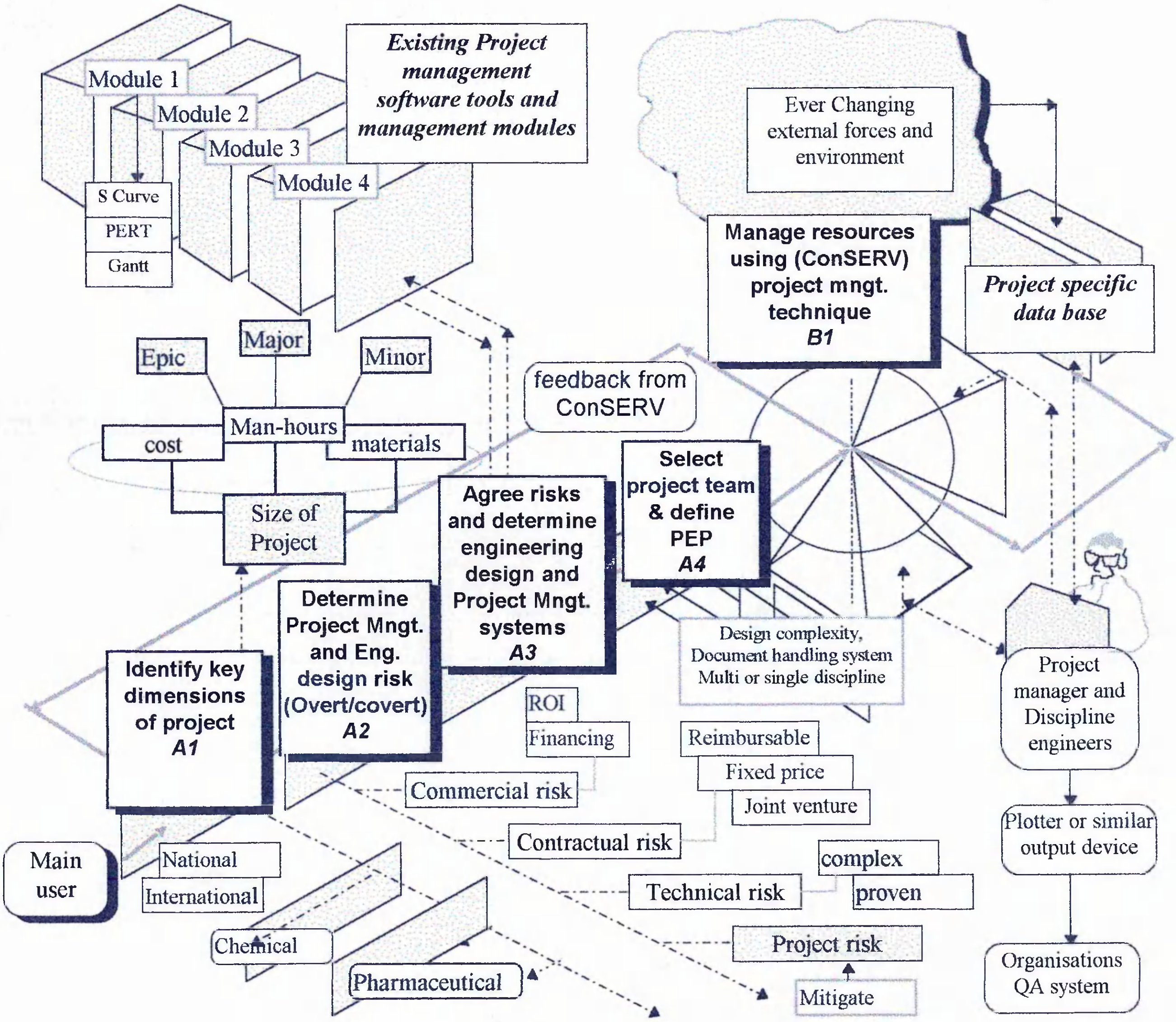
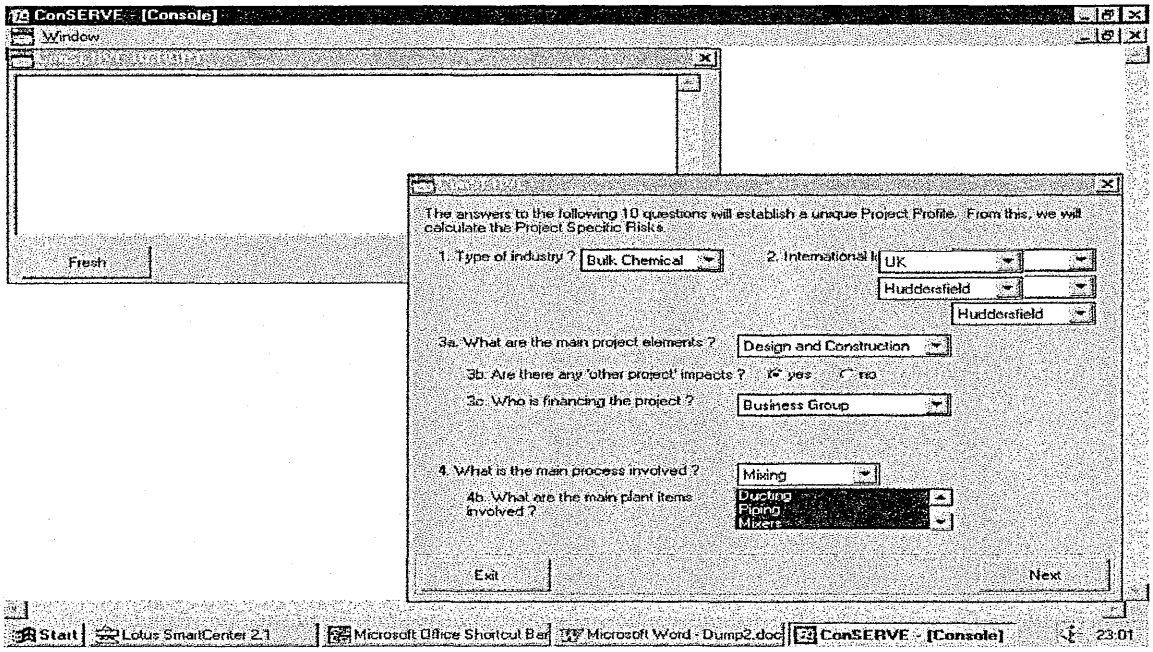


Fig 24 The five stages of the ConSERV concept

From discussions with a selection of APM Corporate members (as at Aug 1997) it is evident that many projects fail to succeed largely due to an overspend of man-hours. The issue is not that the man-hours were overspent, but more about whether or not the man-hours assigned were realistic. Few planning techniques allow for the real world problems such as those identified from the industrial research. E.g. Shared resources, lack of critical design information, poor distribution of information. etc.

Fig 24 shows the 4 main processes involved in the ConSERV concept, A1-A4 inclusive. Identifying the key dimensions of the project is accomplished by means of a GUI screen to obtain the project specific data and identify the project specific risks. Example of the screen GUI is shown below in Fig 25



The answers to the following 10 questions will establish a unique Project Profile. From this, we will calculate the Project Specific Risks.

1. Type of industry ? Bulk Chemical

2. International l UK / Huddersfield / Huddersfield

3a. What are the main project elements ? Design and Construction

3b. Are there any 'other project' impacts ? ● yes ○ no

3c. Who is financing the project ? Business Group

4. What is the main process involved ? Mixing

4b. What are the main plant items involved ? Ducting, Piping, Mixers

Fig 25 Graphical User Interface screen for Project identification

Further screen dumps are shown in Appendices H3-H6.

Identifying the key dimensions of the project allows inference to be made concerning the overall nature of the project being managed, i.e. the global view.

4.5.2 Construction of the Model (A4-B1)

The concept assumes that the risks identified from phases A1-A3 will require suitable resources to manage them, i.e. inevitably the 'engineers'. The second part of the concept therefore involves quantifying the engineering man-hours required to engineer and manage the project, including those required to manage the recently identified risk issues. Figs. 85 and 86 p 159 illustrate the common error of underestimating the man-hours in the early stage of the project due to the fact that specific risks have not been identified. From the data obtained in progressing from A1 to A3 the project specific knowledge, risks and organisational procedures can be integrated into the KBS. The ConSERV technique is then able to generate the Engineering Resource View element shown below Fig.26

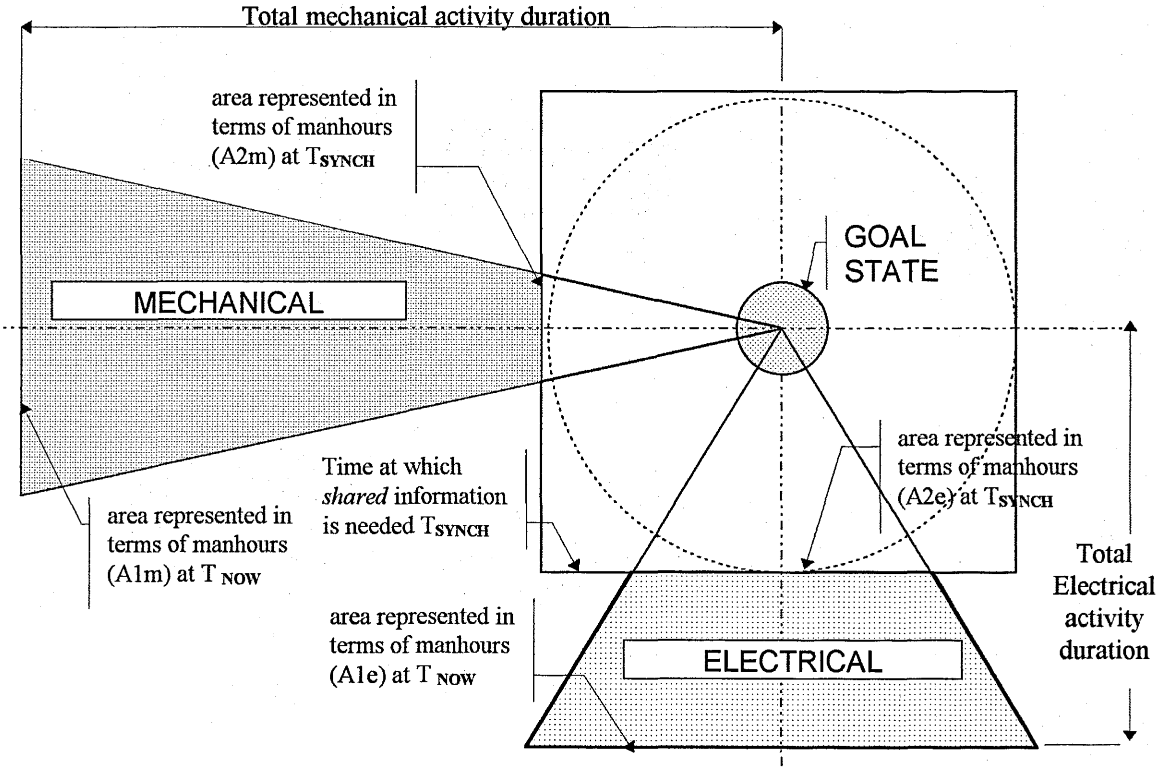


Fig 26 Two dimensional representation of the Engineering Resource View

4.5.3 The mechanics of the concept A4 to B1 (cont.)

The concept is based on three very simple primitive geometrical shapes that represent the main elements of the model, shown in Fig 26, namely :-

The Goal state, which is represented by **a sphere**. The size of the sphere, obviously determined by its radius. The units of measurement can be considered as being units of time, i.e. 100mm ≡ 100 days. The time at which the radius = 0 is the time at which the goal state has been reached, i.e. the centre of the sphere.

Each engineering discipline effort is represented by **a pyramid**. The apex length representing the activity duration for that specific discipline (Mechanical/Elect etc.) The man-hours assigned for the engineering discipline are represented by the base. i.e. 100 man-hours ≡ a base whose sides are each 10 mm long. 1man-hour ≡ 1 mm^2

The synchronisation period or time is represented by **a cube** each side of which intersects the engineering discipline interface, a maximum of six. The units of measurement of the cube are scaled such that its half distance is equal to the sphere radius at T_{now} , i.e. start of multidisciplinary task.

Consider a multidisciplinary activity such as "Designing a pump control system" in which a process engineer produces the Engineering Line Diagram and possibly the P&ID based on the information available at the time. The progress is from point A to point B as shown in Fig 27. At point B the allocated Process department man-hours, the base area of the pyramid, are reduced and the available design information is shared between the Process Dept. and the Civil Dept. and between the Process Dept. and the Mechanical Dept. Concurrent Engineering Design work is then able to commence between the three discipline groups, Process Dept. Civil Dept. and Mechanical

The two dimensional representation of the concept can be seen as a cross section through the three dimensional model as shown in Fig 26. Once the engineering disciplines have been assembled on their respective axis for any given multidisciplinary task, the model is complete. Each discipline pyramid emanates from the centre of the sphere to form the shape shown in Fig. 27. As man-hours are expended against the allocation the base area of the pyramid reduces, if the effort was useful and productive then measurable progress towards the goal state should be achieved.

4.5.4 The 3 Dimensional representation

The three dimensional model shown in Fig 27 represents a multidisciplinary task, such as the design of a pump control system. *Harrington*[11] proposed an object oriented technique for resolving conflict in concurrent design environments, the Concurrent Design Expert. CDEX. The ConSERV concept may be considered as a top level engineering design and project management technique in which numerous other design tools and bespoke software applications such as CDEX might operate.
Research findings indicated that one potential design and project failure mechanism is that of disagreement between the engineers and designers from different disciplines.
In the example alluded to in Fig 27 ConSERV provides the framework by which design information can be relayed between the engineering disciplines via an electronic document management system E.g ADMiT Workflow etc.
Having been supplied with specific data about the project ConSERV can apply knowledge based rules to intercept the flow of design critical data, and where necessary redress the user/s to Design Codes, Guidelines Organisational Procedures and the many internationally recognised Engineering Standards. The technique may also apply, where necessary, to the conflict resolution processes proposed in CDEX.
Cleetus[12] purports that; “Concurrent engineering imposes the requirement that all appropriate viewpoints have been considered. This requires a frequent exchange of information so that the impact of the decisions made at one stage of the design is not allowed to lie un-examined till late in the project”.
ConSERV provides this very facility by allowing the focus of the project and the design basis to be continually revisited by the whole project group as shown in Fig 28.
As can be seen from Fig 27 it is possible to follow the flow of design critical data through the various decision making processes applied by the respective engineers.
Each decision is made on the strength of the individuals knowledge and understanding of the ‘global issues’ of the project. As was stated earlier, the global view of the project is held in the form of the project specific data knowledge base which is continually being updated by the various users

4.5.4 The 3 Dimensional representation (cont)

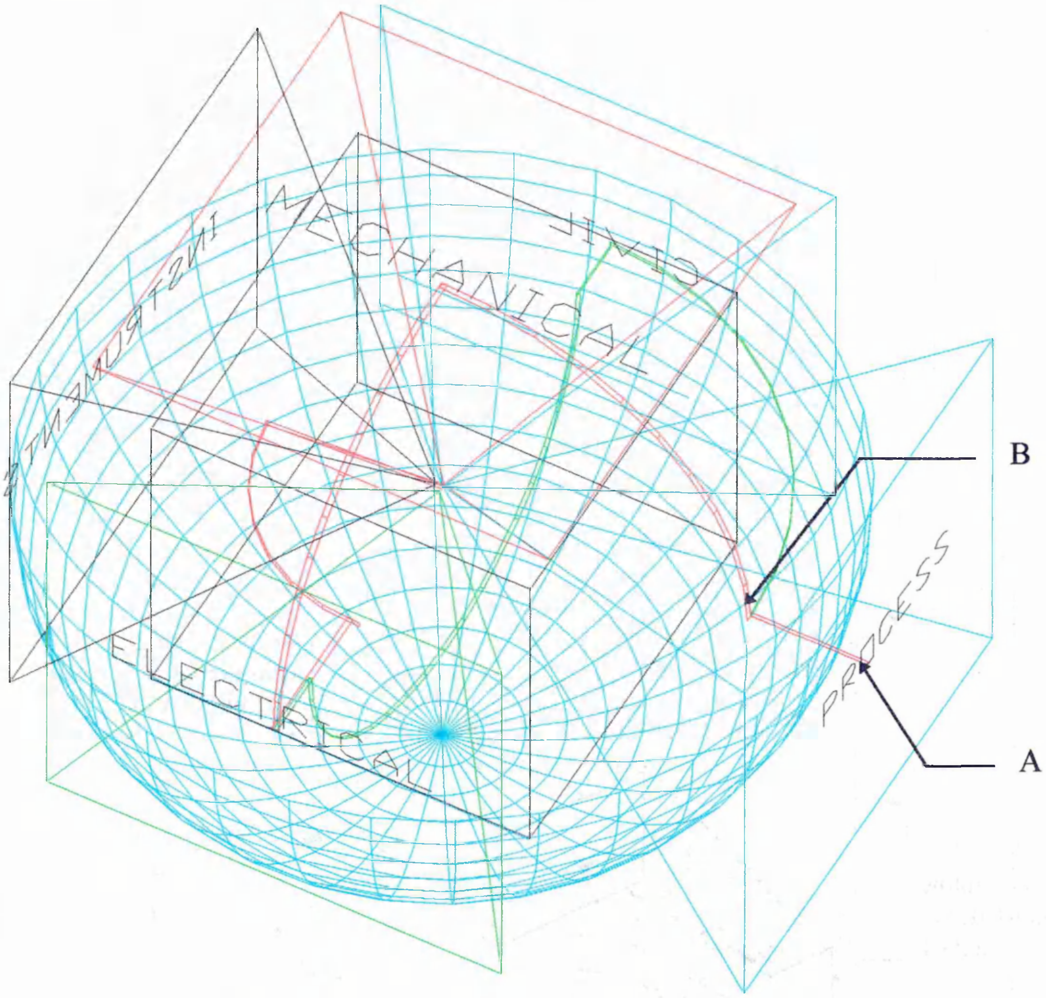


Fig 27 Three dimensional representation of the resource view concept

The vision of the end product is therefore a dynamic continually changing one which shares a distributed database.

In ConSERV, the synchronisation time periods of concurrent engineering activities is reduced to zero thereby minimising the abortive efforts of the engineers and designers. Reaching the 'goal state' in a multidisciplinary design environment is about capturing the necessary information and converting it into a deliverable document such as a P&ID. In the example above the Process Department takes the document from A to B before it is released for the use of other engineering disciplines. At point B design information becomes available to both the Civil and Mechanical Departments. ConSERV shows the flow of critical design information. in much the same way that a PERT analysis shows the flow of critical activities.

4.6 Overview of the concepts operability

4.6.1 The Objective

The main objective of ConSERV is to provide the project team with a more visible and interactive management technique such as that shown below in Fig 28.

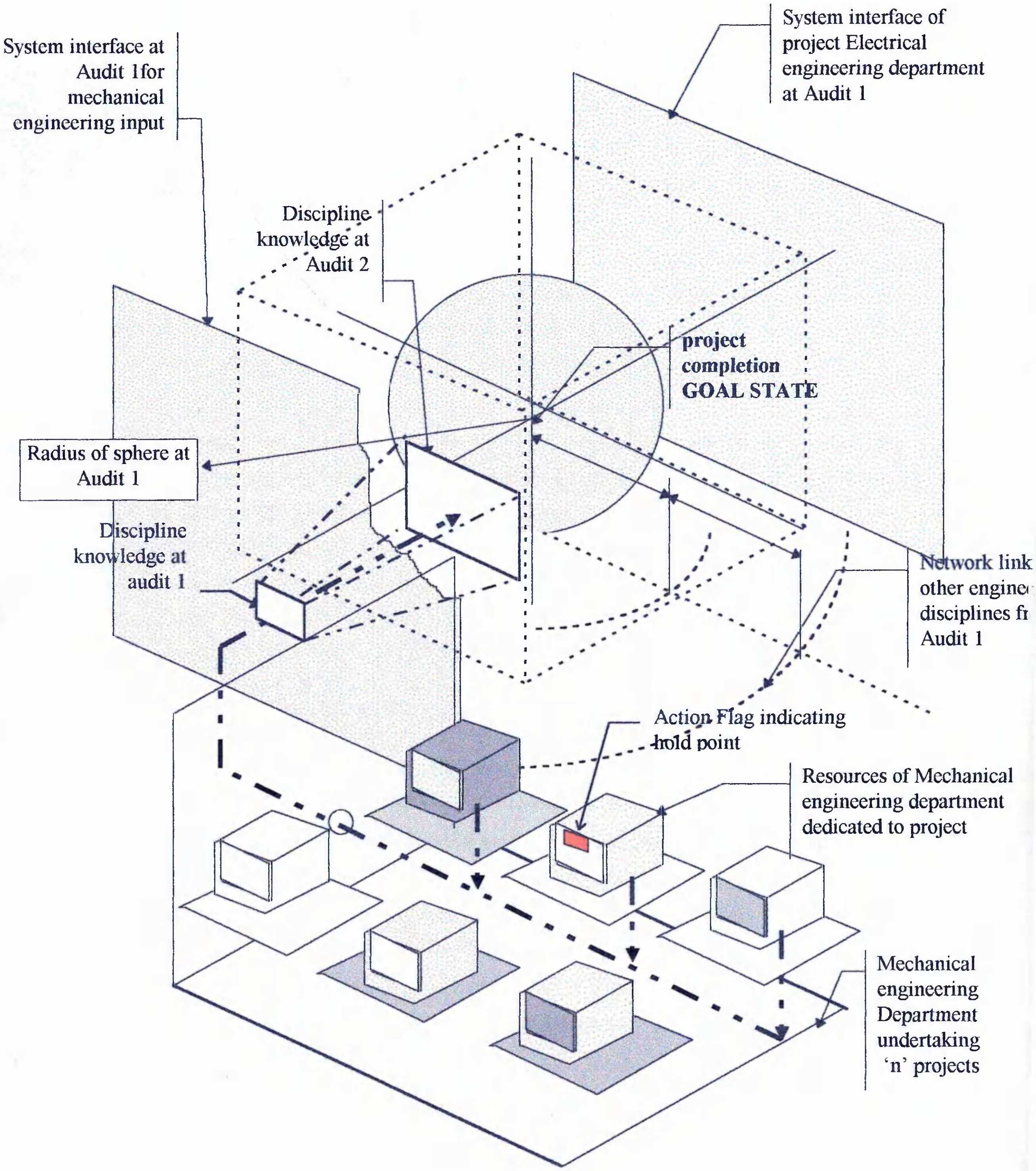


Fig 28 System interfaces

4.6.2 The Operability of the Concept

Windows driven software applications are likely to remain the most effective vehicle for using project management software, it is therefore necessary to ensure that the user interfaces are as visually informative as possible. The three dimensional representation of the resource view concept Fig 8 and Appendix D6 are ACAD 13 generated true 3 D images able to be manipulated in a virtual project environment.

The intention of the concept is to utilise existing commercially available proven software at the system peripherals and develop bespoke KBS architecture for the main system functions. E.g. APM Chaucer product selection software Ref. Appendix E17 (Fig 55)

The system logic is designed to enable multi user interface via a workflow electronic document management system, the physical arrangement of which is shown in Fig 28.

In justifying the KBS approach it became apparent that the main launch platform for the system will be the workstations in the drawing and design offices.

The workstations and their respective servers are equipped with the more able software and most are already LAN linked. Most design offices have ACAD and generic CAD systems interlinked with some type of electronic document management system. E.g. ADMiT

It would be logical for any new project management system that is closely integrated with engineering design functions, like ConSERV, to take advantage of the existing infrastructure of a design office.

Conroy and Soltan[13,14,15] provided a series of three articles, in which the concept was described in some detail. The first of the three articles alluded to the system's ability to be used as a 3D project management model, whilst the second and third outlined the potential self auditing and risk management benefits.

4.7 Summary and References

4.7.1 Summary

This Chapter introduced the ConSERV concept and presented a brief review of the KLIC methodology undertaken in 1996 to establish whether or not the concept was suitable for KBS treatment. The Chapter provided an insight into why the KBS approach was deemed necessary, and how the Opportunity Analysis confirmed the concept as a potential candidate. The Plausibility Study findings were recounted and the goals of the KBS were identified and evaluated. The global plausibility of the candidate concept was presented in the form of a radar graph Appendix D4 (Fig 30) which the KLIC technique concluded in favour developing a KBS to handle the types of problems encountered in design intensive multidisciplinary capital projects.

The mechanics of the two parts of the concept were described and illustrated in Figs 24 and 26, and an overview of the operability of the concept was described with references to the use of the system in a Drawing Office environment shown in Fig 28.

In summarising this chapter it is apparent that whilst the *Guida and Tasso* KLIC system for the development of knowledge based systems is well structured and thorough, it does produce a somewhat voluminous amount of apparent verbiage in order to confirm a KBS application.

It is recognised by the author that the development of a prototype KBS to handle the types of problems described in this Chapter is well beyond the scope of this Ph.D. thesis. It is felt, however that the project management system described in this submission will be worthy of further research effort by others. Ref. Chapter X. Section 10.3.

Chapter V, continues the KBS theme, by identifying the most suitable KBS tools to develop the two demonstrators A and B. The Chapter also includes the development of the *project management* element of the ConSERV knowledge and data base, whilst Chapter VI addresses the *engineering design* element of the concept.

4.7.2 References

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APPENDIX D

APPENDIX D

MANAGEMENT INDICATION
INTEGRATION OF SPECIFICATION
RADAR GRAPH OF GLOBAL PLAUSIBILITY
2D REPRESENTATION OF CONCEPT
3D REPRESENTATION OF CONCEPT
SUMMARY OF LITERARY RESEARCH

APPENDIX D

The following is an extract from the opportunity analysis undertaken December 1995

1.0 Management Indication Document (Brief)

Client:- Conserv Engineering Services Ltd
Business :- Manufacture of Titanium Dioxide pigment (Chemical Processing)
KBS User :- Group Project Engineering Department
Nature of Requirement :- Improving the management of multidisciplinary Capital projects

1.1 Summary

1.1.1 The management of multidisciplinary engineering design projects over recent years has been difficult to accomplish satisfactorily, within the company's procedures and guidelines.
The apparent inability to manage projects within the control criteria is a major concern for the company. Capital projects undertaken by the project group can vary in value from £0.5 to £5.0 million. Virtually all projects are *multidisciplinary*, i.e. they involve more than one engineering discipline (Civil, Structural, Mechanical, Electrical, Instrumentation or Process)
Project overrun of 2% on a £4.0 million project is £80000.

1.1.2 The company procedures are not project specific, i.e. they are considered to be equally applicable to all projects irrespective of size, complexity and time.

1.1.3 Senior management recognise that the success of projects is still very much dependent upon the skill, expertise and commitment of individual project managers. This introduces a level of subjectivity which involves greater risks in predicting project performance.
Ref. "Control and management of Capital projects" Hackney 1992 Ch 47,48 and 49. in which the dilemma is defined with respect to :-
Staffing of Projects
Selection and management of type of contracts
Project management and managers.

1.2 Objectives

1.2.1 To research and report on the present organisational structure of the Project group with respect to the management and execution of Capital projects.

1.2.2 To review the present organisational structure with respect to project management procedures and methods of handling multidisciplinary projects.

1.2.3 To review present "information handling" and "document management" methods with respect to the management of multidisciplinary projects.

1.2.4 To review staffing policy, motivation, qualifications, responsibility and authority of both permanent and contract staff posts and report on findings.

1.2.5 To undertake an **opportunity analysis** study to determine whether or not a case exists for the development of a Knowledge Based Systems application, and if so provide a recommendation, for the design and development of a KBS project management tool capable of handling multidisciplinary engineering capital projects.

APPENDIX D

Integration of Demonstrator specifications

Conserv KBS	Functionality
Type	Decision support, integrated, on line
Inputs	multiple simultaneous users plus others from remote locations via a network link
Behaviour	Intelligent, wide coverage of project management techniques risk management and organisational procedures
Outputs	To VDU , and other users via LAN using existing Workflow data transfer facility via ACAD 13 or similar
Scope	Specified set of functions for specific tasks, interactive facility. Integrated software exchange- separate data bases.
Robustness	Specified level of performance is to be near the borders of coverage/scope.
Friendliness	Natural easy interaction and communication with user. Incorporating explanation system linked to user interface
Effectiveness	Focused and economic use of the available knowledge held within the system knowledge bases.
Efficiency (time)	Maximise response and processing time whilst performing each function.
Efficiency (man)	Maximise amount of available resource whilst performing each function
Interface (user)	typically windows 95 platform with easy to use self help features incorporated into the user interface facility
Interface (other)	Extensive data exchange protocols and EDMs to enable rapid transfer of information between engineer disciplines

10.0 The functional specification(Demonstrator B)

Specification table

Demonstrator	Type	Functionality	Operational	Technical
Vertical A Functions 1-4	Promotional	Identification of project elements	Identification of project elements	Identification of project elements
Vertical B Function 5	Planning	3 dimensional tool	3 dimensional tool	3 dimensional tool

11.0 The Operational specification (Demonstrator A)

Industrial	End users	Locations	Interfaces
Chemical	Various project managers and Engineers typically 12-30 depending on project size	various plant sites in group	Existing p.m. systems
Fine Chemical	Various project managers and Engineers typically 12-30 depending on project size	various plant sites in group	Existing p.m. systems
Bulk Chemical	Various project managers and Engineers typically 12-30 depending on project size	Plant sites in group	Existing p.m. systems
Pharmaceutical	Various project managers and Engineers typically 12-30 depending on project size	Plant sites in group	Existing p.m. systems
Petrochemical	Various project managers and Engineers typically 12-30 depending on project size	Plant sites in group	Existing p.m. systems
Food	Various project managers and Engineers typically 12-30 depending on project size	Plant sites in group	Existing p.m. systems
Construction	Cost. Managers Works Engineers	Plant sites in group	Works planning systems

12.0 The Technical Specification (Demonstrator A and B)

Hardware	Devices	Software
Pentium 160mhz 16 MB Ram PCs linked by Novell network with min 1.0 Gbyte Memory	Essentially as per current PC and workstation input/output located on site	Windows 96 environment with Novell network software. FLEX
CD ROM	External plotter	ACAD 13 windows 3 D Studio Max
Usual peripherals		CYCO Workflow
Standards (Protocol / GUI)	**External Interfaces**	**Reliability / maintainability**
SQL	LAN	As per standard
	Modem Link	
	Back up facility	

Fig 29 Integration of functional, operational and technical specifications

APPENDIX D

The Global plausibility of the concept

The most convenient method of illustrating the global evaluation of plausibility suggested by *Guida* and *Tasso* is to use a diamond diagram (Radar graph) as shown.

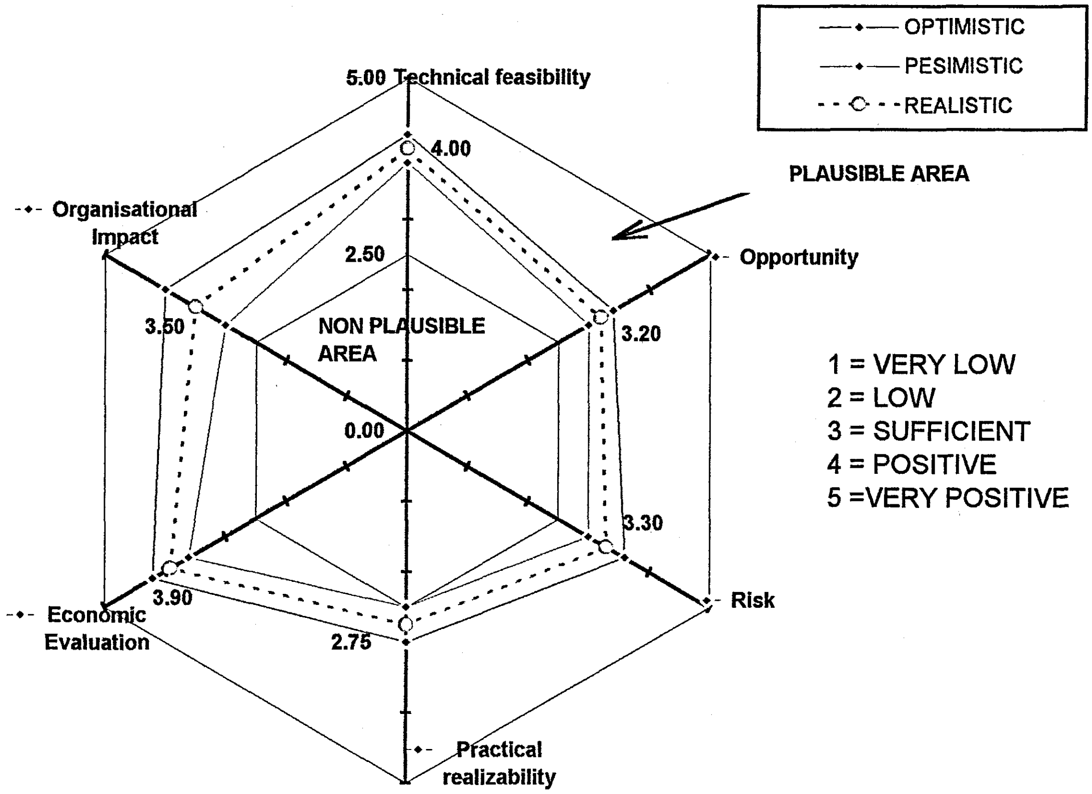


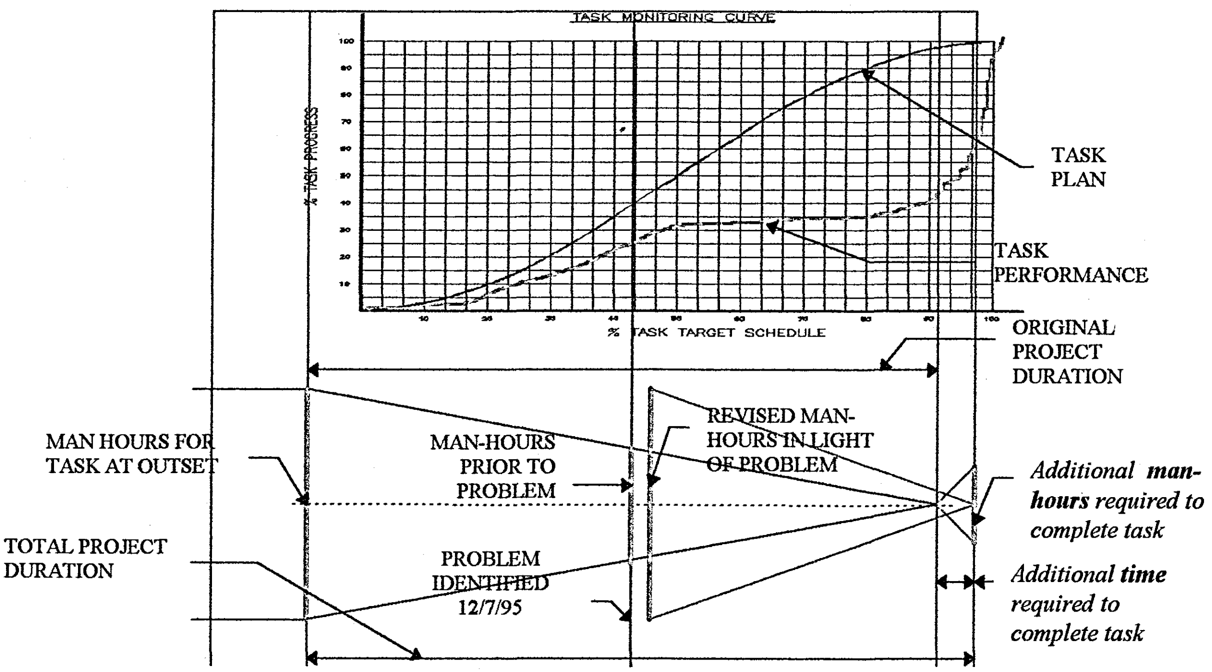
Fig 30 Radar graph of global evaluation of ConSERV candidate KBS

According to *Guida and Tasso* a KBS project is plausible if ,"all the five components considered in the analytical assessment receive a positive independent evaluation". Similarly " If one or more of the components of the plausibility study do not receive a positive evaluation the project is not plausible.

The candidate KBS ConSERV appears to satisfy the *Guida and Tasso* criteria for development as a knowledge based system.

APPENDIX D

The ConSERV three dimensional management tool



Extending the 2 d visualisation of the case study weld failure (Project 2) it is possible to represent the triangular shape shown above the plan view of a pyramid as shown below.

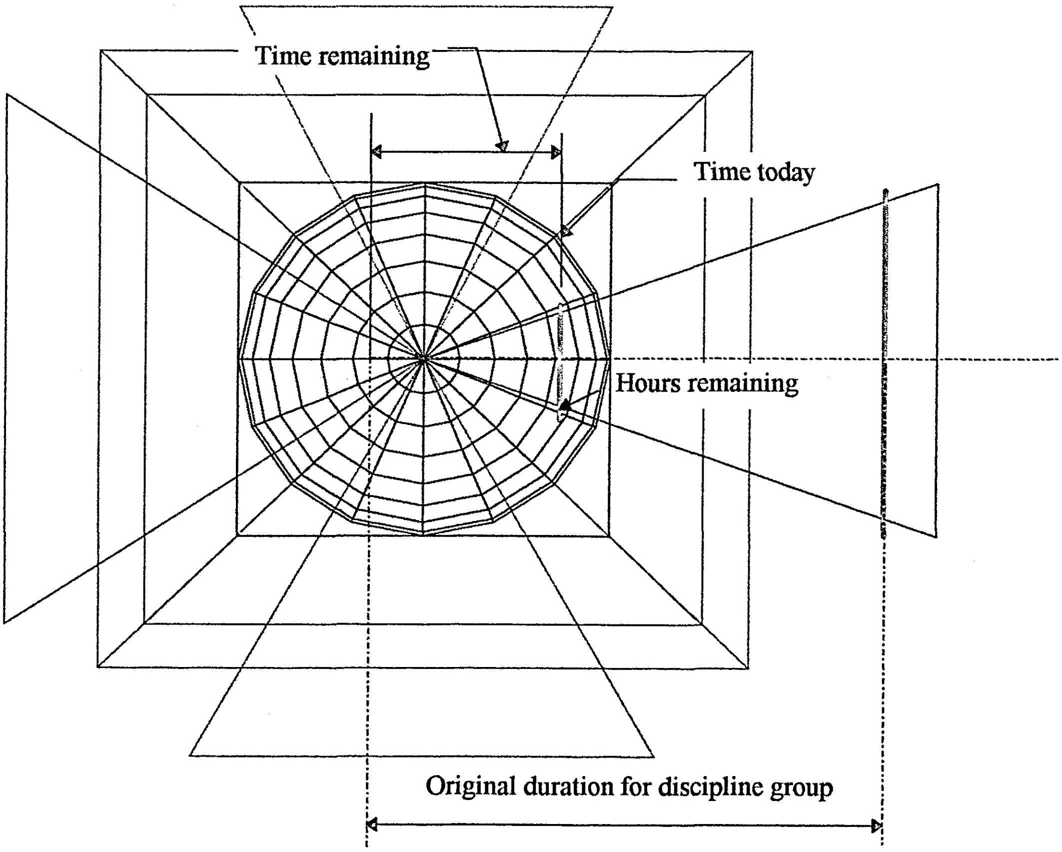


Fig 31 Plan view of three dimensional visualisation

APPENDIX D

CONSERV 3 D PROPOSAL

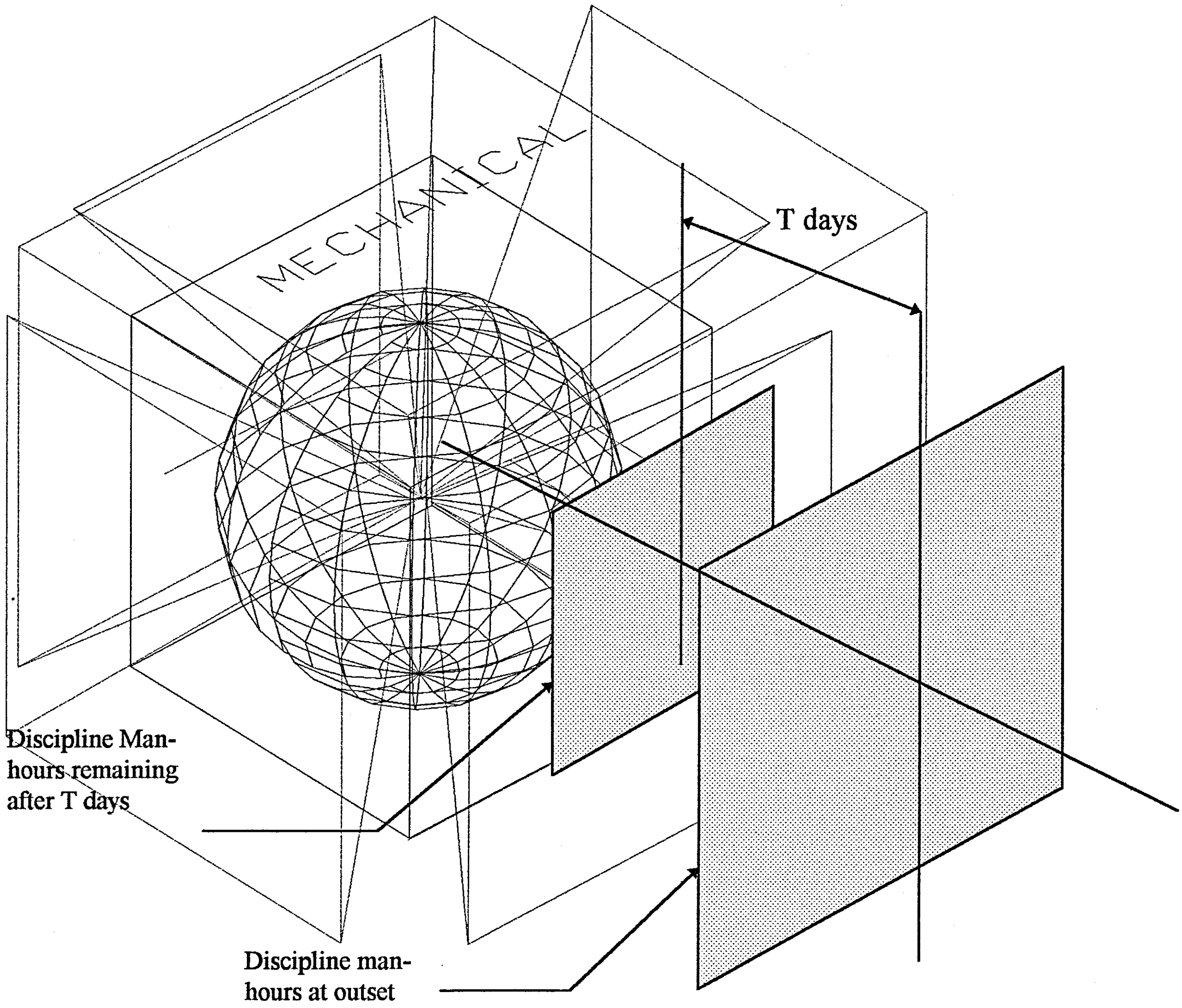


Fig 32 3D View of Model

APPENDIX D

Note books italicised referenced in Ph.D. submission **BOOKS**

SCHOOL OF INDUSTRIAL & MANAGEMENT SCIENCES CRANFIELD UNIVERSITY

LIST OF RELEVANT BOOK TITLES

ISBN	AUTHORS	YEAR	TITLE	PUBLISHER
0-521-40403-7	ADDIS	1990	RESEARCH AND DEVELOPMENT IN EXPERT SYSTEMS	CAMBRIDGE U PRESS
1-55860-165-1	ALLEN ET AL	1994	PRINCIPLES OF KNOWLEDGE REPRESENTATION AND REASONING	MORGAN KAUFMANN
0-521-32617-6	*ARKES,HR*	*1986*	*JUDGEMENT AND DECISION MAKING*	*CAMBRIDGE U PRESS*
0-471-93018-0	AYEL MA	1991	VALIDATION VERIFICATION AND TEST OF KBS	WILEY
0-19-824854-7	BODEN MARGARET	1990	PHILOSOPHY OF AI	OXFORD UNI PRESS
0-19-854743-9	BODEN MARGARET	1989	BENEFITS AND RISKS OF KBS (CSS REPORT)	OXFORD UNI PRESS
0-412-56280-4	*BOOTH.D.J.*	*1995*	*FOUNDATION DISCRETE MATHEMATICS FOR COMPUTING*	*CHAPMAN AND HALL*
0-521-38394-3	BREWKA G.	1991	NONMONOTONIC REASONING LOGICAL FOUNDATIONS OF COMMON SENSE	CAMBRIDGE UNI PRESS
0-85312-830-8	CAMPBELL,J.A.	1985	PROGRESS IN ARTIFICIAL INTELLIGENCE	WILEY
1-85554-356-7	*CARTER. B.*	*1994*	*INTRODUCING RISKMAN METHODOLOGY*	NCC BLACKWELL
0-13-516741-8	CROSS B.T.	1988	KNOWLEDGE ENGINEERING	BRADY NEW YORK
0-471-92215-3	CROSS,N	1989	ENGINEERING DESIGN METHODS	WILEY
3-540-56192-7	DAVID, J.M.	1993	SECOND GENERATION EXPERT SYSTEMS	SPRINGER VERLAG
0-077-07727-X	DOWNTON,A	1991	ENGINEERING THE HUMAN-COMPUTER-INTERFACES	McGRAW HILL
1-55860-328-X	DOYLE ET AL	1994	PRINCIPLES OF KNOWLEDGE REPRESENTATION	MORGAN KAUFMANN
0-273-03048-5	EDWARDS	1991	BUILDING KNOWLEDGE BASED SYTEMS	PITMAN
0-7506-1188-X	GERO,J.S.	1991	AI IN DESIGN	BUTTERWORTH
0-13-048372-9	GOTTINGER,W.	1992	AI A TOOL FOR INDUSTRY AND MANAGEMENT	ELLIS HORWOOD
0-471-92808-4	*GUIDA.G*	*1994*	*DESIGN AND DEVELOPMENT OF KBS*	*WILEY*
0-07-001259-8	*HACKNEY, JW*	*1992*	*CONTROL AND MANAGEMENT OF CAPITAL PROJECTS*	*McGRAW HILL*
1-85554-356-7	*HANCOCK. T.*	*1994*	*INTRODUCING RISKMAN METHODOLOGY*	*NCC BLACKWELL*
1-85091-830-9	HART A.	1989	KNOWLEDGE AQUISITION FOR EXPERT SYSTEMS	KOGAN PAGE
0-13- 515479-0	HAYBALL.C.C.	1993	KNOWLEDGE BASED SYSTEMS ANALYSIS AND DESIGN	PRENTICE HALL
0-07-032353-4	JAYARAMEN,S	1991	COMPUTER AIDED PROBLEM SOLVING FOR ENGINEERS	McGRAW HILL
0-07-Y66360-2	KAST& ROSENZWEIG	*1970*	*ORGANIZATION AND MANAGEMENT*	McGRAW HILL
	KHARBANDA, O.P	*1986*	*SUCCESSFUL PROJECTS*	*GOWER*
0 85295 265 1	*KLETZ, T*	*1991*	*AN ENGINEERS VIEW OF HUMAN ERROR*	*I.Chem.E*
0-070-522634	KNIGHT,K.	1991	ARTIFICIAL INTELLIGENCE	McGRAW HILL
1-871516-17-X	*KRAUSE P & CLARK D*	*1993*	*REPRESENTING UNCERTAIN KNOWLEDGE*	*CROMWELL PRESS*
3-540-56192-7	KRIVINE,J.P.	1993	SECOND GENERATION EXPERT SYSTEMS	SPRINGER VERLAG
0-471-55492-8	KUSIAK,A	1993	CONCURRENT ENGINEERING AUTOMATION TOOLS AND TECHNIQUES	WILEY
0-471-93018-0	LAURENT JP	1991	VALIDATION VERIFICATION AND TEST OF KBS	WILEY
0-07-037495-3	LEVINE,I.R.	1990	AI & EXPERT SYSTEMS	McGRAW HILL
0-291-39741-7	*LOCK. D*	*1987*	*PROJECT MANAGEMENT HANDBOOK*	*GOWER TECH. PRESS*
0-07-112686-4	LUCAS, HC	1992	THE ANALYSIS DESIGN IMPLEMENTATION OF INFORMATION SYSTEMS	McGRAW HILL
0-8053-0139-9	LUGER,F.	1989	AI AND THE DESIGN OF EXPERT SYSTEMS	BENJAMIN CUMMINS
0-07-1003193-3	McCORMICK	199-	HUMAN FACTORS IN ENGINEERING AND DESIGN	McGRAW HILL
0-471-02156-3	MEREDITH & MANTELL	1994	PROJECT MANAGEMENT A MANAGERIAL APPROACH	WILEY
1-899621-02-4	MILNE,R	1994	APPLICATIONS AND INNOVATIONS IN EXPERT SYSTEMS	BRITISH COMP SOCIETY
	MORRIS, P.W.G.	*1987*	*THE ANAOTOMY OF MAJOR PROJECTS*	*WILEY*
3-540-17986-0	MUMPOWER,L	1987	EXPERT JUDGEMENT AND EXPERT SYSTEMS	SPRINGER-VERLAG
0-8053-6840-X	NEGOITA C.V.	1991	EXPERT SYSTEMS & FUZZY SYSTEMS	BENJAMIN CUMMINS
3-540-17986-0	PHILIPS,D.L	1987	EXPERT JUDGEMENT AND EXPERT SYSTEMS	SPRINGER-VERLAG
0-201-62769-8	PREECE,Jenny	1994	HUMAN- COMPUTER INTERACTION	ADDISON WESLEY
0-471-01198-3	RASMUSSEN.J.	199-	COGNITIVE SYSTEMS ENGINEERING	WILEY
0-471-92828-3	RASMUSSEN.J.	199-	DISTRIBUTED DECISION MAKING	WILEY
0-86372-113-0	RASMUSSEN.J.	199-	HUMAN-COMPUTER INTERACTIONS	L.EARLBAUM
0-13-048901-8	RAUCH HINDIN	199-	AI IN BUSINESS SCIENCE & INDUSTRY	PRENTICE HALL
3-540-17986-0	RENN,O	1987	EXPERT JUDGEMENT AND EXPERT SYSTEMS	SPRINGER-VERLAG
0 419 20750 3	*REISS, G*	*1996*	*PROJECT MANAGEMENT DEMYSTIFIED*	*E&FN SPON*
0-070-522634	RICH,Elaine.	1991	ARTIFICIAL INTELLIGENCE	McGRAW HILL
0-89391-494-0	RICHER,M.	1988	AI TOOLS AND TECHNIQUES	ABLEX
0 89859-767-6	*REISBECK,K*	*1989*	*INSIDE CASE BASED REASONING*	*LAWRENCE ERLBAUM*
0-07-1003193-3	SANDERS	199-	HUMAN FACTORS IN ENGINEERING AND DESIGN	McGRAW HILL
0-901800-37-6	SHARPE,J	1994	COMPUTER AIDED CONCEPTUAL DESIGN	LANCS EDC
0-442-01252-7	SHINA,S.G.	1994	SUCCESSFUL IMPLEMENTATION OF CE PRODUCTS & PROCESSES	VAN NOSTRAND
0-13-102765-4	*SHTUB et al*	*1994*	*PROJECT MANAGEMENT ENGINEERING, TECHNOL & IMPLEMENTATION*	*PRENTICE HALL INT.*
0-8247-7022-6	SIDDALL,J.N.	1991	PROBABILISTIC ENGINEERING DESIGN	MARCELL
3-540-56192-7	SIMMONS,R	1993	SECOND GENERATION EXPERT SYSTEMS	SPRINGER VERLAG
0-905-45191-0	SRIRAM,D	1987	AI IN ENGINEERING TOOLS AND TECHNIQUES	SOUTHAMPTON CMPLA
0-340-54378-7	*STARKEY,V*	*1992*	*ENGINEERING DESIGN DECISIONS*	*EDWARD ARNOLD*
0-85312-830-8	STEEL.L	1985	PROGRESS IN ARTIFICIAL INTELLIGENCE	WILEY
0-8053-0139-9	STUBBLEFIELD,W.	1989	AI AND THE DESIGN OF EXPERT SYSTEMS	BENJAMIN CUMMINS
0-85295-380-1	*SWEETING, J*	*1997*	*PROJECT COST ESTIMATING*	*I Chem E*
0-13- 515479-0	TANSLEY D.S.W	1993	KNOWLEDGE BASED SYSTEMS ANALYSIS AND DESIGN	PRENTICE HALL
0-471-92808-4	*TASSO.C*	*1994*	*DESIGN AND DEVELOPMENT OF KBS*	*WILEY*
0-419-19090-2	*TAYLOR, J.R.*	*1994*	*RISK ANALYSIS FOR PROCESS PLANT, PIPELINES AND TRANSPORT*	*E&FN SPON*
0-201-41618-2	THIMBLEBY,H	1990	USER INTERFACE DESIGN	ADDISON WESLEY
0-13-336785-1	TREUR & WETTER	1993	FORMAL SPECIFICATION OF COMPLEX REASONING SYSTEMS	ELLIS HORWOOD
0-07-707946-9	TURNER,J R	1994	THE COMMERCIAL PROJECT MANAGER	McGRAW HILL
3-540-17986-0	UPPULURI,V.R.R.	1987	EXPERT JUDGEMENT AND EXPERT SYSTEMS	SPRINGER-VERLAG
0-201-08313-2	WATERMAN,D.	1986	A GUIDE TO EXPERT SYSTEMS	ADDISON WESLEY
0-13-048372-9	WEIMAN,P.	1992	AI ATOOL FOR INDUSTRY AND MANAGEMENT	ELLIS HORWOOD
0-13-048901-8	WENDY,B	199-	AI IN BUSINESS SCIENCE & INDUSTRY	PRENTICE HALL
0-471-92603-5	WINSTANLEY, G.	1991	ARTIFICIAL INTELLIGENCE IN ENGINEERING	WILEY
0-201-41618-2	WINSTON,P.H.	1991	ARTIFICIAL INTELLIGENCE	ADDISON WESLEY

APPENDIX D

Note Articles italicised referenced in Ph.D. submission **ARTICLES**

SCHOOL OF INDUSTRIAL & MANAGEMENT SCIENCES CRANFIELD UNIVERSITY

LIST OF RELEVANT KBS AND AI ARTICLES

CAT NO	AUTHORS	REF YEAR	TITLE	PUBLISHED IN
KE VOL 1	*ADELI,H.*	1993	KNOWLEDGE ENGINEERING	
ESPRIT 7752	*AKUESON,R*	1994	IMPLEMENTING CONCURRENT ENGINEERING USING INTELLIGENT SYSTEMS	CEEDA
INSPEC	*ALBIN, SL*	1994	CONCURRENT ENGINEERING MEDIUM SIZED MANF	MANF SYSTEMS
ECOSSE	*ALCANTARA ET AL*	1994	MAINTAINING DESIGN RATIONALE IN KBDS-IBIS	EDINBURGH UNI PUB
0263-7863 00064-X	*BELASSI W & TUKEL O I*	*1996*	*A NEW FRAMEWORK FOR DETERMINING CRITICAL SUCCESS/FAILURE FACTORS*	*IJPM*
ESPRIT	*BROWN,M*	1994	A KNOWLEDGE BASED SUPPORT SYSTEM FOR USE OF CAD TOOLS	BRIT COMP SOCIETY
INSPEC	*CLEETUS, K.J*	*1994*	*VIRTUAL TEAM FRAMEWORK CONCURRENT ENG*	*MECH SYS DES NATO*
ECOSSE II	*COSTELLO ET AL*	1994	EPEE; A PROCESS ENGINEERING SOFTWARE ENVIRONMENT	EDINBURGH UNI PUB
INFO MNGT	*CROOKS-BILE,Alison*	1994	GROUPWARE	DATAPRO
STANFORD	*CUTKOKY,M.R*	1994	AN EXPERIMENT IN INTEGRATING CONCURENT ENGINEERING SYSTEMS	COMPUTER
-	*DAVIES.R*	1993	WHAT IS KNOWLEDGE REPRESENTATION	M.I.T. USA
NASA	*DEAN,EB*	1993	QUALITY FUNCTION DEPLOYMENT FOR LARGE SYSTEMS	
-	*DIXON. M.G.*	199-	KNOWLEDGE BASED SYSTEMS FOR CONCEPTUAL DESIGN	LONG BEACH USA
EDINBURGH UNI	*DRABBLE B*	1995	ARTIFICIAL INTELLIGENCE FOR PROJECT PLANNING	AIAI
ESPRIT III	*ENGLEBOROUGHS,E*	1994	USING GROUP TECHNOL TO INTEGRATE DFM & CAPP IN A CE/SE SYSTEM	CEEDA
CRANFIELD	*EVANS.S*	1994	IMPLEMENTATION FRAMEWORK FOR INTEGRATED DESIGN TEAMS	ENGINEERING DESIGN
AI IN DESIGN	*FINGER S.*	1991	REPRESENTING AND REASONING WITH DESIGN INTENT	UK
AI IN DESIGN	*GANESHAN R.*	1991	REPRESENTING AND REASONING WITH DESIGN INTENT	UK
AI EDAN 6(1)	*GARCIA.A*	1992	AQUIRING DESIGN KNOWLEDGE THROUGH DESIGN...JUSTIFICATION	US
AI IN DESIGN	*GARRETT J.*	1991	REPRESENTING AND REASONING WITH DESIGN INTENT	UK
-	*GREEN. M*	1992	CONCEPTIONS AND MISCONCEPTIONS OF KAD	NSERC GRANT 46297 UK
INSPEC	*HARDING ET AL*	1994	SUPPORTING R&M IN A CONCURRENT ENG ENVIRONMENT	CAE IN CE
KBS 9 (1996) 207-215	*HARRINGTON,J*	*1996*	*NEGOTIATION IN A KNOWLEDGE BASED CONCURENT ENG. DESIGN ENVIRONMENT*	*EXPERT SYSTEMS*
AI EDAN 6(1)	*HOWARD.H.*	1992	AQUIRING DESIGN KNOWLEDGE THROUGH DESIGN...JUSTIFICATION	US
INSPEC	*HUANG,G.Q*	1994	AGENTS FOR COOPERATING EXPERT SYSTEMS IN CONCURRENT ENGINEERING	AI FOR EDAM
BRIGHTON UNI	*JONES AND RILEY*	1994	CONCURRENT ENGINEERING AN ALTERNATIVE FOR THE CONSTRUCTION INDUSTRY	APM JOURNAL
BOEING	*KLEIN,M*	1994	CAPTURING DESIGN RATIONAL IN CONCURRENT ENGINEERING	CEEDA
INSPEC	*LANGERER,G.*	1994	BEYOND CONCURRENT ENGINEERING	CAE IN CE
INFO MNGT	*LANGNER R.M*	1994	AIN (ADVANCED INTELLIGENT NETWORKS)	DATAPRO
CSE VOL 3 NO6	*LOGCHER,R*	1992	CAPTURING DESIGN ASSUMPTIONS...IN THE DESIGN PROCESS	UK
ASME CONF	*LU.S*	1990	DESIGN EVOLUTIONMANGEMENT... USING DESIGN RATIONALE	US
-	*LUCAS M.P.*	199-	KNOWLEDGE BASED SYSTEMS FOR CONCEPTUAL DESIGN	LONG BEACH USA
HEWLETT P	*LUNDELL et al*	1993	INTEGRATING QFD INTO SOFTWARE DEVELOPMENT A CASE STUDY	USA
IBM	*MARSHALL,S*	1994	CONCURRENT ENGINEERING WITH MULTIPLE PROJECTS AND SHARED RESOURCES	CEEDA
MARI	*MC CLEMENTS,L*	1994	QUESTIONNAIRE	DTI DUCK
TEXAS INST	*McKNIGHT,Ailsa*	1994	MOWGLI: AN ENVIRONMENT FOR ADAPTABLE DESIGN METHODOLOGY MANGMNT	CEEDA
0263-7863 00057-7	*MUNNS AK & BJERIRMI BF*	1996	THE ROLE OF PROJECT MANAGEMENT IN ACHIEVING PROJECT SUCCESS	IJPM
INSPEC	*NEUMANN,J*	1994	COMMUNICATION, COMMITMENT, CEATIVITY 3 RULES OF CE	LA TECHNIQUE MODERN
0263-7863 00037-2	*PARTINGTON D*	1996	THE PROJECT MANAGEMENT OF ORGANIZATIONAL CHANGE	IJPM
CSE VOL 3 NO6	*PENA.F*	1992	CAPTURING DESIGN ASSUMPTIONS...IN THE DESIGN PROCESS	UK
INSPEC	*PETTS,J*	1994	PAPER ON RISK IN HAZARDOUS WASTE INDUSTRY	NUCLEAR ENERGY
ECOSSE	*PONTON,J ET AL*	1994	DEVELOPING AN ENVIRONMENT FOR CREATIVE PROCESS DESIGN	I.CHEM.E
INFO MNGT	*RICHARDSON,Mary Ann*	1994	DATA MANAGEMENT	DATAPRO
INSPEC	*ROLSTADAS*	1994	CONFERENCE PAPER	IPP TRANSACTIONS
-	*SAGE.A.P.*	199-	KNOWLEDGE SUPPORT SYSTEMS AND GROUP DECISION TECHNOL	VIRGINIA USA
LERI	SCHMITT,G	1994	DESCRIPTION AND EXECUTION OF APPLICATIONS GUIDED BY THE (MAD)	CEEDA
0263-7863 00050-X	*SHERMAN et al*	1996	ASSISTING CULTURAL REFORM IN A PROJECT-BASED COMPANY USING SYSTEMIGRAMS	IJPM
-	*SHROBE.H*	1993	WHAT IS KNOWLEDGE REPRESENTATION	M.I.T. USA
I Mech E VOL 207	*SIMMONS P.E.*	1993	STOCHASTIC DECISIONS IN ENGINEERING DESIGN	E00292 UK
INSPEC	*SOBOLEWSKI,M*	1994	KBS INTEGRATION IN A CONCURRENT ENG ENVIRONMENT	MEYHODOLOGY FOR IS
-	*SZOLOVITS.P.*	1993	WHAT IS KNOWLEDGE REPRESENTATION	M.I.T. USA
CADLAB	*TACKEN,J*	1994	MANAGEMENT OF CONCURRENT DESIGN PROCESSES	CEEDA
LOUGHBORO	*TAH et al*	1993	CONTRACTOR PROJECT RISK CONTINGENCY USING LINGUISTIC APPROXIMATION	COMPUTING SYSTEMS
EDINBURGH UNI	*TATE,DRABBLE & DALTON*	1995	AN ENGINEERS APPROACH TO THE APPLICATION OF KB PLANNING TECHNIQUES	ALVEY/AFOSAR
ASME CONF	*THOMPSON.J*	1990	DESIGN EVOLUTIONMANGEMENT... USING DESIGN RATIONALE	US
INSPEC	*TRAPP,G*	1994	THE EMERGING STEP STANDARD FOR PRODUCTION MODEL DATA EXCH.	COMPUTER
VOL LIX	*TURING,A.*	1950	COMPUTER MACHINERY & INTELLIGENCE IN MIND	
MARI	*TURNER, P&S*	1994	SUPPORTING DISTRIBUTED DESIGN	DTI DUCK
GHENT UNI	*Van LANDEGHEM,R*	1994	SEGAPAN A SIMULTANEOUS BENCHMARKING TOOL	CEEDA
INFO MNGT	*WALDRON,M*	1994	DOCUMENT MANAGEMENT IN QUALITY ASSURANCE	DATAPRO
0263-7863 00062-3	*WANG W et al*	1996	CONTRACT SELECTOR (CTS) A KBS FOR TRAINING YOUNG ENGINEERS	IJPM
263-7863 020103-08	*WINSTANLEY & KELLETT*	1993	A COMPUTER BASED CONFIGURATION AND PLANNING SYSTEM	IJPM
263-7863 020111-07	*YEO KT*	1993	SYSTEMS THINKING AND PROJECT MANAGEMENT A TIME TO REUNITE	IJPM

Chapter V

5.0 PROJECT MANAGEMENT ELEMENT OF THE CONSERV KBS CONCEPT

"Consciousness is being aware of what is happening to you, experiencing sensations, having 'qualia'. Computational processes, the manipulation of symbols, can not have consciousness" Searle[1]

5.1 Introduction and description of the KBS

5.1.1 Overview

It should be made clear from the outset that it is only possible to manage those projects that are manageable. This may seem to be a somewhat profound if not obvious statement. As will be explained during the Chapter however, it is possible to identify those projects that exhibit classical *engineering design* and *project management* failure mechanisms prior to commencing the project.

Inheriting such a project is the project managers worst nightmare.

Chapter IV introduced the ConSERV concept, provided a summary of the reports justifying the need to adopt a KBS approach, and afforded an overview of the way in which the system might operate in practice.

Chapters V and VI are essentially an extension of Chapter IV respectively addressing the more specific risk and management issues of the *Project Management* and *Engineering Design* elements of the proposed concept.

As was identified in Chapter IV knowledge based systems are capable of supporting the explicit representation of knowledge in some specific competence domain and of exploiting it through appropriate reasoning mechanisms to provide high level problem solving performance.

This Chapter describes how this is achieved in the **project management** element of ConSERV, whilst Chapter VI addresses the **design** related issues of the concept.

5.1.2 Differences between Traditional Software and KBS's

Knowledge based systems differ considerably from traditional systems in both performance and structure. In developing the project management part of the concept as a KBS it was necessary to recognise and appreciate the significant differences that exist between traditional project management software systems and the proposed knowledge based system.

The distinction between knowledge based and traditional software technology is very clear in certain cases e.g. a rule-based system and Fortran programming, but is less well defined in others such as a frame-based system and an object-oriented programme, or a logic inference system and a deductive data base.

The focus of attention is no longer on algorithm design but on the representation of *knowledge* considered relevant and useful to the solution of a class of problems in the application domain of the user.

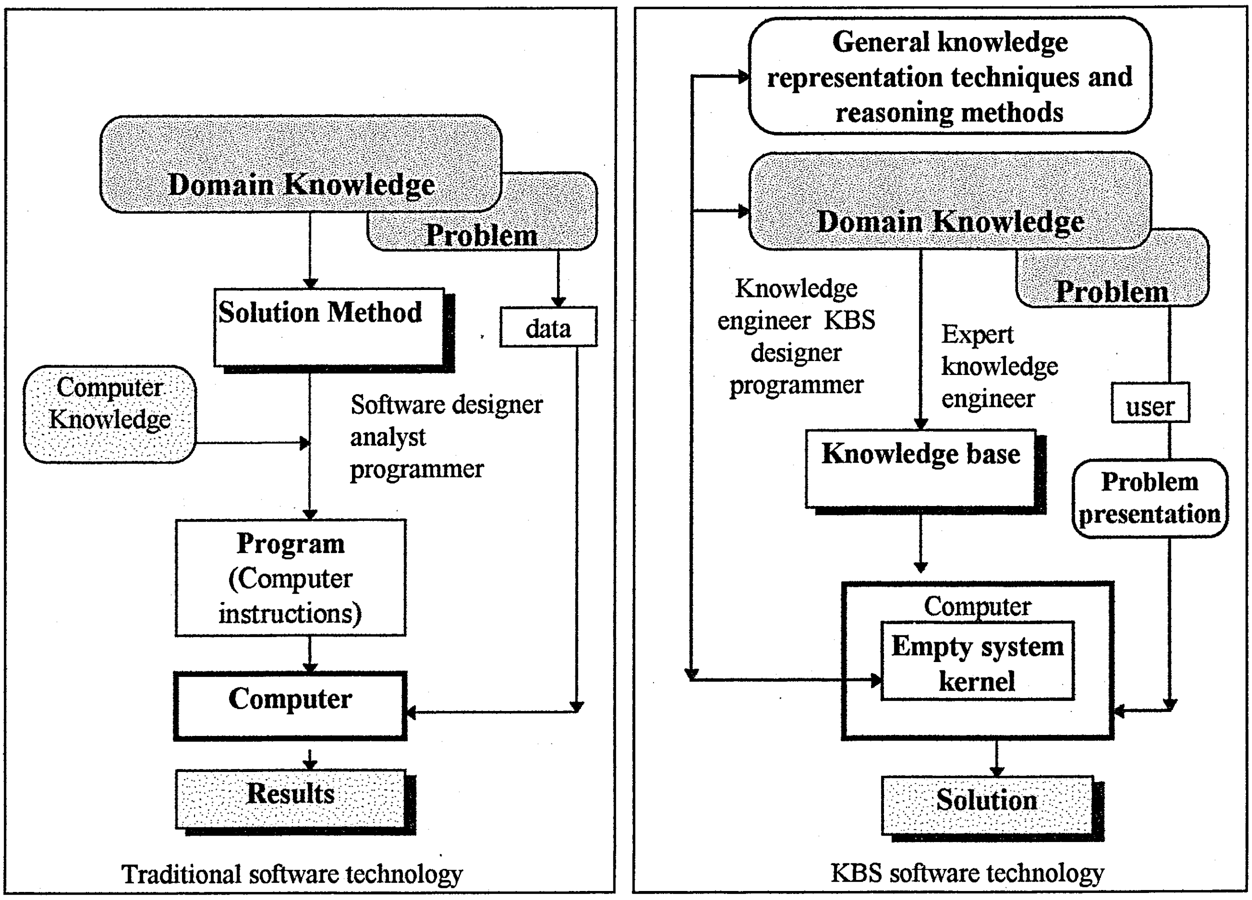
In a well designed KBS the responsibility of 'deciding' which knowledge to use and how to use it can be left to the computer, providing that it is appropriately equipped with an effective *inference engine*.

The most useful distinction that can be made between traditional and knowledge based systems is the ability of the KBS to perform a number of "What if Scenarios".

The structural differences of the two methods is illustrated in Fig. 33.

A table of the descriptive differences is submitted in Table 18.

The author recognises that the table provides a rather extreme view of traditional systems, and that modern object oriented software is likely to lie somewhere between the two categories described. In summarising KBS's can solve problems in a given application domain by the explicit representation of knowledge and by exploiting general reasoning mechanisms, while traditional software systems produce solutions by applying fixed solution algorithms designed by man.



Traditional software technology

KBS software technology

Fig 33 Graphical comparison between traditional and KBS systems

Traditional software systems	Knowledge based systems
Domain knowledge is not explicit in the program code. It is only in the mind of experts, software designers and analysts	Domain knowledge is represented explicitly in the knowledge base
Domain knowledge is fragmented deeply transformed and hidden in program code.	Domain knowledge is represented in a natural structured and organic way.
General problem solving and control knowledge is hidden in the program code	General problem solving and control knowledge is separate from domain knowledge
Computer 'knowledge' is intermixed with problem solving and control knowledge.	Computer knowledge, the populated kernel, remains separate from domain knowledge
Knowledge is mainly represented in procedural form	Knowledge is mainly represented in a declarative form
Only structured and algorithmic knowledge can be represented	Non structured knowledge can be represented
Operation is strictly deterministic	Operation is non deterministic
Knowledge is used by experts and analysts	Knowledge is used by inference engine to construct a solution to problem being considered

Table 18 Descriptive differences between traditional and KBS systems

5.1.3 Classification of KBS's

Guida and Tasso[2] offered four practical classifications of KBS's

First classification is : The intended **goal** of the KBS

Type 1 **Support systems**, which provide expert support to a human operator or to a professional in the execution of specific complex tasks.

Type 2 Prescriptive systems, which constrain and control the activity of the operator or professional. Prescriptive systems have the authority of imposing decisions.

Type 3 Autonomous systems, which have no human interaction and are intended to replace the human operative.

The second classification is : The systems **connection** with **traditional software**

Type 1 Stand alone systems, which do not interact with external traditional software systems.

Type 2 **Integrated systems**, which do interact with heterogeneous problem solvers and operating systems. (The global operation of the system is controlled by the KBS)

Type 3 Embedded systems, which are encapsulated in an external traditional software system which controls the overall operation of the system.

The third distinction is: The **connection** between the **KBS** and **external** environment.

Type 1 **On-line** i.e. directly connected to the outside world through some sensory mechanism.

Type 2 **Off-line** i.e. Not connected with the external physical world. Physical data provided manually to KBS by user.

The fourth distinction is : The **purpose** for which the KBS is being developed.

Type 1 Application-oriented, aimed at solving some concrete problem in a real application context.

Type 2 Exploration-oriented, devoted to supporting the first steps of technology transfer

Type 3 **Research-oriented**, devoted to support basic research and innovative experimentation, by offering a suitable test bed for experimenting new concepts

Type 4 Training-oriented, developed in the frame of a training initiative to support a more concrete and practical acquisition of the main concepts.

5.1.4 ConSERV KBS Design basis

From the distinctions suggested by *Guida and Tasso* it was decided that the Demonstrator 'A' will be:

A research oriented support system integrated with heterogeneous problem solvers able to function both on and off line. The fully developed KBS may well be type 1.

As identified in Chapter IV p79 the 5 main stages of the ConSERV process, include:

The five ConSERV stages	Demonstrator	Part
Stage 1.0 Identifying the project and its key dimensions by using a 10 point questioning procedure	A	1
Stage 2.0 Identifying the main risk elements for project management and engineering design using the input from 1.0	1A and 1B	1
Stage 3.0 Identifying appropriate project and design management system and determining the man-hours.	1A and 1B	1
Stage 4.0 Establishing the resource needs and developing the project execution plan	-	-
Stage 5.0 Applying the ConSERV 3D concept, and monitoring the progress.	B	2

Table 19 The five ConSERV Stages and respective Demonstrators

As we have already established due to the unique nature of projects it is often necessary to employ a **suite** of heterogeneous problem solvers in order to utilise the benefits afforded by the most recent developments in computer technology.

The ConSERV concept is being developed in a bid to provide a more comprehensive project management methodology that provides the user with both a project risk identification and management system facility i.e.

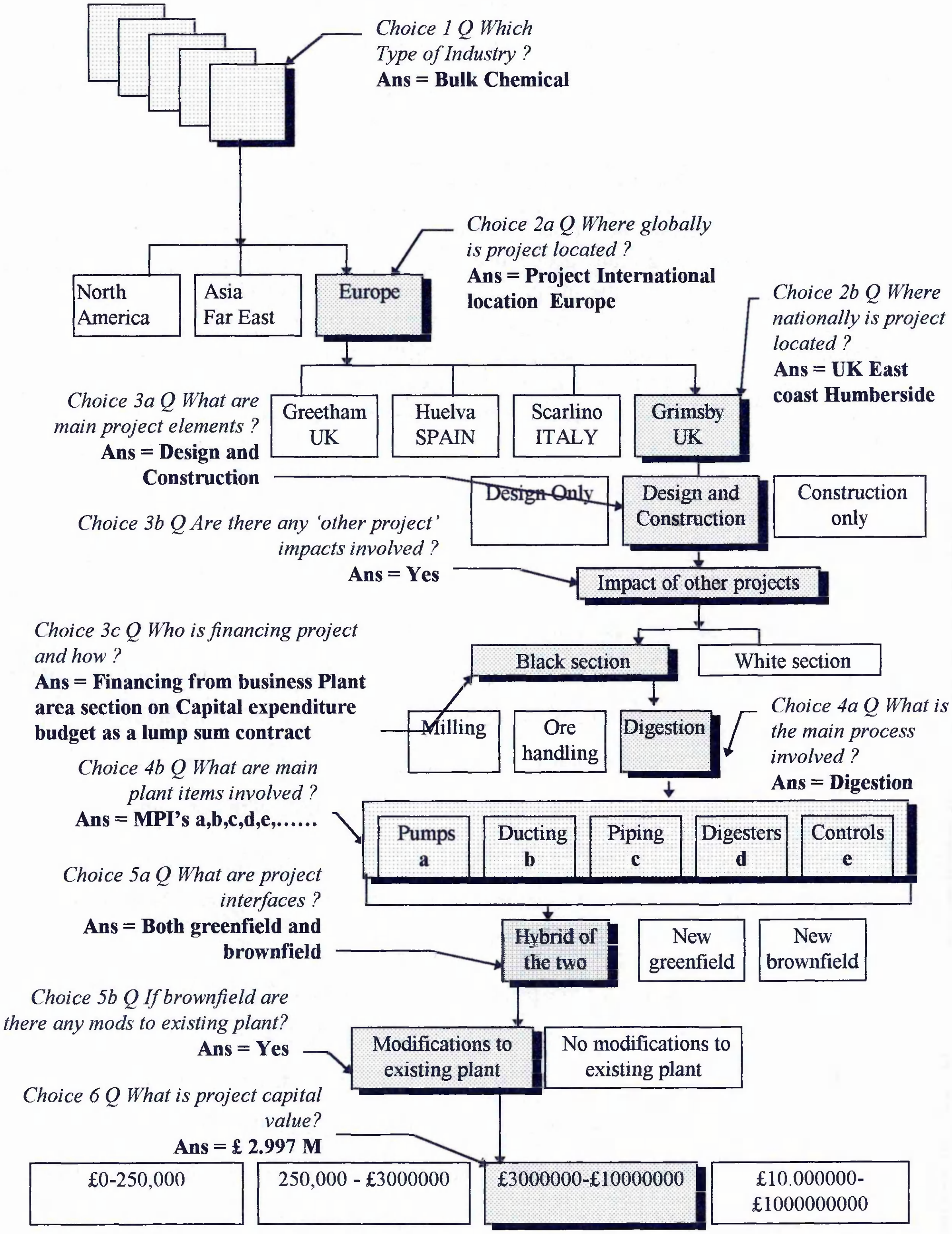
ConSERV Parts 1a and 1b Demonstrator 'A' and A 3 D Engineering Resource Representation *ConSERV Part 2* Demonstrator 'B'.

The specific needs of five live projects has been tabulated to illustrate the purpose of the project identification exercise Ref. Appendix E 2. (Fig 40)

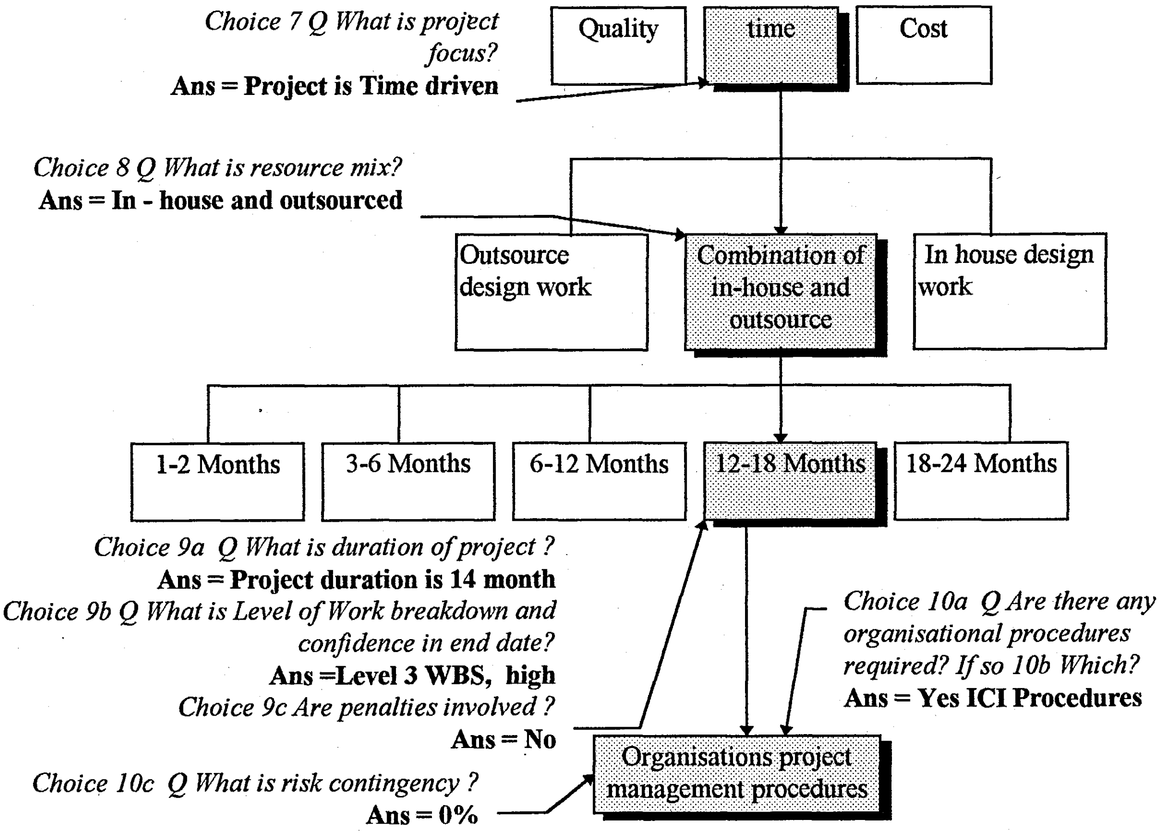
For the purposes of this Ph.D. thesis, the technical design of Demonstrator 'A' is based on the information network submitted in The Plausibility Study, and The Demonstrator Report in which the interconnected elements of the four project stages have been mapped, in some detail. Ref. Chapter IV p 79.

5.1.5 ConSERV KBS Design basis (*project identification*)

The ten key issues pertaining to the technical requirements of demonstrator A are identified from case study 2 as shown in Fig 34 below. Ref. H2-H7 (Fig 87-97)



5.1.5 ConSERV KBS Design basis (*project identification*)



Choice 7 Q What is project focus?
Ans = Project is Time driven

Choice 8 Q What is resource mix?
Ans = In - house and outsourced

Choice 9a Q What is duration of project ?
Ans = Project duration is 14 month
Choice 9b Q What is Level of Work breakdown and confidence in end date?
Ans =Level 3 WBS, high
Choice 9c Are penalties involved ?
Ans = No

Choice 10a Q Are there any organisational procedures required? If so 10b Which?
Ans = Yes ICI Procedures

Choice 10c Q What is risk contingency ?
Ans = 0%

Fig 34 Project Identification process for New Digester project (project 2)

The information obtained from the first pass, *project identification* should allow the project manager to build into the *project specific data base* the following :-

The project is being undertaken in the **chemical industry**$_{1}$ based in **Europe**$_{2a}$ at the **Grimsby**$_{2b}$ plant. The project is a **Design and build**$_{3a}$ capital project that is likely to be affected by **other projects**$_{3b}$ and is financed by the **Black section Dept as a lump sum contract**$_{3c}$. The project involves the **digestion**$_{4a}$ process and includes **a,b,c,d,e,**$_{4b}$ main plant items.

The project will include **modifications**$_{5}$ to existing plant and has a capital value of **£ 3 M** $_{6}$. The project will be **Time driven**$_{7}$. and will use **combined resources**$_{8}$. The project is planned to take **14 months**$_{9a}$ and will be undertaken in accordance with **ICI company procedures**$_{10}$.

5.1.6 ConSERV KBS Design basis *(risk identification and representation)*

For each of the ten key project identifiers obtained from the QA routine illustrated in Fig 34 a number of overt risks (r_{overt}) will emerge. The subjective risks are quantified by taking the user through a QA routine to select the project success / failure criteria and then input a numerical risk value for each of the project identifiers.

Ref. Fig. 24 p78 and Appendices H3-H6. For each success criteria identified ConSERV offers ten screens inviting the user to input his/her subjective risk value.

E.g. For the success criteria "Holding budget" what are the subjective risks from:

i/ The industry, (Chemical/other), ii/ The location (UK, overseas etc.), iii/ The Process iv/ The plan etc. In completing the screens the user will be using his/her own beliefs, values, and experiences. For the risk averse types, the subjective values are likely to be heavily loaded with risk margins and contingencies, this can be misleading as assumptions are made that risks are 'managed' by providing contingencies

By summating the risk values assigned to the key project identifiers it is possible to produce a bar chart showing the user assigned risks as shown in Fig 35 below. Following the same technique with an expert system using knowledge based rules applied to the project identifiers a second set of data is produced.

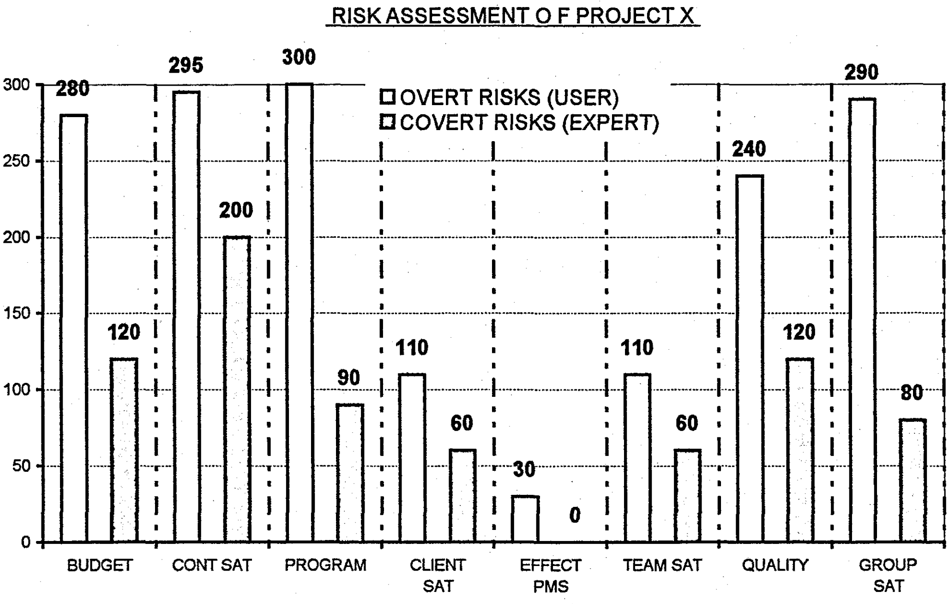


Fig 35 Subjective initial risk assessment for project X

The non hatched y axis bars are: Σ Overt Risk Factors 1-10 for each success criteria

The shaded y-axis bars are: Σ Covert Risk Factors 1-10 for each success criteria.

The information from the key dimensions of the project (the identifiers) is used to populate the Project Specific Data base (PSDB). The Covert risks are generated from **general rules** and principles. E.g. IF Ans. 3a = 'Design and Construction' THEN identify new risk$_c$ factor $r_c f_{3a}$ AND enter into PSD file: "Ensure CDM 1994 Regs. are followed" Covert risks also result from **project specific** rules. E.g. IF Ans. 9b = 'Low' AND Ans. 9c = 'Yes' THEN identify new risk$_c$ factor $r_c f_9$ AND enter into PSD file. Ref. Appendix E8. Each risk identified is then processed using a *risk management* technique such as that illustrated by Fig. 37.

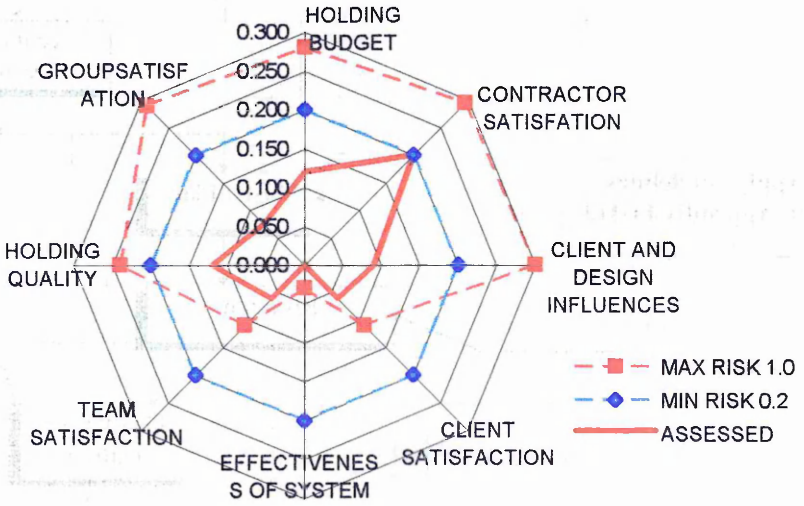
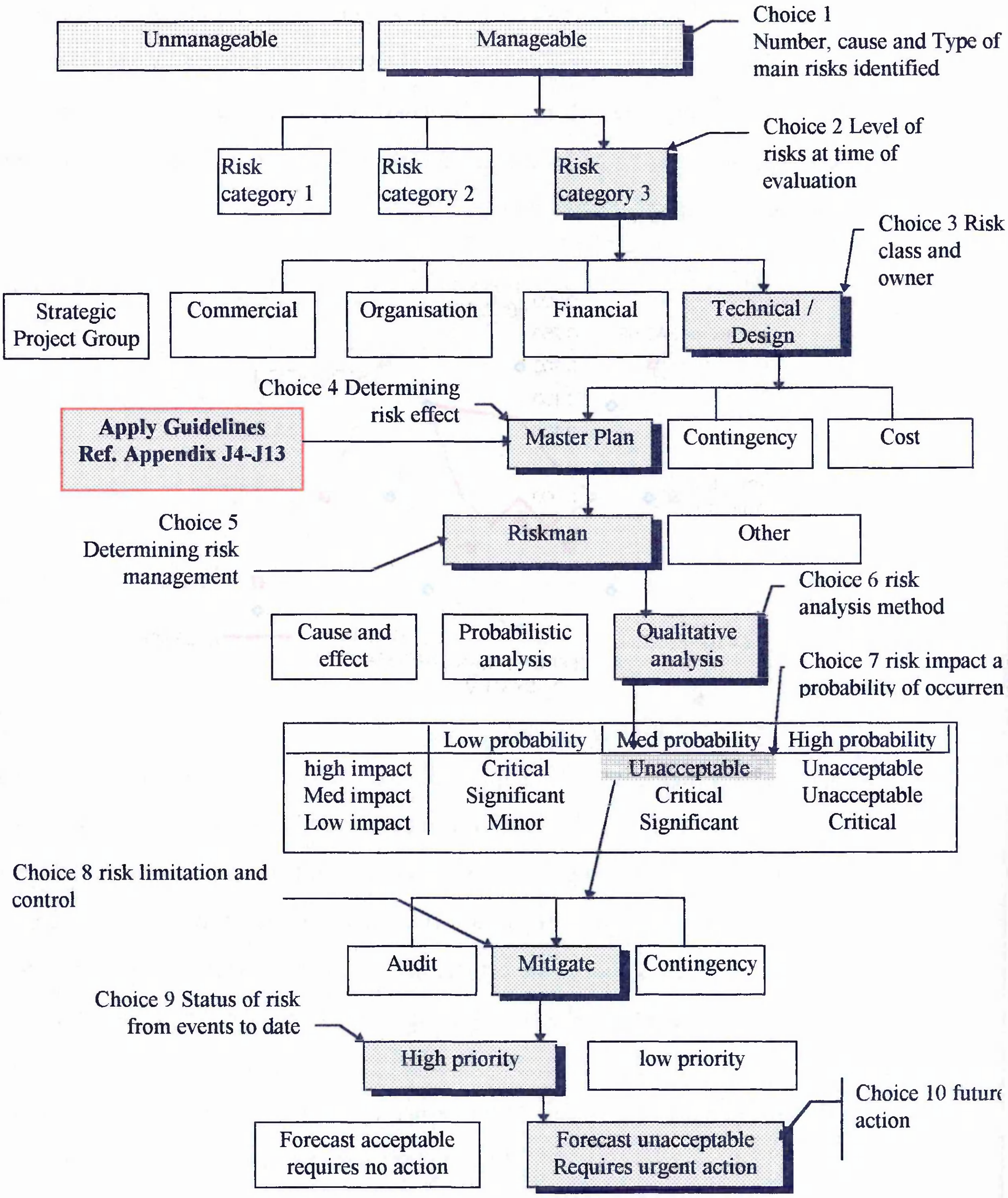


Fig 36 Covert risk assessment of project X

The assessment using a rule based approach provides a more focused risk evaluation which, in combination with the specific project data reduces the level of subjectivity eliminating many of the perceived overt risks. The initial risk assessment was made with the assessor being unaware of any rules that automatically introduce controls over specific risk issues e.g. IF the project involves *long lead items* AND the project is TIME *focused* THEN reschedule other activities to improve the delivery dates of long lead items. By converting the bar chart data to a radar graph Fig. 36, it is possible to view the overall shape of the project risks at a specific moment in time. By setting a level for minimum risk the manager can determine when the risks for a particular project success criteria are in need of being addressed.

5.1.6 ConSERV KBS Design basis (Part 1a) (*risk identification and representation*)

A strategy for addressing specific risks is shown below, the process could be triggered by a risk value exceeding the acceptable level set on the radar graph.



	Low probability	Med probability	High probability
high impact	Critical	Unacceptable	Unacceptable
Med impact	Significant	Critical	Unacceptable
Low impact	Minor	Significant	Critical

Fig 37 A standard Risk management process

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[1] The purpose of this Ph.D. is not to investigate Risk management processes per se, however the application of classical risk management techniques to quantify risk values is recognised as being a suitable option to the subjective assessment used in the ConSERV approach.

5.1.6 ConSERV KBS Design basis (Part 1a) (*Risk identification and representation*)

Following the risk identification procedure on two live projects (Project 3 and Project 4) it was possible to represent the overall **shape** of the project risks using radar graphs as shown below in Fig 38 and Fig 39. Note ten success criteria were identified.

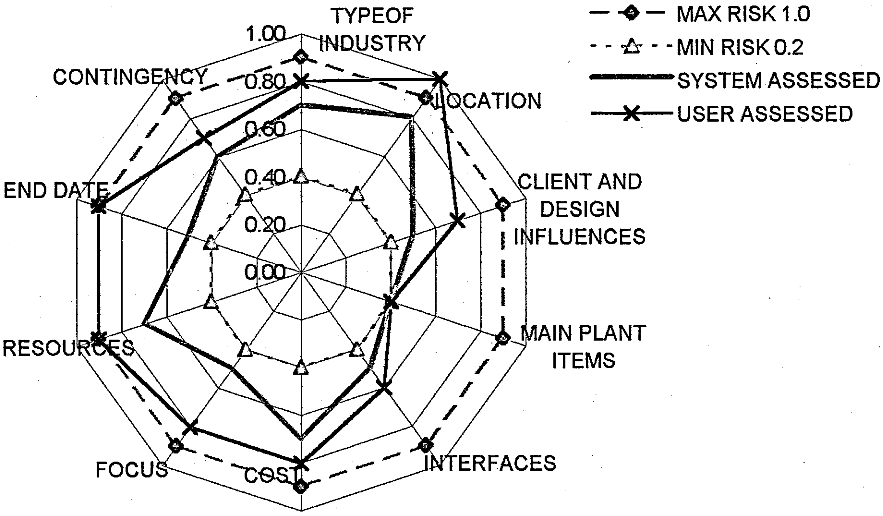

Fig 38 Radar graph of Risk shape for Bangladesh project (Ref. p8 Project 3)

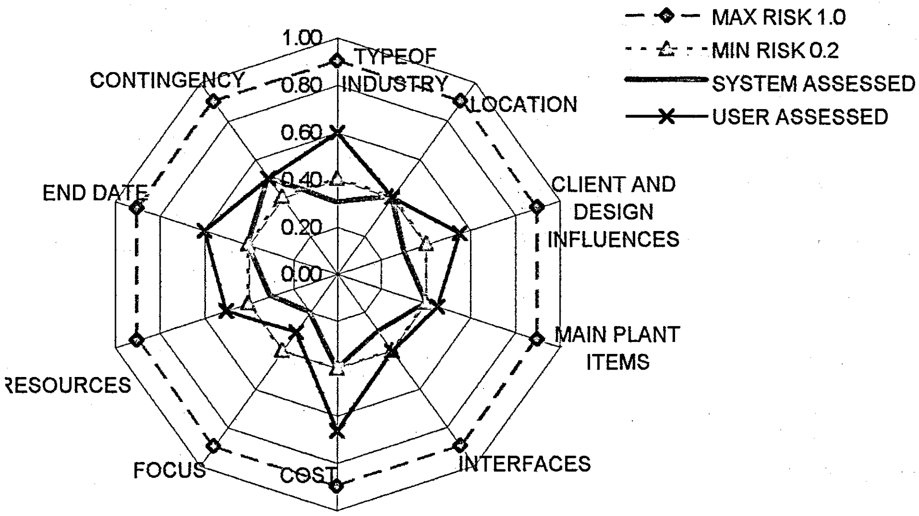

Fig 39 Radar graph of Risk shape for the UK project (Ref. p8 Project 4)

5.1.7 ConSERV KBS Design basis (Part 1a)

The shape of the radar graphs shown in Fig 38 and 39, shows the users assessment of the risks as compared with the systems evaluation. Conflict resolution techniques can be used to resolve the discrepancy between the two assessments. Once agreement has been reached an 'assessment' of the most appropriate project management system can be formed by using the systems *knowledge based rules.*

E.g. For a project likely to be affected by **other projects** with an existing **high risk** of not meeting the **end date,** it may be necessary to incorporate into the p.m.s. dedicated resource to control and limit the effect. i.e. The need for this additional resource may not have been identified in the initial assessment.

A second example might be that if a project has insufficient **contingency** funds **and high risk** of being unable to manage the **costs** then the p.m.s should strongly recommend the application of an 'effective' cost control system.

Other **types** of rules that need to be incorporated include :-

IF the project has been identified as being TIME driven, THEN the project program needs to be accurate and include all contingencies to accommodate foreseeable risks. The calendars need to be established to maximise the available working hours. The program needs to be developed to sufficient detail to enable objective measurement of earned values. i.e. Level 3 WBS

IF the project is COST driven THEN the program should be accurate with the calendars set to minimise the use of premium rate hours.

IF the project is QUALITY driven THEN the plan should facilitate the time factors required in order to maintain the QA functions and checking procedures.

The key to **successful project management** is being able to **identify** early trends and correct them using the in built contingencies. This is the essence of a dynamic project management system that responds to the needs of the project, not simply monitoring the effects.

5.1.8 Temporality

The **data** provided and the **logic** applied during the initial assessment is temporal.'●' i.e. It is only valid for a finite period of time in the project life cycle up to the present moment in time 'o '. The project can be affected by unforeseen changes at any time e.g. The consequence of a change in corporate strategy, finance or in the event of an accident.

According to *Barringer et al*[3] "Temporal logic can be used as a programming language if temporal formula are represented in the form of an implication in which the anticedent refers to the past and the consequent the present and future" i.e. Rules of the form; Anticedent about the past ⇒ Consequent about the future. The author recognises that Executable Temporal Logic does provide a natural alternative to programming languages such as Prolog.

The ConSERV concept attempts to maintain the status of the project **focus** by periodically reassessing the risk status using the routine described in Section 5.1.5. The time intervals '$\prec$ ' would be dictated by the stated confidence level of maintaining the project focus or, alternatively each time a change in project conditions $(\varnothing)_p$ or major design scope change $(\varnothing)_d$ is identified. $\Diamond_t(\varnothing)_p$, or $\Diamond_t(\varnothing)_d$.

E.g. If the project focus shifts from say being TIME driven to being COST driven then the ConSERV concept identifies the shift in focus and resets the appropriate project control mechanisms by applying a new set of knowledge based rules.

In their 1996 seminar 'Effective Project Management' *Hawksmere plc* suggest that there are five classical causes of poor project performance, namely :-

1.0 The objectives changed during the project
2.0 The time and cost estimates were too optimistic
3.0 The roles and responsibilities were unclear
4.0 Top management were too autocratic
5.0 Team members were too parochial

This extract reinforces the view of *Belassi and Tukel*[4] who suggest that;

"The success / failure factors are usually listed as either very general factors or very specific factors affecting only a particular project".

5.2 Selection of Demonstrator 'A' KBS Environment

5.2.1 Selection Criteria

The selection[1] of the KBS demonstrator A development environment was also undertaken in accordance with the KLIC methodology recommended by *Guida and Tasso* . The general purpose programming languages used for building KBS's belong to one, or more of the five well known common programming paradigms, namely :-

1.0 Imperative (C and FORTRAN)
2.0 Functional (LISP, SCHEME)
3.0 Logic (PROLOG, POPLOG)
4.0 Object-oriented (SMALLTALK C^{++} $PROLOG^{++}$)
5.0 Rule-based. (OPS, ECLIPSE, YAPS)

KBS development tools such as EMYCIN, HERESAY III and AGE are well established but due to the temporal nature of the data and the need to integrate information within a Workflow design environment they were considered to be less suited for handling the class problem solving requirements of project management. The two classes of KBS tools were referenced in Chapter IV p 81 and 82, in which demonstrator A was identified as being a promotional planning type of demonstrator falling into the vertical tool classification.

As was identified earlier in this chapter demonstrator A will need to be used as a knowledge elicitation and logic handling tool. A number of candidate environments were considered and on balance the Win-Prolog environment was selected on the grounds that the windows version is a 32-bit programming environment using a windows GUI. Win-Prolog is equipped with its own debugger, dialogue editor and supports DLL and DDE window compatible data exchanges.

FLEX The expert system toolkit provided with Win-Prolog supports frame based reasoning with inheritance, rule based programming and data driven procedures fully integrated within a logic programming environment. FLEX contains its own English like Knowledge Specification Language (KSL). FLEX employs open architecture and allows access to modify the behaviour of the system through a layer of access functions.

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[1] The more rigorous approach for the selection of the KBS environment was not followed on the grounds that the purpose of this Ph.D. is not to develop the prototype Ref. Chapter 1 Fig 1 p 10

5.2.2 KBS Demonstrator 'A' selection criteria (cont.)

The expert system or knowledge based system allows the scarce and expensive knowledge of experts to be explicitly stored into computer programs for the benefit of other, less experienced users. KBS's typically have a set of, `if-then` rules which forms the knowledge base and a dedicated inference engine which provides the execution mechanism. The FLEX tool employs a built in **Question** and **Answer** sub system that allows final applications to query the user for additional input via interactive dialogues.

FLEX has a built in explanation system which supports both how and why explanations. The explanations can be attached to both rules and questions using simple `because` clauses.

FLEX provides four types of data driven procedures namely :- `launches`, `demons`, `watchdogs` and `constraints`.

The Knowledge Specification Language (KSL) is very expressive enabling simple and concise statements to be made about the experts world which can be understood and maintained by non-programmers.

E.g. `kind` (Used in defining the parents of a frame, used with `is a`, `of`)

```
frame bird is a kind of animal
```

The knowledge is explicitly stated in a natural and simple way making knowledge-bases virtually self documenting. The FLEX KSL supports mathematical, Boolean and conditional expressions and functions along with set abstractions.

By supporting both logical and global variables in rules, FLEX avoids unnecessary rule duplication and needs fewer rules than most other expert systems.

The decision to choose the FLEX Win-Prolog environment was based on a combination of the merits listed above but largely on the Question-Answer facility afforded by the tool.

PROLOG allows the system designers to express knowledge declaratively and has a built in inference engine that allows access to low level programming functions.

The development of the software was undertaken by M Pappas, at the behest of the author.

A more detailed review of the selection procedure is described in *Conroy*[5,6,7,8]

5.3 Logic, knowledge bases and data bases

5.3.1 Knowledge Acquisition

Having identified a suitable KBS environment for the project management part of the concept, the next stage of development was to establish and acquire relevant and meaningful knowledge. According to *Guida and Tasso* the single most important step of the KBS KLIC is developing the knowledge base. The main activity being that of knowledge acquisition which should incrementally fill up the knowledge base of the KBS using a cycle of :- "Elicit - code - integrate - verify".

It is important to again recognise that the development of the knowledge base for a prototype KBS is outside of the scope of this submission. The Focal objectives of the industrial research were identified at the outset Ref. p11. Restated in Section 1.6.2.

The *knowledge* elicited from the project managers comprised of raw information in the form of verbal, textual and descriptive data. The elicitation techniques included :- Interviews, observations, brainstorming sessions, audit reviews, project team briefings, group discussions, enquiries and the analysis of project files and reports.

The most valuable 'knowledge' elicitation exercise regarding this submission was obtained by presenting the various "expert" project managers with a 'hypothetical' project case using the 10 key project elements identified in stage 1.0. The project managers were requested to rate the project in terms of the project success criteria using a prepared radar graph and risk measurement scale. Ref. Appendix E5.

Four different scenarios were created over the life cycle of the project and the respondents were each requested to describe their responses justifying their concerns.

Scenario 1.0 At 25% into the project the Client engineer advises that revised production figures indicate the need to increase in production throughput by 20%.

Scenario 2.0 At 50% into the project, the last months progress monitors show a trend of activity slippage of 5%.

Scenario 3.0 At 60% into the project, the CDM planning supervisor is replaced two weeks prior to commencement of site work

Scenario 4.0 At 90% into project commissioning is held up due to control difficulties between the new process and existing equipment.

5.3.2 Analysis of Decision Making Logic

The decision making process employed by the majority of the project managers interviewed was well structured and surprisingly consistent.

The sequence of the decision making logic identified above was analysed in light of the results obtained from the interviewees, a summary of the decision stages and respective domains is provided in Appendix E6. (Fig 44)

The responses of the individuals were tabulated in the form of *factual and inferential* knowledge and were subsequently grouped using *cause and effect* analysis.

A summary of the findings is provided in Appendix E7. (Fig 45)

Protocol analysis techniques were applied to the fragmented knowledge obtained from the knowledge elicitation exercise, resulting in the generation of the **knowledge items chart** shown on Appendix E8 (Fig 46), which also includes coding the knowledge into rules. A very limited sub set of the types of rules is shown in systemigram form on the logic flow diagram in Appendix E8 (Fig 46).

5.3.3 Part 1 KBS Rules and Databases

As a recap, the first pass of stages 1-3 of the ConSERV concept is designed to populate the empty kernel of the KBS with a, ten key word, **description** of *that persons* perception of what the project is about. The generic risks (overt) are then obtained, weighted, factored and represented in the form of a radar graph. The project specific risks (covert) are generated and used in conjunction with the overt risks for comparison against the project management success criteria. The application of the knowledge based rules enables ConSERV to identify project specific risks developing from the project specific data at the time of the assessment. Subsequent information will automatically supersede the current project status and may fire a totally different set of knowledge rules which may challenge the user to take a different course of action.

Having established the KBS environment for Demonstrator 'A' it was necessary to develop a structure whereby the essential elements of the ConSERV project management functions could be presented for conversion into FLEX. i.e. coded.

A disc copy of the Demonstrator 'A' software programme is appended to this submission.

5.4 Application of the research findings

5.4.1 Case Studies

The research findings obtained from the two industrial case studies Projects 1&2, provided a clear indication of those areas in which the projects were less than successful. Ref. Chapter 3 p 52 and 53.

Whilst the main failure mechanism indicators for the projects were not identified formally, a separate cost based risk analysis was undertaken by the author which did demonstrate that potential failure mechanisms were present and could have been identified Ref. Appendix E4 (Fig 42)..

Without the benefit of hindsight, but with recent past experience the 'Project execution plan' developed for project 2 was challenged by the project manager on grounds of inadequate funding and engineering design man-hours.

Senior management, however took the view that the project manager was trying to add a 'comfort factor' and that the project should proceed as sanctioned.

It was the project managers view from the outset that the framework for delivering a successful project was not in place, despite having followed the organisations project execution procedures. As a consequence the subsequent audits simply recorded the predictable outcome.

The main reasons for the project managers concern were difficult to quantify and argue as they were largely based on the errors brought about by the over optimistic man-hour assessments provided by the Drawing Office manager. Many of the risks were of a covert nature, requiring a far more detailed risk evaluation than the generic cost based risk techniques advocated by the organisations procedures.

The mental process of identifying the specific project management risk issues undertaken by the project manager has been developed into the ConSERV concept.

In the final analysis the fears expressed by the project manager proved well founded as the project overshot the budget and as can be seen from the research findings exhibited numerous design related difficulties. Ref. Appendix C10 (Fig 23)

Conflicting issues encountered at the front end pre sanction phase of the project should be able to be resolved using the CDEX technique proposed by *Harrington*[7]

5.5 Conclusions and references

5.5.1 Conclusions

This Chapter has outlined how the ConSERV concept is being developed as a KBS project management technique designed to manipulate and administer the application of various project management tools rather than simply become one of them.

The concept is being designed to handle specific project management problems by employing knowledge based technology to assist with decision making during the management life cycle of multidisciplinary design intensive capital projects.

Correctly applied, the process of *identifying* the project, and its associated *risk issues* should provide sufficient information to allow the KBS to make a valid contribution in determining the real engineering and risk management man-hours incurred.

Insufficient man-hours are a major reason for project failure and design error, that usually translates into some form of mishap or more seriously, an accident.

Kletz [8] suggests that "we should let the term 'human error' fade from our vocabularies, stop asking if it is the 'cause' of an accident and instead ask what action is required to prevent it happening again". Over kill on man-hours is no guarantee of success, and as most experienced project managers are aware, being over generous with contingencies when structuring budgets will simply reduce the viability of the project and the justification of the Capital Expenditure. The dilemma facing project managers is that they instinctively "know" that "things" are likely to occur over the life cycle of the project but they don't know when, why or how. The contribution to project success provided by ConSERV is to extract and use key information concerning the project being managed in order to anticipate the specific needs and satisfy the main success criteria and risk issues. Ref. Appendices E3 and E4.

In concluding it is worth revisiting the opening sentence to better appreciate why it is, that only manageable projects can be managed, i.e. successful projects must incorporate the essential elements for project success from the outset. *Possessing a valued recipe and the ingredients does not automatically guarantee a successful dish. Similarly no matter how good the chef, without the right ingredients the meal will not be a success.*

5.5.2 References

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3 Barringer, H. Fisher, M. Gabbay, D. and Hunter, A (1993) *Meta Reasoning in Executable Temporal Logic.* In: ESPRIT Basic Research Action 3096 (SPEC)

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5 Conroy, G. and Soltan, H. (1997) 'ConSERV, a Methodology for managing multi-disiciplinary engineering design projects'.
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8 Conroy, G. Demonstrator Report (Ref. DR/001/96) submitted Jan 1996

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APPENDIX E

APPENDIX E

CONCEPT SYSTEMIGRAM
STAGES 1 AND 2 OF DEMONSTRATOR A
RISK ASSESSMENT OF CASE STUDY 2
KNOWLEDGE ELICITATION PROFORMA
DECISION MAKING FRAMEWORK
RULE LISTING FOR DEMONSTRATOR A

APPENDIX E

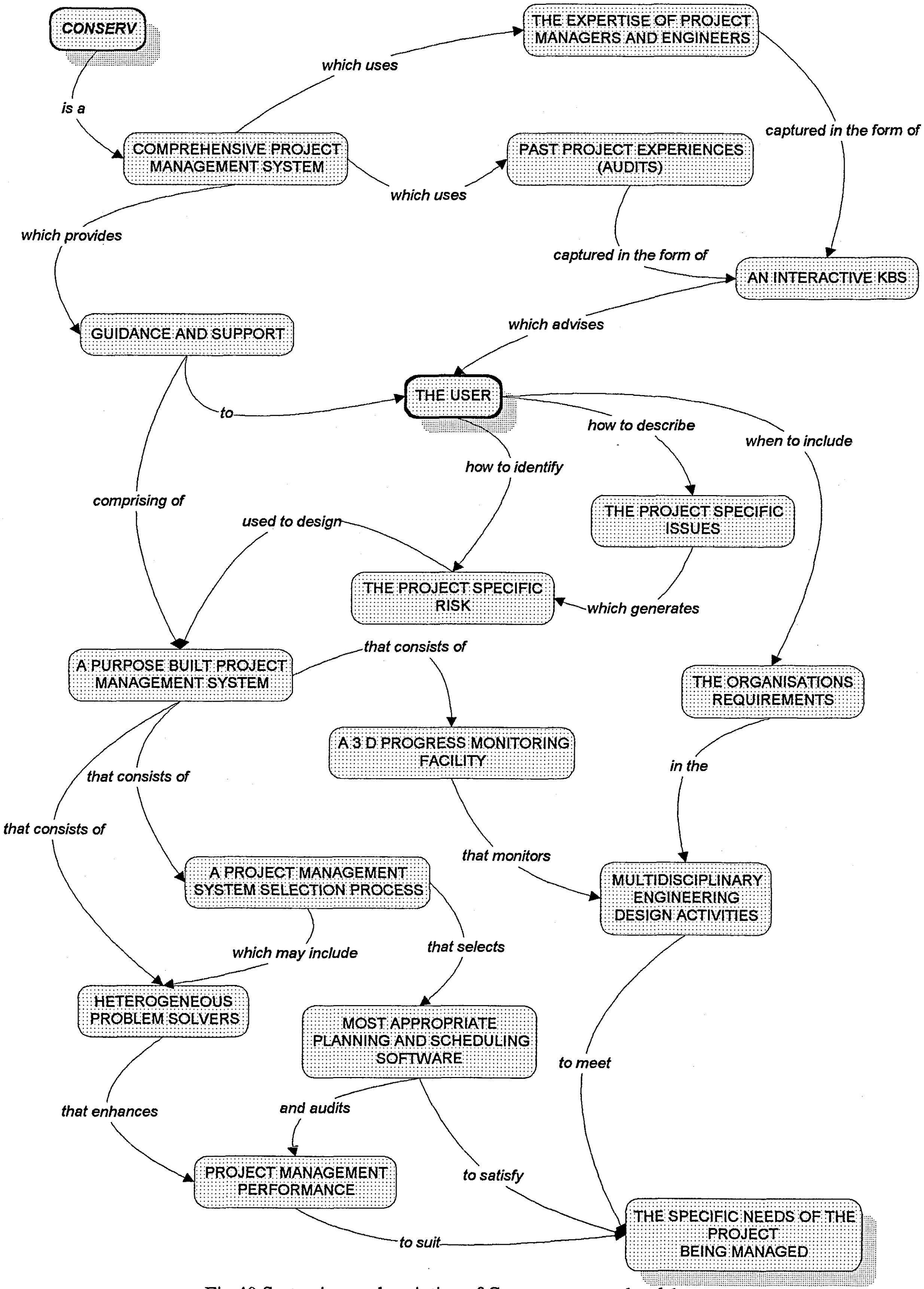


Fig 40 Systemigram description of Conserv concept level 1

APPENDIX E

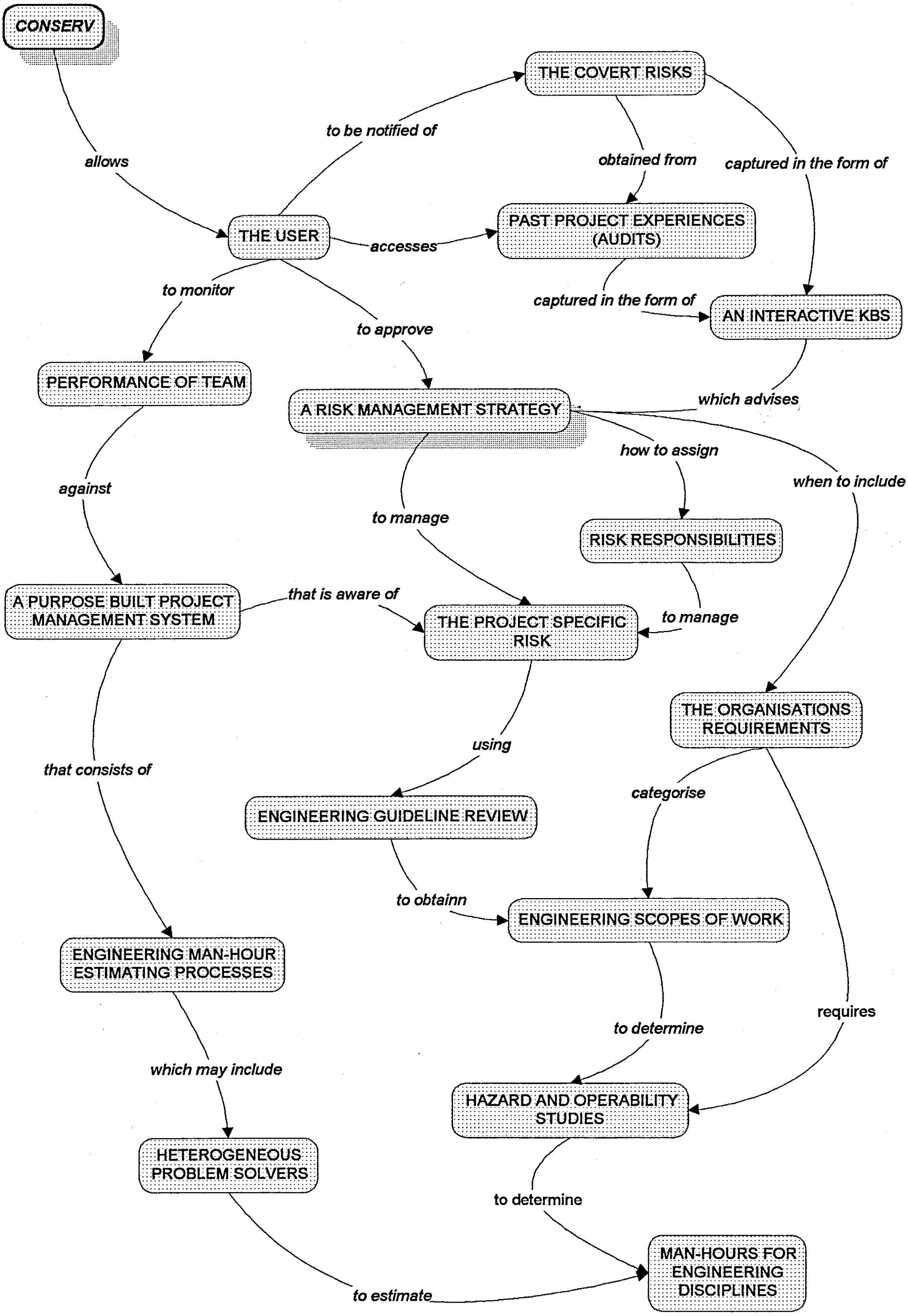


Fig 41 Project risk and identification procedure level 3

APPENDIX E

COST BASED RISK ASSESSMENT OF CASE STUDY 2 PROJECT

GEOFF CONROY

NEW DIGESTER PROJECT RISK ASSESSMENT

		RISK FACTORS		RISK EFFECT	
RISK ELEMENT	A BASIS	B MAX RISK	C REAL RISK	A*C	REMARKS
1.0 TECHNICAL RISKS					
1.1 BASIC ENGINEERING FRONT END	£1,030,000.00	0.2	0.1	1,030.00	
1.2 NEW TECHNOLOGY	£2,800,000.00	0.3	0.15	4,200.00	
1.3 SCALE UP	£0.00	0	0	0.00	
SUB TOTAL	£3,830,000.00			5,230.00	
2.0 ESTIMATION ACCURACY					
2.1 EQUIPMENT (INCLUDING INCIDENTALS)	£804,610.00	0.4	0.2	1,609.22	
2.2 SUB CONTRACT STEELWORKS	£250,000.00	0.02	0.01	25.00	
2.3 CIVILS	£153,200.00	0.2	0.15	229.80	
2.4 PIPING AND VALVES	£388,300.00	0.2	0.1	388.30	
2.5 ENGINEERING HOURS	£186,000.00	0.2	0.1	186.00	
2.6 SITE ELECTRICAL WORKS	£157,000.00	0.4	0.2	314.00	
2.7 SITE CONSTRUCTION	£281,500.00	0.4	0.2	563.00	
2.8 INSTRUMENTATION	£218,905.00	0.2	0.2	437.81	
2.9 INSURANCE	£0.02		0.05	0.00	
SUB TOTAL	£2,439,515.02			3,753.13	
3.0 EXECUTION RISK					
3.1 ENGINEERING RISKS	£1,000,000.00	0.2	0.17	1,700.00	
3.2 CLIENT INFLUENCE RISKS	£200,000.00	0.8	0.2	400.00	
3.3 SUPPLIERS INFLUENCE RISKS	£240,000.00	0.4	0.2	480.00	
3.4 SPECIAL NEEDS RISKS (SPARES)	£85,813.00	0.4	0.2	171.63	
3.5 ERECTION RISKS	£281,500.00	0.4	0.2	563.00	
3.6 COMMISSIONING RISKS	£100,000.00	0.5	0.25	250.00	
3.7 SNAGGING / CLOSE OUT RISKS	£50,000.00	0	0	0.00	
3.8 RISK OF INACCURACY OF EQUIP LIST	£24,000.00	0.3	0.15	36.00	
SUB TOTAL	£1,981,313.00			3,600.63	
4.0 COMMERCIAL / CONTRACTUAL RISKS					
4.1 RISKS FROM DEFERRED PAYMENTS	£0.00	0	0	0.00	
4.2 RISK OF NEGATIVE CASH FLOW	£80,000.00	0	0	0.00	
4.3 RISK OF CURRENCY FLUCTUATION	£0.00	0	0	0.00	
4.4 RISK OF UNFORESEEN TAXES	£0.00	0	0	0.00	
4.5 TOTAL LIABILITY RISK (10% MPI/CONST)	£483,900.00	0.3	0.1	483.90	
4.6 RISK OF FAILING TO MEETPERFORMANCE	£2,000,000.00	0.2	0.1	2,000.00	
4.7 RISK OF DEFECTIVE MATERIALS	£100,000.00	2	0.5	500.00	
4.8 OTHER CONTRACTUAL RISKS	£50,000.00	0	0	0.00	
SUB TOTAL	£2,713,900.00			2,983.90	
5.0 EXTERNAL RISK FACTORS					
5.1 RISK OF ADVERSE CLIMATIC CONDITIONS	£200,000.00	0.4	0.2	400.00	
5.2 RISK OF INDUSTRIAL DISPUTES (STRIKES)	£100,000.00	0.3	0.15	150.00	
5.3 RISK OF INFRASTRUCTURE BREAKDOWN	£500,000.00	0.2	0.1	500.00	
5.4 RISK ISSUES PECULIAR TO PROJECT	£0.00	0	0	0.00	
SUB TOTAL	£800,000.00			1,050.00	
OVERALL TOTAL				16,617.66	
RISK DILUTION FACTOR BASED ON LIKIEHOOD OF SIMULTANEOUS RISK OCCURANCE			0.6	**9,970.59**	

Fig 42 Project 2 Cost based Risk Assessment summary

APPENDIX E

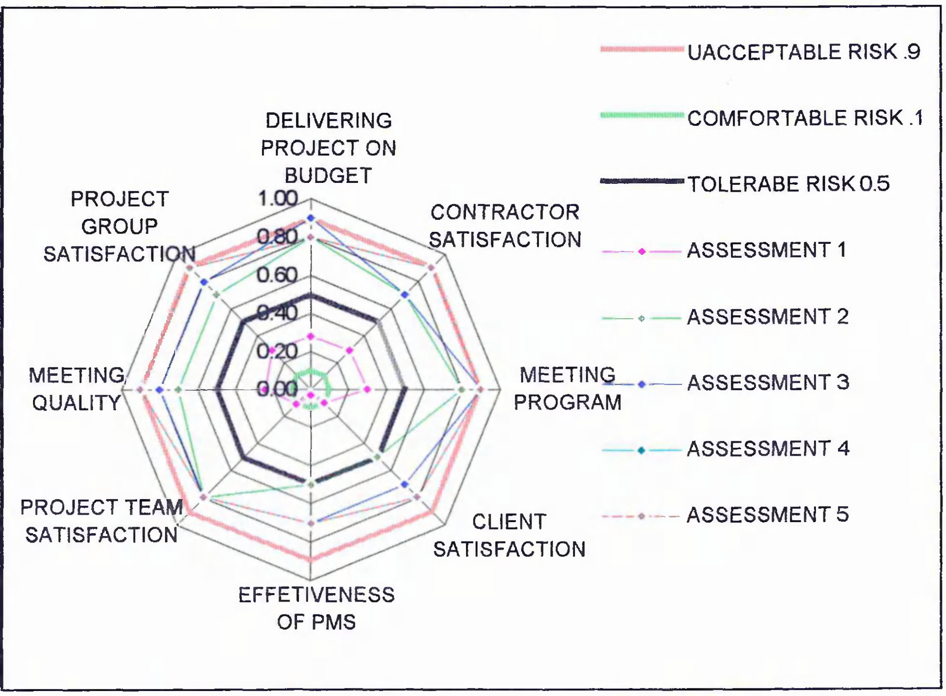
HYPOTHETICAL PROJECT AND SCENARIOS

Project X is being undertaken in the **chemical industry**$_1$ based in **Europe**$_{2a}$ at the **Birmingham**$_{2b}$ plant. The project is a **Design and build**$_{3a}$ capital project that is **unlikely** to be affected by **other projects**$_{3b}$ and is financed by the **Parent organisation** as a **lump sum red book contract**$_{3c}$.
The project involves **Distillation processes**$_{4a}$ and the main plant items include:- **Vessels, pumps, distillation columns and tanks**$_{4b}$. The project which **includes modifications**$_5$ to existing plant has a **capital value of £ 5.6 M** $_6$. The project will be **Time driven**$_7$. and will use **combined engineering design resources**$_8$. The project will be undertaken in accordance with established **company procedures**$_{10}$. and using Microsoft V4 **Level 3 WBS** is planned to take **17 months**$_{9a}$
From the information and scenarios given Ref p 102 Please rate the project success criteria using the prescribed assessment forms, assume project reverts to initial conditions (Assessment 1) after each scenario.

RISK MEASUREMENT

0.0 = No quantifiable Risk
0.1 = comfortable risk
0.2 = little risk
0.3 = possible risk
0.4 = measurable risk
0.5 = tolerable risk
0.6 = considerable risk
0.7 = significant risk
0.8 = excessive risk
0.9 = unacceptable risk
1.0 = Max risk

Representation of certainty
CF = Certainty factor
+1 = sure proposition is true
-1 = sure proposition is false
CF = (MB - MD)
Where MB = Measure of belief and,
MD = Measure of disbelief



Project success criteria	DELIVERING PROJECT ON BUDGET	CONTRACTOR SATIS	MEETING PROGRAM	CLIENT SATIS	EFFECTIVE PMS	PROJECT TEAM SATIS	MEETING QUALITY	GROUP SATIS
Assessment 1 (As described)	0.3	0.3	0.3	0.1	0..3	0.1	0.25	0.3
Certainty Factor								
Assessment 2 (Scenario 1)	0.8	0.7	0.8	0.5	0.5	0.8	0.7	0.7
Certainty Factor								
Assessment 3 (Scenario 2)	0.9	0.7	0.9	0.7	0.7	0.8	0.8	0.8
Certainty Factor								
Assessment 4 (Scenario 3)	0.8	0.5	0.8	0.5	0.7	0.8	0.5	0.8
Certainty Factor								
Assessment 5 (Scenario 4)	0.8	0.9	0.9	0.8	0.7	0.8	0.9	0.9
Certainty Factor								

Fig 43 Hypothetical Project showing risk changes due to various scenarios

APPENDIX E

Relationship between knowledge based planning and analysis

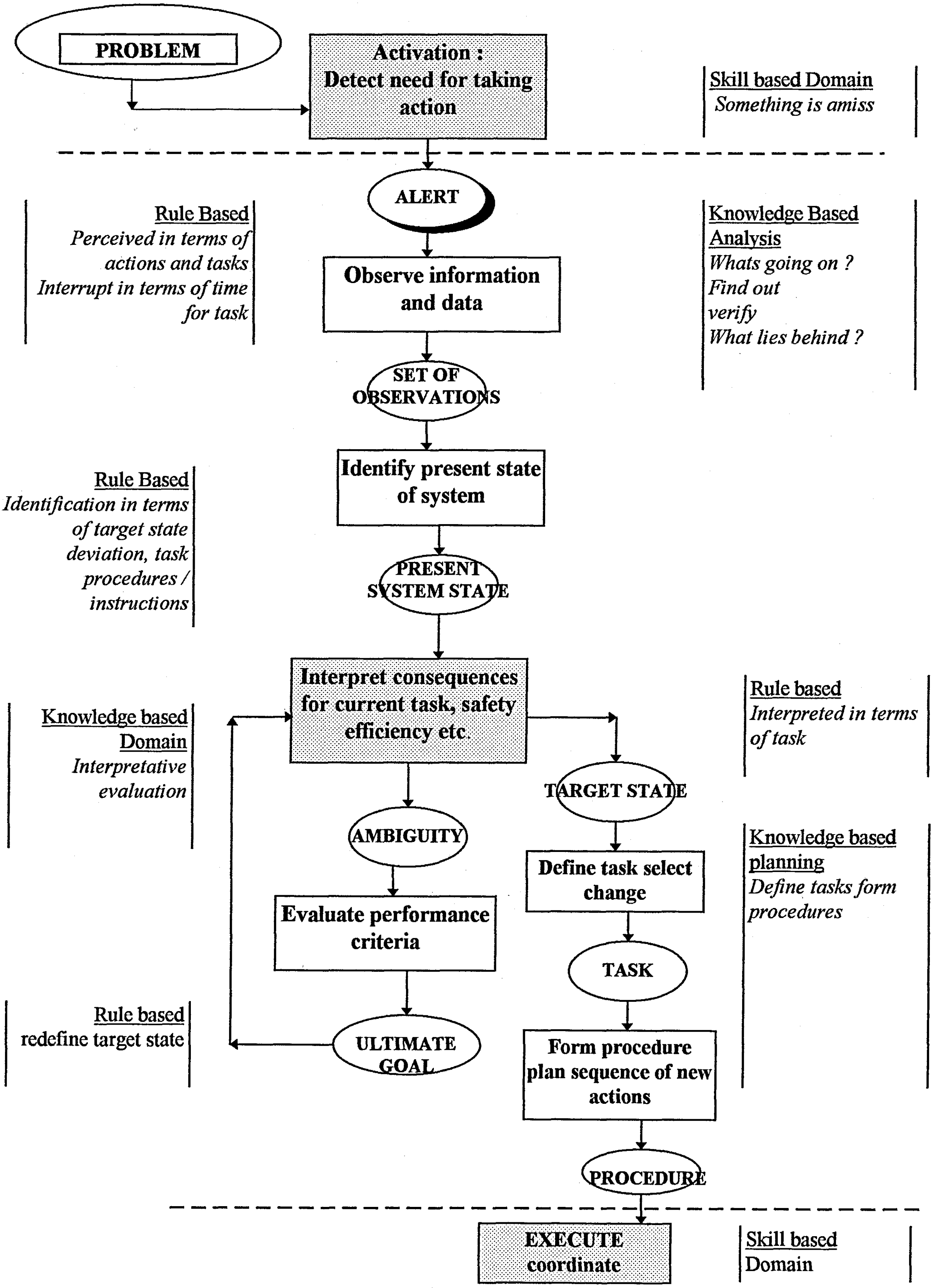


Fig 44 Diagramatic representation of relationship between planning and analysis

APPENDIX E

Hypothetical project X Cause and Effect Analysis

The general census

On face value the shape of project X is good, Process is known, there are no likely adverse affects from other projects, planning is to a level 3 WBS, the main plant items have been identified, Company procedures are being followed the success criteria have been identified and the budget and duration seem reasonable.

The Effects of Scenario 1

Cause: 25% into life cycle of project requirement for 20% increase in production capacity

This is a late scope change which requires redressing the whole project risk category 3

Effect 1 Unable to proceed with any further design or construction work

Effect 2 need to undertake redesign work resulting in abortive effort

Effect 3 Re order of main plant items necessary incurring cancellation costs

Effect 4 If Scope change covered by contract should result in no budget effects
If alliance type contract may impact profit margins

The effects of Scenario 2

Cause 50% into project a 5% slippage is recorded

This is a situation requiring investigation by the project manager as the cause is uncertain.

Effect 1 Reduces confidence in out turn of project Risk of meeting program increases

Effect 2 Triggers actions 5% slippage is considerable so early into the project.
Resource usage Problem or Information flow problem.

Effect 3 Increases risk in effectiveness of project management system

The effects of Scenario 3

Cause replacement of Planning Supervisor 60% into project

Outside of the control of the project manager, change to planning supervisor (PS) so late causes major difficulties to construction works.

Effect 1 Reduces confidence, increases risk of meeting programme client sat etc.

Effect 2 Requires strategic input to ensure project needs are understood by new PS

The effects of Scenario 4

Cause control interface difficulties at 90% into project

Should have been picked up during design phase

Effect 1 Badly reduces confidence in maintaining program, client satisfaction, budget etc.

Effect 2 Triggers an emergency response from project team due to timing

Fig 45 Cause and effect diagram

APPENDIX E

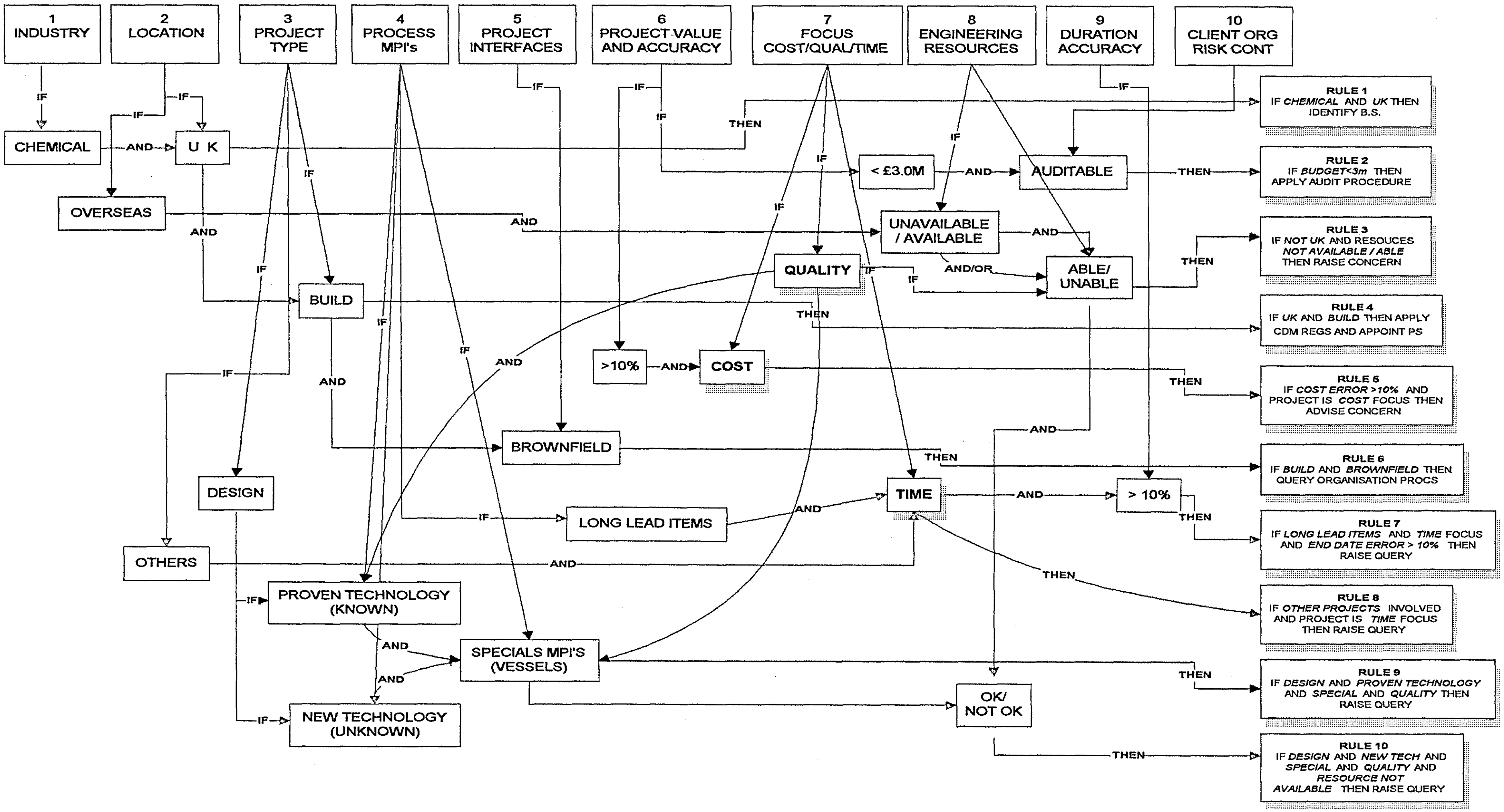


Fig 46 Key project dimensions and knowledge rules

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 1 DELIVERING PROJECT ON BUDGET (ASSESSMENT 1)

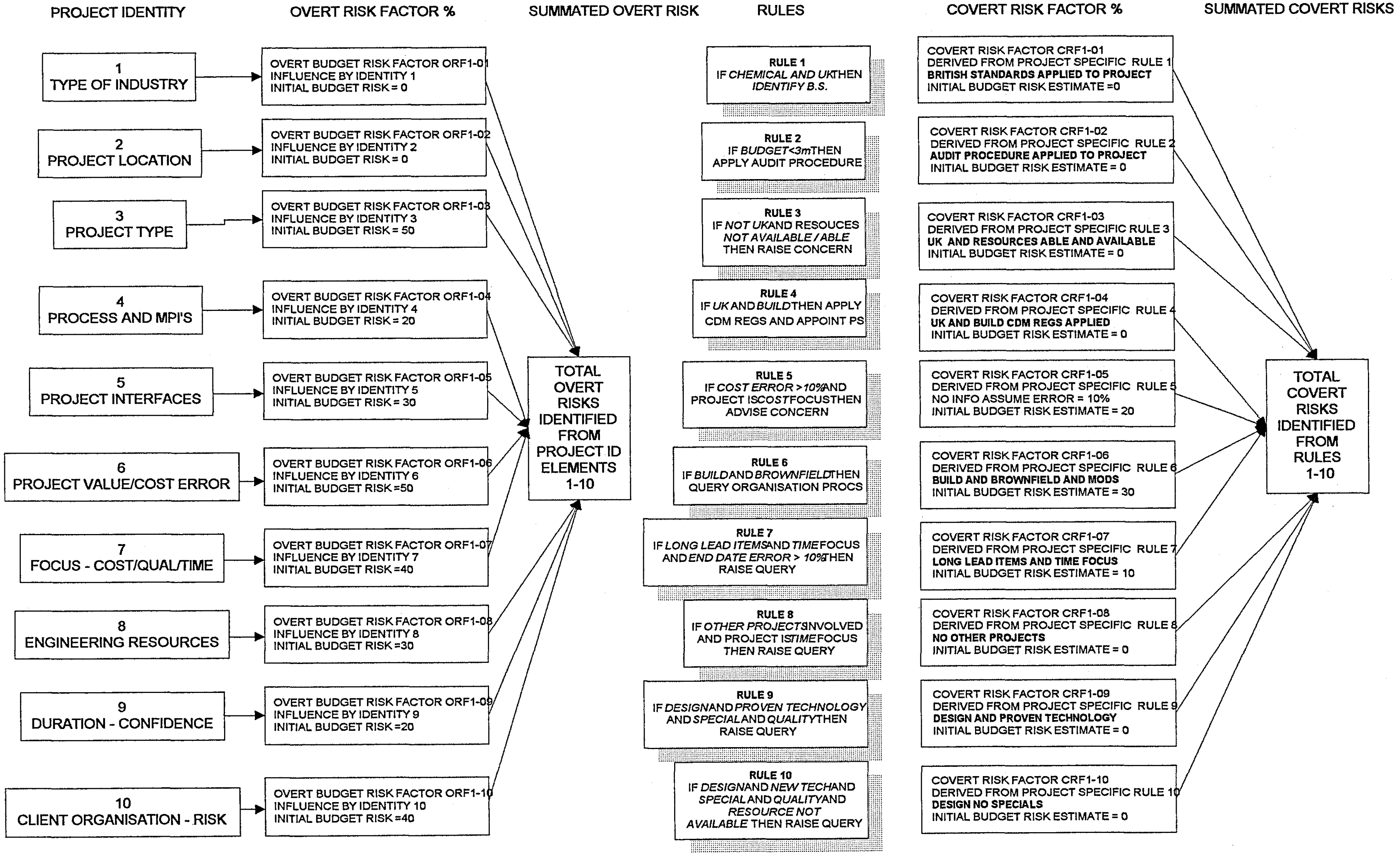


Fig 47 Success Criteria 1

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 2 CONTRACTOR SATISFACTION (ASSESSMENT 1)

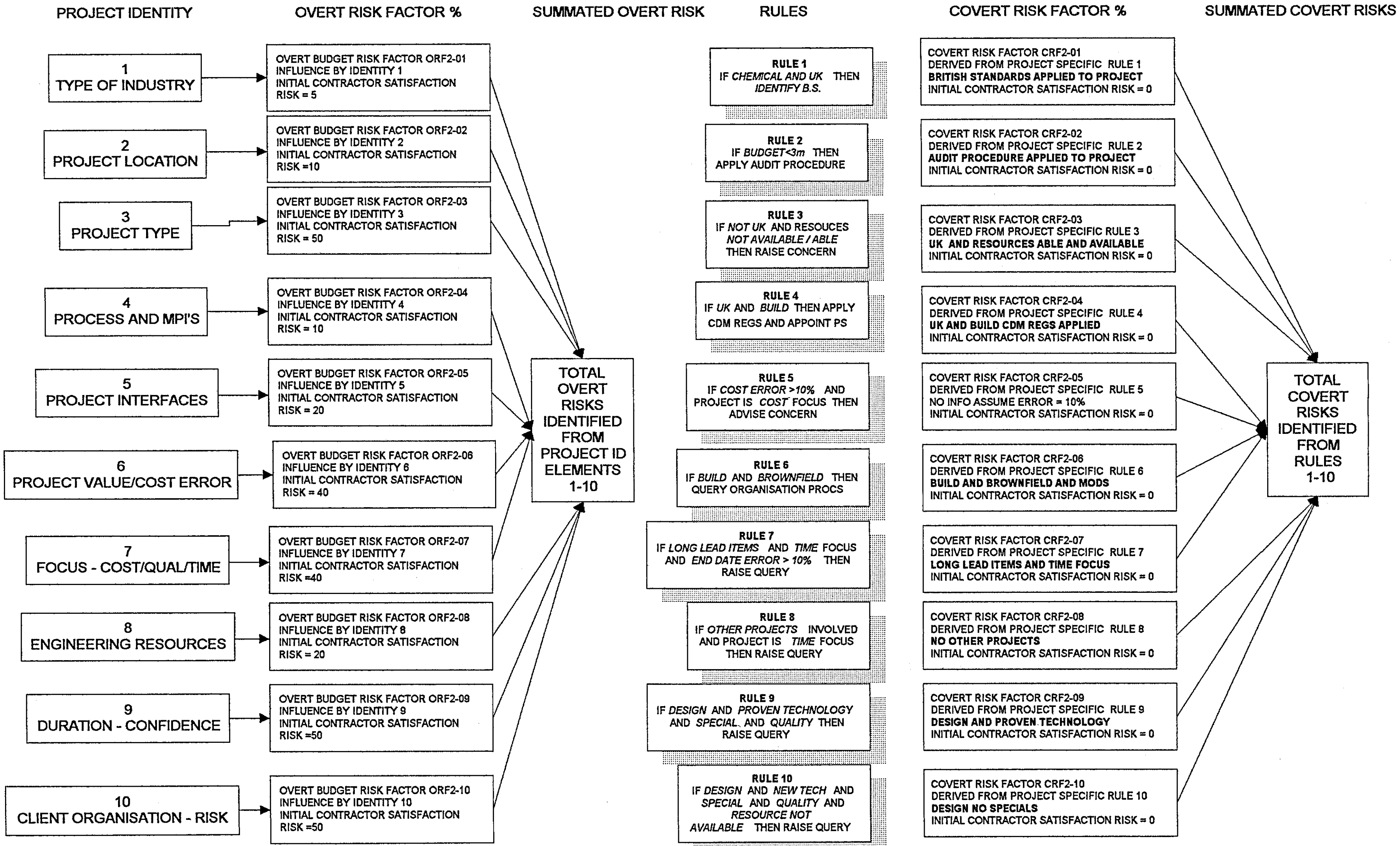


Fig 48 Success criteria 2

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 3 MEETING PROGRAM (ASSESSMENT 1)

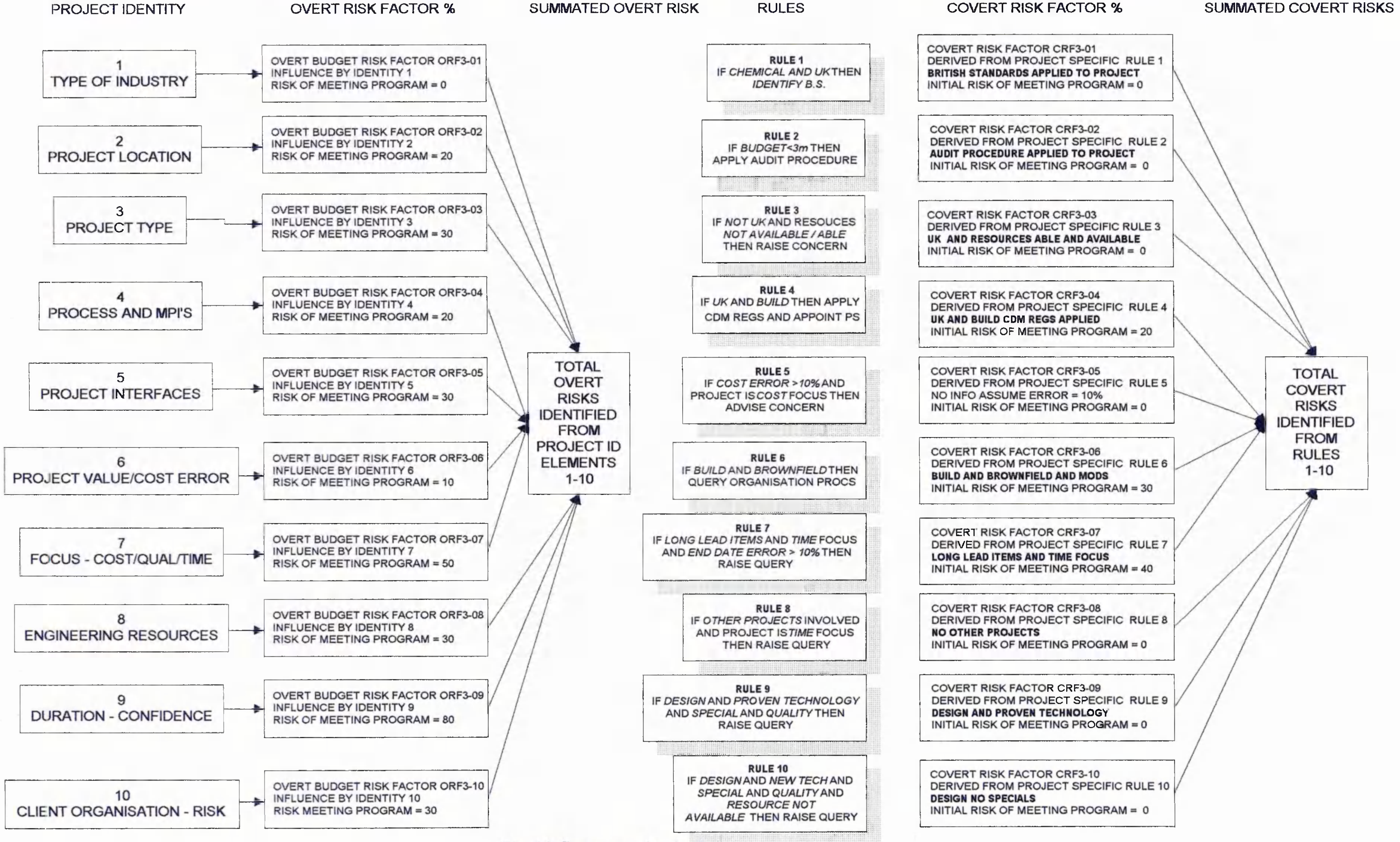


Fig 49 Success criteria 3

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 4 CLIENT SATISFACTION (ASSESSMENT 1)

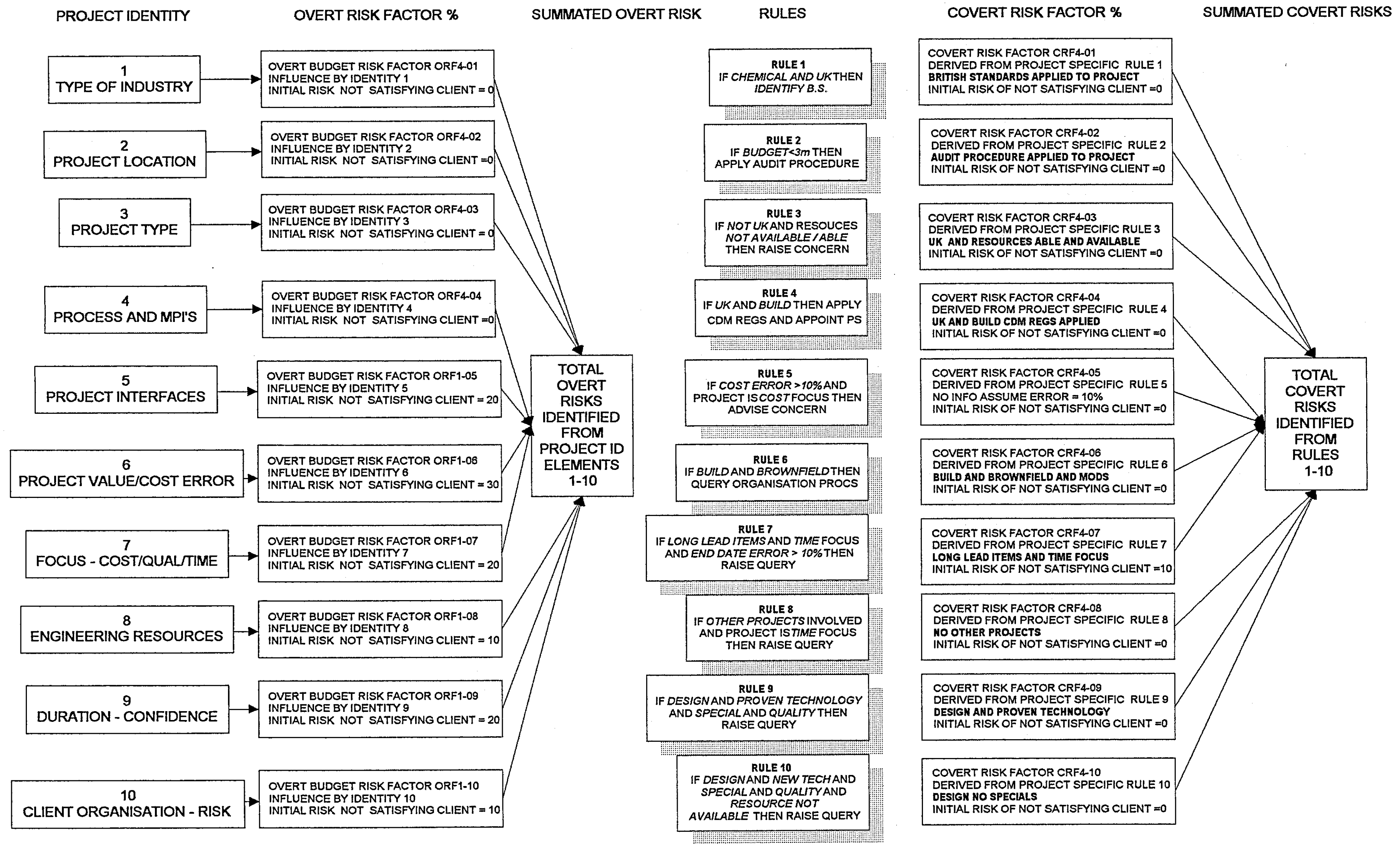


Fig 50 Success criteria 4

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 5 EFFECTIVENESS OF PMS (ASSESSMENT 1)

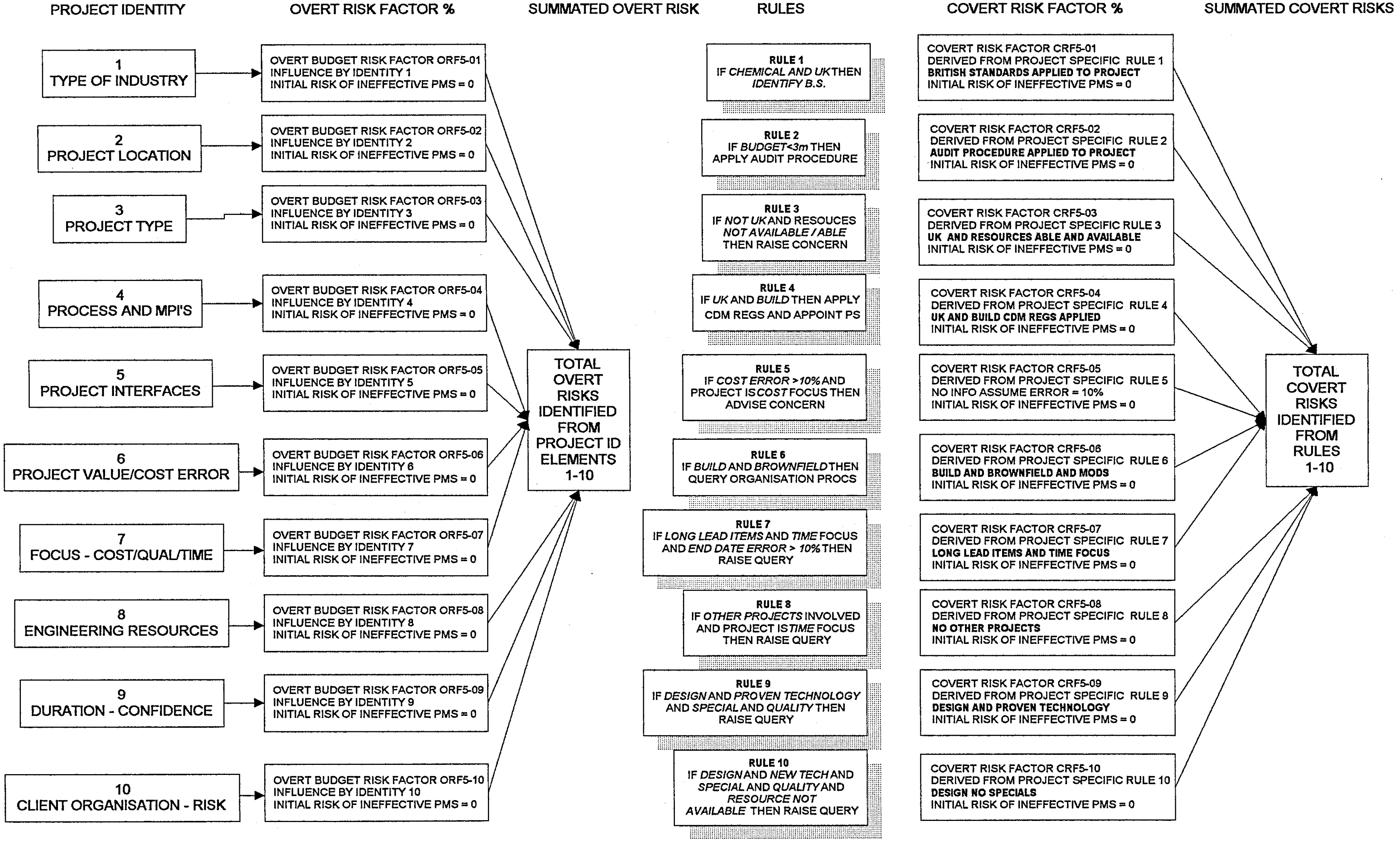


Fig 51 Success criteria 5

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 6 PROJECT TEAM SATISFACTION (ASSESSMENT 1)

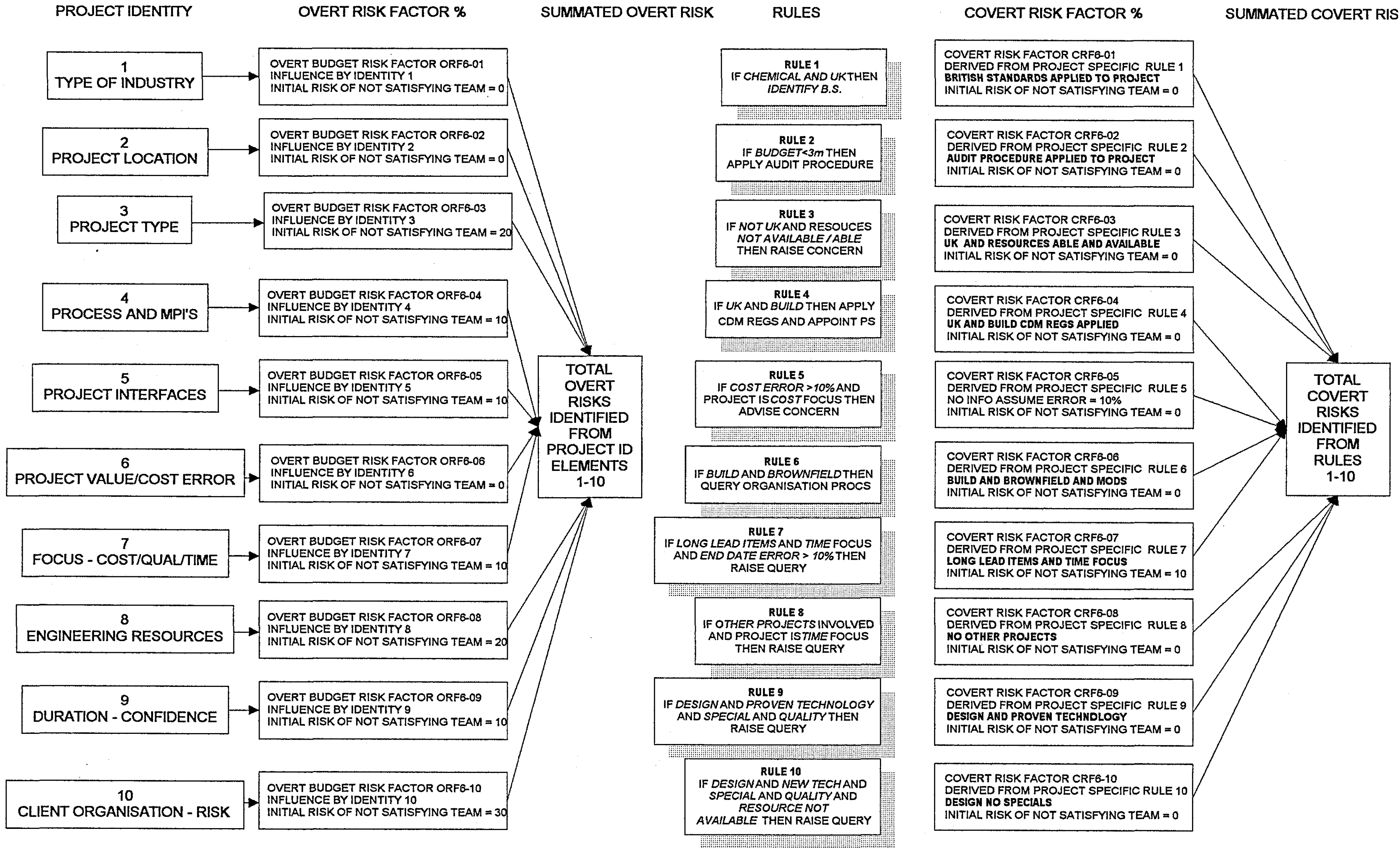


Fig 52 Success criteria 6

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 7 MEETING QUALITY (ASSESSMENT 1)

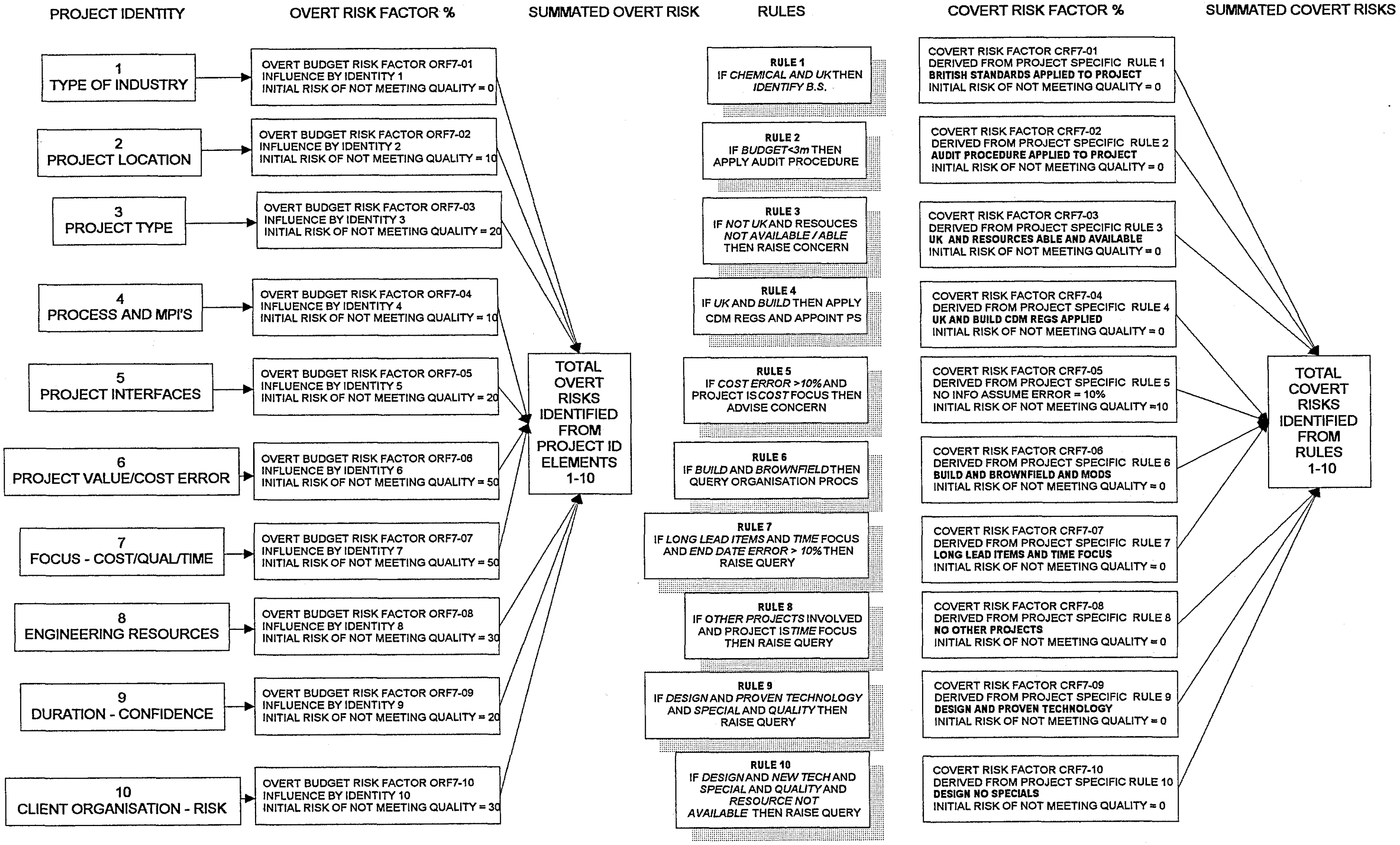


Fig 53 Success criteria 7

APPENDIX E

HYPOTHETICAL PROJECT X FACTORS AFFECTING SUCCESS CRITERIA 8 PROJECT GROUP SATISFACTION (ASSESSMENT 1)

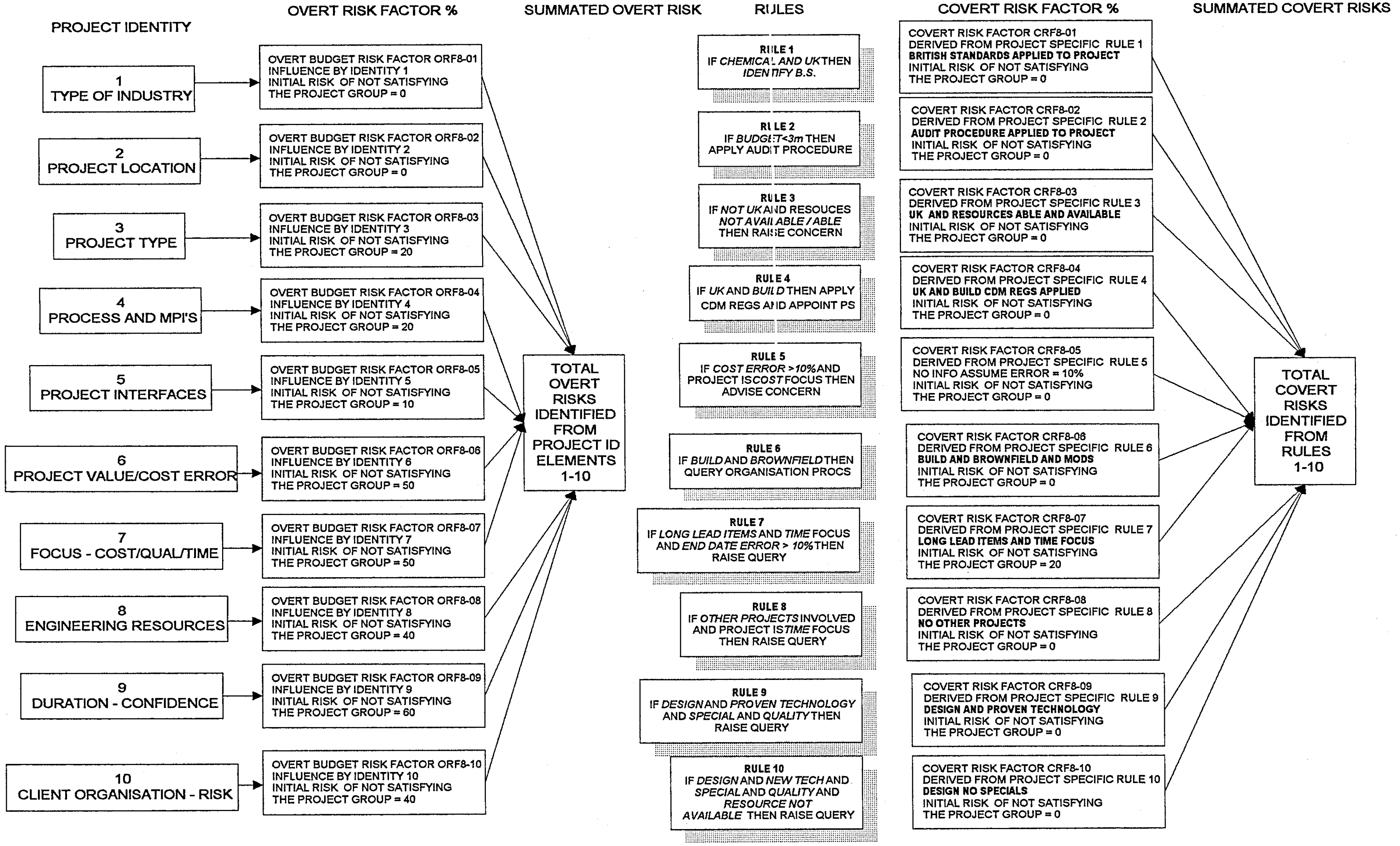
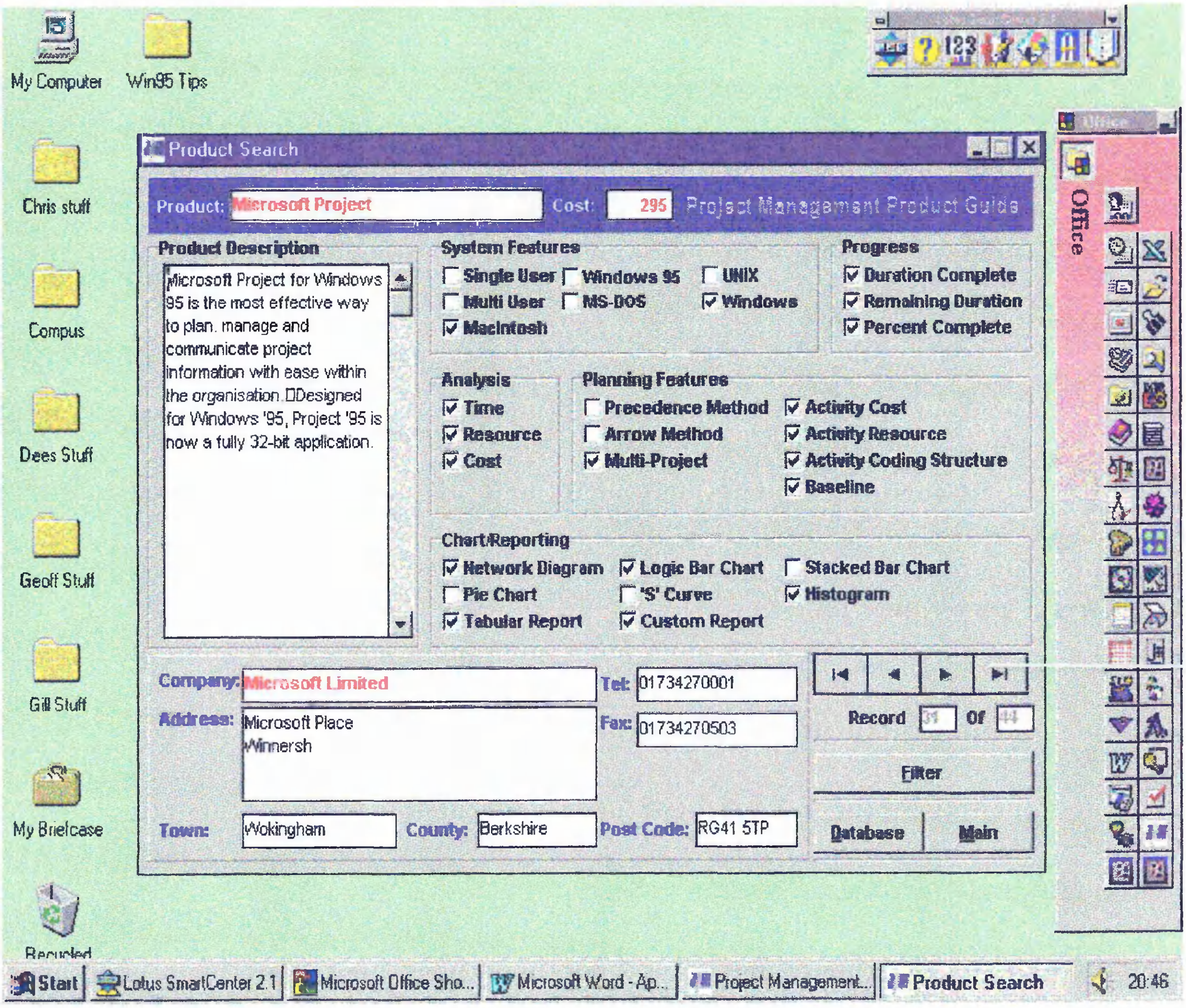


Fig 54 Success criteria 8

APPENDIX E



Product: Microsoft Project
Cost: 295

Microsoft Project for Windows 95 is the most effective way to plan, manage and communicate project information with ease within the organisation.□Designed for Windows '95, Project '95 is now a fully 32-bit application.

☐ Single User ☐ Windows 95 ☐ UNIX
☐ Multi User ☐ MS-DOS ☑ Windows
☑ Macintosh

☑ Duration Complete
☑ Remaining Duration
☑ Percent Complete

☑ Time
☑ Resource
☑ Cost

☐ Precedence Method ☑ Activity Cost
☐ Arrow Method ☑ Activity Resource
☑ Multi-Project ☑ Activity Coding Structure
☑ Baseline

☑ Network Diagram ☑ Logic Bar Chart ☐ Stacked Bar Chart
☐ Pie Chart ☐ 'S' Curve ☑ Histogram
☑ Tabular Report ☑ Custom Report

Company: Microsoft Limited
Tel: 01734270001
Address: Microsoft Place
Winnersh
Fax: 01734270503
Town: Wokingham
County: Berkshire
Post Code: RG41 5TP
Record 31 Of 44

Fig 55 Product selection software

Chapter VI

6.0 DESIGN ELEMENT OF THE CONSERV KBS CONCEPT

"Each time the Designer makes a decision there will result either a benefit or a penalty...designers decisions are never straight forward there is always the trade off to be made between the ideal and the practically achievable" *Starkey*[1]

6.1 Introduction

6.1.1 Overview

Chapter V described in some detail the more specific issues concerning the project management part of the ConSERV concept and provided an explanation of how the information obtained from the user could be employed in identifying the key issues of any given project.

The Chapter also alluded to the risk factoring process and the application of knowledge based rules associated with the key project elements, culminating in the generation of a radar graph Ref. Appendix E5. (Fig 43)

It was shown that the shape of the graph provides the user with a strong indication of the main risk areas of the project, and how the system provides a selection basis for determining which project management tools and methodologies are deemed most suitable to satisfy the specific needs of the project being managed.

In contrast, Chapter VI looks at the *engineering design* process associated with the concept and how the information flow issues are `managed` in a Workflow environment.

This Chapter has been included to provide examples of the various engineering design failure mechanisms identified from the industrial research and how they can be minimised by using the ConSERV concept.

This Chapter also describes how the knowledge and information obtained in the project management element of the concept (*the project specific data*) can also be used to assist the design effort.

6.1.2 The Background

The background of the concept originates from the design approach commonly used to handle the engineering design information associated with multi-disciplinary engineering activities. A number of similarities exist between engineering design and project management, specifically those associated with managing multidisciplined personnel, information, data and documentation within the constraints of a major organisation.

The similarities between *engineering design* and *project management* lead to the notion of developing a visual representation of the multifaceted aspect of multi-disciplinary engineering design and project management, i.e. the 3D model.

In order for the "Engineering resource view" element of the concept to function as a knowledge based system it was necessary to develop a structure in which the *engineering design* risk issues could be identified, evaluated and ultimately integrated into the framework of the concept as a whole.

The very fact that the *project management* and *engineering design* functions are inextricably entwined within the project group presents something of a dichotomy.

The advantage of merging the two functions is, that if structured correctly, the project specific data obtained in the question and answer routine can be used to identify both project management and engineering design risk issues. Ref. E8. (Fig 46)

The disadvantage being that *engineering design* activities are somewhat autonomous and do not readily lend themselves to being integrated into the *project management* environment.

The comprehensive knowledge based project management system proposed in this submission affords a practical method of not only integrating the design function but also providing both decision support and a visualisation of the design functions and design progress.

6.1.3 Managing Engineering and Engineering Design activities

The management of engineering design activities within a major organisation embodies the same kinds of hard and soft skill problems as those identified in Chapter II . The main functional similarities that exist between *project management* and *engineering design* are shown in Fig 56 below.

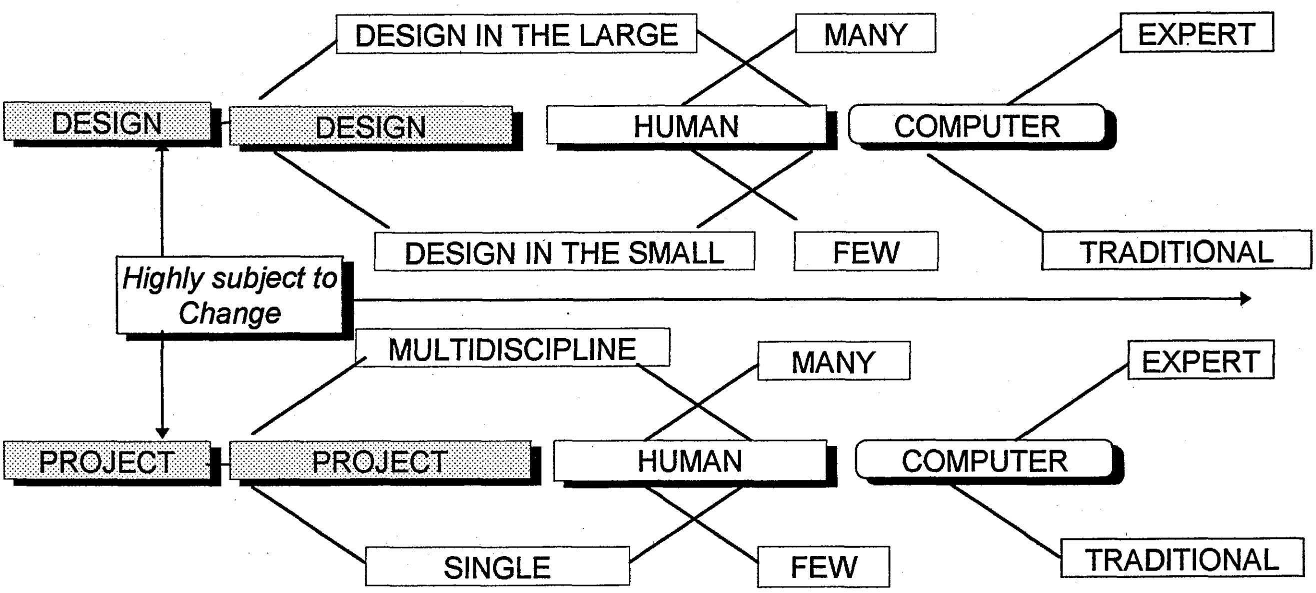


Fig 56 Structural similarity between project and design functions

Fig. 56 shows the strong similarity between the 'Design' domain and the 'Project' domains. In many organisations the two functions are not fully integrated as the *engineers* interests are often in conflict with those of the *project manager*.

Engineering man-hours are the only **real** resource that a design intensive project has. Managing the design effort and estimating engineering design man-hours is a very difficult process as a fine line has to be drawn between over-designing and under designing whilst maintaining and satisfying the project requirements. *Newtown* [2] identified one of the major causes of project failure as ambiguity concerning the project objectives, this is particularly true for the engineering design objectives.

E.g. The design specification, engineering standards, QA procedures. etc.

6.1.4 Planning design activities

All planning tools use 'activity data' supplied by the planner or the engineer, this data is generally based on the organisations norms[1] and the experience of the planners or the engineers responsible for developing the project program.

As was identified earlier traditional planning methods involve no intelligent input from the software packages, consequently any unrealistic program will not be challenged by the system, but will simply be executed. These types of software tools are entirely dependant upon the *quality* and *accuracy* of the data supplied for, the preparation of the plan, the updating of the programme status, and forecasting the probabilistic out turn.

Many projects in the Chemical industry, particularly multi-disciplinary **design intensive** projects, often fail to behave in a pre-determined fashion. i.e. they do not follow the master plan despite a high level of planning, scheduling and work breakdown. The design element of the ConSERV concept, is primarily concerned with the control and flow of *design critical* information between the respective engineering disciplines. Ref. Fig 27 p 82.

As was also identified earlier Ref. A5 (Table 1) engineering and engineering design activities involve considerable domain knowledge in order to address the specific design issues. Ref. Appendix A5 (Table 1)

Design information relating to a specific design problem is often incomplete and conflictory. The progress of design activities is dependent on the number and speed of the design cycle iterations. One of the main difficulties in developing programs for design activities was identified in the industrial research Ref. Appendix C8 (Fig 21).

The original estimate of the design man-hours associated with the activity, considered only the **actual** design time involved with engineering calculations and draughting time. As can be seen from the example, the design element was far more involved and required numerous design revisions and interdisciplinary exchanges to reach a satisfactory conclusion.

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[1] By Norms we mean the industry accepted durations for performing measurable amounts of work E.g. The man-hours to produce an isometric pipe drawing.

6.1.5 Concurrent Engineering (CE)

Most project managers are aware that projects are built up of tasks and tasks are a collection of activities. Planners tend to divide the activities into sufficiently small elements such that they can effectively define *work* in the form of a Gantt chart or bar chart activity program. i.e. Duration, resources, dependencies etc.

Where these activities are shared by more than one discipline, such as *engineering design*, it is necessary to obtain interdisciplinary agreement in order to proceed.

E.g. The agreement between a process engineer and an instrument engineer on the most suitable control system for a specific process.

Disagreement or conflict can exist, not only between discipline engineers, but also between engineers and the organisations procedures they are obliged to follow.

In order to resolve these subjective issues it is considered necessary to now look towards more able software techniques such as Knowledge Based technology which affords expert advice in making complex decisions.

Obtaining concurrence in the design environment can be achieved if the design objectives are clear and precise, unfortunately in many projects the front end engineering design work is often undertaken with sketchy and uncertain information. In such cases the engineers may have to make assumptions about the design objectives. E.g. Design for cost, design for quality, design for reliability etc.

In making these global assessments, the designer will also make decisions about the design itself. The design specific assumptions are influenced by the individuals heuristics concerning the complexities and sensitivities of the project. E.g. The clients QA requirements, the safety issues, the plant location and interface problems etc.

The lack of detailed information available at the front end phase of the design cycle places an onerous responsibility on the part of the designer who is often the least informed about the global factors of the project as a whole. This was one of the major complaints of the designers interviewed during the research. By capturing the salient elements of the project in a few paragraphs Ref. p93 (Fig 34), the design group can assess the design involvement in a far more informed manner than having to rely on third party interpretation.

6.1.6 Design controls

Virtually all major organisations employ 'controls' as a pre requisite when undertaking engineering and engineering design activities. The main functions of the control mechanisms are to minimise the risks of non productive, abortive, or misdirected effort. It is generally accepted that the effects of these risks are far greater in the early conceptual stages of multi-disciplinary design than at any other time in the project. Ref. Ullman diagram Fig 57.

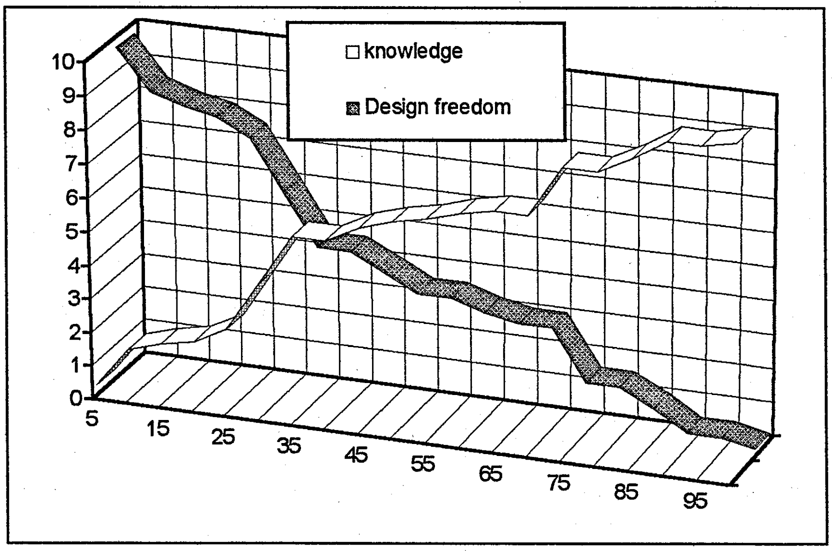

Fig 57 Ullman diagram

Design controls, normally include engineering standards and procedures that are agreed with the client at the outset of the project.

Due to the generic nature of engineering design procedures it is likely that they may well prove to be too general to be applied to a specific engineering design problem. Engineering designs require a combination of both innovative (creative reasoning) and structured (methodological reasoning) processes. This esoteric relationship often appears to be contradictory, however as *Starkey*[1] identified, "the two widely differing skills are usually applied to the design process consecutively rather than concurrently with the less productive **conceptual design** phase preceding the more productive **detail design** phase".

6.2 Design Risk factors and success criteria

6.2.1 Risk factors

The project management element of the concept used *project specific data* in order to establish *project specific risks* and applied knowledge based rules to select the most suitable *project management system*.(pms).

The design element employs a similar approach in obtaining *design specific data* to establish *design specific risks.* Design specific data can also be inferred from the project specific data. Ref. E8 (Fig 46)

The main risk factors associated with the *design related* activities include:

i/ The risk of **not** understanding the level of engineering involvement, and the **complexity** of the design issues. Ref. p177.

ii/ The risk of misinterpreting the **design/project brief**.

iii/ The risk of **omitting** the mandatory design/engineering constraints imposed by the client organisation.

iv/ The risk of omitting legislative and industrially imposed **design or procedural constraints.** E.g. EA or CDM regulations.

v/ The risk of **not** recognising the **limitations** of the respective discipline designers.

The types of risks identified have traditionally been managed through a combination of experience, heuristics, standards and procedures.

Without the use of a knowledge based system, the identification of the potential risk issues depends entirely on the expertise of the individual designer. As was identified from the test data on page 177 this is not always the most dependable method.

As we have already identified from the research work, expertise of this type is normally restricted to a single engineering discipline and is inevitably prone to human error. By definition any single discipline engineering designer (Mech. Elect.) will be unlikely to recognise and identify all the potential design risks associated with any multi disciplinary design.

The whole issue of identifying design risks is further complicated when the design basis is constantly changing, as tends to happen at the front end of design intensive projects.

6.2.2 Success Criteria

Identifying and managing design success criteria is just as complex as managing the project success issues. The design process can be a highly subjective business in which the designers preferences may be challenged for 'apparent' cost savings, usually by non engineering senior management stakeholders. Much of the recent CAD and CAE technology is designed to work within a 'workflow' environment such as ADMiT, however conflicting design issues do emerge during the design phase. Managing design conflict is essential to design success, and subsequently project success. *Harrington*[3] proposed a knowledge based approach CDEX to resolve engineering design conflicts, however in the business of managing the design issues of a major capital project, it is necessary to look beyond the *prima facie* purchase only costs of main plant items. Most plants are designed to give continued service for 10 to 15 years, many, operate considerably longer, a major selling point for a design group is the claim to offer a higher quality of *engineering design,* few deliver on the promise. Whilst most contracts are specific in terms of performance guarantees warranties and defects liabilities, the real costs to the project resulting from inferior equipment or inept design effort can be disastrous. BPEO and BATNEEC techniques are also an integral element in the process of developing a successful design.

6.2.3. Research Developments in Engineering Design

The *Engineering Design Research Applications*[5] being undertaken by the 6 EDC's are now showing a number of interesting results. Lancaster EDC for example have developed an expert system 'Schemebuilder' to improve the generation of conceptual design in a CE environment. Plymouth EDC have developed 'Adaptive Search' algorithms for closer integration with the design process. Newcastle EDC have recently (1996) selected/adapted 'Pro/ENGINEER' for joint company ventures.
The Design Council's research program builds on existing knowledge bases in such areas as *organisational behaviour, engineering, economics, strategy, finance* etc. The program is organised around research agendas overseen by an advisory board which also vets and monitors the projects. Strathclyde University is developing a process to integrate design specialists through the use of 'shared workspaces' designed to speed up the design process by linking people at different locations.

6.2.4 The Structure of the ConSERV Design aspect

The structure of the design aspect of the concept is similar to the project management element, with the subtle difference being that it is designed to monitor rather than select. The structural difference is shown below in Fig 58.

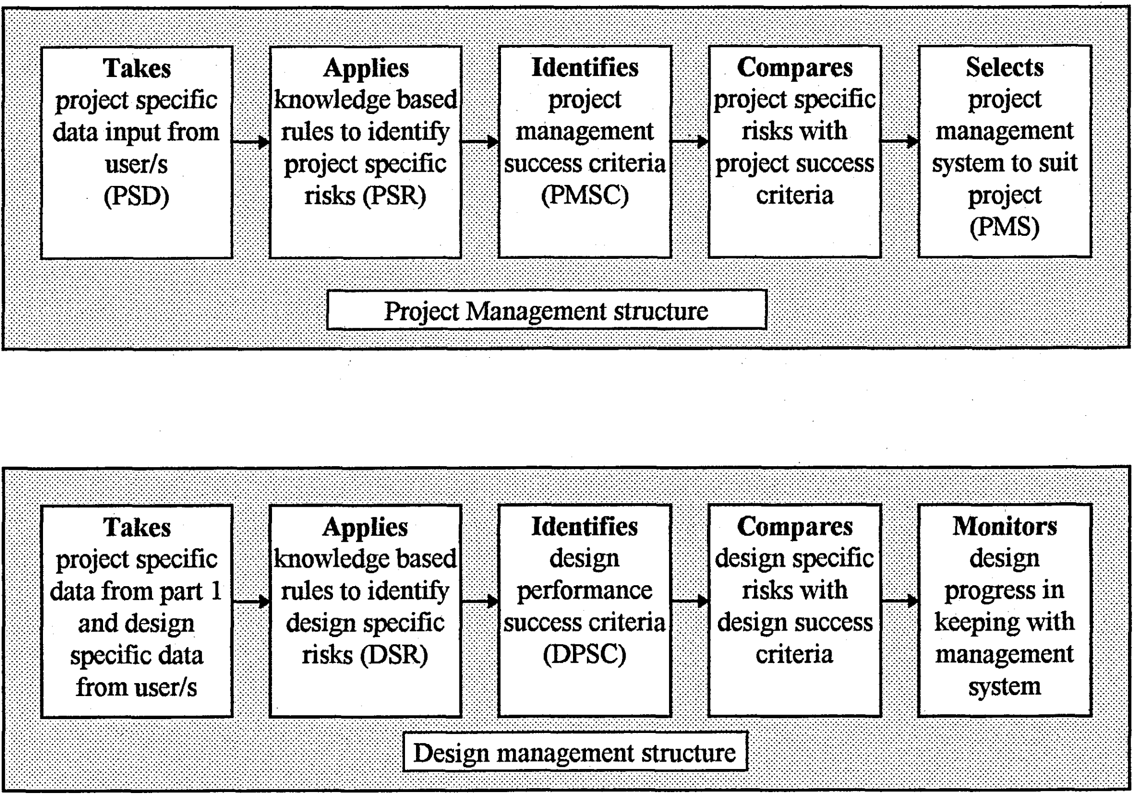

Fig 58 Structural differences between project management and design

Recognising the need for any system to operate within a workflow environment, the design element of the concept is being developed to view the exchanges of design critical information flow between the respective engineering disciplines.

6.2.5 Design Support

By employing the project specific data obtained from the first part of the concept, it is possible to introduce a number of strategic design support functions including :-

i/ Support in the management of design change control procedures.

ii/ Support in undertaking in depth design reviews and Hazop studies.

iii/Support in managing the legislative and environmental design requirements.

The design support is administered through the three dimensional visualisation element discussed later in the submission.

The technique enables each user to both interact with respective design engineers and monitor their own departmental performance. Ref. p83 (Fig 28).

Being knowledge based the system is also able to challenge design assumptions, by addressing the designer to key design considerations both during the conceptual stage and the detail stage of the design.

By allowing the 'knowledge base' to support the front end design team in their decision making the time required to 'close in' the design freedom indicated by the Ullmann diagram p112 could be drastically reduced.

E.g. Consider the task of 'designing' a control circuit for a pump system, in which the process fluids and transfer conditions are known. The design process is relatively easy as most circuits obey laws of Newtonian physics and are therefore mathematically predictable. Indeed many pump manufacturers will even provide bespoke software for sizing their products.

Many design problems are less to do with the algorithmic representation of the problem and more to do with the real world issues regarding installation, maintenance and operability.

E.g. Is the circuit design efficient ? Are the units repairable. ? Are the circuit controls integrated into a plant wide DCS (Distributed Control System) ? Are the drives suitable for the environment ? Is the design in keeping with CDM requirements ? Are the circuits adequately protected ? Does the design comply with the organisational requirements regarding preferred standards ? Does the design comply with the accepted industrial standards.? Does the design afford any contingency.?

6.2.6 Design Influence on Project Failure

In the eyes of the recipient, it is the lack of attention to the secondary issues that is often responsible for the 'apparent' failure of the project. The failure of a single design element will almost certainly be construed as a "project failure" even if the design issue involved is trivial. All too often the relatively small design omissions result in a much greater effect on the project as a whole, even to the detriment of the performance of the project and the inability to satisfy contractual performance criteria. The distinction between *project success and project management* success was clarified by *Munns and Bjiermi*[5] Ref. p5 As part of the testing of the concept it was applied to a project being undertaken in Huddersfield which showed that it is possible to identify design omissions and having recognised the potential for project failure, to implement corrective measures. In the case in point a formal hazard study had not been carried out and the project was 30% under budget when sanctioned. The project engineer had left the company and the project was shelved from Nov 96 to June 97. By applying a paper version of the concept to the project design issues a number of important design issues were identified.

i/ That the DMS storage vessel was not fit for purpose.

ii/ That the pump circuit could not be adequately flushed.

iii/ That the tanker discharging logic was flawed.

E.g. Having established from parts A1-A3 (Fig. 24) p 77 the project involves a **design** element and that the product being stored 'Dimethyl Sulphate' is a CIMAH classified substance then there was clearly a need to undertake a detailed Hazard study. *Taylor*[6] suggests a number of techniques to identify Causes of Failure and Hazards. The issue concerning this research effort is that the main *potential failure mechanism* for the whole project was identified as being the omission of critical design issues and the lack of communication between engineering disciplines. The fact that the main plant items had been ordered built and supplied demonstrated that the major project failure mechanism was the deficiency of the organisations management in failing to apply quality procedures. Had the vessel (as supplied) been put into service then a very real risk of vessel failure and DMS spillage existed, the consequences of which would have been catastrophic.

6.3 Logic, knowledge and data bases

6.3.1. The system's logic Ref Appendices F2 and F3 (Fig 63 and 64)

The logic employed in developing the design management element is generally of the *symbolic model* form. The key facet in determining the most appropriate uncertainty management technique for a given application is the consideration of how uncertainty is to be used in that reasoning task.

In recent years decision support systems have been developed which operate in highly circumscribed domains. In engineering for example decision support systems are applied to sub groups or restricted domains such as thermodynamics, fluid transfer, control theory etc. Determining a logic technique for a universal system is difficult as was identified by *Krause and Clarke* [7] who advocate that: "For small domains characterised by extensive quantitative data, Bayesian systems combined with classical decision making techniques may provide an appropriate platform for the implementation of expert advise systems. For the construction of systems in broad domains that are not extensively quantitatively parameterised, and where there are a vast number of potential tasks that may require assistance, Bayesian techniques in isolation will not be appropriate." Project management and more appropriately engineering design can be viewed as two such cases.

Symbolic decision theory proposed by *Clarke et al* [8] suggests that "It is frequently not the case in AI that a probability structure will exist for a given problem, rather, elicitation and construction of such a structure is a problem that has to be faced by the system designers. Similarly in decision analysis, a large part of the skill of the decision analyst is centred on the construction of a decision framework".

The requirements of a symbolic decision theory include :-

i/ To dynamically propose decision candidates.

ii/ To dynamically generate evidence relevant to the decision candidates.

iii/ To dynamically identify relationships among decision candidates relating to conjunctivity and exclusivity.

iv/ To operate in the absence of statistical parameters, but

v/ Incorporate these when available, and

vi/ To be generic and not limited to any particular decision task

6.3.2 Knowledge representation

In the design element of the concept knowledge is represented at three different levels of abstraction corresponding to :-

Domain facts, task specific knowledge, and generic decision procedures.

The **domain facts** are contained within the **design management knowledge base**, the **task specific knowledge** is that obtained from the **project specific data** of the concept and the **generic decision procedures** are governed by the **knowledge based rules** and the **organisational procedures**.

The domain facts employed in the design element of the concept are essentially descriptive propositions about the field of interest which may express qualitative relations (about causes, associations, taxonomic relations etc.) amongst entities, or quantitative parameters associated with these qualitative relations, such as the strength of an association.

In the field of engineering design qualitative relations can be sub divided into a number of classes including :-

Cause of design failure include_ Human

Kinds of Human failures include_ Inexperience. Ref. Appendix F4

Cause of design failure include_ Organisation.

Kinds of Organisational failures include_ Lack of communication. Ref. Appendix F5

Cause of design failure include_ Design group.

Kinds of Project Group failures include_ Inadequate design reviews. Ref.Appendix F6

Cause of design error include_ Inexperience

Cause of design error include_ No design checks

Cause of inefficiency include_ Lack of strategy

Cause of inefficiency include_ Failure to communicate requirements

Quantitative parameters

Prior probability of design failure = 0.03

Prior probability of inaccurate process data = 0.04

Prior probability of client scope changes = 0.05

6.3.3.Design Failure mechanisms

The main design failure causes identified from the industrial case studies are illustrated in Fig 59 below.

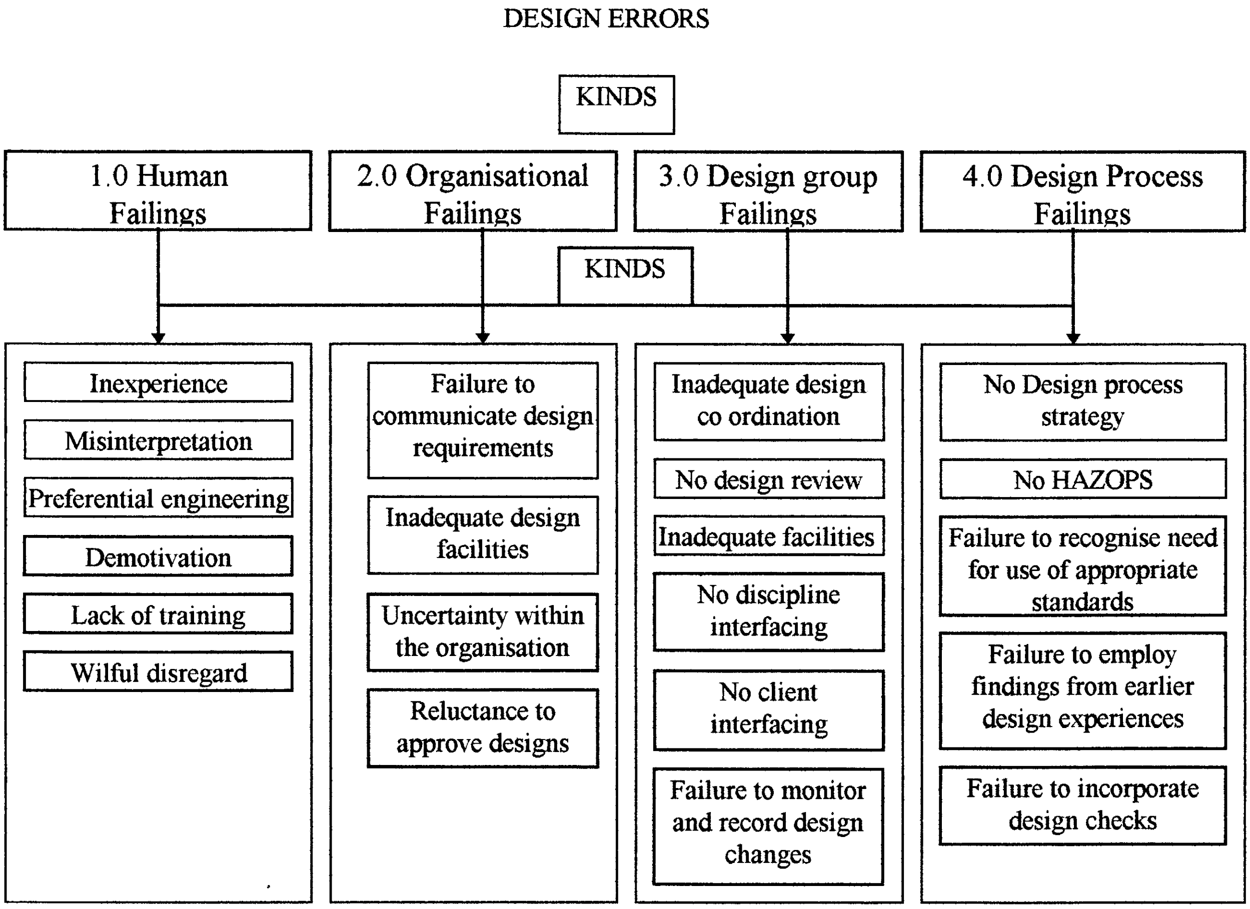

Fig. 59 Types of design failure mechanisms

The domain facts listed above can also be represented in a more descriptive manner using the systemigram technique mentioned earlier in this submission. Ref. Appendix F2 and F3 (Figs 63 and 64)

The task or project specific knowledge is represented propositionally, being more general the task specific knowledge is only proceduralised in as much as it specifies the functional domain facts in reasoning processes. i.e. symptoms and causes of design failure. Ref. Appendices F3-F4

6.3.4.Representation of Success Failure criteria for Engineering Design

The design success criteria can be represented in the same manner as the project success criteria using a radar graph as shown in Fig 60 below.

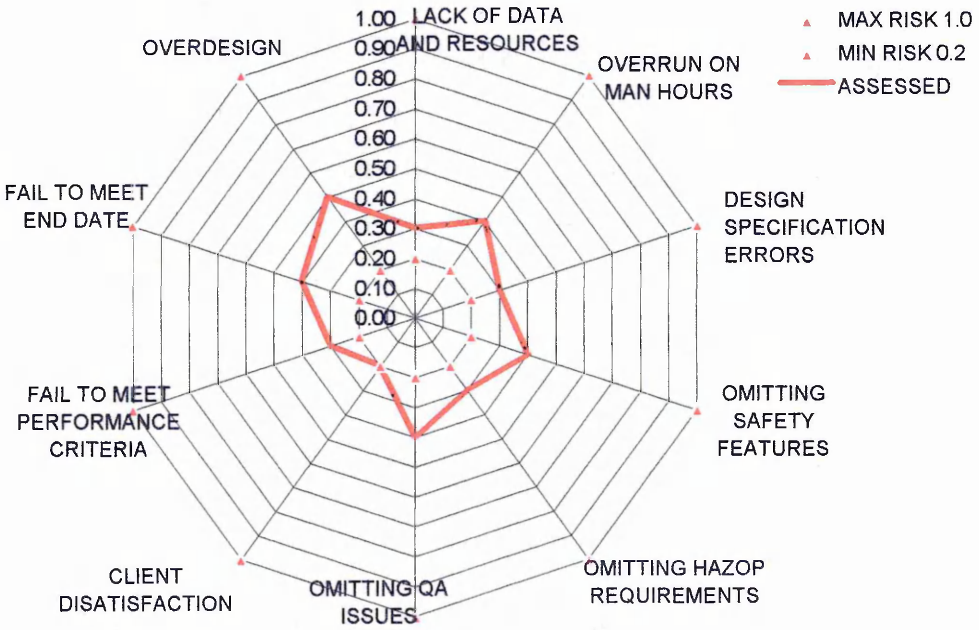

Fig 60 Potential Design failure mechanisms

The measurement of the risk follows the same subject evaluation technique as that in the project management system used on project X Ref. Appendix E5 (Fig 43)

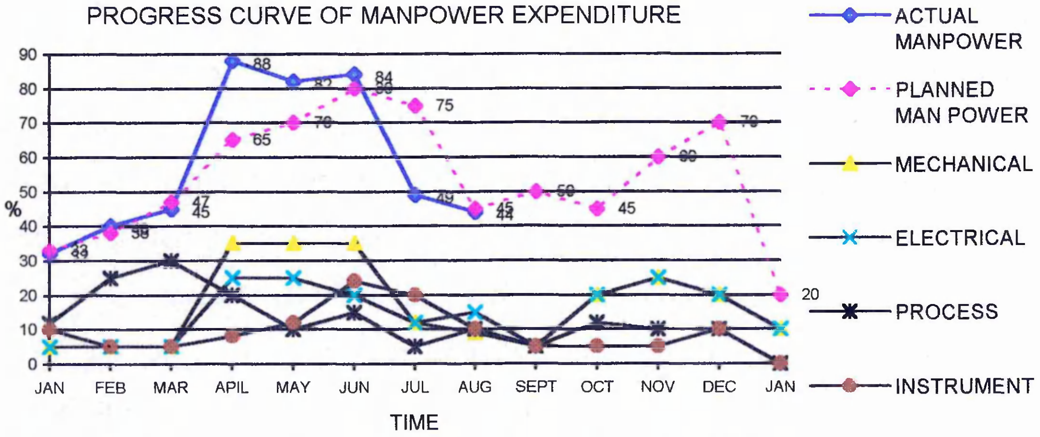

Fig 61 Traditional method of measuring multidisciplinary design man-hours expended

The traditional method of tracking engineering design man-hours spent against a given project, shown in Fig 61 above provides no method of predicting additional man-hour expenditure.

6.4 Knowledge rules

6.4.1 Design rules

For Proposing decision candidates.

Proposal criteria of diagnoses include causes of design problems.

Proposal criteria of diagnoses include kinds of supported design failure mechanisms.

Proposal criteria of diagnoses include causes of supported design failure mechanisms.

For arguing about decision candidates.

Supporting arguments of diagnoses include positive signs.

Contradicting arguments of diagnoses include negative signs.

Eliminating arguments of diagnoses include excluding signs.

The knowledge based design rules applied to the design management process will be extensive. Rules 9 & 10 in Appendix E8 (Fig 46) have been included in order to illustrate the **principle** of how the design specific issues interact with the project specific elements.

It must be understood that these are by no means exhaustive but are merely a representation of the types of knowledge based rules that are generated from the project specific data extracted from the users initial assessment.

In the examples provided the project specific data was able to identify that the project included a **design** involvement.

Having prompted the fact that design is involved, the second level of questioning queried whether or not the technology associated with the project was **known** (proven) or **unknown** (new). The project specific data also confirmed the inclusion of a given number of **main plant items** (MPI's) and from deductive reasoning was able to show that a design risk was emerging, i.e. Special (non standard equipment) needed to be designed for a process using new (unproven) technology.

Whilst these conditions alone might well give rise to a risk issue, the situation becomes compounded by applying project specific data regarding the availability and ability of engineering resources.

If the data identifies that the project **includes** a design element, **and** new technology **and** special purpose plant items **and** the project focus is on quality **and** there are no suitable resources, **then** we have the conditions for a high risk design issue.

6.5 Application of the Research Findings

6.5.1 Causal relationships

Having identified the main factors influencing the risk of design failure it was necessary to incorporate the knowledge of the causal relationship, such that prompts can be introduced to allow the user/s to seek advise from the KBS and thereby obtain decision reinforcement and support.

E.g. In the second of the two case studies "The new digester project" an incident in Task No 1 occurred which very nearly resulted in the project becoming unsalvageable, namely the weld failure of the digester ring. Ref. P06 Appendix C5

The experiential knowledge used in *engineering design* is often limited to a finite set of applications and is seldom equally applicable to similar design problems.

E.g. The in-depth knowledge of say, the design of pressure vessels, does not automatically mean that the same knowledge is of equal value in the design of atmospheric vessels. The general principles however do hold, namely material of construction compatibility, relief systems, support details, nozzle details, corrosion allowances etc.

It is also recognised that the front end engineering design is by nature temporal and iterative. The design process recommended by the concepts design management system is being developed to accommodate the temporal and iterative nature of the design process by restating the design assumptions each time the project identification routine is run. i.e. Changes in the project data that impact the design issues will automatically fire a new set of rules which will invoke a design review procedure.

E.g. Initial pump discharge head changes from x bar. g. to y bar. g.

Kletz [9] warns of the dangers of 'designers mind sets' citing the example of an Ethylene storage vessel which split near the base during commissioning. The cause was due to condensate water freezing which had been introduced initially as a design solution to prevent the Ethylene vapour falling to ground. *Kletz* suggested that the design team were "so hypnotised by their solution that they were blind to its deficiencies", but went on to concede that the design proposal had not been fully reviewed.

6.6 Conclusions and References

6.6.1.Conclusions

This Chapter has described how the engineering design function will operate within the framework of the concept. It has also explained how certain design risk issues associated with the design function can be identified and managed. Engineering design is a complex process that is difficult to proceduralise due to the fact that it requires a combination of both innovative mental skills and methodological thought processes.

Engineering design is an integral part of the project management life cycle, as such it needs to be incorporated into both the 'project team' and the 'management system'.

Engineering design impacts both *project management success* and *project success*. E.g. Mismanaged design effort may lead to an overspend of project budget man-hours. Design errors may only surface in the latter stages of the plant commissioning phase, at which time it is difficult to retrofit or apply corrective measures.

Any design failure will be construed by the client as a failure on the part of the contractors to manage both the project and the engineering design.

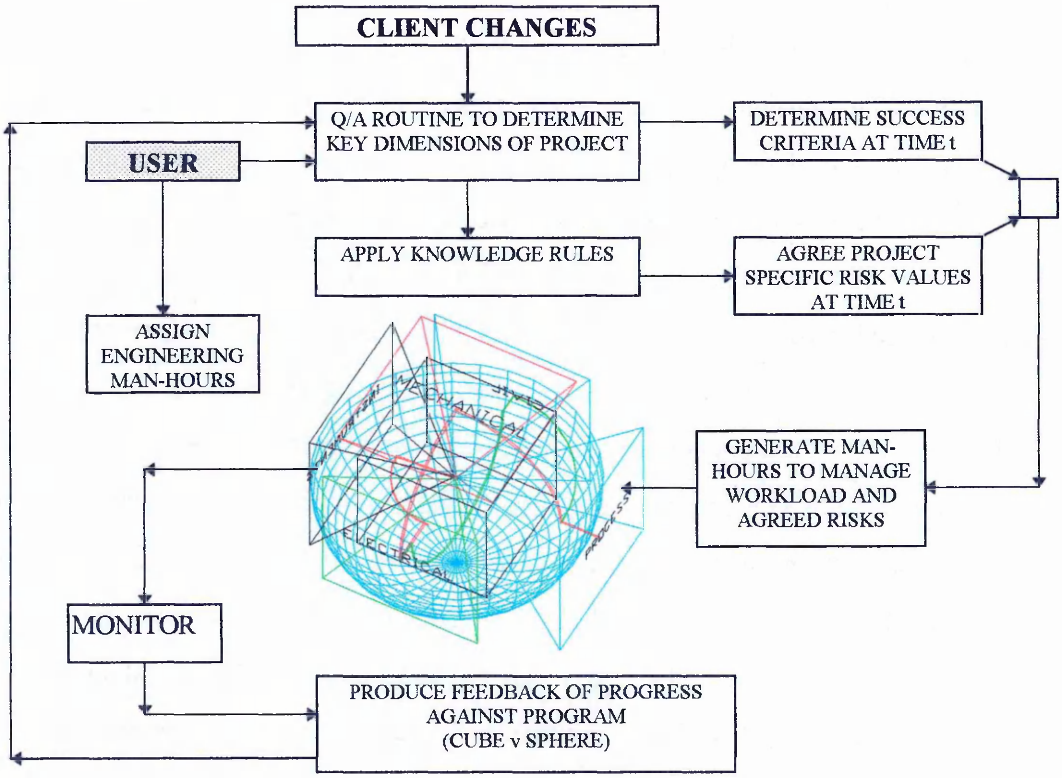

Fig 62 Outline of ConSERV process

6.6.2 References

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Note EDC refers to Engineering Design Centres

APPENDIX F

APPENDIX F

DESIGN CHALLENGE AND PROCESS
SYSTEMIGRAMS
DESIGN ERROR MAPS

APPENDIX F

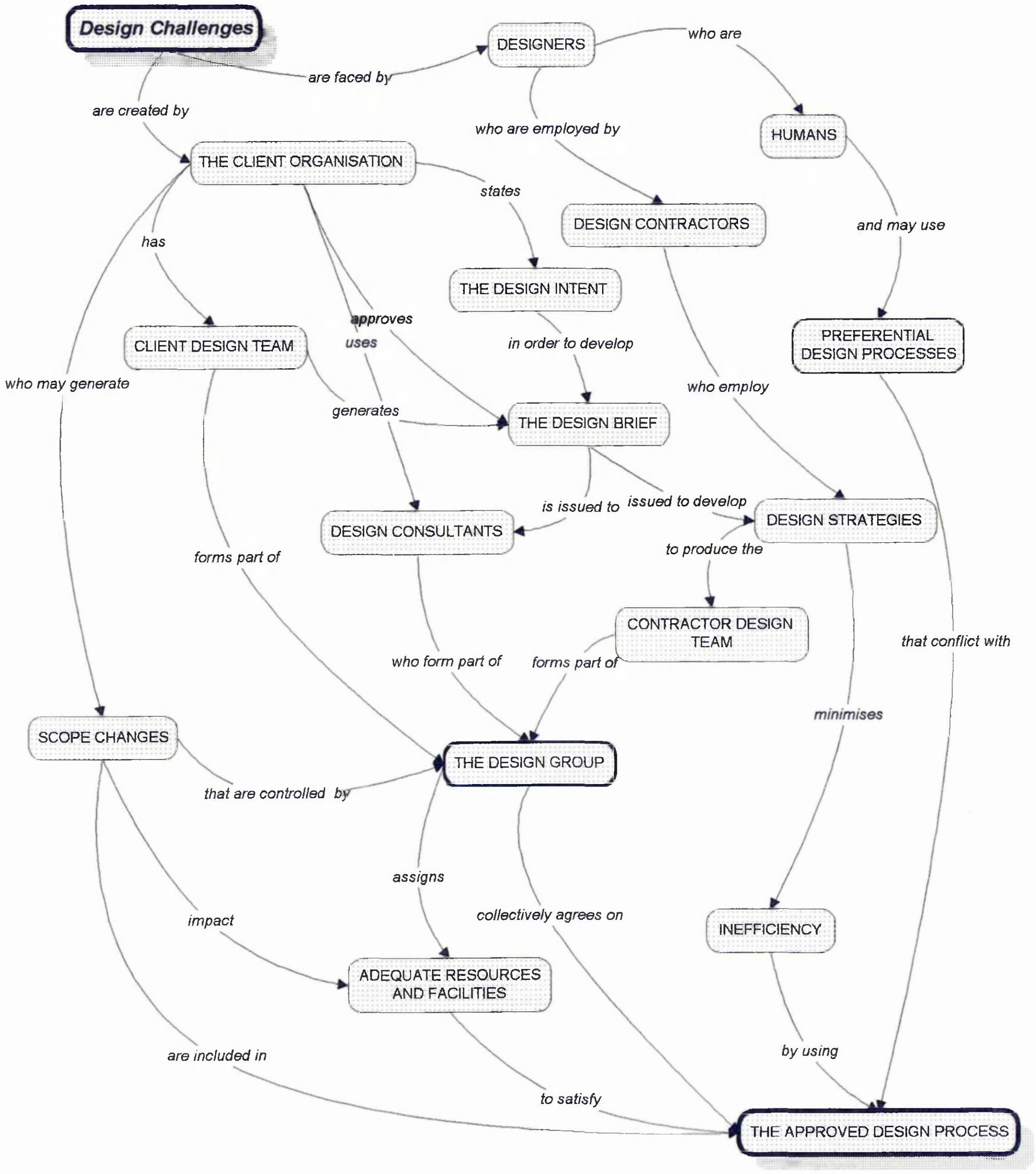


Fig 63 Systemigram 1 Design challenge through to the design process

APPENDIX F

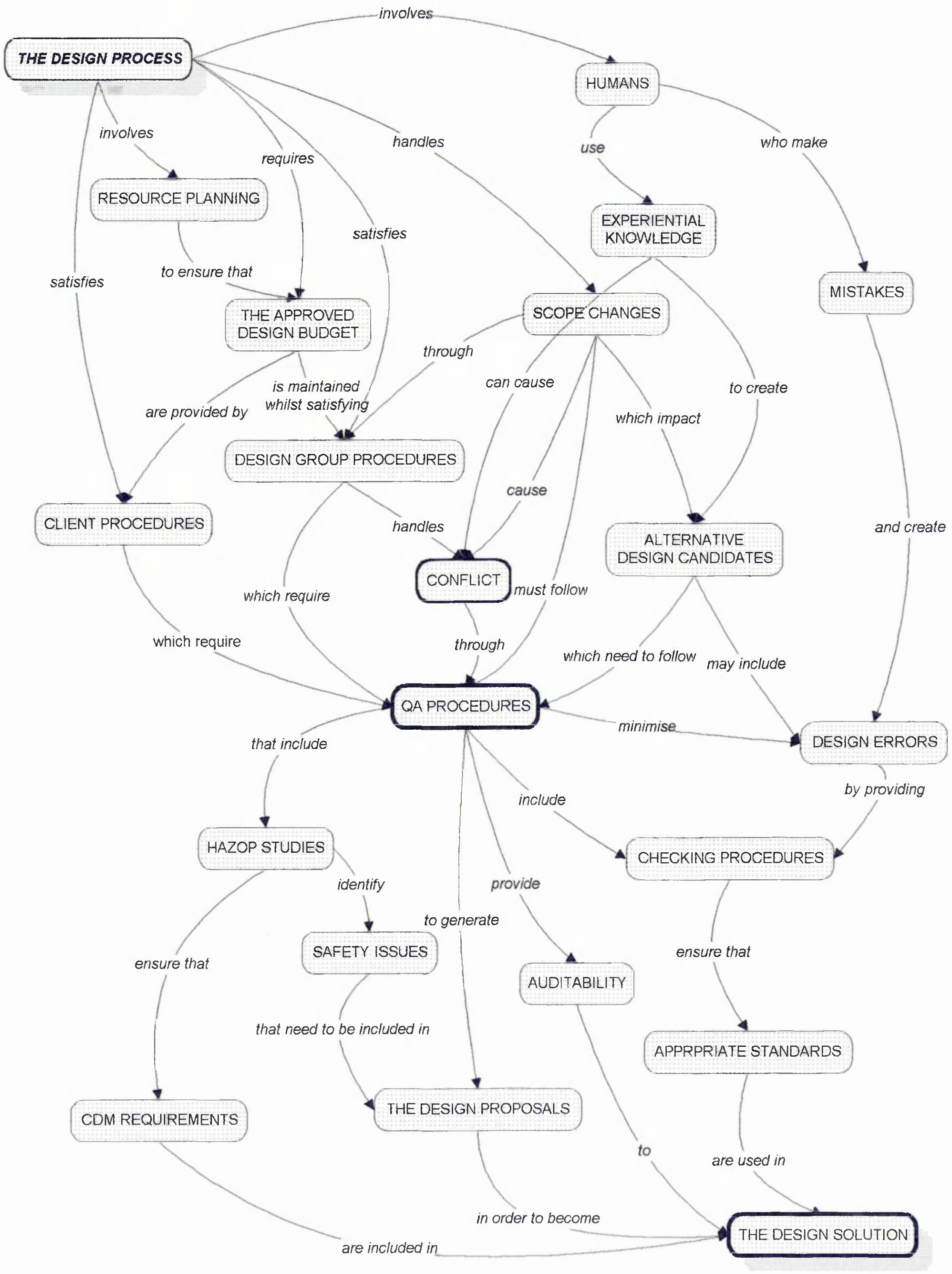


Fig 64 Systemigram 2 Design Process to the Design

APPENDIX F

DESIGN ERROR MAP 1 CAUSAL RELATIONSHIP OF DRAUGHTING ERRORS

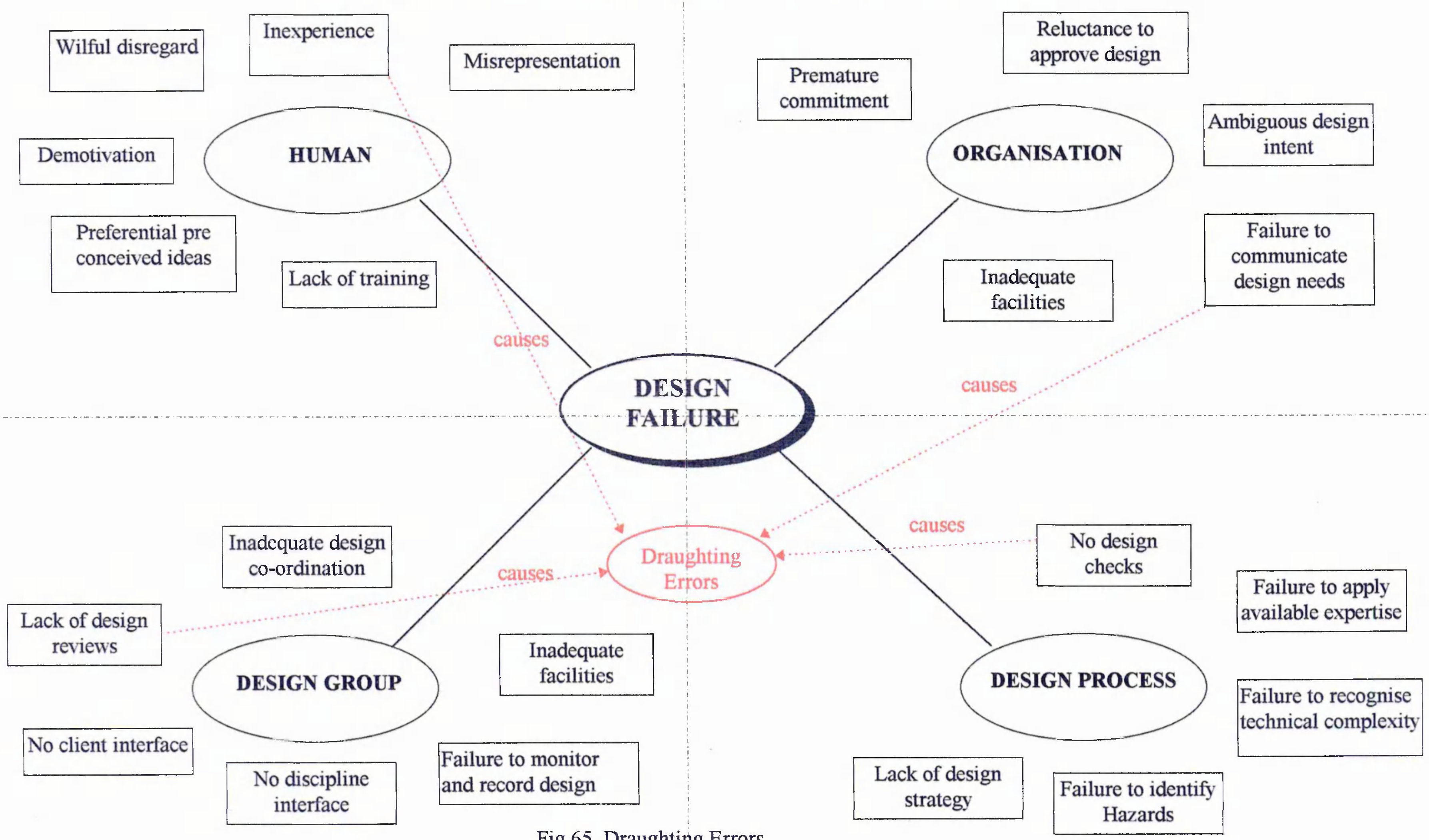


Fig 65 Draughting Errors

APPENDIX F

DESIGN ERROR MAP 2 CAUSAL RELATIONSHIP OF CONFLICT

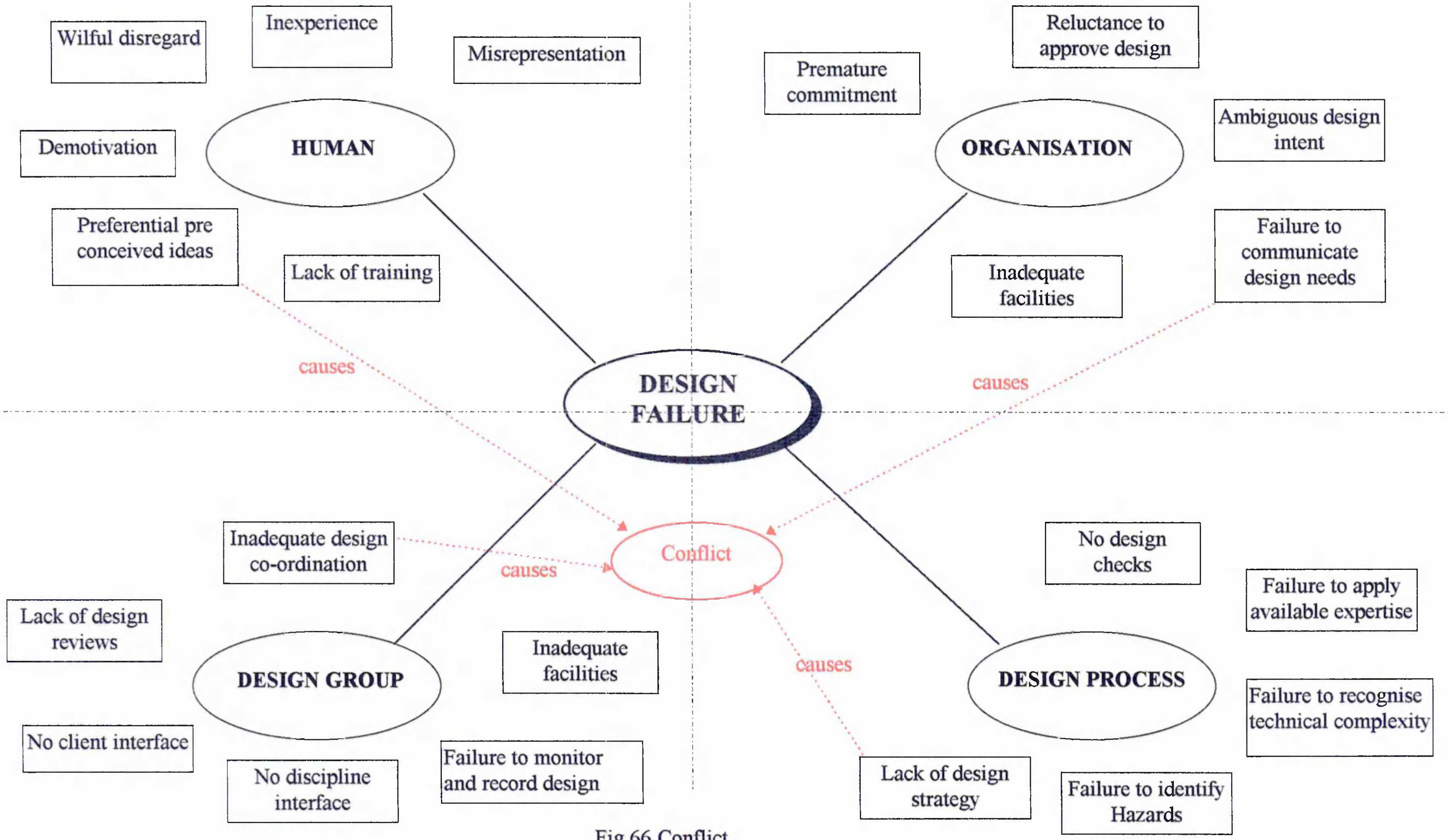


Fig 66 Conflict

APPENDIX F

DESIGN ERROR MAP 3 CAUSAL RELATIONSHIP OF SAFETY OMISSIONS

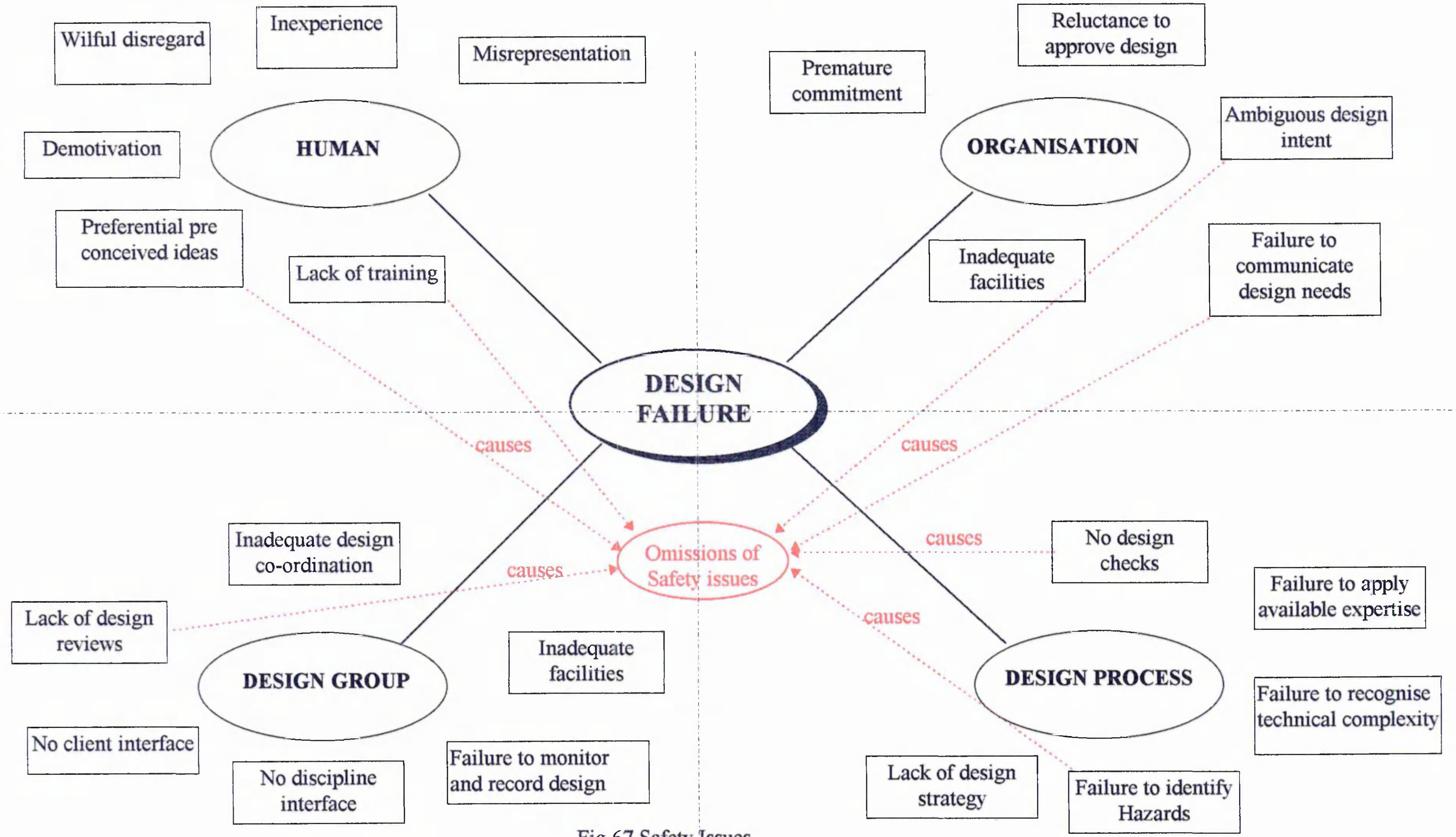


Fig 67 Safety Issues

APPENDIX F

DESIGN ERROR MAP 4 CAUSAL RELATIONSHIP OF OVER DESIGNING

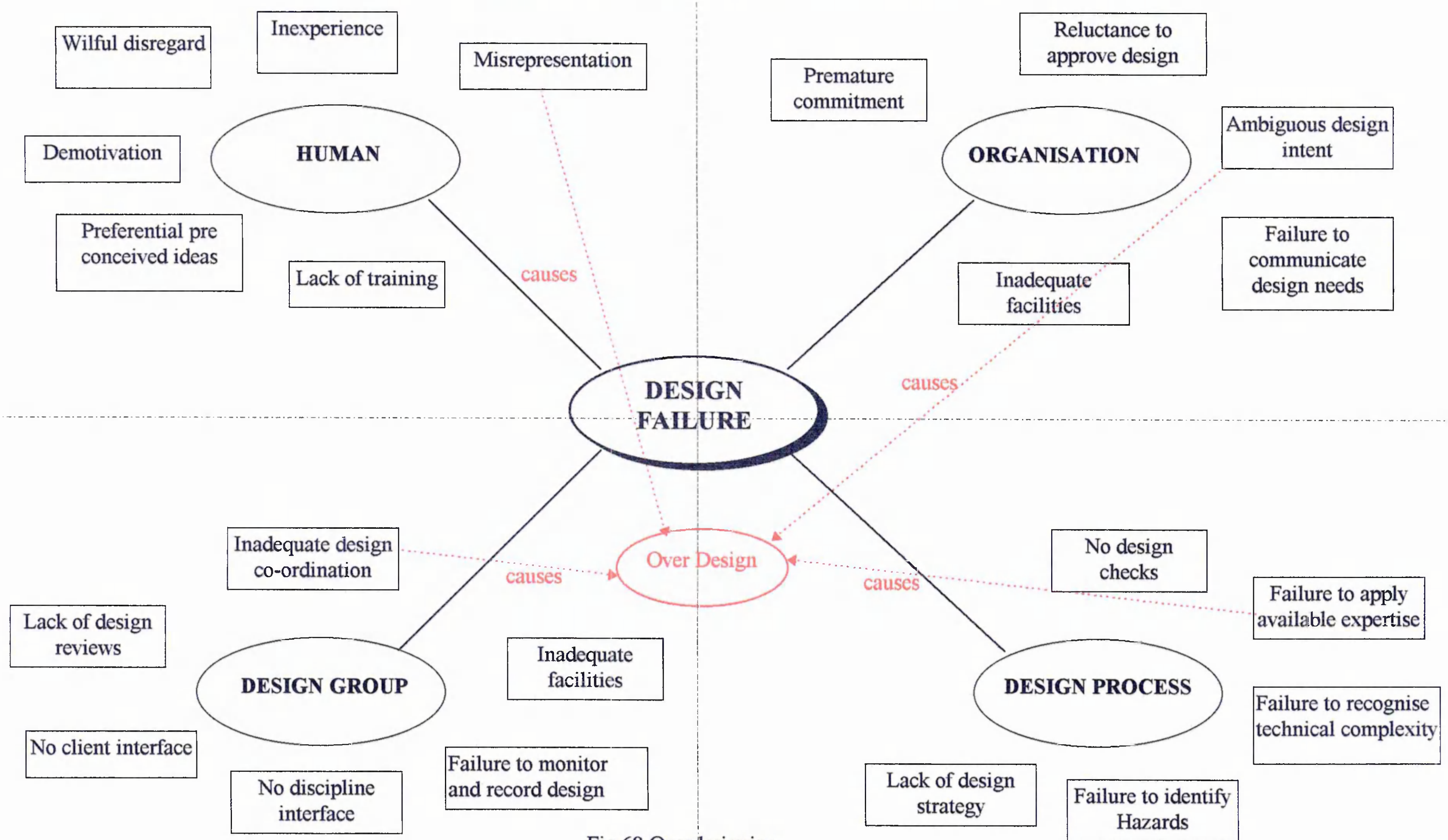


Fig 68 Overdesigning

Chapter VII

7.0 THE CONSERV 3D MODEL

"Expert systems need not necessarily be capable of making decisions per se, but they should be able to marshal, propagate and combine information that can potentially assist in a decision task." Clarke and Krause[1]

7.1 Introduction

7.1.1.Overview

The earlier Chapters, V and VI, provided a description on how the two integrated functions, *project management* and *engineering design* would need to relate within the framework of the ConSERV concept.

This Chapter is concerned with the second part of the concept and describes how the 3D representation of the Engineering Resources will function using project specific data to handle and process the flow of design critical information between respective engineering disciplines.

The Chapter provides a brief description of the 3D demonstrator tool, *3DStudio Max* by Kinetix, which is able to illustrate how the 3D model can be used in a workflow environment to provide the animated true 3 D visualisation.

3 D Studio is CAD 3D modeling and animation package designed to run on Windows NT.

Ref. Appended file Conserv.max. and Appendix G2-G4 (Figs. 77-79)

The quotation at the beginning of the Chapter, is particularly apt, for this part of the concept as by providing a global perspective of the design process over a period of time it is possible to view the rate of progress for each engineering discipline.

7.1.2. 3D Studio MAX^{TM}

The network structure illustrated on p83 (Fig 28) is typical of many DO workflow environments in which electronic information is generated by individual users, stored into a central repository, manipulated by various algorithms and redistributed via a network server.

With the exception of "intelligent" P&ID's, many drawing offices handle 2D drawing files effectively using workflow software. It is therefore considered realistic to use existing 2D electronic document file management systems as a network environment for the transportation of 3D files. The 3D studio max software depicts the engineering resource pyramid described on p81 (Fig 26) in the form of a *primitive object*. Being an object oriented program with parent-child hierachial links it is possible to position "the object" in a in a true 3D model space environment and fix the location of the objects "key parameters". In 3D studio all "objects" are defined by three general properties, the *creation parameters, a pivot point* and a *bounding box.*

These properties describe the form, local origin, initial orientation and extents of the object in the scene. The object space is the co-ordinate system unique to each object in the scene, it tracks the location of everything applied to the object. World space is the universal co-ordinate system that is used to track objects in the scene.

The internal structure of the object, i.e. bend, twist etc. is controlled by the *modifier* functions, whilst the orientation of the object is controlled by the *transform* functions.

The ConSERV concept is intended to provide a visual representation of the Engineering Resources applied over a period of time. It is therefore necessary to incorporate a time base to model the changes over the design life cycle. One of the most useful tools in producing computer animation is the ability to link objects together to form a hierarchy. By linking one object to another it is possible to create a *parent-child* relationship in which the transforms applied to the parent are automatically inherited by the child.

7.1.3 Choice of demonstrator 'B' development environment

The choice of the tool used for demonstrator B was based on the fact that it would need to be fully interactive within an *engineering design* environment. Given that the vast majority of engineering design is still undertaken in the DO (Drawing office) it seemed appropriate to look initially at the existing types of software systems and technology normally employed in the D.O.

By far and away the most popular engineering design package used in the Chemical industry at present would seem to be ACAD 13 and ACAD LT

A more detailed description on the selection of the demonstrator for the 3D element of the concept was submitted to the school 23/7/96 in the form of the "Construction of demonstrator report" Ref. p10.

7.1.4 The vision

In looking towards the future I am reminded of the words of the late *Starkey*[2] who recognised in 1992 that, "Attention is being turned to using a computer which is programmed as an *intelligent design assistant*. The idea is to create a symbiosis between the human designer and the machine. Each would do what they were best capable of doing but both would learn by their experiences and up-date their knowledge bases".

One of the main elements of this research has been to transform the vision of what the engineers perceived computer technology could do to aid in engineering design into a workable methodology.

7.2 Engineering resource management (Engineering Design)

7.2.1 Traditional approach

The traditional method of managing engineering and engineering design resources has been one of communication through face to face dialogue. It is generally accepted that each member of the engineering team has sufficient expertise to translate the “Design brief” into elements of work that can be managed by the respective department. The normal pre contract award procedure is shown below.

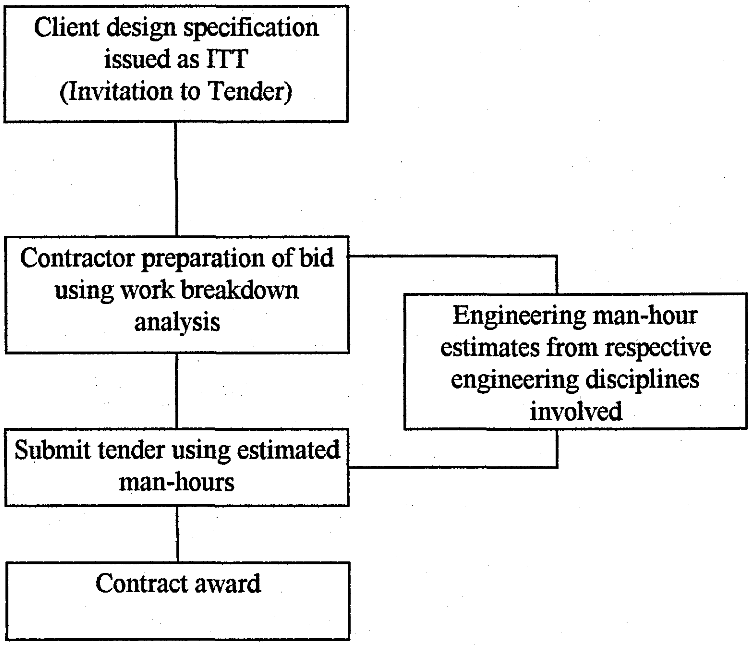


Fig 69 Pre contract award procedure

In this traditional form of tendering there is a strong temptation, due to client pressure, for the sales personnel to shave the costs of the man-hours provided by the engineering/design manager. The result is effectively underselling the job, which has already been identified as a major project management failure mechanism.

From the industrial research investigations it is evident that in some organisations, engineering man-hour estimates are inflated by the respective engineering managers in anticipation of this tendency to undersell the job. The inclusion of contingency factors for undertaking “unknown” design elements and resolving design complexities is a common method of artificially enhancing the original estimate.

7.2.2 Estimating Man-hours

Subjective estimating processes make a mockery of the established estimating procedures advocated by the more professional organisations.

Research findings from Project 2 identified that the man-hour estimates for the design element (£ 24,000) was estimated by the DO manager using a highly subjective method with no sound estimating basis and the absence of any recognised norms.

On project 1 'The Sulfacid project', the same DO manager had estimated £ 15,000 for the design work. On completion of the project the final figure was in excess of £30,000.

From the earlier experience gained from Project 1, it was obvious that the estimating method was flawed and there was no real confidence in the £ 24,000 estimated for Project 2.

Despite protestation by the project manager the cost estimate for design was included in the Capital expenditure proposal and, once approved, became the working budget for the design element.

On completion the design costs were in excess of £48,000. The estimating error was consistent i.e. + 100% (identical to the budget error in project 1).

Many man-hour estimating techniques use the rule of thumb method in which man-hours are expressed as a percentage of the total project budget. This method is also flawed as it fails to take into account whether or not the project is design intensive.

The effect of starting a project deficient in design man-hours manifested itself in project 2 in the form of "Design problems identified in project 2" p52 (Table 11)

The research findings revealed other problems directly related to designing with inadequate resources mainly involving draughting errors. The effect of the design errors on the construction work is shown on p53 (Table 12)

The costs of correcting the errors was well in excess of £150,000, 5% of the total budget and over 6 times the budget afforded to the design element of the project.

One of the first casualties of cost cutting exercises in the DO is that of quality.

This was evident from the research findings of Project 2 in which the whole issue of project success ultimately hinged on the decision to `undersell` the project.

7.2.3 Problems using Gantt Charts on design activities

The 3 main problem of managing engineering resources using Gantt charts identified from the research include :-

i/ Productivity of conceptual and detail design effort
ii/ Information flow between engineering disciplines
iii/ Multi disciplinary activities and shared resources

The Ullman diagram shown in Chapter VI p112 (Fig 57), illustrates the problems of quantifying productivity in undertaking design activities.

It is recognised that the top end planning tools do afford a non linear representation of activities, however the tools do not provide any real facility to view the overall effect of non productive periods between engineering disciplines.

As was identified from the industrial research work undertaken on project 2 the flow of design critical information was seen as being essential in the progress of engineering design activities.

The greater the number of engineering disciplines involved with a task the more complex the information network becomes and the iterative nature of the design process. Multidisciplinary tasks are especially difficult to program using Gantt techniques due to the problems of structuring the logic of the design process.

E.g. Brainstorming sessions. Hazop studies etc.

Gantt charts can accommodate shared resource pools between projects, but struggle when trying to model the progress of multi discipline activities with multiple engineering resources.

Gantt charts are tools that are entirely dependant on the level of detail and planning accuracy of the individual creating the program, they have no 'awareness' of the project sensitivities. As can be seen from the progress sheet for task 1.0 on Project 2 Ref. Appendix C9 (Fig 22). The identification of the problem on 12/7/95 is very difficult to visualise using 2D graphics.

7.3 Design concurrence

7.3.1 Agreement

Design agreement between engineering disciplines requires :-

i/ A common understanding and appreciation of the problem

ii/ A common understanding and appreciation of the specific project issues

iii/ A common understanding of the design constraints

iv/ A common understanding of the organisational design requirements

v/ A method of communicating between disciplines

vi/ An integrated design methodology

vii A common design tool

Representing the inter related design issues using a Gantt chart requires that many activities become "jointly resourced"

E.g. The task "Design of vessels" in project 2 required :-

i/ *Mechanical* designers for steel shell design and vessel lids

ii/ *Structural* design for vessel support legs

iii/ *Electrical/Instrument* design for instrument nozzle location

iv/ Civil engineers for piling, support slab, plinths and refractories.

v/ Process engineers for ensuring material compatibility and basic design data.

A typical common design activity might be :-

Activity 0101 Determine nozzle orientation on vessel.

This activity could be undertaken using one of two methods.

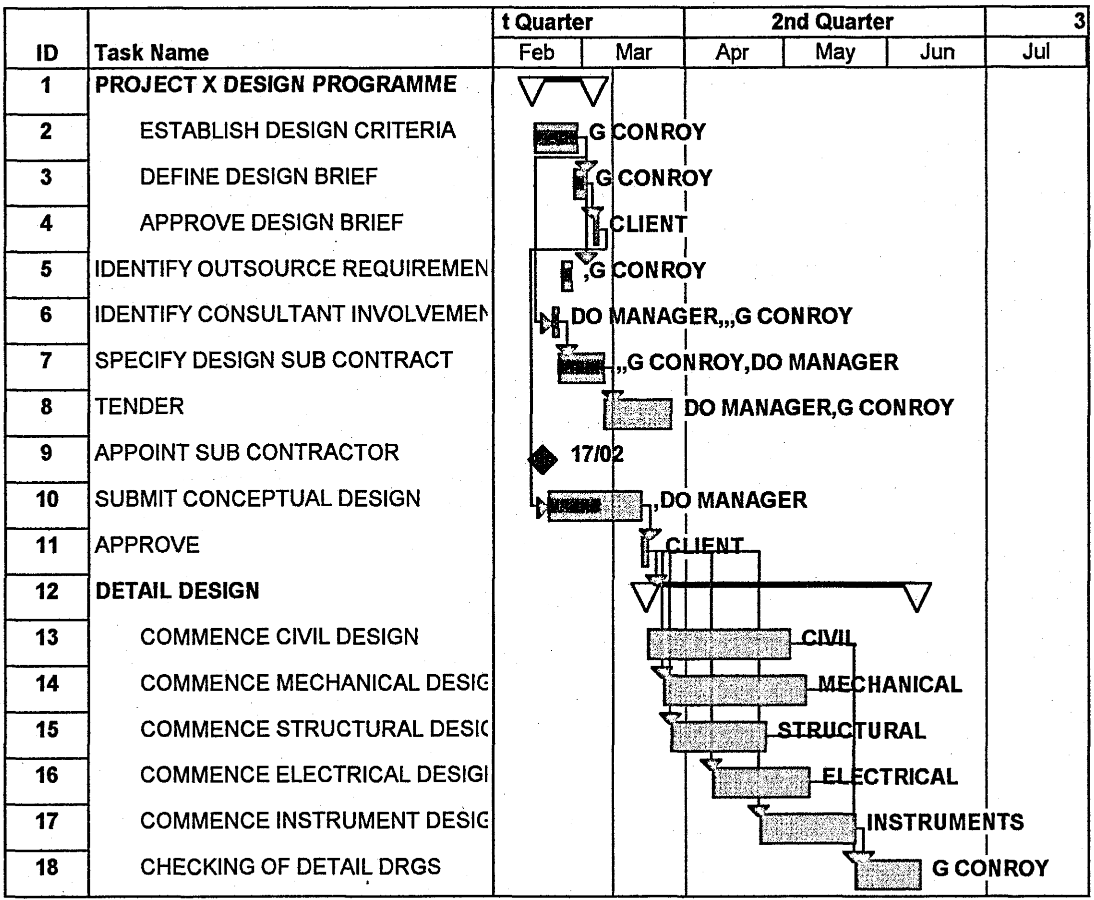
a) To allow a single discipline lead designer to fix the orientation of the nozzles (Process engineer) and to obtain subsequent acceptance of the nozzle orientation from each discipline engineer involved.
b) To hold a 'design review' involving all the respective engineering disciplines and work to a clearly defined objective.

A new methodology for resolving conflict in engineering design using CDEX, a KBS approach was proposed by *Harrington*[34]

7.4 ConSERV 3D model

7.4.1 Limitations of 2D representation

It can be seen that the 2D representation of engineering and engineering design activities is a very limited method of representing the multidisciplinary effects of the flow of design data between disciplines. In a 2D environment the point of concurrence and release of design data for use by others are key milestones that are difficult to visualise using the 2D techniques.



ID	Task Name
1	**PROJECT X DESIGN PROGRAMME**
2	ESTABLISH DESIGN CRITERIA
3	DEFINE DESIGN BRIEF
4	APPROVE DESIGN BRIEF
5	IDENTIFY OUTSOURCE REQUIREMEN
6	IDENTIFY CONSULTANT INVOLVEMEN
7	SPECIFY DESIGN SUB CONTRACT
8	TENDER
9	APPOINT SUB CONTRACTOR
10	SUBMIT CONCEPTUAL DESIGN
11	APPROVE
12	**DETAIL DESIGN**
13	COMMENCE CIVIL DESIGN
14	COMMENCE MECHANICAL DESIG
15	COMMENCE STRUCTURAL DESI(
16	COMMENCE ELECTRICAL DESIGI
17	COMMENCE INSTRUMENT DESIG
18	CHECKING OF DETAIL DRGS

Fig 70 2D representation of design activities using traditional Gantt

7.4.2 Converting from 2D to 3D

Despite its somewhat complex appearance the ConSERV 3D model of the design effort undertaken by the combined engineering resources is relatively simple Ref. p79 (Fig 26) and p82 (Fig 27) The man hours of each resource assigned to the project are normally represented in the form of a resource graph as shown in Fig 72 below.

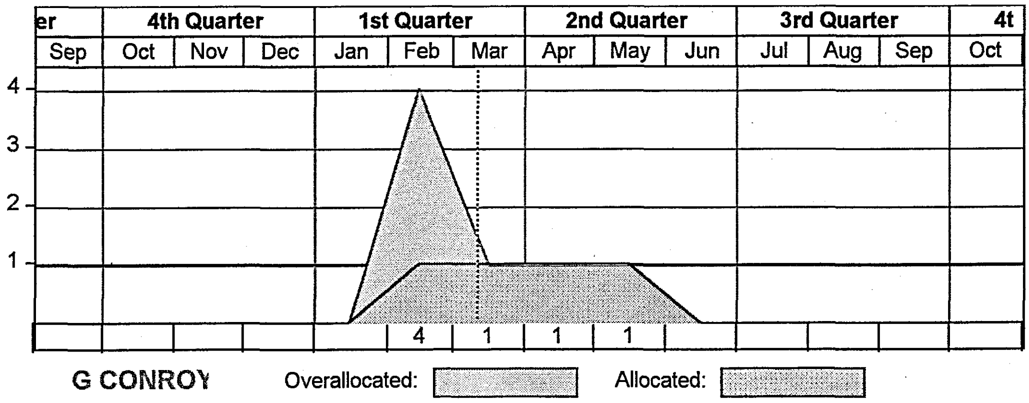


Fig 71 Resource graph of single resource for hypothetical project

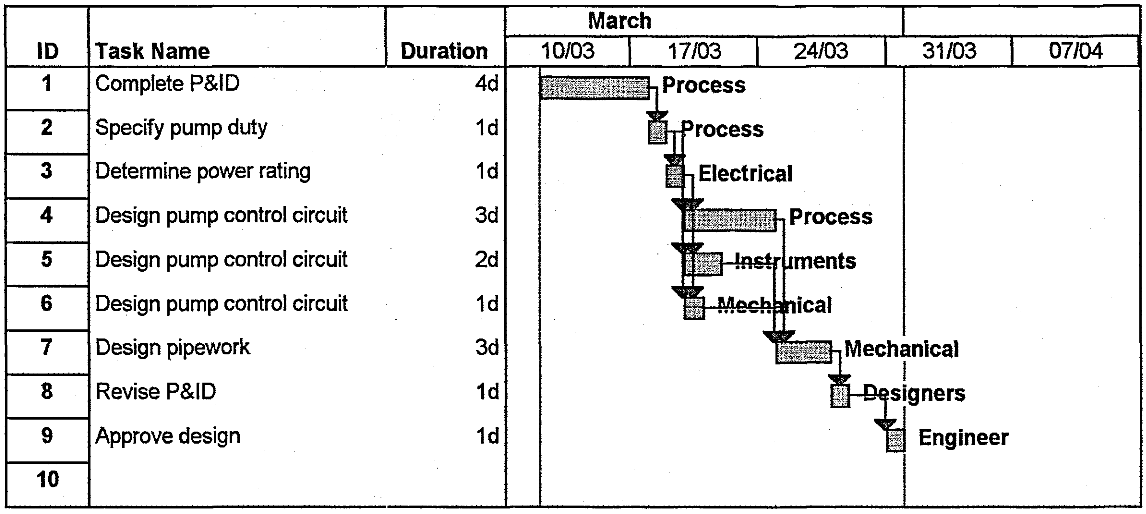
The example provided above illustrates the limitations of planning tools, having applied the logic and resources to the trivial Gantt program the planning tool is able to produce a resource graph, showing that resource G Conroy has been over allocated. i.e. That on the calendar set up (8 hours/day) G Conroy is unable to undertake the work assigned. The planning tool is able to 'level' the resources to suit the activities assigned by extending the duration of the program.

The 2 D representation of the resources is unable to show the effects of sharing activities between a number of resources E.g. Activities 6, 7 and 8 are shared activities in which G Conroy and the DO manager are involved.

The respective resource man-hours can be assigned to the activity and the overall man-hour commitment for each resource can be viewed on the resource graph.

In the above example the resource graph shows that the program is unworkable as 4 G Conroy's are required in Feb. In the planning tool used it is possible to 'level' the overallocated resources by extending the activity duration to suit the available resources.

The activity logic and dependencies can easily be shown on the 2D Gantt.
The interdisciplinary exchanges in undertaking shared activities can only be shown by defining the work in a level 4 WBS with each activity restricted to a single engineering discipline, or by introducing dummy activities.



ID	Task Name	Duration
1	Complete P&ID	4d
2	Specify pump duty	1d
3	Determine power rating	1d
4	Design pump control circuit	3d
5	Design pump control circuit	2d
6	Design pump control circuit	1d
7	Design pipework	3d
8	Revise P&ID	1d
9	Approve design	1d
10		

Fig 72 Example of repeating activity to facilitate disciplines

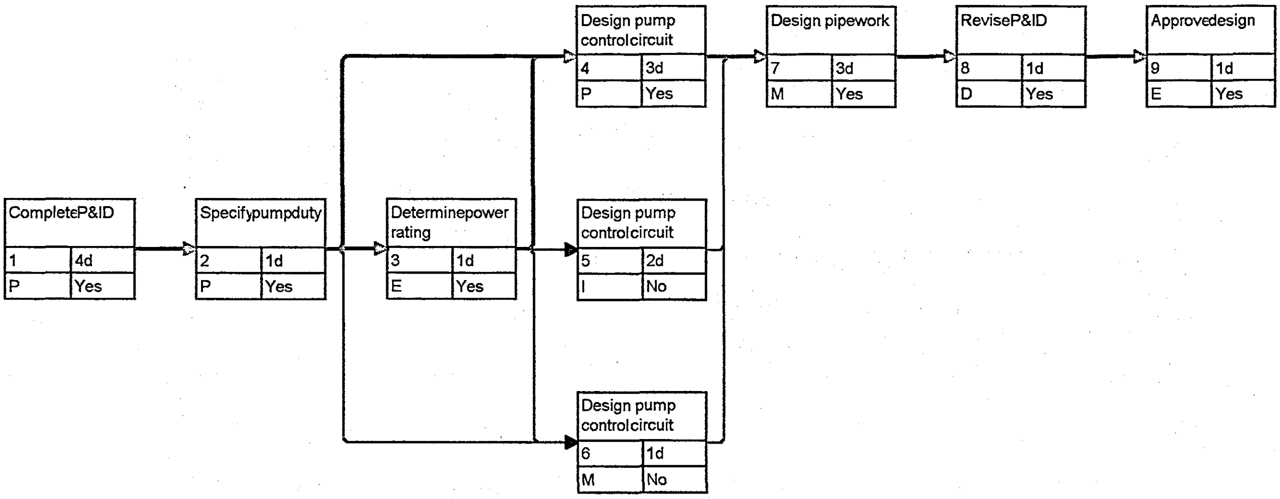


Fig 73 PERT analysis of the Gantt chart

As can be seen from the trivial example above it is possible to show the combined involvement of engineering disciplines by duplicating the activity and assigning a single resource to each activity.

E.g. Activities 4, 5 and 6 are the same, "Design pump control circuit"

Having established that process department need 4 days, the planning tool identifies activity 4 as being critical. The formation of the program is incorrect as it assumes that each of the activities 4 to 6 are independent, unfortunately this is the only way to actually show the combined engineering resource involvement and the engineering resource graph in the same file.

This 2D representation depends entirely on the input from the planner and whilst it is possible to analyse the PERT and Gantt data in order to assimilate meaning to the 2D representation, the interdisciplinary exchanges are not immediately apparent.

7.4.3 Multidisciplinary design processes

The multidisciplinary engineering design resources are notoriously difficult to manage. The activities of the individual discipline engineers may not necessarily be knowledge intensive, but the management of the collective effort of the designers is. Ref. B12.

From the research findings the reasoning mechanisms employed by the engineering designers within the project team were identified as being heuristical, hypothetical and procedural. The interactive element of the concept as described on p83 (Fig 28) allows the discipline team (Mech. Elec. Etc.) to view and therefore better understand the significance of their respective contribution to the project.

The information requested between the various groups is handled electronically and is therefore transparent. E.g. Mechanical engineer requests design data from Process engineer. The calling and transference of data in this manner allows the data to be routed via the systems project specific data files which can verify and assist in specific design requests.

E.g. If the request from the Mechanical designer was for information required to size a line, then the KBS, might choose to attach a message reminding the parties of recent project developments and newly emerging risks.

7.5 Recapitulation

7.5.1 Processes

The first part of the concept uses knowledge based rules to establish project specific data, which by the application of further rules, enables the user/s to identify global risks, success criteria and the need for additional resources. The second part provides an on line decision support facility to determine and monitor the engineering design activities. A summarised version of the process is illustrated in Fig 75 below.

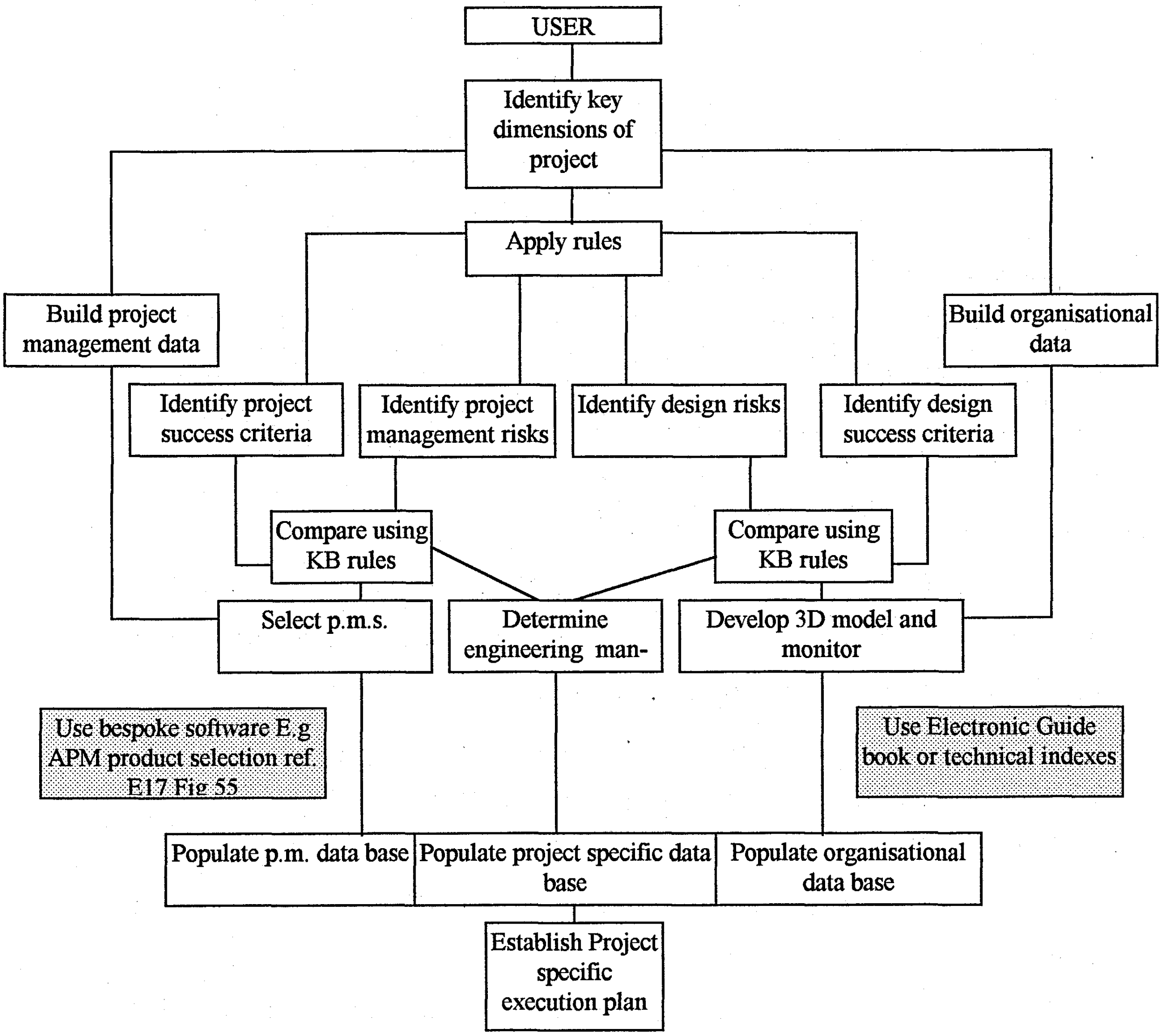


Fig 74 Summary of ConSERV processes

The result of completing parts 1a and 1b should be the generation of a project specific plan, complete with a well populated knowledge and data base.

7.5.2 The Engineering Resource View

In any multidisciplinary environment there will be a number of `goal states` that need to be reached. I.e. The hypothetical example, "Designing the pump control circuit" or the real world example Activity 0101 "Determine nozzle orientation on digester vessels". Each could be represented as a goal state, which is achieved when :-

a/ The control circuit has been designed or

b/ The orientation of the nozzles has been realised.

It is the authors view that the contribution of each engineering discipline necessary in achieving the goal state objective can be better represented using the 3D engineering resource view described earlier.

Where ConSERV differs from conventional project and design management structures is in the use and application of *project specific data* which directly influences both the project management and engineering design issues simultaneously.

If, after having established a 3D representation of the engineering design resources for a given task, a major problem is encountered then the 'system' will recognise the change and invite the users to repeat the project identification process in order to redefine the project and design specific risks.

The effect that the scope change has on the original man-hour estimates can then be represented using the 3D visualisation technique.

The resource view enables the user to not only view the current status of his/her own discipline progress but also to view the status of other disciplines involved in the design activity.

By having an open interactive network operating through a 'workflow' environment it is possible to use the system as a planning tool in which the respective engineering groups can provide advanced notice of their requirements from other disciplines.

In this way the 3D model effectively becomes a 'neural network' in which information is requested by engineering disciplines, recorded in the project specific data files, challenged, verified and subsequently distributed via knowledge based rules to the respective engineering discipline.

The technique being proposed may be considered as being a 'configuration[1]' in its own right. The Engineering Resource View consists of a method of presenting the engineering man-hours assigned to the project in a rather unique way. The man-hours estimated for any given project will normally be developed from the work breakdown structure (WBS). The process is simply to identify the work and then apportion man-hours against the respective work elements (Activities). Depending on the level of work breakdown the activities involved may have 'shared resources'. i.e. more than one resource assigned to an activity.

By applying resources to activities a 'resourced Gantt' can be produced from which resource histograms can be generated as shown in Fig 72 p135.

The focal issue of this research is to improve on current project management methodology, it is therefore important to appreciate the limitations afforded.

The traditional technique of generating workload histograms assumes that once the program has been developed it is effectively frozen for the project duration. In many capital projects the early, level 1 WBS's are often used as a basis for 'the contract' and milestones quickly become linked in terms of progress payments and ultimately penalties. Considerable research work has been undertaken on planning techniques.

E.g. *Chatzoglou* [5] who recognised that in the management of software development only 1% of projects finish on time and to budget, suggesting that "existing planning models only make predictions about the project development process as a whole".

Gokhale [6] who suggested an Objective Based Dynamic Planning and Monitoring System, for the planning and control of R&D projects comprising of a blend of configuration management, reduction in formula control and portfolio management.

Dawson [7] purported that "activity networks are limited by their inflexible structure and so they cannot explicitly identify and control potential risk points and uncertainties within projects".

Pillai [8] observed that "In PERT activities are not assigned a priority ranking, the criticality of an activity is assessed if it is on the critical path, under PERT the latent complexities and uncertainties of an activity remain covert"

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[1] Configuration as defined in BS 6488 : 1984

The views of researchers to date, seem to imply that existing software technology applied to programming and scheduling is highly structured in terms of the algorithms and the logic applied to the program data.

The logic accommodates "real world event changes" by allowing new activities into the original programme, which is tantamount to conceding that the original program was apparently deficient[1]. If we *intuitively know* that certain programs are 'unworkable' then a more rational view, might be to look at how long projects **actually** take to complete (descriptive) and contrast this with the original plan (normative) to understand where the main discrepancies lie. This is essentially what this research has done. Ref. Section 1.4..3 a) i to iii.

The research data obtained from Project 2 case study revealed that in practice the work *scheduled* was actually undertaken in a very stop-start fashion as shown in Fig 75 below. Using the pyramid representation for a single discipline it can be seen that work is undertaken from 'A' to 'B', information is found to be missing a hold is put on the activity and once the information has been provided 'C' man-hours are again expended and the work continues to 'D'

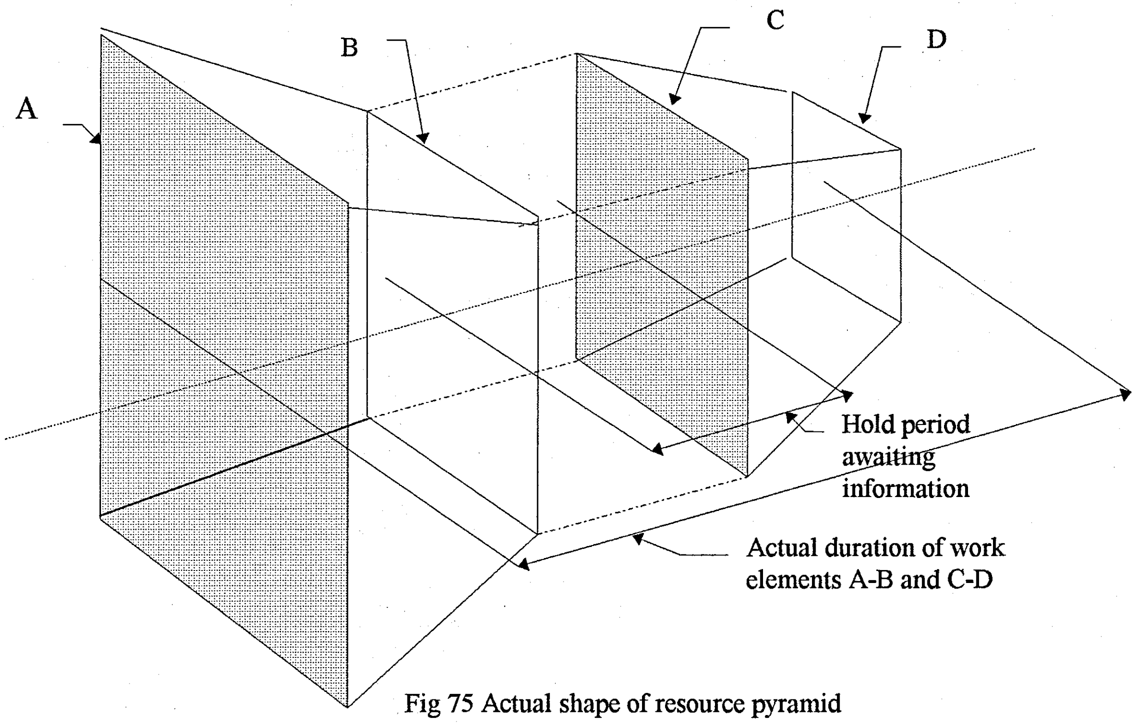

Fig 75 Actual shape of resource pyramid

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[1] During the authors 25 years in project management he is unable to recall a single case where the original level 3 WBS program and the number of activities were held over the project life cycle

7.6 Information transfer

7.6.1 Design Critical Data

The transfer of design critical data between the respective engineering disciplines was identified as being a major factor in the success of both the performance and the management of the project. Ref. C8 (Fig 21)

The benefit of a three dimensional visualisation showing the transfer of information is that the user can view the progress of the verified request and the delays in the responses.

In this way ConSERV is able to act as a sentinel for the information transfer, by applying knowledge based rules to the transfer of design critical data.

Examples of the type of knowledge rules might include :-

i/ **If** data being transferred includes reference to pipework or plant equipment **then** advise process group **and** query need to undertake Hazard studies.

ii/ **If** data being transferred includes reference to changes **and** P&ID **then** advise process group **and** query need to revise original P&ID.

iii/ **If** data being transferred **includes** reference to pressure **and/or** pipework/plant equipment **then** advise user of current pressure design codes **and** request confirmation that codes are being followed. The process is illustrated below :-

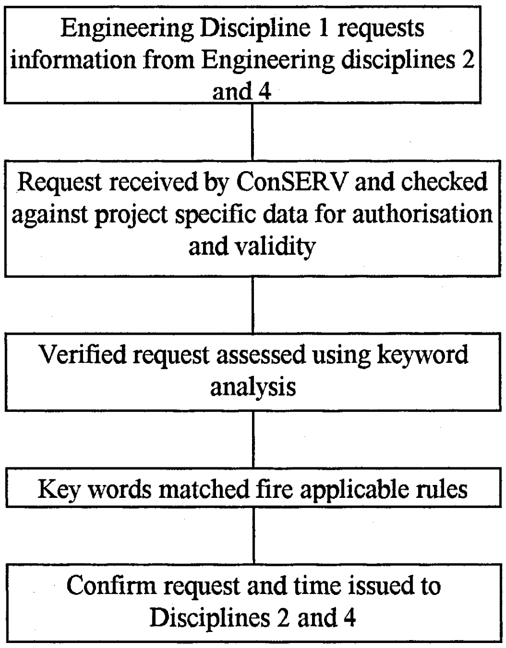

Fig 76 Information transfer process

7.6.2 The knowledge rule connection

The earlier knowledge rules generated from the key dimensions of the project scenario illustrated in Appendix E8 provided information that allowed a number of rules to be generated based on the expertise of project managers.

Rule 10 considered five elements,

<Design>, <Technology>, <Special purpose>, <Quality> <Resource Availability>

Knowing that the project involves the `design` of `main plant items` and that the items concerned are `specials` and that there are 'presently' no `available resources` then the combination of these facts presents a major challenge to the design element of the project.

The response shown in Fig 46 is simply to raise query, in reality the whole success of the project hinges on being able to secure the expertise to generate a satisfactory design solution. To compound the matter it is likely that the design for the special equipment identified will also need to be developed, approved, detailed, built, and tested. Furthermore depending upon the type of industry, the application and the location the critical piece of equipment will have to satisfy all the pre requisites of the organisational requirements concerning 'fit for purpose' maintainability Hazard and Operability, functionality etc. In order to get down to the real man-hours required to design the piece of equipment to meet industrially acceptable standards i.e. The Digesters in Project 2, it is necessary to incorporate sufficient engineering time to ensure that none of the design requirements are omitted.

It is only at this level of abstraction that the actual engineering and engineering design effort can be accurately quantified. It is evident from the research that the actual duration of time taken to meet a goal, was virtually always greater than the time allotted. The reasons are complex, basically because estimators have to take a positive, occasionally optimistic view which assumes that unless told otherwise all activities will start and finish in accordance with the 2D representation of the Gantt chart. The author accepts that considerable flexibility is provided with current planning tools, i.e. lag, earliest start latest finish etc. It is very difficult for any individual to process the many complex issues required to ensure that no single issue has been overlooked, hence the need for the ConSERV concept.

7.7 Conclusion and References

7.7.1 Conclusions

The Engineering Resource View proposed by ConSERV comprises of a number of pyramids converging at the centre of a sphere as described in section 4.5.2 and illustrated in Fig 26 and 27 The shapes are all modelled from the project data extracted from the system's user. The ultimate aim is to provide a technique able to support the more dynamic and complex issues of managing the multidisicplined engineering resources and the flow of design critical data between them.

Kharbanda [9] recognised that " it would be most useful to use hindsight as a science".

It is the authors view that project environments, including the design and drawing office elements, will ultimately form part of a 'Smart space' milieu or a 'virtual project' environment, in which Chemical processes are modelled and tested, (WITNESS), processes simulated, (ADEPT), intelligent P&ID's generated (REBIS), plant layouts created (ACAD) and the finished built plant visualised in true 3D. (3D STUDIO MAX).

In such an environment it would seem perfectly reasonable to employ a fully interactive 3D visualisation of the engineering resources employed over the project life cycle as well as the impact of 'real world' interactions essential in converting the 'image' into an 'artefact'.

7.7.2 References

1 Krause, P and Clark, D (1993) *Representing Uncertain knowledge.* Intellect Books

2 Starkey, C.V. (1992) *Engineering Design Decisions.* Edward Arnold

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5 Chatzoglou, P. and Macaulay, L. (1996) A review of existing models for project planning and estimation and the need for a new approach
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7 Dawson, C.W. and Dawson R.J. (1995) Generalised activity-on-the-node networks for managing uncertainty in projects.
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9 Kharbanda, O.P. and Stallworthy, E. (1990) *Project Teams: The human Factor.* Blackwell, Oxford.

APPENDIX G

CONSERV SYSTEMIGRAM

APPENDIX G

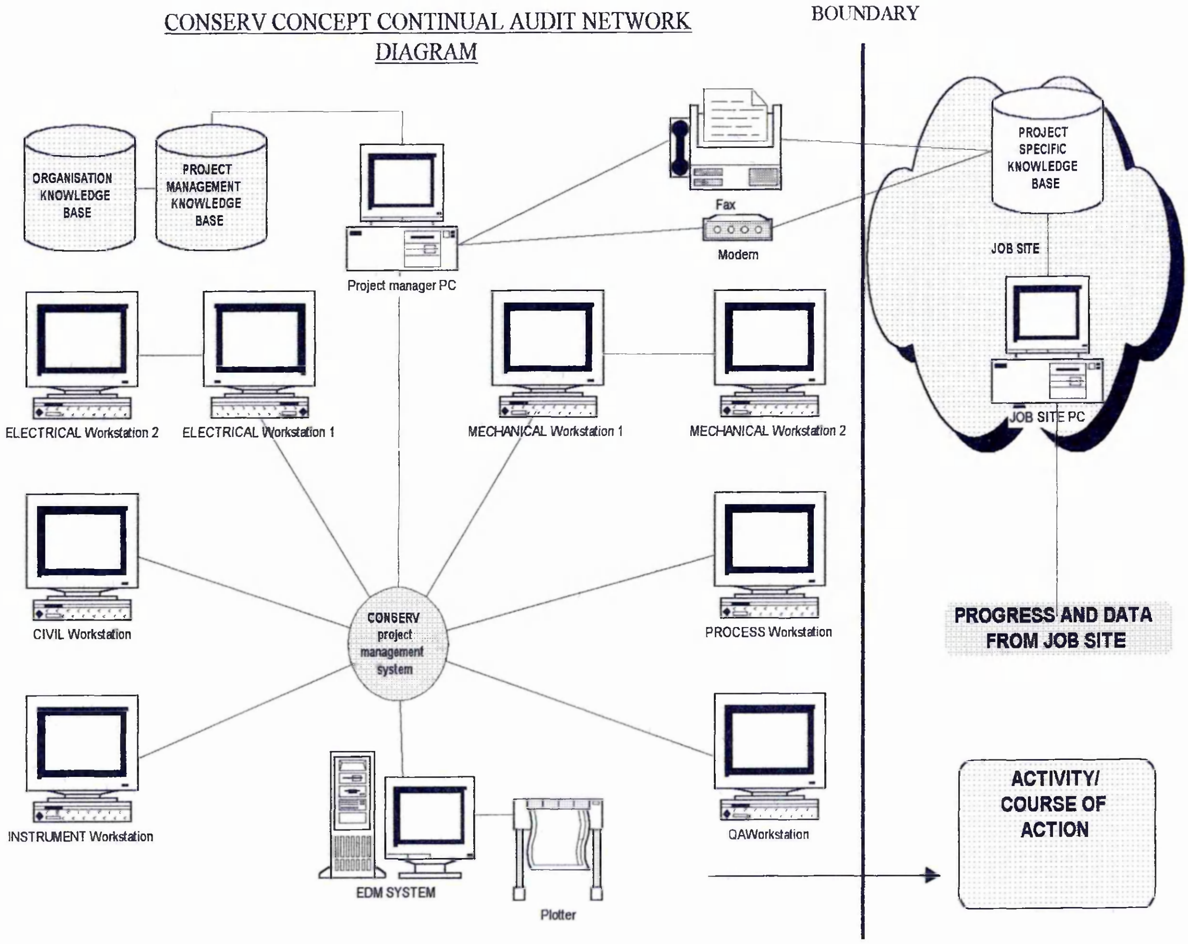
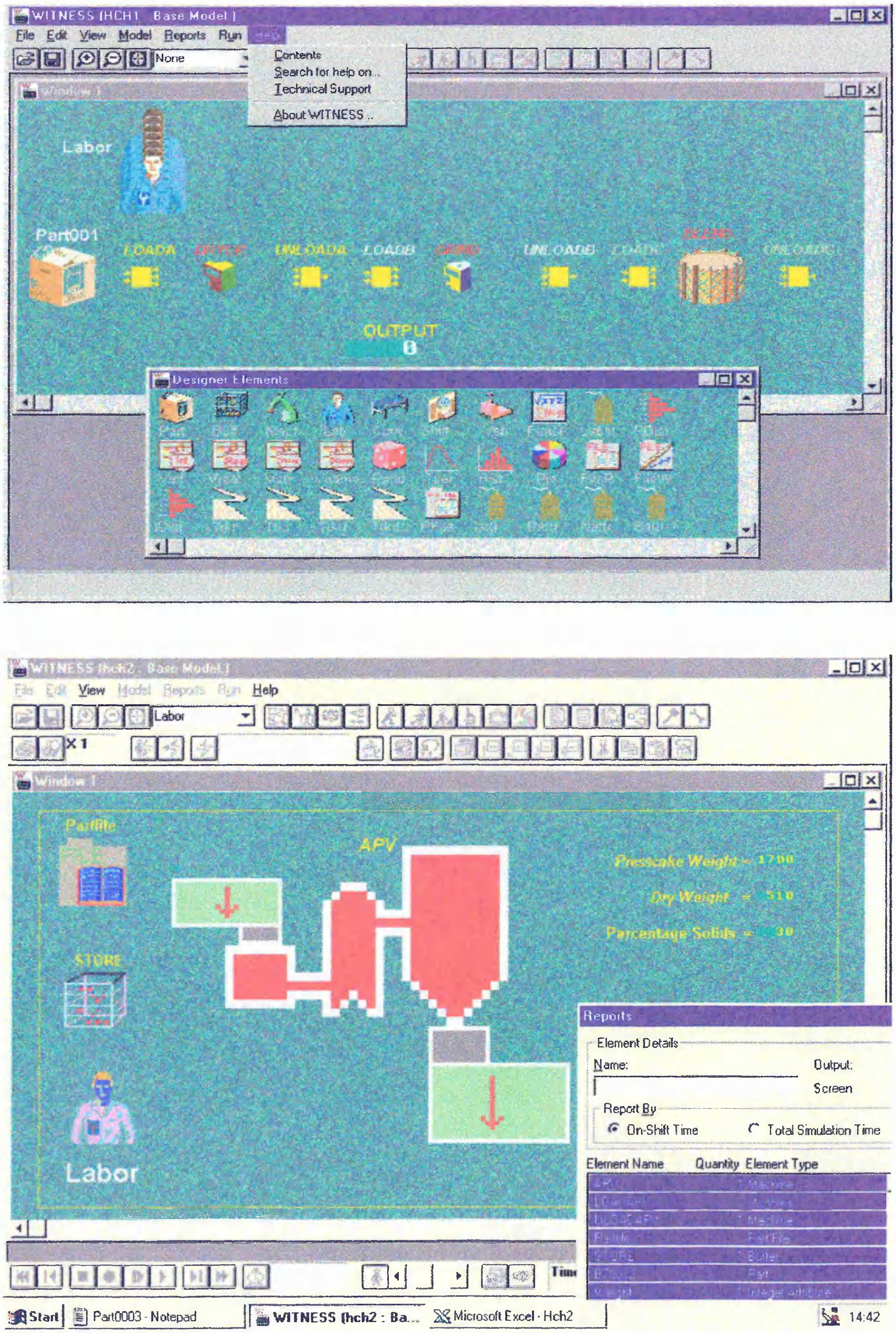


Fig 77 Typical Project and design office arrangement

APPENDIX G



Reports

Element Details

Name:

Output: Screen

Report By

● On-Shift Time ○ Total Simulation Time

Element Name Quantity Element Type

Fig 78 Witness Software screen dump

APPENDIX G

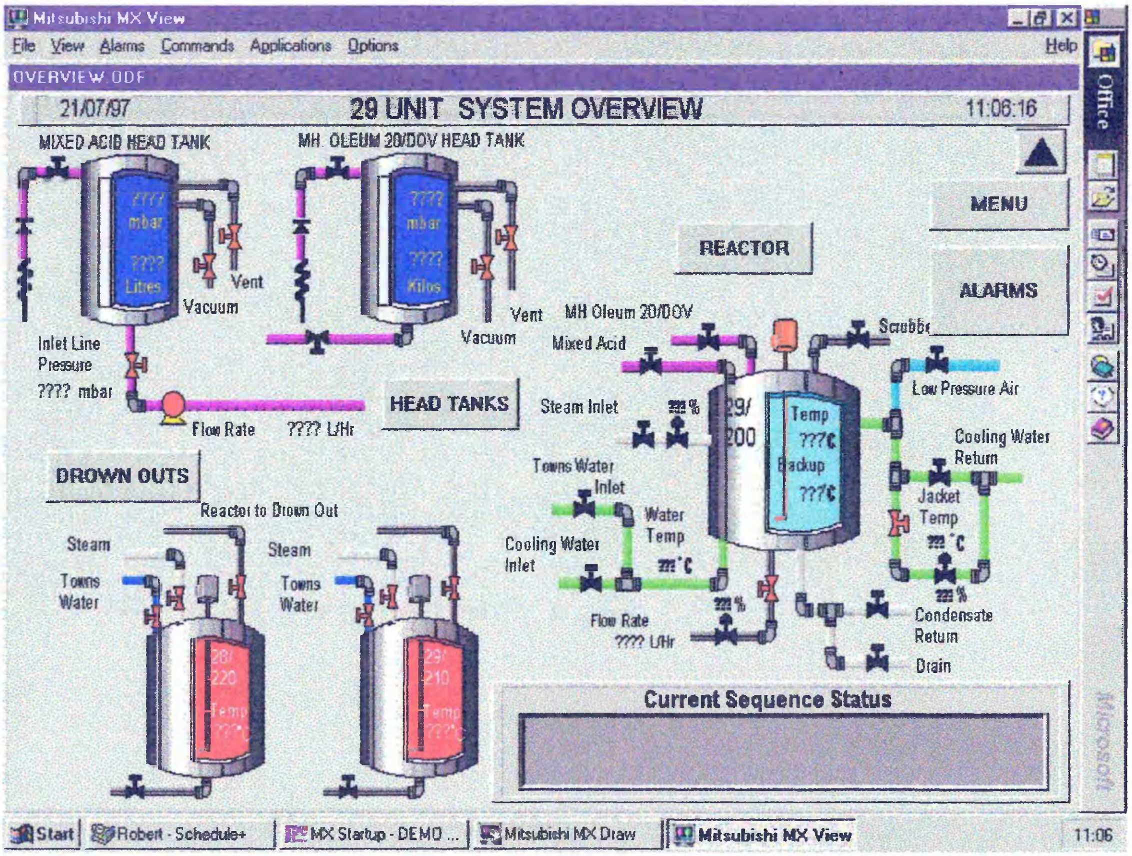


Fig 79 Mitsubishi graphics for Scada system

Chapter VIII

8.0 THE CONCEPT PROCESS AND DEMONSTRATORS

"The only thing that is certain in project management is that nothing is certain"
Author Unknown

8.1 Introduction and review of Uncertainty

8.1.1 Introduction

Chapter VII described how the 3D element of the concept will enable interdisciplinary communication and interaction whilst providing a visualisation of the overall status of the project at any given time. In the final analysis what is important to the project manager is the ability to foresee, anticipate and hopefully avoiding the potential failure mechanisms and thereby achieve an acceptable level of "project success".

Any technique, that goes some way to improving the likelihood of delivering a 'successful' project has therefore to be worthy of consideration.

The ConSERV system software is being designed to assist in identifying the risk elements and uncertainties that are ever present in the management of multidisciplinary capital projects.

As was illustrated in Appendix E5 Fig 43 the risk pattern for each of the project success criteria can be displayed using a radar graph.

A more detailed level of risk evaluation is afforded by the concept, but this has not yet been developed as part of the Demonstrator. i.e. Appendix J4 (Table 21).

Having established the main risks, ConSERV is then able to advise on the more sensitive areas of the project and the application of a unique project management system, designed to 'handle' the critical elements of the project.

This Chapter reviews the issues of managing uncertainty using knowledge based systems, the processes of the two demonstrators, the logic used, the processing requirements and the proposed system architecture.

8.1.2 Review of Focal theory and Hypothesis.

The main purpose of the demonstrators is to provide proof of the concept as required for the purpose of the Ph.D. Reverting to the Table of hypotheses Appendix A9 (Table 2) it can be seen that hypothesis 1,2, and 3 have been addressed as the focal theory of this submission in Chapters 1 and 2. Hypothesis 4 was alluded to in the research findings in Chapter 3. This Chapter considers how the uncertainties in project management can be addressed, and how project sensitivities and the lessons learned from other less successful projects can be incorporated into a comprehensive project management system, i.e. hypotheses 5 and 6.

Traditional project management techniques, the hard skills, are designed to handle a very limited set of project data. The data provided to the planning tools e.g. Microsoft Project V4 is in the form of.

The number of activities.

The dependencies of the activities.

The duration of the activities and the overlap or lag.

Ref. Section 7.4 Fig 70 p 133.

The processing of the data requires that a 'base line' is set for the program and the clock starts running. Updating the data is allowed at any time and the % progress is assigned to each activity. The software uses constraint based reasoning techniques to process the new data and provide a revised assessment of the status of 'the plan'.

No data input is challenged for relevance or validity.

From analysing a number of planning packages used during the industrial research on projects 1 and 2 it was found that whilst the packages themselves varied.

Suretrack v1.5, Microsoft V4 and PrimaVera 4, the method of use and value of the data provided was in reality very limited due to the following reasons;

Insufficient level of work breakdown.

Unrealistic activity durations

Poorly constructed logic.

Overly optimistic resource assumptions

Lack of appreciation of 'external' global issues.

8.1.3 Essential elements

In order to apply the ConSERV technique a number of main elements are in place namely :-

1 A fully sanctioned and justified capital project.

2 Information relating to the specific nature of the project being managed.

3 Knowledge rules concerning the inter related nature of the key project dimensions.

4 The project specific success criteria

5 The user/expert agreed project specific risks.

6 A product selection process able to match the project management and engineering design sensitivities to an appropriate management methodology.

7 A feedback facility able to evaluate the performance of the management systems.

8 A dynamic interactive multi user, multidiscipline interface facility

9 A mechanism to allow organisational requirements to be integrated into the p.m.s.

10 A means of validating maintaining and updating the rules employed.

The concept proposed in the context of this PhD is in the embryonic developmental stage. As was stated at the outset, it was only intended to develop a demonstrator version of the concept, not a prototype version. Ref. p10 (Fig. 1)

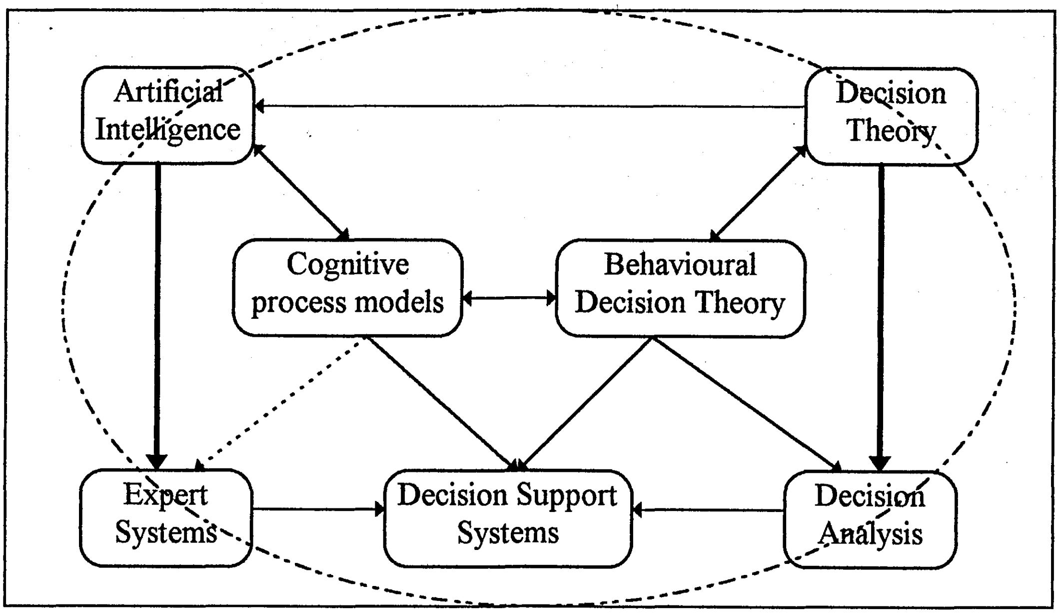


Fig 80 Influence diagram showing the various processes embraced by ConSERV

The key elements of knowledge employed in project management and engineering design have been reasonably well identified Ref. Appendix A3-A4 (Figs 4 and 5). Whilst it is generally held that project managers should be 'competent' in all areas of project management it is recognised that the actual knowledge elements and depth of knowledge used is unlikely to be equally applicable to all projects.

Each project is unique and will, therefore, require a unique sub set of the complete knowledge domains described in the APM/PMI Body of Knowledge, Appendices A4 and A5 (Fig 5 and Table 1) in order to manage it.

The dynamic nature of the project management and engineering design activities will invariably mean that the status of project specific data will be *temporal,* virtually throughout the engineering design and project management life cycle.

In the ConSERV concept, the project **focus** is maintained by ensuring that the project risks and success criteria are constantly redefined and revised against the ever changing project elements.

8.1.3 Methods of representing uncertainty

In developing the concept one of the main challenges was to determine the most suitable technique to handle the uncertainty issues identified in the types of decision making problems facing project managers.

It is beyond the scope of this PhD to provide a rigorous treatise of the various uncertainty programming techniques available, further information on the selection of the development environment is available in the Plausibility study and Demonstrator report submitted to the school 9/2/96. A summary of the more common techniques considered is worthy of inclusion in this section, namely :-

i/ Bayesian methods

ii/ Certainty factor approach and Belief functions

iii/ Epistemic probability (Dempster-Shafer theory of evidence)

iv/ Non monotonic reasoning and Default logics

The Bayesian approach was seen as being a strong contender for managing the many uncertain aspects of project management, as it is able to offer a subjective view of probability in the form of the degree of belief that an ideal (rational) person has about a given hypothesis. The Bayesian rule of conditioning allows a revised degree of belief about the hypothesis to be derived from the observation of some evidence to support the hypothesis. In the Bayesian approach probability is seen as a continuous monotonic function `p` in which :-

The probability value should lie in the range [0,1] and that the probability of a true hypothesis is unity, and that either the hypothesis or its negation will be true.

The Bayesian approach allows the query "Given that I know 'e' what is now my belief in 'h'?". Whilst the modularity of rule based systems makes them computationally efficient, they require extensive representation of the inferences which may be drawn from them. The Bayesian approach does not accommodate concepts such as ambiguity, inconsistency and incompleteness. In project management sciences the cause of the uncertainty is often as important to appreciate as the degree of uncertainty, the Bayesian method of "managing" uncertain issues is very limited in this respect.

The Certainty factor Model was intended for use with rule-based expert systems, and is an interesting example of a heuristic approach which attempts to weaken some of the axioms of the probabilistic techniques whilst still being computationally efficient.

The CF formalism makes the distinction between supporting and conflicting information explicit by using concepts of measure of belief (MB) and measure of disbelief (MD) CF = MB-MD

The syntactic approach to uncertainty propagation adopted by the CF formalism is computationally efficient since it requires only a small number of local computations. Using the CF formalism involves both eliciting appropriate rules for the generation of evidence for and against the hypotheses and eliciting the associated CF's. One benefit afforded by the CF approach is that it is theoretically possible to identify ignorance about a proposition (where MB=MD=0).

Epitemic probability. The D-S theory allows expressions of ignorance to be used and also the rejection of the law of additivity on the basis that it is too strong a constraint. E.g. I may have only weak evidence to support hypothesis (a) but non at all to support (¬ a). The D-S theory offers a technique for pooling evidence from a variety of sources. The view of probability being based on the assessment of prior knowledge is one of specific interest to the field of project management. The basic probability assignment (bpa) is defined with respect to a finite universe of propositions Ω referred to as the frame of discernment. The empty set $\varnothing$ may be thought of as the logical constant *false*.

The D-S theory seems to be a natural model for measuring subjective beliefs. *Shafer*[1] developed a view with *Tversky*[2] that subjective probability judgements should be made by comparison of one's evidence to a scale of canonical (authorised) examples.

The D-S theory allows expressions of partial knowledge which seems to satisfy the main forms of characterisation of types of knowledge employed in project management Ref. Appendage A5. In the Conserv concept the shape of a project is determined by the application of a set of knowledge based rules to a unique set of project specific data.

Non-monotonic logic and default rules,

Krause and Clark[3] suggest "The deductions of non-monotonic logics are not the nature of categoric proofs, they are contingent proofs whose conclusions may become invalid in the light of further information or in a different context.

Formal logic involves the manipulation of symbols using a language and a method of constructing sentences. In first order logics we can define a procedure that will terminate in a finite number of steps if a given formula is valid.

If presented with a false formula, such a procedure may run indefinitely and is said to be semi-decidable. Non-monotonic logics allow us to draw additional contingent conclusions over and above those of classical logic, when it is consistent to do so. There are according to *Krause and Clark*, "Two alternative approaches to extending the expressiveness of traditional logic. The first is to extend the language of the logic itself, the second is to provide additional inference rules.

Modal logics include operators as illustrated on page xxii enabling the construction of statements that facilitate expressions of the form "It is possible that", or "It is necessary that" or "It is consistent that".

Default rules allow conclusions to be drawn without obtaining confirmatory evidence to support the argument. The conclusions drawn can be considered sound if they are based on previous experiences successfully applied in identical scenarios. This form of reasoning facilitates the use of 'experiential' knowledge.

Default rules may be used to construct *contingent* proofs, i.e. proofs whose conclusions may need to be retracted in light of further information becoming available. Prolog uses negation as failure to prove a proposition is true. i.e. If the Prolog interpreter is unable to prove a proposition is a consequence of a program then it will assume it is false. Non-monotonic logics address aspects of ignorance through partial knowledge. Prolog is still seen as being an expressive language for prototyping and implementing expert systems with some non-monotonic capability.

In summarising it would seem that the most appropriate type of uncertainty management approach for the business of project management is a hybrid of the use of *default techniques* as used by Prolog combined with the *symbolic model* argumentation techniques. The same conclusion was reached in the *Plausibilty study* and *Demonstrator Report* presented in June 1996 undertaken in accordance with the KLIC procedure advocated by *Guida and Tasso*[4].

Of the four methods reviewed it was concluded that there were benefits and disadvantages of each. The Win Prolog tool however afforded the greatest flexibility as it was able to combine elements of the Certainty Factor model, epistemic probability and default rules. A more detailed explanation of the selection of the development environment is found in the Plausibility study report.

8.2 The processing requirements of the concept demonstrators

8.2.1 The main processing functions

The starting point for developing the processing requirements of the concept is the project management and engineering design sytemigrams shown in Appendix E2, E3 (Figs 40 and 41) and Appendix F2 and F3 (Fig 63 and 64).

It can be seen that the main objectives of demonstrator A is to provide a project overview that identifies 'the specific needs of the project being managed' and the data transfer and information flow process associated with the engineering design functions The uncertainty issues pertaining to "Project management" that were identified from the industrial research were consistent with the findings from *Hawksmere* and *Bellassi and Tukel*[5] which can be summarised as being :-

The lack of a sufficiently well developed coherent evaluation of the overall shape of the specific needs of the project being managed.

By generalising the global dimension factors of 'typical' projects there is a very real limitation on precisely how the factors can be applied to a given set of conditions pertaining to a specific project at a given time.

E.g. Most project managers *know* that the factors related to the project size and value will influence the success or failure of a project. Ref. Appendix A6 (Fig 6).

One of the main questions that project managers need answering is :-

"How do I identify and subsequently manage the **known** risks in real world project environment ?"

The ConSERV approach recognises the difficulties of processing the numerous risk dimensions of a given project as does *Chapman*[6] ,whose generic process, PRAM highlighted insights into the need for "a more formal process of defining the project to be assessed". For the purpose of expedience the processing functions of the concept are split between the two demonstrators, A and B Ref. p 158 (Fig 84)

In an attempt to provide greater clarity in describing the functionality of the processes involved, a series of screen shots of the demonstrators have been included in Appendix H (Figs 87-89).

8.3 The Demonstrator programs

8.3.1 The Win Prolog ConSERV demonstrator 'A' (Disc Appended)

Demonstrator 'A' consists of 6 specific data processing functions

i/ The extraction of project specific data from the user.

ii/ The extraction of project specific success criteria from the user.

iii/ The extraction of the users subjective risk evaluation of the project.

iv/ The application of knowledge based rules to generate the "experts" risk factors.

v/ The resolution of user-expert differences in risk evaluations.

vi/ Confirmation of project specific data at a given time in the life cycle.

From the project specific data obtained, it is possible to apply further knowledge based rules to identify the project specific design issues. The research identified a number of specific design failure mechanisms which allow a greater level of risk identification Ref. Appendix F (Fig. 65 to 68).

In the initial assessment Appendix E (Fig 52) The overt risk factor assigned to the success criteria "Meeting Quality" was 240, whilst the covert value was 10. i.e. On initial inspection the "expert" system could find no reason to assign risk.

At the second level of analysis however there is a newly identified risk, namely;

Firing Rule 10 Appendix E8 (Fig 46) triggers the secondary Q/A routine

Q1-d ?Are design resources a) experienced', b)'inexperienced', c)'satisfactory'

Q2-d Assuming Company procedures, (Choice 10c p93) = yes then ?Do procedures include 'design reviews.'

Q3-d ?Does design process include 'design checks'

Newly generated risk resulting from design queries

Rule701 `If` Q1-d = b `and` Q2-d = no `and` Q3-d = no `then` let CRF7-09 = [CRF7-09] + 110

Other permutations might include:

Rule702 `If` Q1-d = c `and` Q2-d = no `and` Q3-d = yes `then` let CRF7-09 = [CRF7-09] + 40.

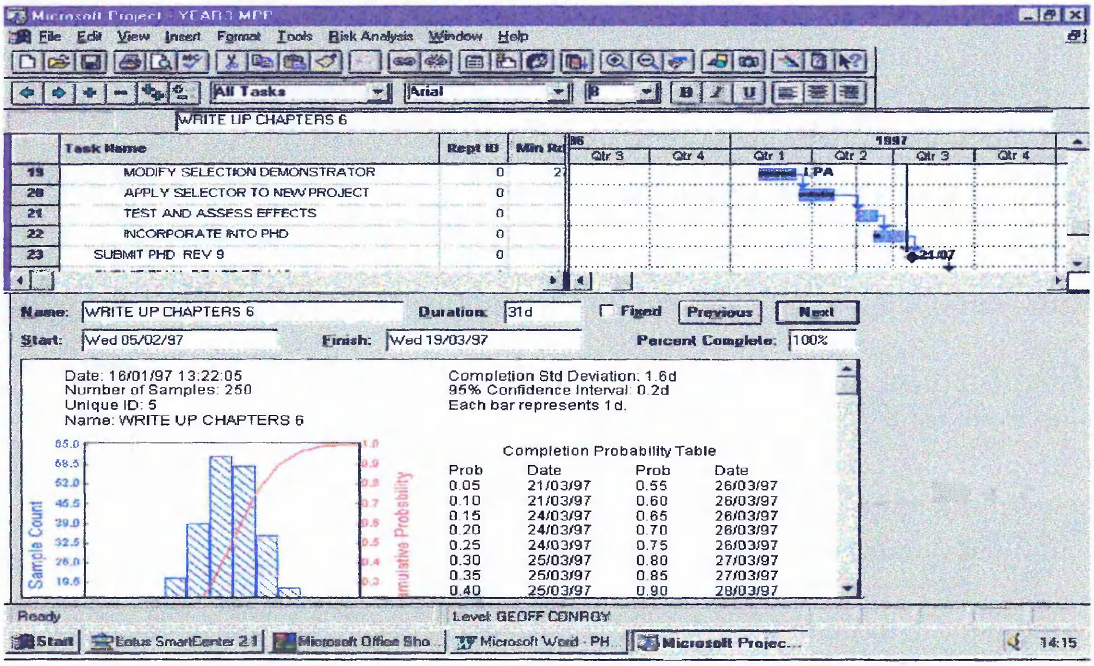
Ref. Fig 35 p 94

8.3.2 Risk Identification and Management

The ConSERV approach uses a risk identification technique to quantify project uncertainties. The main reason for identifying the project specific risks is that a risk management strategy can be developed to take account of the specific risks identified. Again there are many risk management techniques recommended an example of one such process "The Riskman methodology" has been shown on p96 (Fig 37) whilst a cost based risk evaluation is shown in Appendix E (Fig 42) Probabilistic risk evaluations can be undertaken for activity duration's using Monte Carlo simulations Ref. (Fig 81) below.

Risk assessments require that risks have been identified and quantified, this is usually the most difficult part of risk management as each risk has its own trigger mechanism and impact, and each manager has his/her own perception of what constitutes a risk. The ConSERV concept recognises the problems of identifying risks and their temporal nature, hence the structure of the demonstrator which is intended to facilitate the multiusers of the system by allowing periodic risk reviews.

The concept also recognises the potential for discrepancy between user subjective risk assessment and the 'expert' evaluation of the risk issues pertaining to a given set of circumstances. i.e. The project specific data.



WRITE UP CHAPTERS 6

	Task Name	Rept ID	Min Rt
19	MODIFY SELECTION DEMONSTRATOR	0	2
20	APPLY SELECTOR TO NEW PROJECT	0	
21	TEST AND ASSESS EFFECTS	0	
22	INCORPORATE INTO PHD	0	
23	SUBMIT PHD REV 9	0	

Name: WRITE UP CHAPTERS 6
Duration: 31d
☐ Fixed
Start: Wed 05/02/97
Finish: Wed 19/03/97
Percent Complete: 100%

Date: 16/01/97 13:22:05
Number of Samples: 250
Unique ID: 5
Name: WRITE UP CHAPTERS 6

Completion Std Deviation: 1.6d
95% Confidence Interval: 0.2d
Each bar represents 1d.

Completion Probability Table

Prob	Date	Prob	Date
0.05	21/03/97	0.55	26/03/97
0.10	21/03/97	0.60	26/03/97
0.15	24/03/97	0.65	26/03/97
0.20	24/03/97	0.70	26/03/97
0.25	24/03/97	0.75	26/03/97
0.30	25/03/97	0.80	27/03/97
0.35	25/03/97	0.85	27/03/97
0.40	25/03/97	0.90	28/03/97

Fig 81 Probabilistic risk evaluation for a single activity

8.3.3 Knowledge based rules

The ConSERV concept demonstrator has only a very limited set of knowledge rules as shown in Appendix E8 (Fig 46) and pages 153 and 155. From the research data analysed from projects 1 and 2 it is felt that these rules are sufficient to justify that a Knowledge Based technique can be applied to the global issues of managing capital multidisciplinary projects. The fully developed version will be required to take account of a much greater number of rules in order to be able to apply risk values to the secondary issues. The "expertise" lies in the ability to interpret risk issues by comparing potential oversights and known causes of project failure with the project specific data made available by the user/s. An example of typical organisational guidelines is presented in Appendix J4 (Table 21). The fully developed version of the concept will use the guidelines in order to generate further knowledge based rules that use "expertise" to obtain a more detailed picture of the likely project risks that may emerge. Once the risk issues have been identified the user can then determine the level of risk that is considered acceptable to proceed with 'managing' the project.

E.g. Having identified that the project involves a 'known' process it should be possible to address a number of secondary project specific risk issues.

Q1-p ?Does process involve hazardous chemicals. 'Yes', 'No'

Q2-p ?Does process involve exothermic reactions. 'Yes', 'No'

Q3-p ?Does process involve pressure relief. 'Yes', 'No'

Q4-p ?Does process involve by-products. 'Yes', 'No'

Q5-p ?Does process involve emissions. 'Yes', 'No'

The overt risks assessed against the 'Client Satisfaction' success criteria were 110, whilst the covert risks were again only 10, i.e. The system has no reason to apportion risks against client satisfaction. The newly generated project risks resulting from the secondary process QA routine provides a new risk factor from:

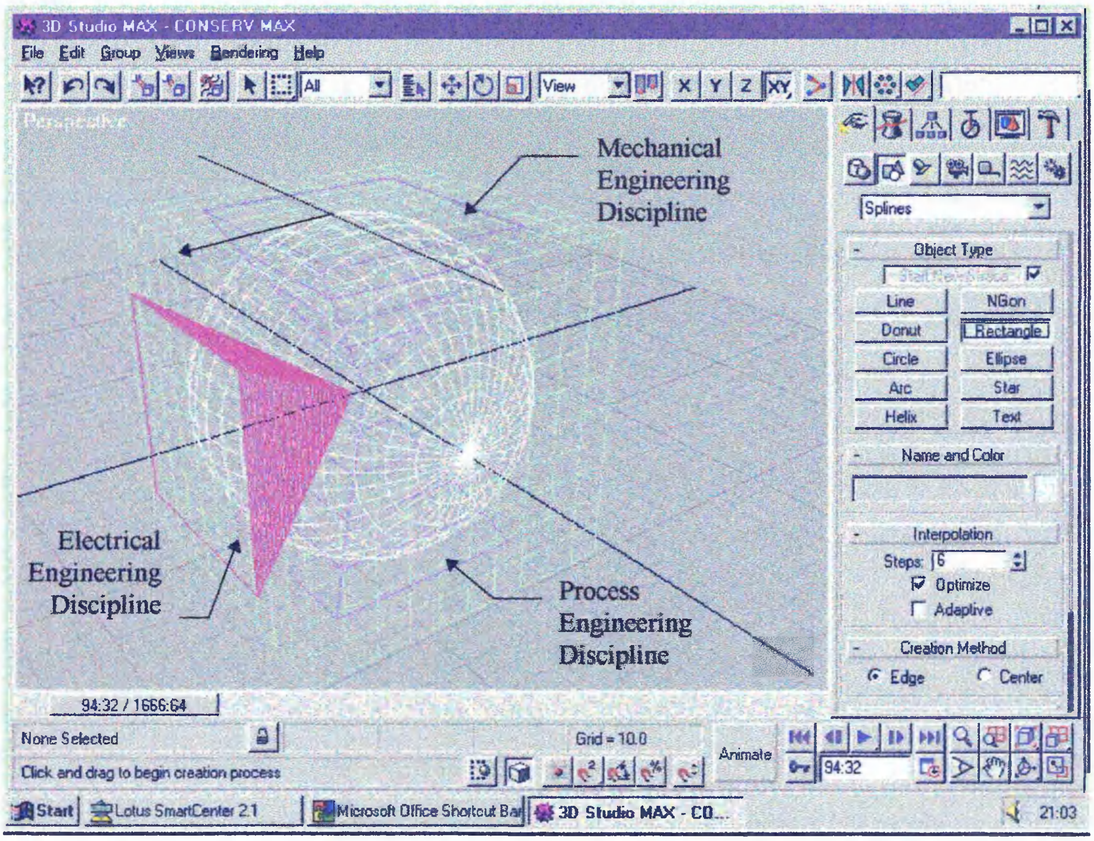
Rule 401 If Q1-p = yes and Q2-p = yes and Q3-p = yes and Q4 = yes and Q5 = yes then ? Do engineering and design man-hours include for "Pressure relief regulations design" and "emission controls"

if no then let CRF4-08 = [CRF7-08] + 50

8.3.4 The Kinetix 3D Studio Demonstrator B

The 3D Studio software has already been described in Chapter VII Section 7.1.2.

In the demonstrator “Conserv.max” A 3dimensional visualisation of a project involving ‘3’ engineering disciplines has been simulated. The animation shows the sphere reducing over a period of time frames until progress is ‘apparently’ held up by a single pyramid which is not reducing in length and is therefore preventing the sphere from reducing. The fact that the sphere has not reduced over a given period of time means that one or more engineering discipline is ‘slipping’. i.e. The length of the pyramid has not reduced. The benefit of the 3D visualisation is that the user can see at a glance which engineering discipline is causing the problem.



94:32 / 1666:64

None Selected

Click and drag to begin creation process

Grid = 10.0

94:32

Steps: 6

☑ Optimize

☐ Adaptive

● Edge ○ Center

Fig 82 Screen dump of ConSERV 3D

8.4 The concept architecture and structure

8.4.1 The basic elements of the KBS

Fig 83 shows the main elements required in the ConSERV KBS.

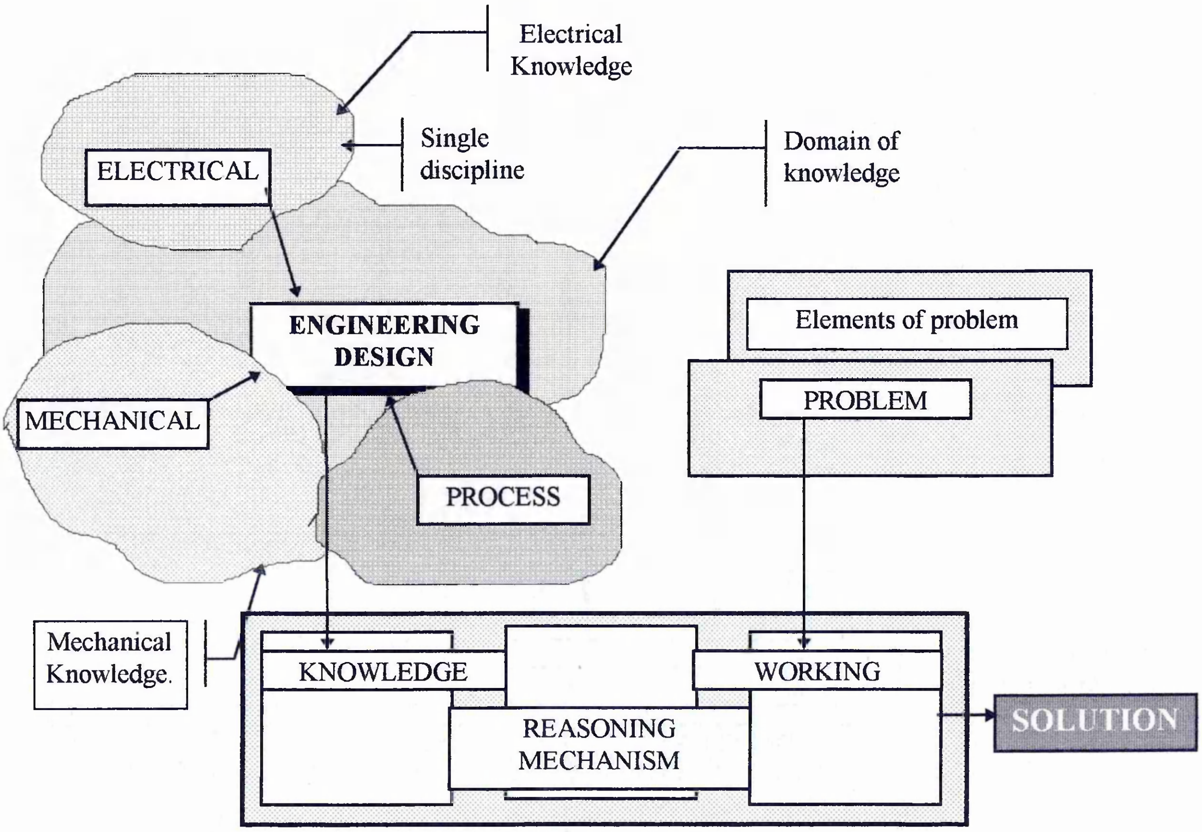


Fig 83 Diagramatic representation of the knowledge based system

8.4.2 The architecture and structure

The main differences between traditional software and knowledge based systems was discussed in Chapter V Section 5.1.2 pp88-89. An example of the system architecture is shown below in Fig 84.

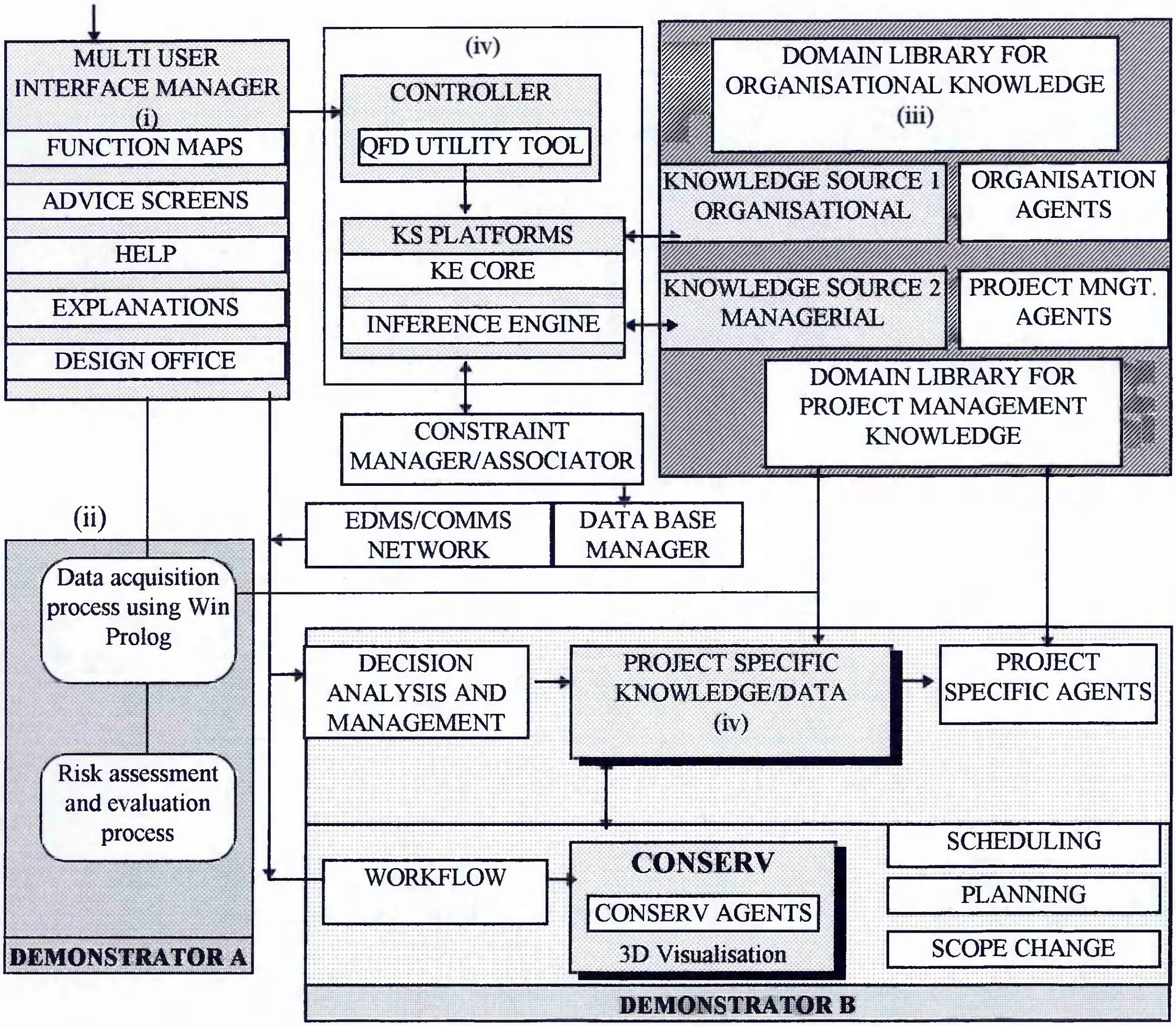


Fig 84 Architecture for comprehensive project management concept

The system architecture proposed for the concept consists of :-

i) The interface manager
ii) Data acquisition and risk evaluation
iii) The Domain library
iv) The Conserv 3D model and its interfaces
v) The system controller

8.4.3 What ConSERV does.

In order to better illustrate how the concept works in practice the two Figs 85 and 86 shown below have been provided. The comparison is intended to demonstrate how the ConSERV concept should be able to improve the likelihood of project success by identifying and assigning responsibility for managing the project specific risk issues.
It is anticipated that there are likely to be more engineering man-hours required to "engineer" a workable solution in order to satisfy the primary and secondary risks.
In the new concept these will be useful productive man-hours assigned to specific risk issues at the requisite period in the project life cycle, rather than man-hours retrofitted to the project in the form of an apparent oversight.

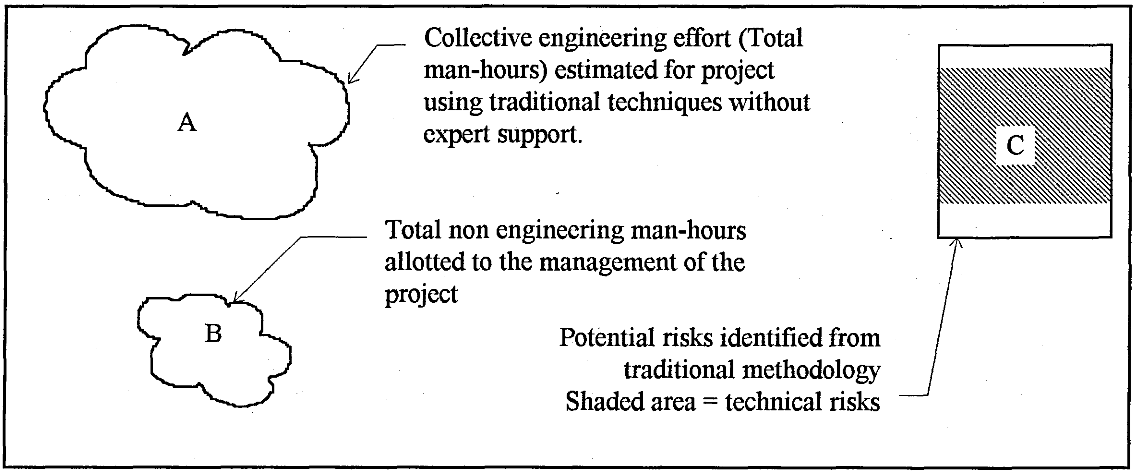


Fig 85 Proportion of engineering and non engineering man hours in project obtained by traditional means

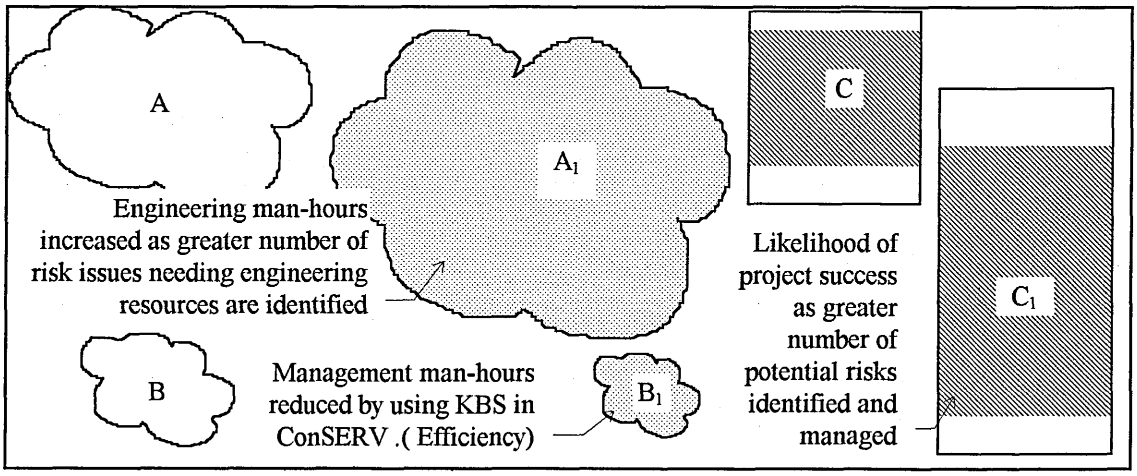


Fig 86 Proportion of engineering and non engineering man hours obtained by ConSERV

8.4.4 How it does it

The way that ConSERV works is to develop a pathway to the heart of the project risk issues by using four levels of evaluation techniques
i/ Level 1.0 The overall project risk level
ii/ Level 2.0 The project specific risk level
iii/ Level 3.0 The quantifiable risk level
iv/ Level 4.0 The detailed risk level

Level 1.0
Subjective global project risks evaluated, using unfounded assumptions and heuristics assessments

The risk evaluation undertaken by the project manager (user) is recognised as being error prone due to lack of experience, unnecessary caution, optimism, pessimism etc.

Level 2
Objective **project specific risks** determined using "experiential" knowledge from system

The risks identified from the initial assessment by the "concept" are unique to the project being managed.

Note The overt (apparent) project risks identified at level 1 are unified using the covert (hidden) risk Level 2 assessment.

Level 3
Objective in depth **project specific risks** identified from the use of **guidelines process** for engineering reviews (Ref. Appendix J) Engineering level

The risks identified from the Level 3 assessment are done so by using a structured engineering review process of the project specific design (Not a Hazop study) in which the impact on cost and design hours can be indicated from the item reference for each specific guideline.

Level 4
Objective project specific risks isolated from the **guideline process** analysed using an **in depth** Hazop assessment technique to generate **detailed risks**

The risks identified during the final level of analysis are those risks that are unique to the project being managed, the processes being employed and the specific difficulties that the processes and the technology present.
The risks are further refined by the experiential knowledge incorporated within the knowledge bases and knowledge based rules.

8.5 Conclusions and references

8.5.1 Conclusions

This Chapter has reviewed various methods of representing uncertainty using different logic reasoning processes. The Chapter alluded to the processing requirements of the concept and described the function and processing capabilities of the two Demonstrators.

Most project managers recognise the need to identify and assign ownership for risks, they also recognise that there are many potential pitfalls that can be eliminated by simply being aware of their presence. The guidelines listed in the Appendix J are normally applied as part of the company procedures in a bid to reduce the level of uncertainty. This procedure is obviously better than nothing but, as most project managers will agree, the nature of project management is highly temporal, and the risks identified at the outset will invariably be replaced by new risks over the project management and engineering design life cycle. Here the concept comes very much into its own, as it allows the user to not only identify and therefore manage the initial risks, but also to revisit the key dimensions of the project at regular time intervals in order to identify the most recent risks that have emerged since the previous assessment. *Madachy* [7] has developed the Constructive Cost Model (COCOMO) which aids project planning by identifying, categorizing, quantifying and prioritising project risks. *Toth* [8] has also provided an approach for automatically determining project risk factors based on answers to questionnaires. The systems are designed to assist in software development, and as such are not applicable to the types of project difficulties faced in the Chemical industry.

8.5.2 References

1 Shafer, G (1987) *Probability Judgement in Artificial Intelligence and Expert Systems*
Statistical Science vol. 2, no 1, 3-16

2 Shafer, G and Tverskey, A (1985) *Languages and Designs for Probability Judgement*
Cognitive Science vol 9 309-339

3 Krause, P and Clark, D (1993) *Representing Uncertain knowledge.* Intellect Books

4 Guida, G. and Tasso, C. (1994) *Design and Development of knowledge based systems* J Wiley London.

5 Belassi, W. and Tukel O.I. (1996) 'A new framework for determining critical success/failure factors in projects'
International Journal of Project Management vol. 14, no.3, 141-151.

6 Chapman, C. (1997) 'Project risk analysis and management PRAM the generic process'.
International Journal of Project Management, vol.15,no. 5, 273-287

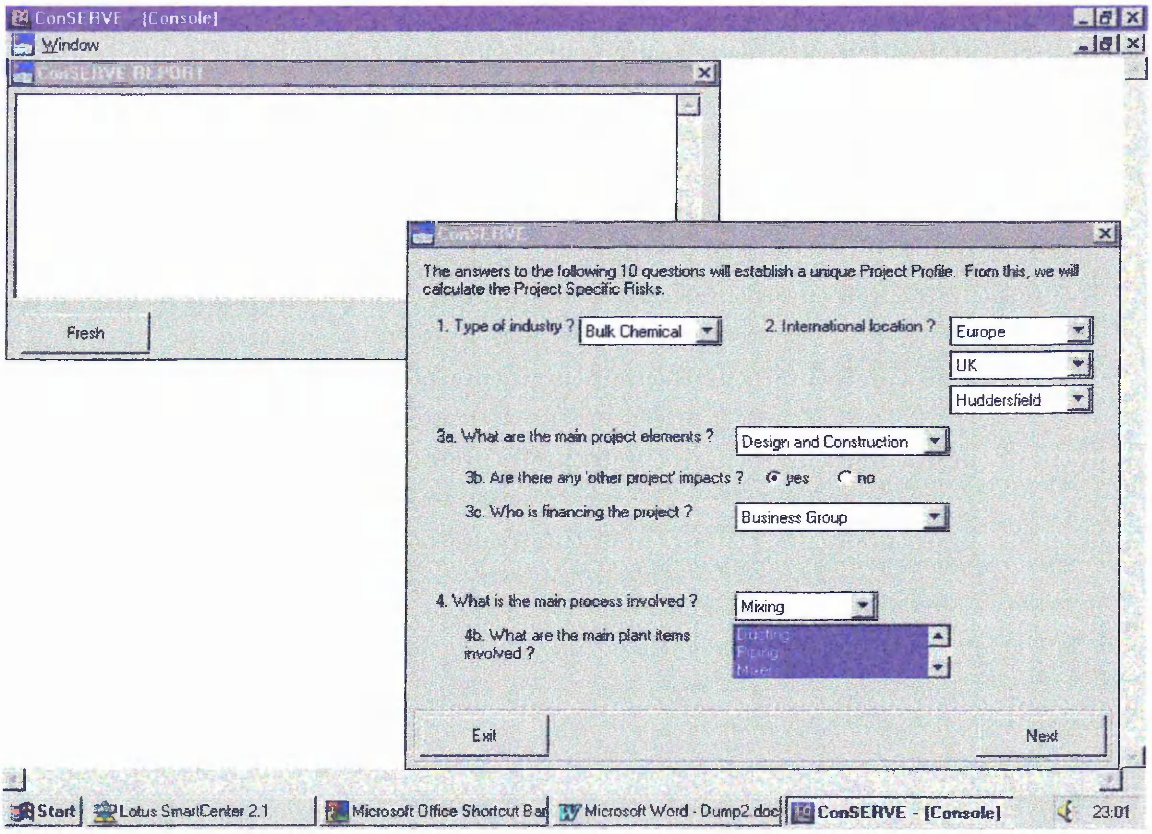
7 Madachy, R. J. (1995) *Knowledge-based risk assessment and cost estimation.*
Automated Software Engineering vol. 2, no. 3, 219-230. (INSPEC)

8 Toth, G.A. (1995) 'Automated method for identifying and prioritising project risk factors'. Automated Software Engineering vol. 2, no. 3, 231-248.

APPENDIX H

DIAGRAMATIC REPRESENTATION OF KBS
CONSERV SYSTEM ARCHITECTURE
ELICITATION PROCESS SCREENDUMPS
SUCCESS CRITERIA SELECTION SCREENDUMP
SUBJECTIVE RISK INPUT SCREENDUMPS
PROJECT CONFIRMATION SCREENDUMP
RISK FACTOR COMPARATOR
RADAR GRAPH OF SPECIFIC PROJECT SHAPE

APPENDIX H



The answers to the following 10 questions will establish a unique Project Profile. From this, we will calculate the Project Specific Risks.

1. Type of industry ? Bulk Chemical

2. International location ? Europe / UK / Huddersfield

3a. What are the main project elements ? Design and Construction

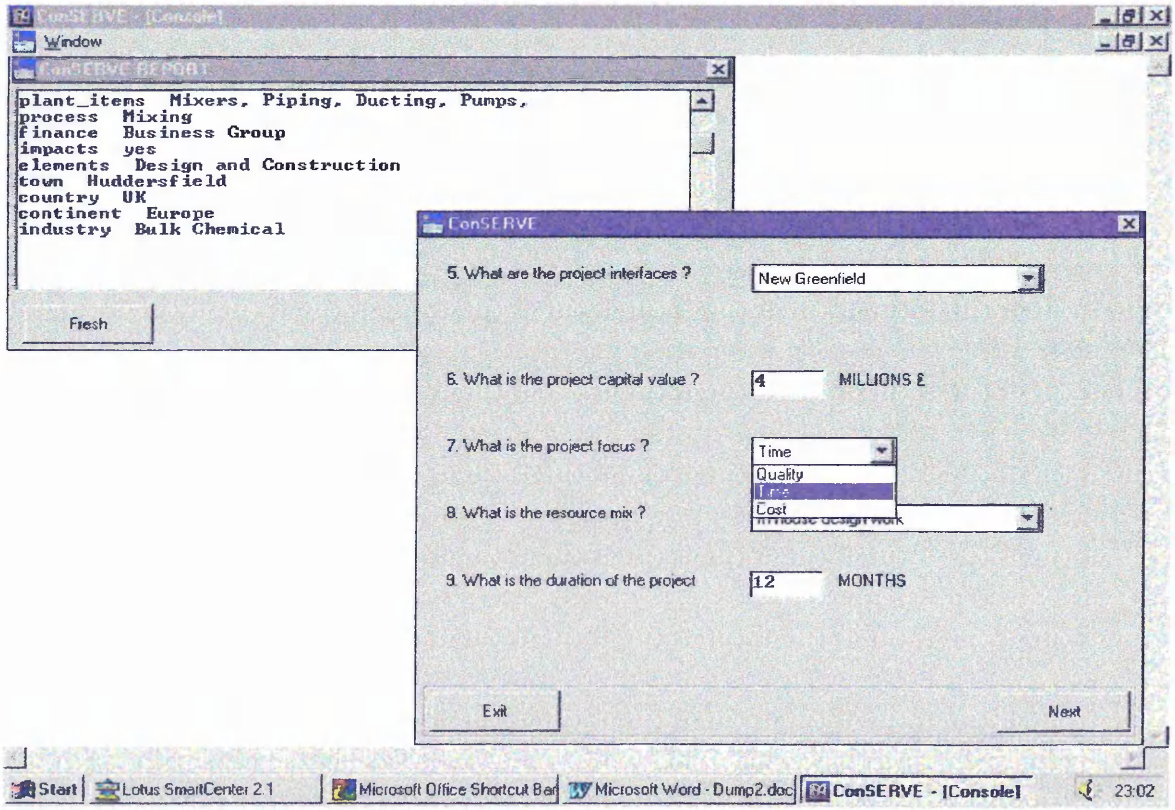
3b. Are there any 'other project' impacts ? ● yes ○ no

3c. Who is financing the project ? Business Group

4. What is the main process involved ? Mixing

4b. What are the main plant items involved ? Ducting, Piping, Mixers

Fig 87 The Conserv project specific data extraction process Demonstrator A Screen 1



```
plant_items  Mixers, Piping, Ducting, Pumps,
process  Mixing
finance  Business Group
impacts  yes
elements  Design and Construction
town  Huddersfield
country  UK
continent  Europe
industry  Bulk Chemical
```

5. What are the project interfaces ? New Greenfield

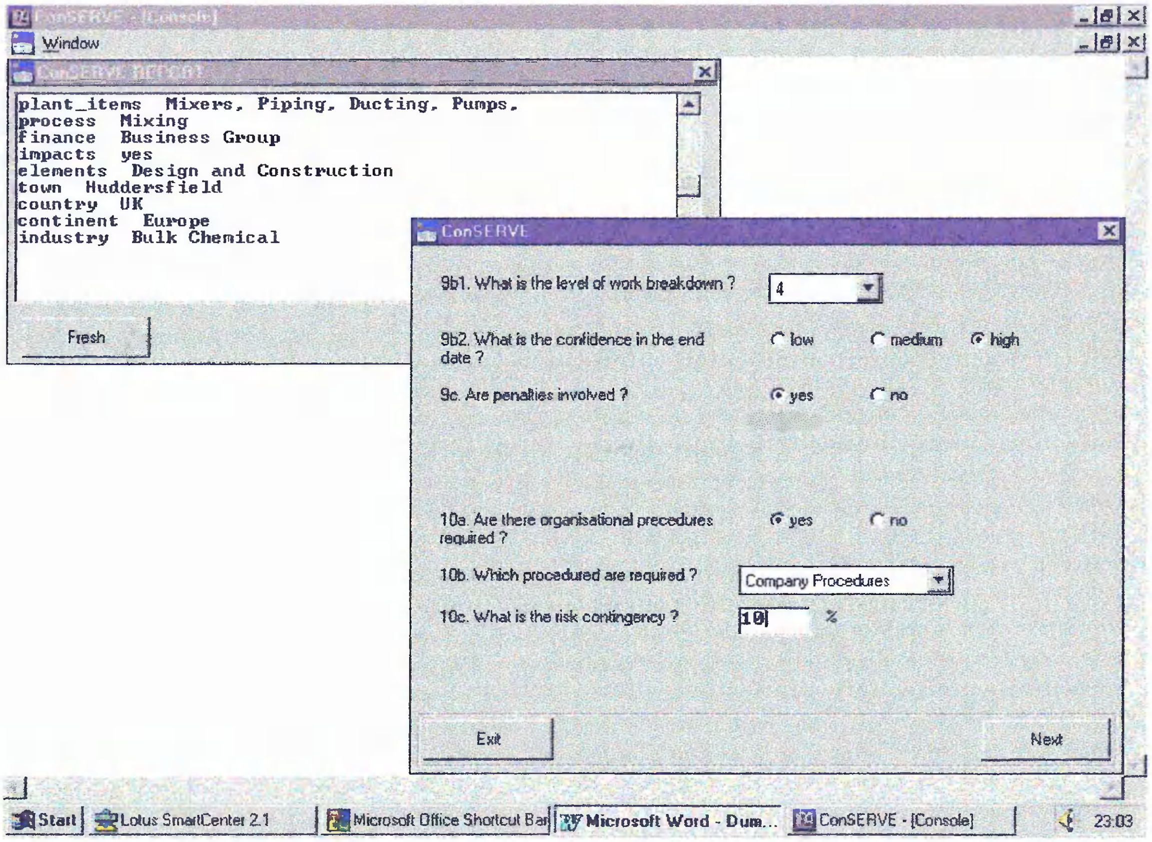
6. What is the project capital value ? 4 MILLIONS £

7. What is the project focus ? Time

8. What is the resource mix ? In house design work

9. What is the duration of the project 12 MONTHS

Fig 88 The Conserv project specific data extraction process Demonstrator A Screen 2



```
plant_items   Mixers, Piping, Ducting, Pumps,
process   Mixing
finance   Business Group
impacts   yes
elements   Design and Construction
town   Huddersfield
country   UK
continent   Europe
industry   Bulk Chemical
```

9b1. What is the level of work breakdown ? 4

9b2. What is the confidence in the end date ? ○ low ○ medium ● high

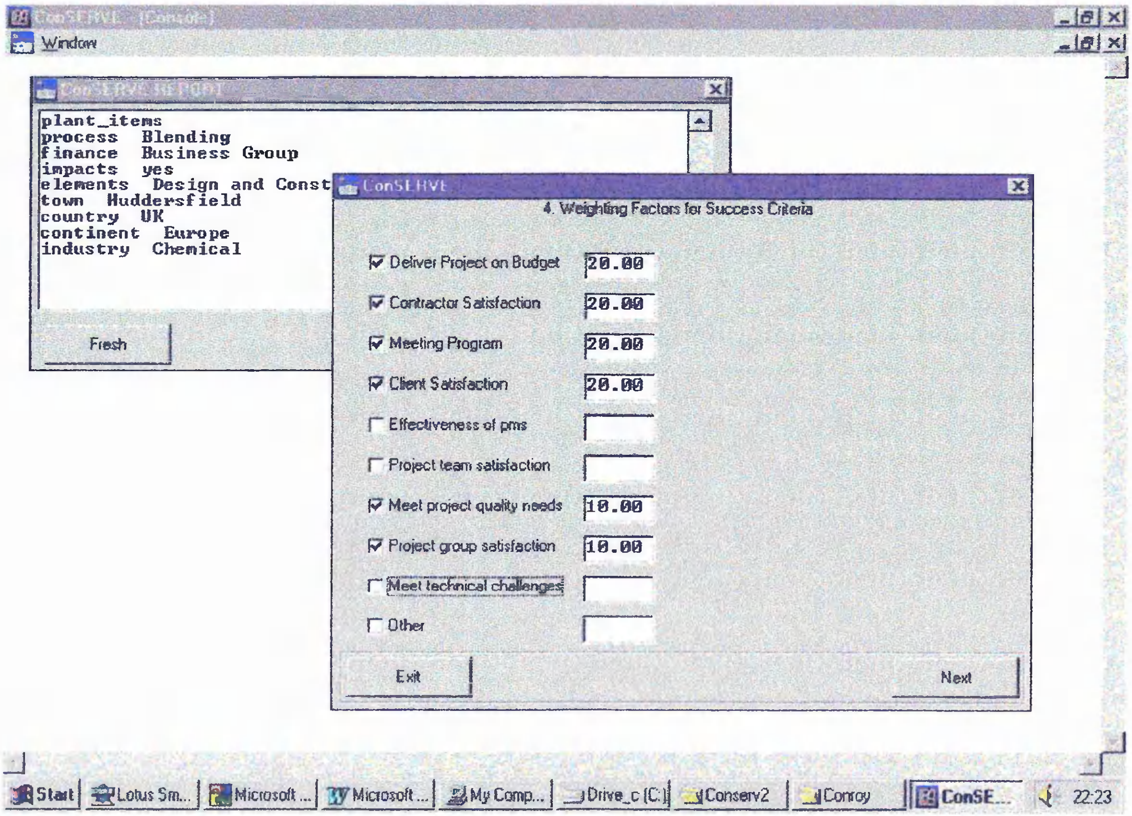
9c. Are penalties involved ? ● yes ○ no

10a. Are there organisational precedures required ? ● yes ○ no

10b. Which procedured are required ? Company Procedures

10c. What is the risk contingency ? 10 %

Fig 89 The Conserv project specific data extraction process Demonstrator A Screen 3

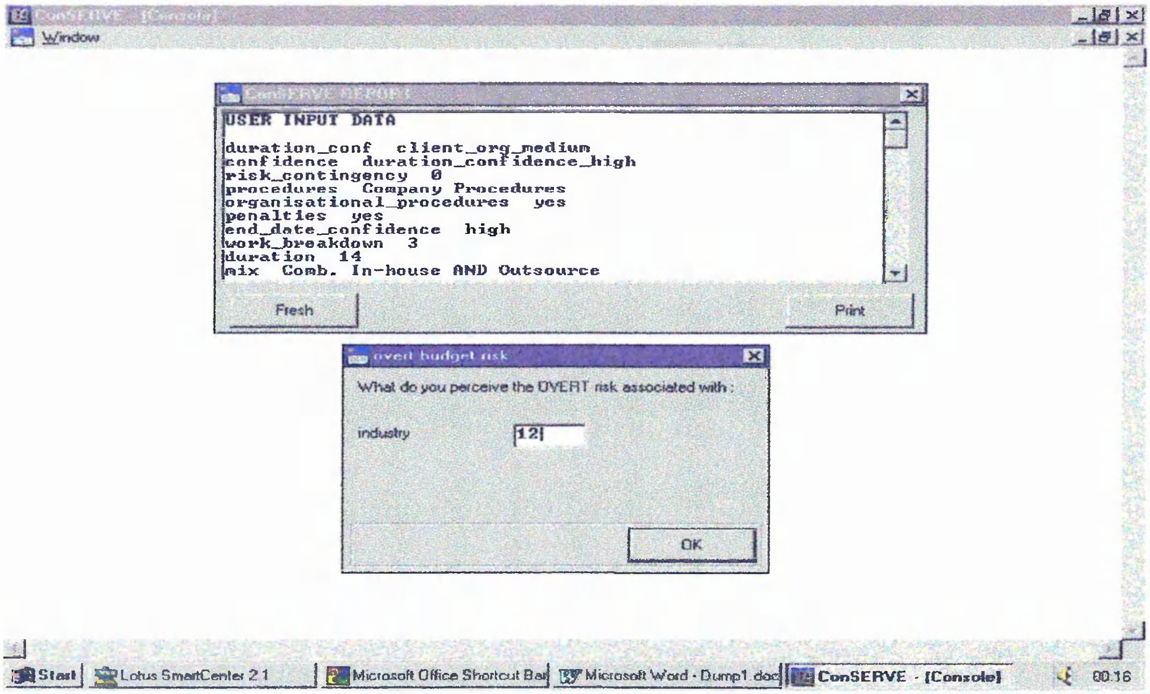


```
plant_items
process   Blending
finance   Business Group
impacts   yes
elements   Design and Const
town   Huddersfield
country   UK
continent   Europe
industry   Chemical
```

4. Weighting Factors for Success Criteria

- ☑ Deliver Project on Budget 20.00
- ☑ Contractor Satisfaction 20.00
- ☑ Meeting Program 20.00
- ☑ Client Satisfaction 20.00
- ☐ Effectiveness of pms
- ☐ Project team satisfaction
- ☑ Meet project quality needs 10.00
- ☑ Project group satisfaction 10.00
- ☐ Meet technical challenges
- ☐ Other

Fig 90 Success criteria input Demonstrator A screen 4



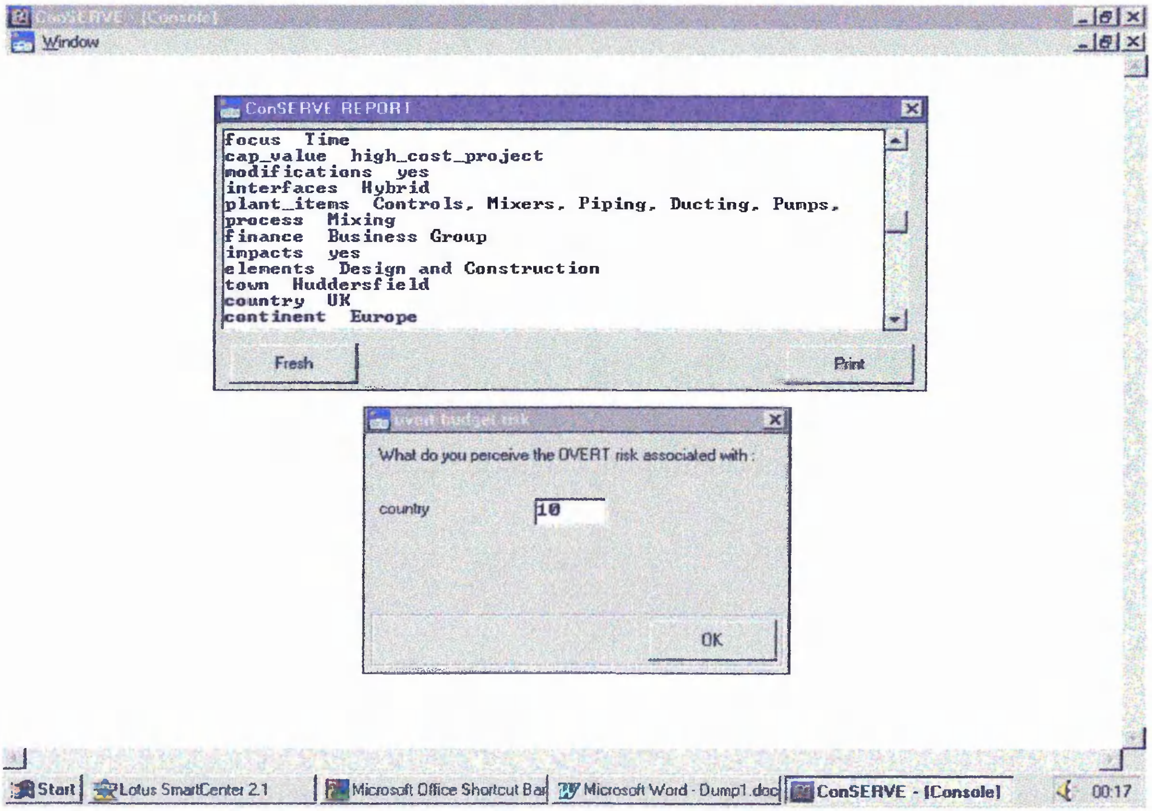
```
USER INPUT DATA

duration_conf  client_org_medium
confidence  duration_confidence_high
risk_contingency  0
procedures  Company Procedures
organisational_procedures  yes
penalties  yes
end_date_confidence  high
work_breakdown  3
duration  14
mix  Comb. In-house AND Outsource
```

What do you perceive the OVERT risk associated with :

industry 12

Fig 91 Subjective risk assessment of each success criteria (Budget) industry

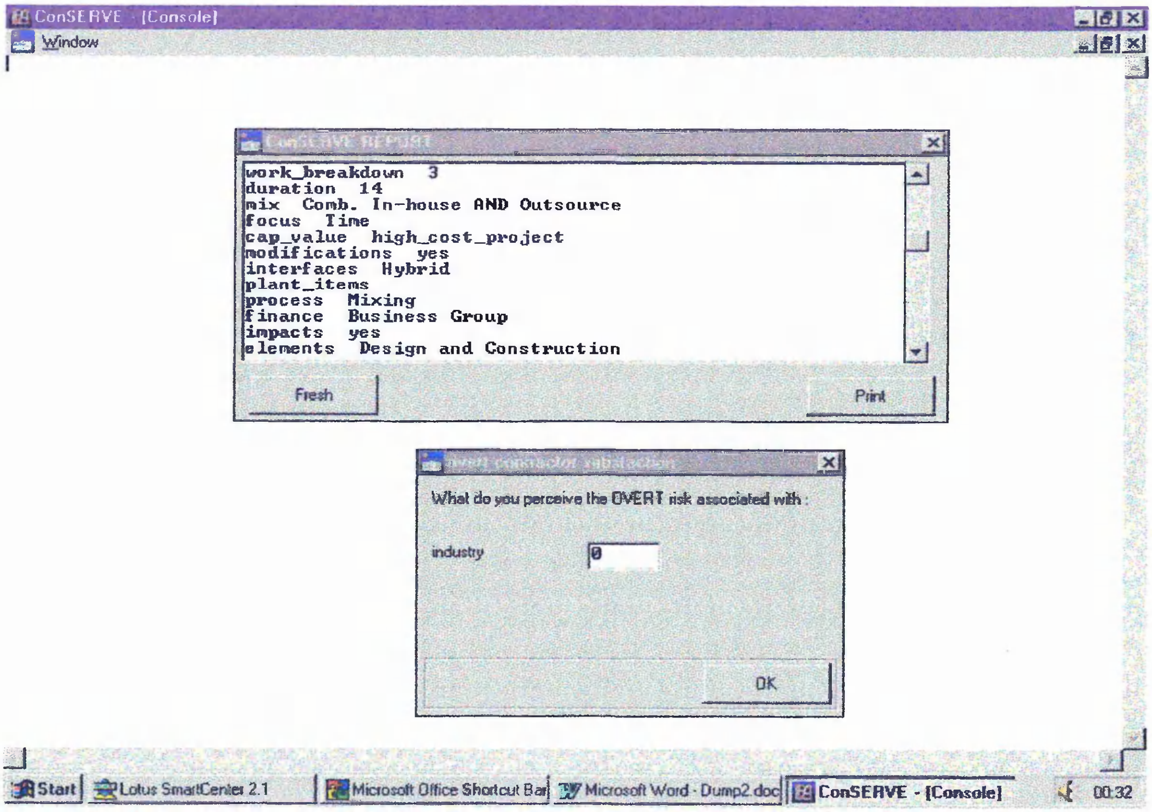


```
focus  Time
cap_value  high_cost_project
modifications  yes
interfaces  Hybrid
plant_items  Controls, Mixers, Piping, Ducting, Pumps,
process  Mixing
finance  Business Group
impacts  yes
elements  Design and Construction
town  Huddersfield
country  UK
continent  Europe
```

What do you perceive the OVERT risk associated with :

country 10

Fig 92 Subjective risk assessment of each success criteria (Budget) location

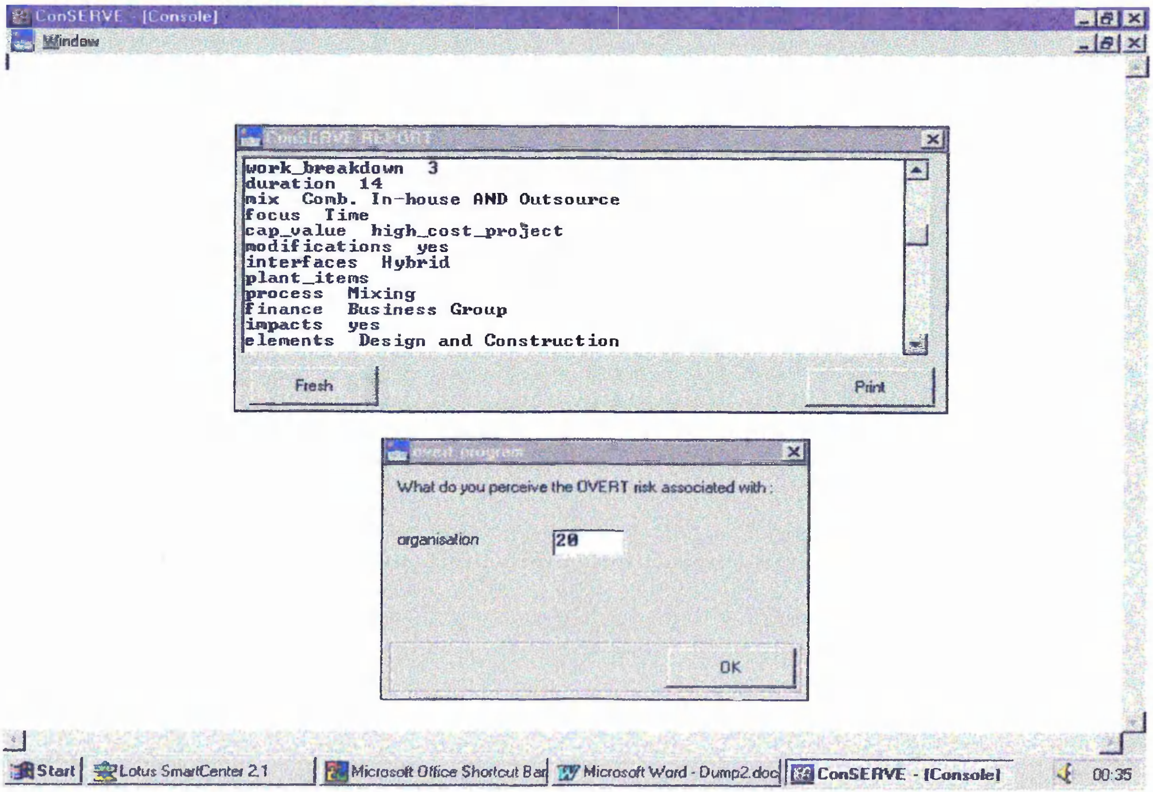


```
work_breakdown  3
duration  14
mix  Comb. In-house AND Outsource
focus  Time
cap_value  high_cost_project
modifications  yes
interfaces  Hybrid
plant_items
process  Mixing
finance  Business Group
impacts  yes
elements  Design and Construction
```

What do you perceive the OVERT risk associated with :

industry 0

Fig 93 Subjective risk assessment of each success criteria (Contractor satisfaction) industry

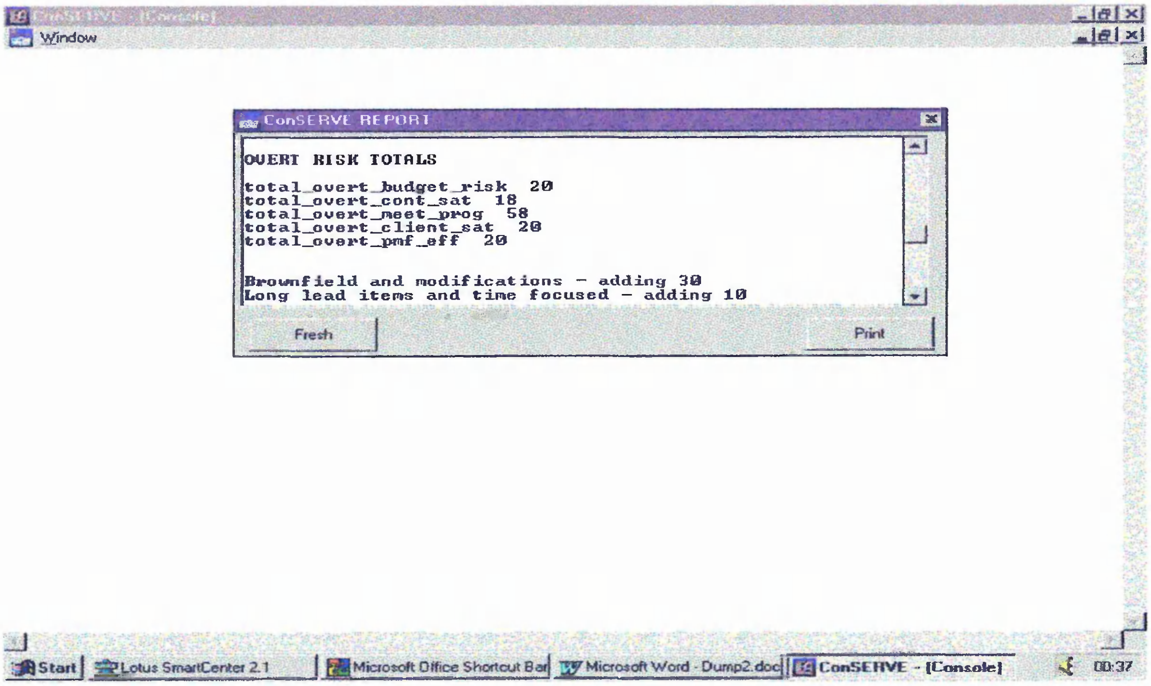


```
work_breakdown  3
duration  14
mix  Comb. In-house AND Outsource
focus  Time
cap_value  high_cost_project
modifications  yes
interfaces  Hybrid
plant_items
process  Mixing
finance  Business Group
impacts  yes
elements  Design and Construction
```

What do you perceive the OVERT risk associated with :

organisation 20

Fig 94 Subjective risk assessment of each success criteria (Program) organisation

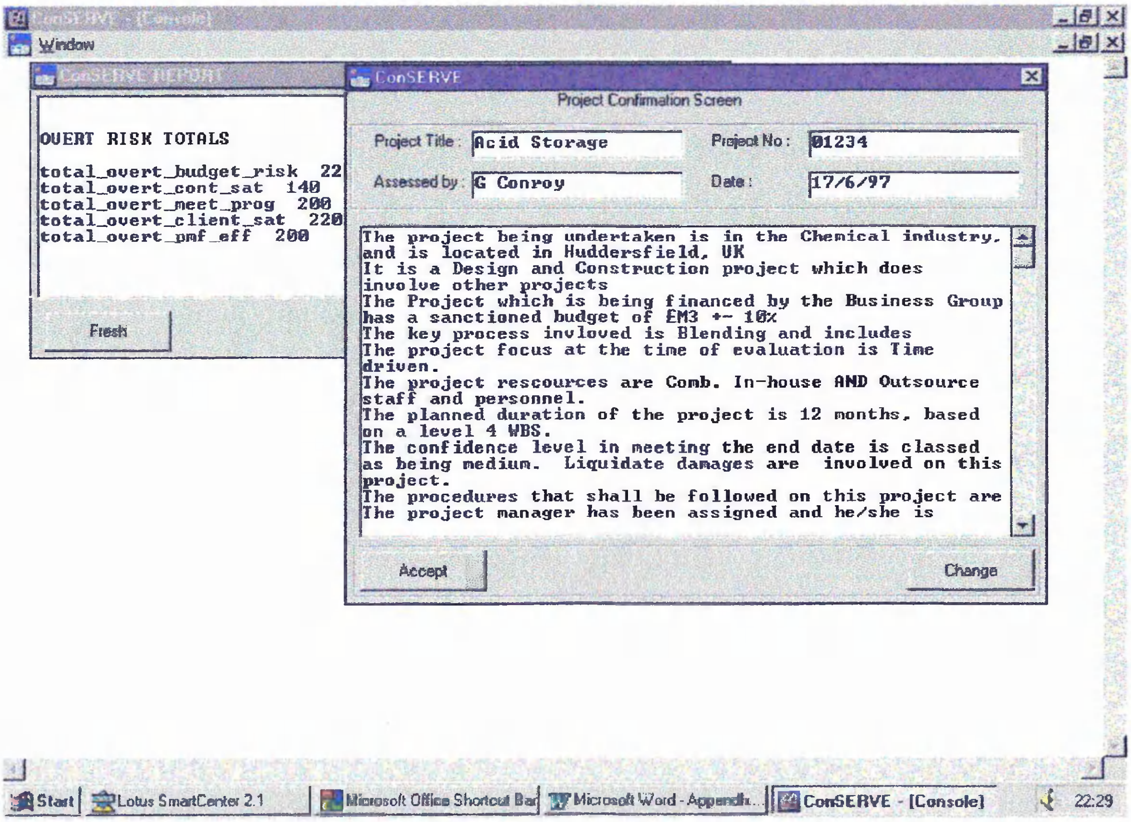


```
OVERT RISK TOTALS

total_overt_budget_risk  20
total_overt_cont_sat  18
total_overt_meet_prog  58
total_overt_client_sat  20
total_overt_pmf_eff  20


Brownfield and modifications - adding 30
Long lead items and time focused - adding 10
```

Fig 95 Summary of subjective risks advised by user



```
OVERT RISK TOTALS

total_overt_budget_risk  22
total_overt_cont_sat  140
total_overt_meet_prog  200
total_overt_client_sat  220
total_overt_pmf_eff  200
```

Project Title : Acid Storage

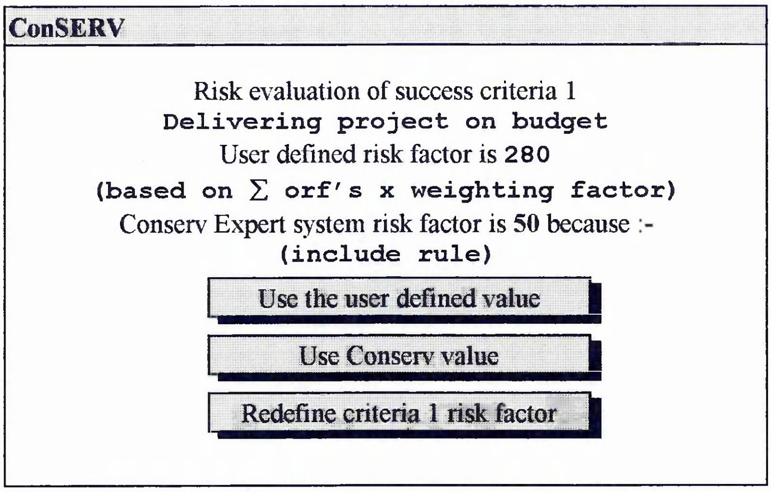
Project No : 01234

Assessed by : G Conroy

Date : 17/6/97

```
The project being undertaken is in the Chemical industry,
and is located in Huddersfield, UK
It is a Design and Construction project which does
involve other projects
The Project which is being financed by the Business Group
has a sanctioned budget of £M3 +- 10%
The key process invloved is Blending and includes
The project focus at the time of evaluation is Time
driven.
The project rescources are Comb. In-house AND Outsource
staff and personnel.
The planned duration of the project is 12 months, based
on a level 4 WBS.
The confidence level in meeting the end date is classed
as being medium.  Liquidate damages are  involved on this
project.
The procedures that shall be followed on this project are
The project manager has been assigned and he/she is
```

Fig 96 Project summary confirmation screen



ConSERV

Risk evaluation of success criteria 1
`Delivering project on budget`
User defined risk factor is `280`
`(based on ∑ orf's x weighting factor)`
Conserv Expert system risk factor is **50** because :-
`(include rule)`

Fig 97 Risk factor comparison screen

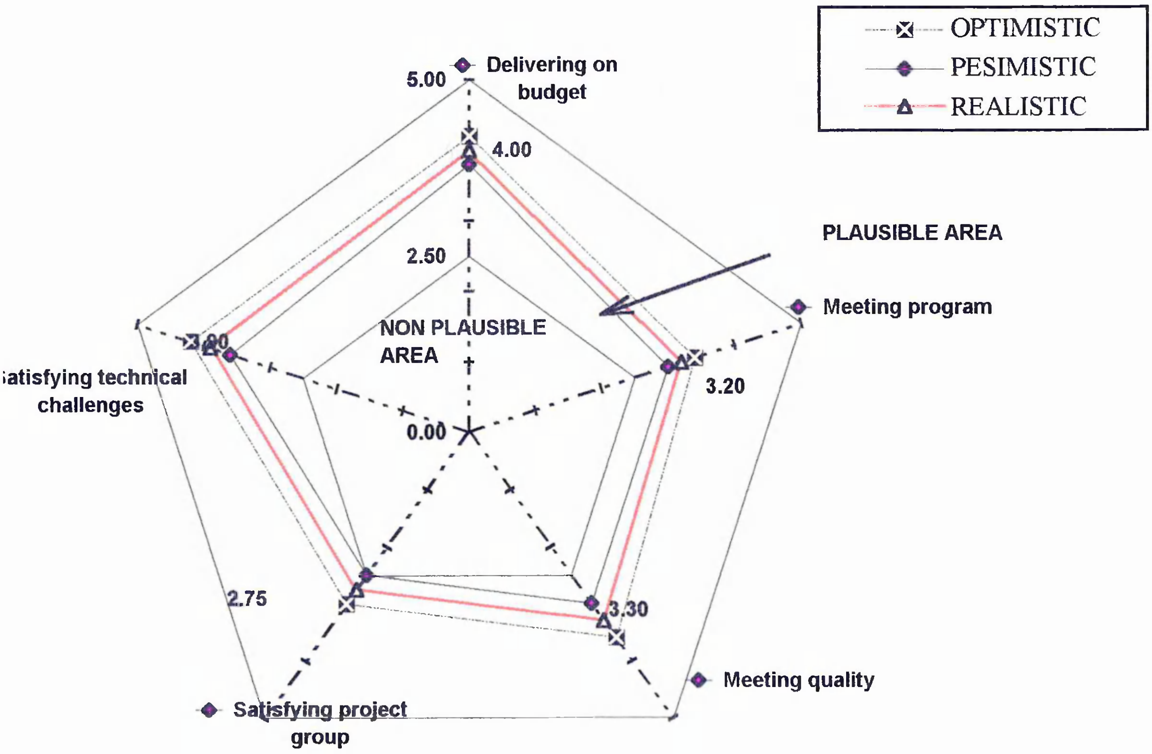


Fig 98 Radar Graph of overall project shape

Checklists and Guidelines for specific aspects of plant design

Plant Layout

Are high toxicity gas releases possible ? Is the new plant downwind ? Can toxic or flammable emissions gather in hollows ?
Is separation distance of unit adequate ? Are trenches under critical plant items ?
Can gas gather in trenches ? Are there any high level overflow or vents over operator access or other plant items ?
Can gas releases flow into unprotected (unclassified areas) ? Are there known ignition sources in close proximity to flammable materials
Is ventilation intake areas clear of gas or vapour release vents ? Are all plant items and valves accessible ?
Is access provided for plant protection and fire fighting facilities ?

Roadway and Exits

Is a clear route available for emergency vehicles ? Are headroom restrictions identified and fitted with crane protection boards
Are road access and egress routes clearly marked and identified ? Do swing doors for trucks trolleys and FLT's have clear panels fitted ?
Are floor areas even and tripping hazards avoided. ?

Buildings

In the event that the building houses potentially explosive materials, is it designed for explosion damage limitation ? Blast walls, blow out panels etc. Have explosion relief studies been undertaken ? Are windows designed to tolerate explosion.
Are lighting systems able to tolerate explosions Are emergency lights needed for assisting with egress ?
Are emergency exits sufficient, identified, clear and marked. ? Are there any known potential tripping hazards.
Are floors designed to accommodate, product spills, water, oil mud etc. Are floor surfaces non slip ?
Do stairs and platforms have correctly sized handrails, kicking strips, headroom. ? Is building equipped with heating, ventilation. ?
Is building equipped with an alarm system. ? Are all processes correctly protected ?
Is no smoking policy in place, if so are signs posted. ? Is ventilation adequately sized, reliable, can it be polluted, can exhaust be ignited.
Is electrical supply correctly sized for processing needs, are circuit breakers readily accessible, do staff know location and how to use isolators in event of emergency. Are circuits explosion proof, are they interlocked, is a backup needed / available.
Are there adequate provisions for the containment of waste matter. Are emergency showers, washing / toilet facilities correctly located.
Are supplies for potable water and process water completely separate. ?
Are separate drains provided for process waste and sanitary waste. ? Are they sealed.
Are floor loading limits adequate ? Are roof loading limits adequate. ? Are specially lifting beams provided. ? Are snow and wind loads accounted for. Are surfaces painted, is plant and equipment correctly colour coded ?

Piping

Has the pipework been designed in accordance with appropriate standards ? are the routes safe and economic.?
Are the pipe supports correctly designed ? Located. ? Fixed ?
Is there adequate fall on the pipe runs ? Is there two phase flow in any of the pipe sections under normal or abnormal conditions.
Are there any condensate collection pockets which can lead to liquid slugs in gas flows. ?
Are there any long pipe runs following pressure reduction, which can lead to excessive vibration. ? If so is the pipework damped. ?
Are the thermal expansion stresses accommodated in the design ?
Are the pipe materials and fittings correctly selected for the normal operating conditions and the hydraulic pressure tests. ?
Are there any screw fittings used on flammable liquids which could leak if affected by fire, or could vibrate loose. ?
Are pipes correctly tested and certified and coded. Is the direction flow indicated. ?
Has the design and installation been undertaken in accordance with an auditable QS. ?

Vessels and piping

Has vessel been designed and tested in accordance with the appropriate codes. If so has evidence been provided ?
Has the vessel design criteria (Pressure, Temperature and relief) been the subject of Hazop studies. If so is the evidence available ?
Has the Hazop considered the various chemistries and potential combinations of energy release that may occur in the vessel ?
Is the vessel supported correctly in accordance with manufacturers recommendations.? Can it be drained and internally inspected. ?
Have the static and dynamic loads been confirmed. ? Is an agitator included if so is it correctly sized and fitted to the vessel. ?
Have the flanges, gaskets and jointing materials been correctly specified. ?
Can any vibration be transferred from vessel to pipework or vica versa.? Do the pipe supports accommodate vibration / movement ?
Has a vessel preventive maintenance and corrosion inspection system been set. ? Is it auditable. ?
Has the Hazop identified the need for special relief conditions such as negative pressure, breathers etc.
Are there any mechanically weak areas that require special protection, ? Glass pipework, Glass coated steelwork. ?
Are vessels and tanks fitted with adequately sized ventilation or pressure balance lines ?
Has the vessel and process been registered with appropriate authorities. Press. Regulations, IPC.

Reactions

Is the heat and energy balance calculated for all likely exothermic and or endothermic reactions and possible conditions.
Are the material properties and fluid references tabulated for Raw materials, products and by products. ?
Are the material properties known for all conditions during the process and reaction.? I.e. Toxicity, explosivity flammability ?
Is the reaction matrix completed and all raw materials clearly defined.
Is the process chemistry known and understood, can residual materials cause problems if not correctly neutralised or cleaned ?
Is a runaway reaction possible, are there sufficient contingencies in the design to handle such conditions, i.e. Dump tanks ?
Do reactions accelerate with high temperature and or high pressure, is cooling adequate for worse case conditions.
Are side or wrong reactions possible under unplanned conditions, i.e. temperature, pressure, catalyst, concentrations etc. ?
Are cleaning and maintenance procedures and accesses available /
Are the criteria for safe operation fixed i.e Availability of correct spares, emergency equipment, operating staff etc. ?
Is agitation required ? can it fail ? can the failure be detected ?
Does material deteriorate on standing if left at high temp ?, if no agitation ? is deteriorated material dangerous ?

Do the material properties change if process is stopped, Are warnings and corrective actions known and understood ?
Can batches be incorrectly mixed, if so are results known from trials and test data.
If reaction fails is provision afforded for reworking materials, if so is rework process safe and tested.

Ignition

(The conditions dictating ignition concerns are those where the presence of flammable liquids or gasses are present)
Has the area classification been made ? Has it been zoned and all plant items correctly identified ? Local panels etc.
Is all the equipment correctly earthed including support steelwork.? Has the earthing been continuity tested.?
Are lightning conductors provided on the plant building. ? Are static sources of ignition possible ? Are balls in ball valves earthed ?
Are long pipework sections entering the plant and any railway lines earthed. Are power cables correctly supported and isolated ?
Are manhole lids independently earthed ? are filter screens earthed ? Do filling hoses have earth clips and are they in good condition ?
Is it possible for flammable vapours to enter switching or instrument rooms ?
Are there any local hot surfaces forms of friction or steam leaks that could generate sufficient heat to cause explosion ?

Electrical Equipment

Are all high voltage connections/cables/bus bars protected by suitably rated insulation, cabinets or guards. ?
Do high voltage cables carry the correct warning labels ? Are the circuits clearly marked, coloured etc.
Are the correct separation distances for high and low voltage cables maintained. ?
Are there any redundant power supplies, if so are they correctly terminated ?
Are there live circuit warning lamps with circuit testing capabilities. ?
Are all cabinets and equipment correctly specified (IP rating) insulated and earthed ?
Are there any high voltage cables routed through fire hazard areas ?
Are wiring installations tested with full load ratings ? Is evidence of line tests available. ? are wiring diagrams available ?
Is over current protection fitted. ? Is over voltage protection fitted. ? Is dust and moisture protection fitted ?
Are cabinets able to be cooled safely ? Are arcing parts enclosed to satisfy area classification standards ?
Are the circuits designed for ease of maintenance ? de energisation, marking of failed circuits, key locking and isolations, ?
Are safety devices correctly sized and grounded. ? Are power points required if so are they to suitable industrial standards ?
Is earth voltage pattern from the main supply known. ? can it induce currents in the plant items ?
Are junction and terminal boxes hermetically sealed. ? If so are any electrical components likely to overheat. ?
Are MCC cubicles correctly sized with adequate “spares” for additional plant.?
Are variable speed inverters required. ? If so are they Locally controlled by PLCs. Are PLC cabinets able to be cooled.?
Are electronic shear pins required ? if so are they able to be reset from remote location or at unit.?
Are the cabinets and switching gear protected by VESDA systems. If so are the protection systems able to be tested. ?
Are all cable routes adequately supported to ensure they can not be damaged by sharp corners, operations, traffic, maintenance ?
Are high resistivity liquids present, are there long lengths of plastic piping ? If so are conducting materials used to dissipate static ?

Control and Instrumentastion

Are all control signals measurable at the required test points ?
Has the control philosophy been established. ? has the logic been tested by simulation ? Has it been debugged ? Is there evidence?
Are the loop gains known ? have they been checked. ? Are the instruments correctly specified for the conditions being tested ?
Are the failure directions known and correct (Fail open, fail closed, fail frozen)
Are set point adjustments locked ? if not should they be ?
Has the interlock logic been developed ? (Prevent action if condition false allow action if condition true)
Have the alarm conditions been identified ? have the set points been determined. ?
Have all trip points been identified ? are they necessary ? Are trips recorded ?
Are the instruments wetted surfaces compatible with the range of fluids. ? Are instruments correctly specified ?
Are the instruments registered ? calibrated ? is there evidence. ?
Do all instruments measure the correct variable ? Is there a compensatory factor ?
Are the power supplies for the instruments reliable ? Do any need UPS supplies ?
Are instruments sufficiently accurate, robust, responsive for normal and abnormal conditions. ?

Control Room

Is it designed and built to withstand an explosion ? Are windows wired or clear. ?
Is it important to view any of the process from the control room ?
Is emergency lighting required for the control room ? Are control room air intakes clear of process environment ?
Is control room pressure to be maintained higher than process room pressure ? If so by what means ?
Is there an interlocked chamber required between the control room and the plant environment ?
Are detectors required in control room, ? gas masks ? Fire doors ? Hand held fire extinguishers ?
Is an escape route required from control room away from process plant.
Is equipment in control room to be intrinsically safe.

Drainage

Are all leaks, releases, washdown materials collected in bunded/drain system for all operating floors and levels ?
What is the collection capacity of the sumps and drains ? Are drains trapped and sealed ?
Will bund overflow in the event of fire fighting ? if so what facility is there for secondary containment ?
Is surface water drain system independent from effluent drainage system ? is there any likelyhood of cross contamination?
Is drainage adequate for fire fighting. ? are fire water drains free and unblocked.
Are drainage materials suitable for the product spillages ? Temperature Acidity Akalinity.
Are drains accessible for rodding and maintenance purposes.
Are the falls sufficient to ensure material will flow to sump.

Chapter IX

"Summative evaluation concentrates on assessing effects and effectiveness and is likely to cover the total impact of the program, not simply the extent to which the goals are achieved" Robson[1].

9.0 TEST PROCEDURES FOR THE CONSERV CONCEPT

9.1 Introduction and review

9.1.1 Introduction

Chapter VIII looked at the difficulties encountered when representing uncertainty in logic structures, language and code. The Chapter also included further details of demonstrator 'A' and the proposed system architecture.

Chapter IX , the penultimate Chapter in this submission, describes how the concept performs when compared with the more traditional management procedures used in the industry today. As the research effort has been predominantly industry based it was considered fitting that the concept should be taken back into the Chemical industry to be evaluated.

Chapter IX provides an explanation of the testing methods and procedures, along with a brief description of the research observations and findings.

The purpose of the tests was to determine whether or not the concept affords any real benefits in the management of design intensive multidisciplinary capital projects.

As the most obvious starting point, Chapter IX revisits the 10 hypotheses submitted at the outset of this dissertation Appendix A8 (Table 2) in a bid to provide a basis from which the proposed concept might be evaluated.

Appendix J provides the raw data obtained from the evaluation, in the form of the identified risks, cost and design implications.

In order to test how the concept would perform in practice it was necessary to use a paper version of the second tier "knowledge" rules represented in the form of :

i/ Industrially recognised Guidelines and check lists. Ref. Appendices J6-J14 and

ii/ The Design failure mechanisms Ref. Appendices F4 -F7.

Examples of the Second tier rules are provided on pages 153 and 155

9.1.2 Review

The proposals and test methods for the 10 hypotheses is presented below ;-

	Description of Hypothesis / Argument and Consequence	Proposal to improve on current methods	Testing method
1	That the majority of capital projects being managed in the Process industry today employ traditional project management and engineering design techniques. **Success rate of project out turn is considered 'poor'.**	To use knowledge based project management techniques more able to determine the "specific" needs of a given project. **Improve on success rate by maintaining focus on project risks.**	To interview project managers to establish perception of project risks then use Demonstrator A to identify specific needs. Share observations and gauge response using interview techniques.
2	That the management techniques employed include an assortment of commercially available and bespoke planning, scheduling and costing software tools combined with organisational procedures and human expertise. **Uncertainty as to suitability of tools and lack of training results in tools being misused.**	To rationalise the selection and use of the available project management and engineering design software tools by incorporating decision support and expertise in the kb management tool selection process. **Improve on project success rate by ensuring that tool applied is appropriate**	To use the Association of Project managers bespoke product selection software to establish extent of project managers knowledge of availability of tools. *Note the selection criteria could be incorporated in the project specific data acquisition process.*
3	That project management, engineering design and risk management theories are generalised and broad based and therefore difficult to apply to any specific cases. **Creating confusion for project manager to determine which theory to apply**	To identify and maintain a clear focus of the project by means of a risk management technique able to recognise the real project issues throughout the life cycle. **The systems risk assessment then able to indicate appropriate theory**	By interviewing user to establish level of appreciation of project management theories then revisit initial risk assessment using a hypothetical change of circumstances and obtaining a response (*Using Paper system guidelines*)
4	That traditional project management and engineering design techniques do not readily integrate with the organisational procedures in which they operate. **Organisational procedures are often dated and not applicable to current methodology**	To incorporate organisational procedures into the knowledge bases and use knowledge rules to determine preferences and resolve conflict. **Improve progress success rate by establishing suitability of organisation procedures or providing alternative.**	To allow project managers to respond to an example in which organisational procedures fail to give sufficient guidance then compare with concept approach.
5	That traditional project management and engineering design techniques fail to identify project sensitivities. **Autocratic design processes undertaken in isolation of project lack team input**	To identify the project sensitivities by using risk management techniques combined with knowledge based rules. **Shared vision of team effort enables other discipline inputs and quality of design.**	To allow project managers to compare their own risk evaluation of the project against the concepts evaluation.
6	That traditional project management and engineering design techniques fail to capture the reasons for, and the knowledge and lessons learned from, 'unsuccessful' projects. **Repeating errors will result in project failure**	To incorporate a historical record of the key decision making points in the life cycle and the subsequent effects of the decisions made. **A fully developed KBS will allow comparative similarities to be drawn between projects and identify traps.**	To compare current methods of collecting experiential knowledge and retrieving it against the concept, and obtain feedback (*Using Paper system guidelines)*
7	That traditional project management and engineering design techniques are heavily dependent upon the skills and expertise of the individual. **Projects totally dependent on individuals are prone to project failure through error.**	To provide a decision support system at both project management and engineering design levels in which the user can perform a limited number of "what if" scenarios. **Supporting human decision making process with expertise of 'others'**	To interview project managers to confirm hypothesis and test the effects of the knowledge based rules employed by the demonstrator (*Using Paper system guidelines)*
8	That traditional project management and engineering design techniques fail to differentiate between project failure and project management failure. **Lack of design resources as a consequence of not recognising need to design properly**	To maintain a clear distinction between the project management activities and engineering design activities, whilst integrating them within a comprehensive framework. **By providing clear view of risks, scope and necessary resources to manage them**	To interview project managers to confirm whether the concept enables the distinction to be made whilst managing the combined multidisicplinary design activities
9	That traditional project management methods do not necessarily improve the likelihood of project success. **Most methods are effectively static i.e. one design review, one hazop one risk eval etc.**	To improve the chances of project success by continually evaluating the specific risk issues. **Improve chances of project success by continually addressing risk issues and self auditing**	To compare history of past project performances with project managers views. To determine whether traditional methods or procedures are dynamic or static
10	That traditional project management and engineering design techniques do not interact in a multi disciplinary environment. **Disciplines that are not integrated into the team are invariably isolated from it.**	To incorporate engineering design process into the concept using a visual form of interdisciplinary involvement and input. **Improve project success by allowing all engineering disciplines to visualise contribution at same time ConSERV**	To compare existing method of managing design activities within the project group and obtain views from engineers.

Table 20 Hypothesis, proposals and test methods

9.2 Objectives and Methods of testing the concept.

9.2.1 Objectives

The test procedures were designed to satisfy four specific requirements, namely :-

1.0 To evaluate the "ConSERV" concept against the 10 hypotheses stated at the outset of the submission, and reiterated on the preceding page.

2.0 To undertake the evaluation using a proven structured test procedure in order to obtain valid test data, consistent with recognised research techniques, specifically those suggested by *Robson*[1]

3.0 To identify whether or not a case exists for the further development of the concept as a fully integrated knowledge based project management and engineering design technique.

4.0 To identify the limitations and flaws of the concept, by comparing a part demonstrator and part paper based version of the concept against the traditional management methods currently being employed on two live test projects in the UK Chemical industry. (June-Sept 97)

9.2.2. Background

Testing the strength of any hypothesis requires data that is representative and meaningful. It was decided that since the hypothesis had been generated from the industrial research and interviews taken with practising project managers, it would be wholly appropriate to test the hypothesis in the same environment.

Holliday Dyes and Chemicals Ltd is a medium sized Chemical company based in Huddersfield West Yorkshire, it employs some 250 employees and produces acid based dye stuffs using Sulphanation and Nitration processes. Ref. Appendix C13,p12

The project Group employs 11 project engineers and project managers handling a number of small to medium sized capital and revenue projects. (1998 Spend ~ £6M.)

The company was approached and were agreeable to allowing the ConSERV project management system to be tested on the front end engineering of three projects :-

i/ "A new Pilot plant facility"

ii/ "Phase 1 of the Acid bulk store project". and

iii/ "A new Dimethyl sulphate storage facility"

9.2.2 Test Procedures

The procedure for undertaking the study was as follows:

i/ To undertake an initial interview with each of the 11 project group members to establish what is perceived as being current / traditional project management practice.

ii/ To obtain from the user, by interview, then via Demonstrator 'A' their perception of the key project specific elements of the three projects about to be managed.

ii/ To obtain from the user by interview then via Demonstrator 'A'. The generic project success criteria for typical projects being managed by the group.

iii/ To obtain by interview the users' initial evaluation of the project risks.

iv/ To contrast the users' understanding of the project risks with the "concepts" evaluation of the project risks. NB Differences of views were anticipated as the concept does not assume risks unless there are specific grounds for them to exist.

v/ To obtain agreement between 'the user' and 'the system' on the specific project management risks as they are perceived at various stages over the project life cycle.

vi/ To develop the "Engineering design" risks using a 'second tier paper system' in which the project specific data obtained from the Demonstrator 'A' can be applied to a set of structured "guidelines" and "knowledge rules". The paper system is used to establish the main engineering risk issues, and the subsequent additional engineering man-hours required to satisfy the additional activities generated from the technique.

The guideline check list procedures provided in Appendix J and Appendix F may be considered as a second layer of the Demonstrator 'A' in which the finer details of the project, specifically the engineering implications are identified. Ref. p 153 and 155

The key issue being that the Engineering Design requirements become unique to the project specific criteria and no longer the subjective evaluation of the design manager.

The ultimate goal of the concept is to be able to relate the project and engineering design issues to the respective engineering discipline man-hours and thereby obtain continual design agreement and concurrence within the whole project team.

From the industrial research findings it was seen that in the seven organisations researched, this process has been difficult to obtain. Broadly speaking the 'concurrence model' advocated in the company Quality Systems (The normative methodology) has not been followed in practice .

The testing was undertaken from mid May 1997 to mid Aug 1997.

The testing procedure for the Concept was determined as being essentially a parallel process running alongside the companies existing project management procedures.

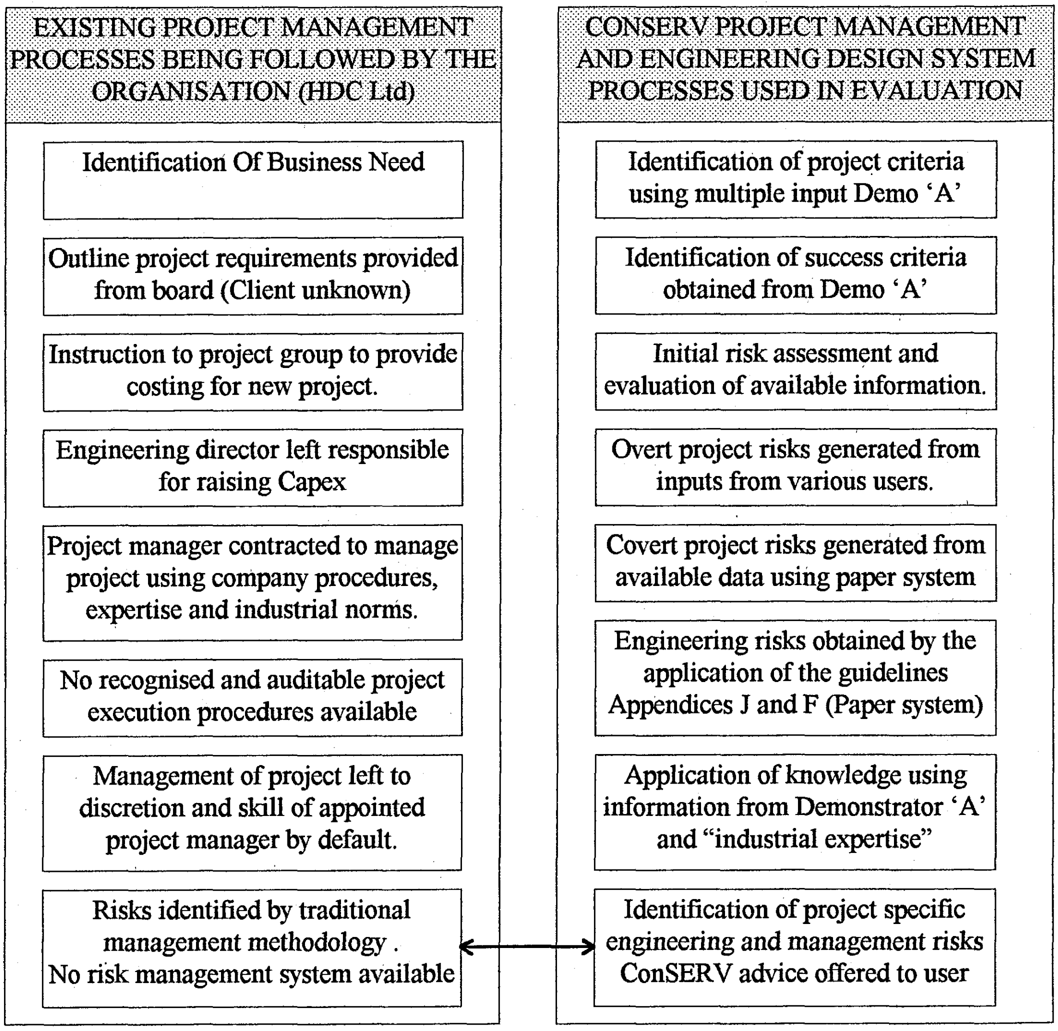


Fig 99 Application of ConSERV system on live projects

The ConSERV guidelines and checklists used were those listed in Appendix J5 Table 21 and Appendices H8 and H9 namely, i/ The Flow sheet review, ii/ The P&ID review iii/ The Site layout review iv/ The Equipment layout review v/ Electrical power review vi/ Control philosophy review vii/ Piping review viii/ Cable routing review.

Taylor [2] and *Kletz* [3] both recognise the need for the application of structured engineering design checklists when developing work scopes.

9.2.3. The test subjects

It was recognised at the outset that one of the main measures of determining whether or not the system has any real possibility, is the feedback from the potential users of the system. It was therefore decided that a number of project management personnel should be incorporated into the testing procedures in order to evaluate reaction and obtain constructive *real world* criticism on the concept and the possible benefits that it might offer. For the initial trials a group of project engineers and managers with similar engineering backgrounds and experiences were interviewed these included: *John, Paul, Chris, Mick, Heath, Stuart, Richard, Alan ,Indy, Robert, and Keith.*[1]

Due to the very small sample size structured evaluation assessment forms (Appendices J2 and J3) were produced for the purpose of the trials in order to standardise the input obtained from the questioning procedures.

The forms were designed to provide information that could be used in establishing the validity of the assumptions, confirmation of the earlier research findings and a basis for the evaluation of the hypotheses submitted in Table 20, p 164.

The first of the two questionnaire forms was designed to obtain information concerning the individuals understanding of *existing* organisational project management procedures. All the subjects interviewed had experiences of working with 'other similar organisations' in the Chemical industry.

The information provided was therefore useful in establishing how typical the HDC Ltd. organisations procedures were of traditional project management techniques applied in the industry as a whole.

The second questionnaire was intended to be used after the subject had been given the opportunity to evaluate and test the ConSERV concept. The intention was to identify whether or not any change of belief had occurred as a consequence of using the concept software and paper system, and whether or not the 10 hypothesis could be substantiated. The subjects were each advised that the purpose of the exercise was **to test the concept**, not the system software or the subjects understanding of project management.

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[1] Whilst all 11 subjects were actively involved in the management of projects, non were certificated project managers.

9.3 Test Case Studies

9.3.1 Outline of study 1.0 'The new production facility'.

The need for a pilot plant was identified from the companies research and development team and their consultations with the client concerning a new product.

Contrary to normal practice, in order to take advantage of the business opportunity the board decided to build the shell of the processing building and then equip it.

An inventory of the main plant items was provided from the R&D group along with a sketchy outline of the types of processes that the building would need to support.

The company project management procedures were found to be woefully inadequate in assisting the front end engineering and feasibility study. Using the concept identification process it was established that:

The project was identified as being undertaken in the ***Chemical Industry*** *based in* ***Europe*** *at the* ***Huddersfield*** *site. The project is a* ***Design and build*** *capital project that is* ***not*** *likely to be affected by* ***other projects*** *and is being financed by the* ***Board*** *as a* ***fixed price*** *lump sum contract. The project involves* <u>***Chlorsulphonation***</u> ***reactions****, including* <u>*solvent*</u> ***washing, centrifuging*** *and* ***drying.*** *The process includes* ***reactors, centrifuges, dryers,*** *and* ***scrubbers.*** *The project will* ***not*** *involve modifications to existing plant the shell and fit out has a capital value of* ***£1.0 million.*** *The project will be* ***cost*** *driven, and will use combined resources. The project is planned to take 14 months, and will be undertaken with* ***no*** *recognised* ***company or QA procedures.***

9.3.2 Outline of study 2.0 'The Bulk Acid and Alkali project'

The need for the Bulk acid plant project was triggered by the issue of a directive from the Environmental Agency concerning the safe storage and movement of 'drummed' acid on HDC Ltd. site at Huddersfield. The acids included Oleum 65 Oleum 20 Monohydrate and mixed acids. Using the concepts identification procedure the project was summarised as:

Being undertaken in the ***Chemical Industry*** *based in* ***Europe*** *at the* ***Huddersfield*** *site. The project is a* ***Design and build*** *capital project that is likely to be affected by* ***other projects*** *and is being financed by the* ***Board*** *as a* ***fixed price*** *lump sum contract. The project involves* <u>***Acid mixing***</u> *and requires Bunded Storage, new pumping and distribution systems. The main plant items include* ***storage vessels, scrubbers, pumps and pipework.*** *The project will involve modifications to existing plant and has a capital value of* ***£2.2 million.*** *The project will be* ***quality*** *driven, and will use* ***combined resources.*** *The project is planned to take* ***10*** *months, and will be undertaken with* ***no*** *recognised* ***company or QA procedures.***

9.3.3 Outline of study 3.0 'The Dimethyl Sulphate (DMS) storage facility'.

Dimethyl Sulphate (DMS) is a particularly difficult substance to store as being almost colourless and odourless it is virtually undetectable. DMS is highly toxic and if inhaled, will cause death. The exposure limits are less than 0.1ppm. Exposure of 100ppm for 10 mins is considered fatal. The quantities being stored at the HDC site necessitate CIMAH registration. The CIMAH classification for the chemical is:

R45 May cause cancer

R25 Toxic if swallowed

R26 Very toxic by inhalation

R34 Causes burns

A number of risk assessments had been undertaken in accordance with the recommendations laid down by the Health and Safety Executive Major Hazards assessment unit MHAU. Using the concepts project identification technique it was:

Iidentified as being undertaken in the ***Chemical Industry*** *based in* ***Europe*** *at the* ***Huddersfield*** *site. The project is a* ***Design and build*** *capital project that is likely to be affected by* ***other projects*** *and is being financed by the* ***Board*** *as a* ***fixed price*** *lump sum contract. The project involves* ***Storage and distribution of DMS*** *requiring Bunded Storage, and new tanker off loading and pumping and distribution. The process includes a* ***storage vessel, scrubber, pumps and pipework.*** *The project will not involve modifications to existing plant and has a capital value of* ***£0.17 million.*** *The project will be* ***quality*** *driven, and will use* ***combined resources.*** *The project is planned to take 2 months, and will be undertaken with* ***no*** *recognised* ***company or QA procedures.***

Project 3 was part complete at the time of applying the technique. The previous project manager, who had recently left the company had specified, designed and procured the main plant items a P&ID had been produced and Hazops 1,2 and 3 had been undertaken. The storage vessel and pumps were on site.

9.4 Analysis of the test data

9.4.1 Objective responses to Pre-evaluation

A summary of the tabulation of the test data is provided in Appendix J4.

From the tests undertaken it was observed that the majority of the project managers interviewed felt that the *project management* processes employed by the company were mostly of the ***traditional*** type and included a ***combination*** of organisational procedures and commercial planning software (q1and q2).

None of the managers interviewed had used risk management theories as part of the organisations procedures, but over half had used Hazop techniques. i.e. Risks ***were being identified***, but no risk management theory was being applied (q3).

It was felt that the company's organisational procedures ***did not specify*** engineering problems or scopes of work, and that it was ***not possible to quantify*** all the engineering and project management issues.(q4)

The subjects interviewed agreed that the traditional project management techniques provide ***no new information*** about the project (q5) and ***did not*** capture the ***experiences*** of unsuccessful projects (q6) but all felt they should.

The majority of the interviewees felt that ***project managers*** had a greater bearing on project success than the ***systems.***(q7)

The data obtained from (q8) was inconclusive, but the inference was that whilst a number of subjects were not clear on the difference between project success and project management success they ***were prepared*** to identify ***critical elements*** for project and project management success.

The majority of the project engineers and managers interviewed felt that procedures ***should improve*** the likelihood of project success but the ones available did not.(q9)

Only one of those interviewed felt that the engineering design systems interacted with the project management systems (q10)

9.4.2 Subjective responses to Pre-evaluation

The subjective response was evaluated by using a key word analysis and content analysis. A summary of the tabulated data is shown in the Appendix J4

The summary of the evaluation being :-

(q1) The organisations project management process was considered to be largely ***ineffective.***

(q3) That ***subjective*** risk management was the most common method employed, and that project engineers and managers ***were*** in the main ***comfortable*** with their own risk assessments.

(q4) That the company procedures do highlight ***certain areas*** that may need further engineering effort, and that it was ***not possible*** to quantify all engineering and project management issues.

(q8) The main elements of project success were identified as being mainly associated with attention to ***engineering detail*** and well ***defined specifications***, whilst the main elements for project management success were seen as being ***teamwork*** , ***effective systems and a systematic approach.***

(q9) The general response to the question was fairly predictable, procedures ***should*** improve the likelihood of project success but the ones being applied ***didn't.***

(q10) Caused the most consideration prior to giving an answer, reluctantly virtually all the respondents concluded that there was no real interaction between the design group and the project management personnel.

9.4.3 Objective response to the Pre-evaluation

The objective responses have also been presented in the data summary tabulated in Appendix J4

The objective responses are shown in Fig 100 below:

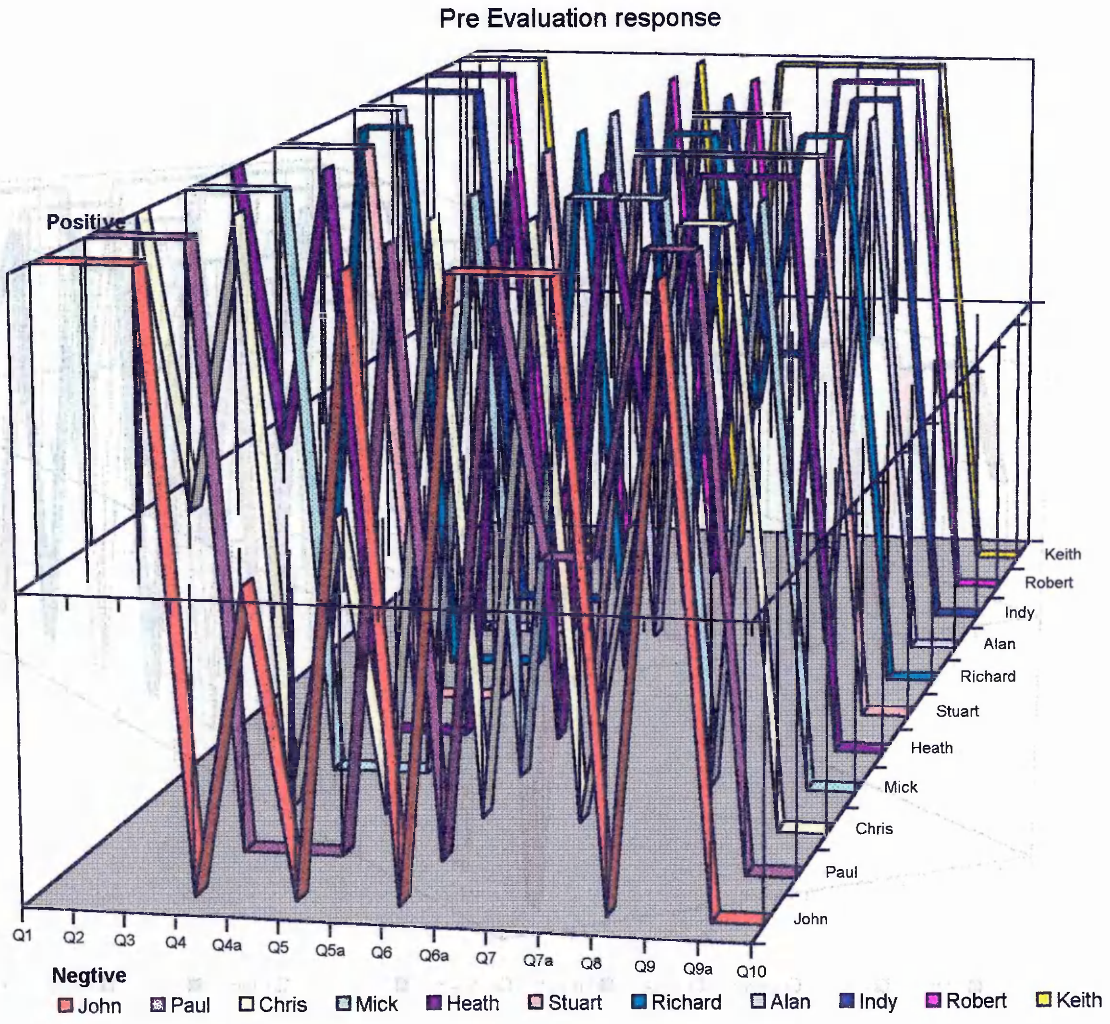

Fig 100 Graph showing responses to Pre evaluation Questionnaire

9.4.4 Objective response to the Evaluation

The objective responses have also been presented in the data summary tabulated in Appendix J4

The objective responses are shown in Fig 101 below:

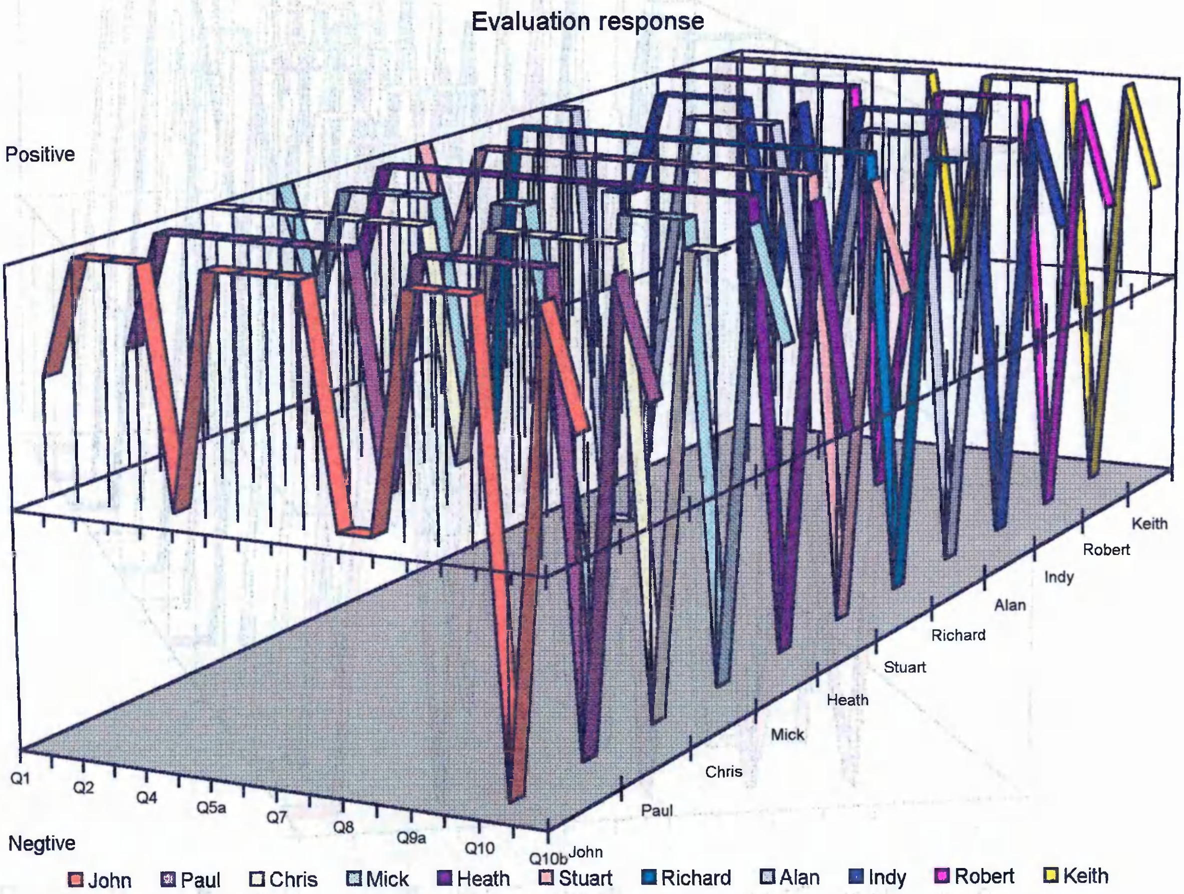

Fig 101 Graph showing responses to second questionnaire

9.5 Evaluation of the test Data

9.5.1 Correlation of subjective and objective Data

The format of the experiment was mainly one-on one interviews. Enquiry into the decision making processes of project managers is essentially, exploratory, descriptive and to a lesser extent explanatory. The interview surveys were designed to provide material useful in developing the descriptive part of this enquiry, whilst the case studies are considered more appropriate for the exploratory nature of the research. Organisational Psychologists, suggest that the design and conduct of quasi-experiments and true experiments in field settings explicate four kinds of validity:

1. Statistical conclusion validity, that drawn on the basis of statistical evidence about whether a presumed cause and effect co-vary.
2. Internal validity, which refers to the conclusions we draw about whether the statistical relationship implies cause.
3. Construct validity, which refers to the validity with which cause and effect operations are labelled in theory relevant terms.
4. External validity, which refers to the validity with which causal relationships can be generalised across persons, settings and times.

Laplin[4] defined the term experiment as:- "Any experimenter controlled, or naturally occurring event, which intervenes in the lives of the respondents and whose probable consequences can be empirically assessed".

They also defined the term field as any setting which respondents do not perceive to have been set up for the primary purpose of conducted research. The experimentation used in this submission could be described as Quasi experimental, the survey itself refers to the collection of standardised information from a specific population. In this case the eleven project engineers and project managers.

9.5.2 Data Evaluation

The hypotheses 1-10 Table 20 p 164 were tested against the results obtained from the enquiry. It is recognised that the data sets obtained from the investigation are limited and that the sample populations are low. There is however no evidence to suggest that the sample population are not representative of project engineers and managers employed in the industry as a whole.

The main purpose of the test is to determine whether or not the respondents felt that there is any mileage in the new concept.

Q4a *Pre evaluation* Asked the question "Do you believe it is possible to quantify all the engineering and project management issues of a major project over its life cycle".

As the test was spread over a 12 week period, it was decided to include the same question in the subsequent evaluation sheet i.e. Q7a.

The initial response was that 8 out of the eleven interviewees felt that it was not possible to quantify all the issues, yet after the evaluation of the concept 6 of the eleven felt that it would be.

9.5.3 Evaluation Case study 1 Observations

The observations made from analysis of the data was that the traditional (existing company procedures) were not able to provide any real project management assistance in developing the Front end engineering scope of work. This was primarily due to the fact that the majority of the work involved *Civil and Structural* engineering disciplines and the company procedures were developed to address the *Process Engineering* requirements.

The fact that the company did not employ a staff 'Civil' engineer presented a problem from the outset, namely that by default the project manager was involved in developing the ITB for the civil front end engineering design package.

The traditional method of developing engineering scopes is to incorporate the services of a suitably qualified and experienced engineer from the relevant discipline, to provide 'Technical' input into the enquiry document.

In the first of the three examples the organisations procedures, and the traditional project management techniques appeared provided no benefit what so ever.

The ConSERV concept however was able to provide the i/ *The global identity* of the project as shown on p 169 ii/ *The main risk issues* and iii/ *The success criteria* for the project.

By applying the paper system part of the concept i.e. the Guidelines shown in Appendices J6 - J14, in conjunction with the three items listed above, it was possible to recognise the next logical sequence of activity by following the checklist items Section D items a-r Table 24.

This was to develop an outline building design, obtain client agreement on basic size, shape and location then draw up plans for the first long lead element of the project, namely obtaining planning permission from the local Planning Authorities. The enquiry document was developed based largely upon experiences from similar projects and the main issues emerging from the Guidelines.

9.5.4 Evaluation Case study 2 Observations

The bulk Acid and Alkali storage facility project was initially being developed along the traditional project management route using the experience of a newly appointed operations manager. Being a qualified Chemical engineer the manager had taken it upon himself to provide the basic design brief to the project group.

The organisations procedures recognised the need to provide a basic design brief but were unclear as to what the brief should include and the level of detail to which it should be developed.

The inventory of materials to be accommodated in the bulk facility were extensive and involved a combination of substances that must not share the same bund. Shortly after providing the basic storage inventory the manager went on a well earned three week vacation. The project manager was again faced with something of a dilemma, as being a Mechanical engineer he was faced with making decisions concerning the storage, mixing and distribution of a number of complex acids. The difficulty being that of undertaking design responsibilities in areas outside of the individuals domain.

The organisational procedures did provide generic checklists but were well short of addressing the in depth issues shown on the ConSERV checklists for detail design Appendices H8 and H9.

By identifying the major risks, namely the project is *quality driven* yet there are no *QA procedures* the project manager is able to structure the project such that the global risk issues can be addressed. i.e. Given the rate of spend, the limited in house capabilities, the engineering and engineering design issues, a proposal was submitted to the board recommending that the project be managed using a **task force** approach. This recommendation would not have been made without a better appreciation of the larger picture provided by using the ConSERV approach.

9.5.5 Evaluation Case study 3 Observations

The project was in the early stages of construction when the ConSERV concept was applied E.g. Fig 102 P&ID/45/68/141 Revision E drawn 6/12/96 as shown below :-

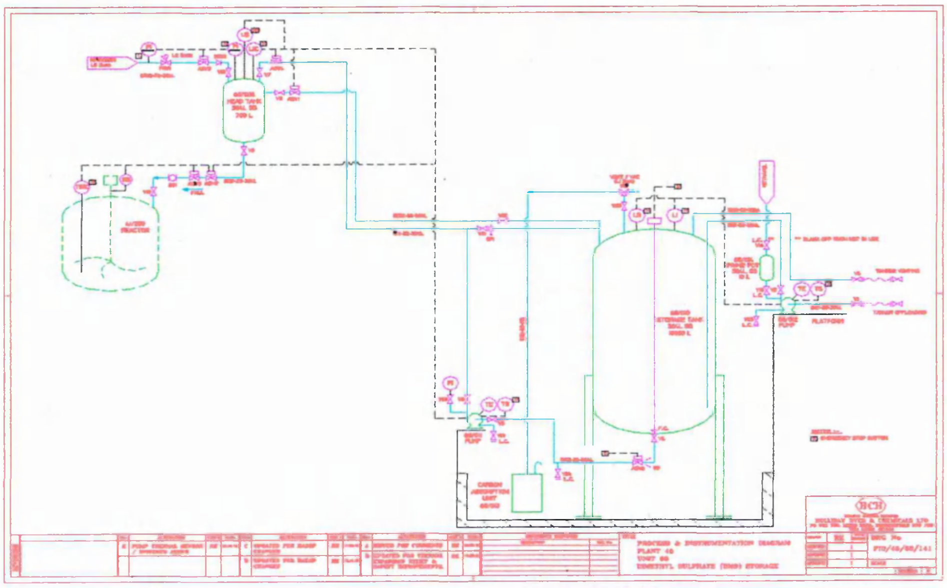

Fig 102 Pre ConSERV P&ID

As can be seen by comparing Fig 102 with Fig 103 numerous design changes were introduced in order to bring the P&ID up to an acceptable construction standard.

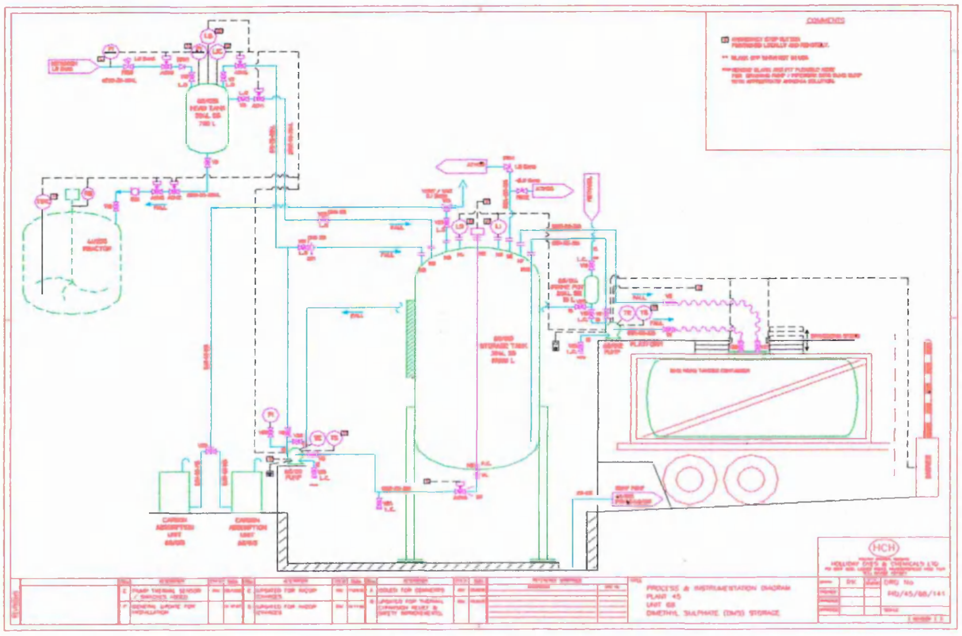

Fig 103 Post ConSERV P&ID

The DMS storage tank (vessel ref. 68/010) had been specified, built and delivered to site as a BS 5500 Cat 1 vessel with a design duty of +1 barg. The vessel was designed to the limit with no vacuum capability or corrosion allowance. The project engineer had rated the design risks as being low. i.e. There was no overt risks assigned to the success criteria "Client and design influences". Following the expert system guidelines however ConSERV identified that as the vessel was operating in a closed system, single event failure analysis showed that it was possible for the vessel to be subjected to a negative pressure of approximately 0.5 bar g. and positive pressure of 1.7 bar g. when the pump dead heads. In either event the vessel would have failed.

As a consequence the vessel was returned to the manufacturers, redesigned to suit a new duty of +2 barg and -1 barg. The vessel was stiffened using 4 internal rings and recertified. Ref. Photographs P13 and P14 Appendix J15. The Hazop studies undertaken using the ConSERV concept guidelines also identified the need to provide a 'twinned' carbon adsorber arrangement, and a flush line to facilitate the removal of the pumps.

This example demonstrates how the **success of the project** (maintaining the vessel integrity) and the **success of the project management** (optimisation design and team effort) are inextricably linked by the *engineering domain knowledge* associated with the process and vessel design.

The application of the ConSERV concept to assist in developing the engineering design man-hours, and the level 3 WBS activities proved to be most useful on the DMS storage case study.

Engineering design omissions of the type identified in the third case study, are by no means uncommon. As *Kletz* purported "Human errors are events of different types,...made by different people (managers, designers....) and that different actions are required to prevent them from happening again". The companies organisational procedures should ensure that the design errors identified in case study 3 should not have occurred, in the event the procedures failed to protect the business. The paper version of the KBS, however did identify the shortfall in the design in sufficient time to allow corrective measures to be implemented.

9.6 Conclusions and References

9.6.1 Conclusions

In conclusion it would seem that the hypothesis [1] and [2] are in fact valid and are substantiated by the test cases. From the interviewees responses it appears that the concept could afford real benefit to the management of capital projects in the Chemical industry. The data also supported hypothesis [3] in that risk management theories are generally considered to be too generalised and are difficult to apply in real world day to day situations. The findings concerning hypothesis [4] were really quite conclusive, it should however be noted that most of the individuals interviewed were from a design background. The concept demonstrator did manage to provide an insight into how the concept would work in practice although it was generally seen as a lengthy process, with many of the risk elements difficult to relate in terms of risk assignments. Users also had difficulty in recognising the weighting factors of the risk and how they would be used in assessing the overall project risk. It was also difficult to establish the users level of conviction in assigning the values.

Hypothesis [6] was strongly substantiated by the respondents with a number of practical examples being alluded to. Not surprisingly the influence of individual expertise in determining the success of *the project* and the success of *managing* the project proved to be the most difficult area in which to obtain impartial comment.

Hypothesis [7] remains unsubstantiated and will require a more detailed study in order to fully understand the more complex issues of human error in project management.

The proposal for hypothesis [8] was well received by those interviewed, suggesting that a synergy is missing between the engineering design and project management functions. The concept was seen as a distinct advantage in this regard.

Hypothesis [9] also prompted quite an emotive response, with the conclusion that whilst traditional techniques do not necessarily improve the likelihood of project success neither do they detract from it.

The final hypothesis [10] was substantiated by the response to the tests with all the respondents immediately recognising the benefits afforded from a more visual 3D representation of the multidisciplinary 'shape' of the engineering man-hours being expended on the project and the facility to actually view the flow of design data.

In summarising, the whole issue of just how useful an "expert system" is in the field of project management will most probably be determined by the acceptance of the systems recommendations. There will always be considerable differences between the individual preferences of engineers at the detail level of design. A mature system will recognise this and only challenge the design principles when there appears to be a potential for a serious oversight. E.g. The DMS tank specification.

From the preliminary testing of the concept it is believed that whilst the population sample was small, it was reasonably representative of the industry as a whole. The main reason for this assumption is that 2 of the 11 subjects interviewed agreed to in depth interviews using Questionnaires 1 Ref. Appendix B2, and Questionnaire 2 Ref. Appendix B7. The findings were found to be wholly consistent with those of the research findings obtained from the 20 interviewees discussed in Chapter II.

The basis for the testing was to attempt to try to support or dispel the authors hypothesis. Having undertaken the preliminary testing of the concept it is clear that the hypothesis need to be revisited in order to revise them into a more statistically acceptable format such that they can be tested individually using greater population samples and recognised hypothesis testing techniques. In contrasting the findings with other researchers it is interesting to note that the premise for the concept does appear to be well supported.

Sweeting[5] suggested that :- "Computers are tireless but brainless : they follow instructions with incredible speed and precision but have not one jot of intelligence"

It is beyond the scope of this dissertation to investigate the highly complex issue of machine intelligence and the whole question of "qualia", there is however one undeniable fact. The rate of technological development in computer technology, is unprecedented. Having witnessed the effects of these changes over the past two decades who can possibly foresee what this technology will produce in the next Millennium. *Leintz*[6] identified the types of challenges that organisations will be facing in the future and concluded that new methodologies are likely to be required for the types of difficulties that can be anticipated in the next Century.

Maylor [7] reinforces the view that successful project management depends on a blend of the hard and soft skill elements, paying specific attention to the issues of problem solving and decision making. *Hameri* [8] argues that "strict management protocols, combined with efficient communication infrastructure provide the best means to ensure that the project goals are met under the given budget, schedule and quality requirements".

The degree to which the concept is applicable in 'other' areas has not been fully addressed in this submission. The concept is being developed specifically for the low to medium value (£0.15 m to £15m) capital projects being undertaken in the industries mentioned.

9.6.2 References

1 Robson, C, (1992) *Enquiry in the real world* Oxford: Blackwell

2 Taylor, J.R. (1994) *Risk Analysis for Process Plant, Pipelines and Transport.* E&FN SPON

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APPENDIX J

EXAMPLES OF EVALUATION SHEETS
SUMMARY OF TEST RESULTS
LIST OF GUIDELINES USED FOR TESTING THE CONCEPT
TEST RESULTS FROM TEST CASE 1 PILOT PLANT
TEST RESULTS FROM TEST CASE 2 BULK ACID PLANT
TEST RESULTS FROM TEST CASE 3 DIMETHYL SULPHATE STORAGE
COMPARISON OF FINDINGS

ConSERV A methodology for the management of capital projects and concurrent engineering design using knowledge based technology.

APPENDIX J

Evaluation sheets used to evaluate the conserv against the company project management procedures on two live projects the Pilot plant and acid storage test cases at HDC Ltd (Sheet 1 Pre Evaluation)

DATE **................**	**Conserv Trials Sheet 1** **PRE-EVALUAITION SHEET**		**SUBJECT CODE** **.............**

	Question	Subjective Answer	Objective Answer	Analysis
Q1	Please describe the project management process employed by your company, and its effectiveness. a) Traditional b) Purpose designed			
Q2	Which management techniques are included in the process identified above ? a) Company/organisational procedures b) Commercial software c) Bespoke software d) A combination e) Non			
Q3 Q3a	Do the procedures employ any Risk management theories or strategies that have been applied to projects managed by yourself over the past 3 years ? a) Yes b) No If yes do you evaluate project risks yourself ? a) Yes b) No If yes what method do you use and how comfortable are you with your risk assessment ?			
Q4 Q4a	Do the Company/ Organisations project procedures or loss prevention procedures quantify project specific problems and engineering scopes ? a) Yes b) No Do you believe it is possible to quantify all the engineering and project management issues of a major project. a) Yes b) No			
Q5 Q5a	Do traditional project management techniques (Gantt charts S Curves and Planning tools) provide any new information about the sensitivities of the project being managed ? a) Yes b) No Is such information necessary in order to manage the projects effectively ? a) Yes b) No			
Q6	Do the project management systems employed by the organisation capture the experiences from unsuccessful projects ? a) Yes b) No Do you feel such information is important when preparing the project execution procedures ? a) yes b) No			
Q7	Do you think that the success of a project depends more on the ability of the project manager or the capability of the management system being used ? a) The manager % b) The system %.			
Q8	Is the success of a project the same as the successful management of a project ? a) Yes b) No What are the main elements to project success ? What are the main elements to project management success ?			
Q9 Q9a	Do project management procedures improve the likelihood of project success ? a) Yes b) No Do the procedures remain valid over the life cycle. ? a) Yes b) No			
Q10	Do the project management and engineering design systems employed in the organisation interact ? a) Yes b) No If yes how are the interactions managed ?			

ConSERV A methodology for the management of capital projects and concurrent engineering design using knowledge based technology.

APPENDIX J

Evaluation sheets used to evaluate the conserv against the company project management procedures on two live projects the Pilot plant and acid storage test cases at HDC Ltd (Sheet 2 Evaluation)

DATE	**Conserv Trials Sheet 2** **EVALUAITION SHEET**			**SUBJECT CODE** ....
	Question	Subjective Answer	Objective Answer	Analysis
Q1 Q1a	Please rate the ConSERV project management concept. a) Gimmiky, b) Limited value, c) Useful d) High Potential Please assess the feasibility of the concept as an alternative to the traditional project management processes. a) No chance b) unlikely c) Possible d) Most probable			
Q2	Please advise whether or not you feel the system could provide a selection criteria for a project management software package. a) Could b) Unlikley			
Q3	Please compare your comments on sheet 1 with your assessment of the concepts approach to identifying the key project specific dimensions and risks. Does the concept improve risk identification a) Yes b) no c) Unable to tell.			
Q4	Please compare your comments on sheet1 with your assessment of the ConSERV guidelines used to identify the engineering elements of the project. Are the elements identified by the ConSERV process better or worse than those identified from traditional techniques a) Better b) worse c) No different			
Q5	Does the ConSERV concept identify the project sensitivities and provide any new information ? a) Yes b) No Was your overt risk assessment sufficient to be used for risk contingency. A) No b) Yes Were you able to come to agreement on the project specific risks and success criteria ? a) Yes b) No			
Q6	Does the concept afford any additional benefit over traditional methods ? E.g. past experiences and/or expertise ?			
Q7 Q7a	Has the trial of the concept changed any of the earlier beliefs concerning project success ? a) Yes b) No Do you believe it is possible to quantify all the engineering and project management issues of a major project. a) Yes b) No			
Q8	does the concept provide a mechanism for managing the project success issues (engineering design) and the project management issues concurrently ? a) Yes b) No			
Q9 Q9a Q9b	Does the ConSERV concept allow experiential knowledge including past project experiences to be used in new / future project management processes ? a) yes b) No Does the ConSERV concept maintain a focus on the project key issues over the life cycle ? a) yes b) No If yes how important is it to maintain the project focus ? a) Extremely b) Very c) fairly d) Reasonably			
Q10 Q10a Q10b	Do the project management and engineering design systems employed in the ConSERV concept interact ? a) Yes b) No If yes are the interactions controlled and managed ? a) yes b) No How do you rate the 3D visualisation of the multidisciplinary engineering design resources a) Essential b) Useful c) unhelpful d) Gimmicky			

APPENDIX J

NAME	DISCIPLINE	TERMS	AGE RANGE	Q1	Q2	Q3	Q3a	Q4	Q4a	Q5	Q5a	Q6	Q6a	Q7	Q8	Q9	Q9a	Q10
John	Mech	Staff	over 35	a	a	a	non	b	?	b	a	b	a	a	a	a	b	b
Paul	Process	Staff	over 35	a	a	a	non	b	b	b	a	b	a	a	b	a	b	b
Chris	Mech	Staff	over 35	a	e	e	non	b	b	b	a	b	a	b	b	?	b	b
Mick	Mech	Staff	under 35	a	a	a	non	b	b	b	a	b	a	a	a	a	b	b
Heath	Inst	Contract	under 35	a	?	a	non	b	b	b	a	b	a	a	a	a	b	b
Stuart	Mech	Staff	over 35	a	a	a	non	b	?	b	a	b	a	a	b	b	b	b
Richard	Mech	Staff	under 35	b	a	a	non	b	b	b	a	b	a	a	b	a	b	b
Alan	Process	Staff	over 35	a	a	b	non	b	?	b	a	b	a	a	a	a	b	b
Indy	Process	Contract	over 35	a	a	a	non	b	b	b	a	b	a	a	b	a	b	b
Robert	Elect	Staff	over 35	a	a	a	non	b	b	b	a	b	a	b	a	?	b	b
Keith	Inst	Contract	under 35	a	a	a	non	b	b	b	a	b	a	a	b	a	b	b

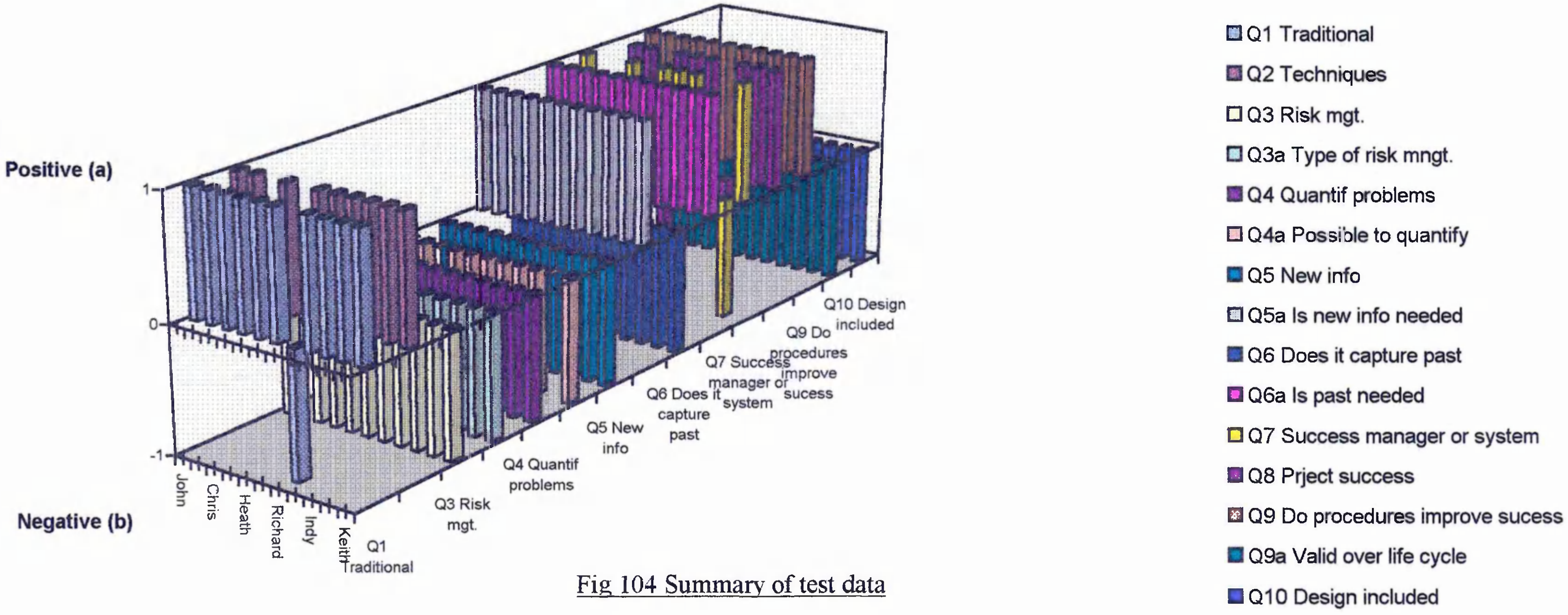


Fig 104 Summary of test data

APPENDIX J

	DISCIPLINE	TERMS	AGE RANGE	Q1	Q1a	Q2	Q3	Q4	Q5	Q5a	Q6	Q7	Q7a	Q8	Q9	Q9a	Q9b	Q10	Q10a	Q1
John	Mech	Staff	over 35	c	d	a	a	a	a	a	a	a	?	a,	a	a	a	a	a	b
Paul	Process	Staff	over 35	c	c	a	a	a	a	b	a	a	b	a	a	a	a	a	a	b
Chris	Mech	Staff	over 35	c	d	a	a	a	a	b	a	a	a	a	a	a	a	a	a	b
Mick	Mech	Staff	under 35	d	d	a	a	a	a	a	a	a	?	a	a	a	a	a	a	c
Heath	Inst	Contract	under 35	c	c	a	c	c	a	b	a	a	a	a	a	a	a	a	a	c
Stuart	Mech	Staff	over 35	c	d	a	c	a	a	a	a	a	?	a	a	a	a	a	a	b
Richard	Mech	Staff	under 35	d	d	a	a	a	a	a	a	a	a	a	a	a	a	a	a	c
Alan	Process	Staff	over 35	c	d	b	c	a	a	b	a	b	a	a	a	a	a	a	a	b
Indy	Process	Contract	over 35	d	c	a	c	c	a	a	a	a	b	a	a	a	a	a	a	b
Robert	Elect	Staff	over 35	c	d	a	a	a	a	a	a	a	a	a	a	a	a	a	a	c
Keith	Inst	Contract	under 35	c	c	a	c	a	a	b	a	a	a	a	a	a	a	a	a	b

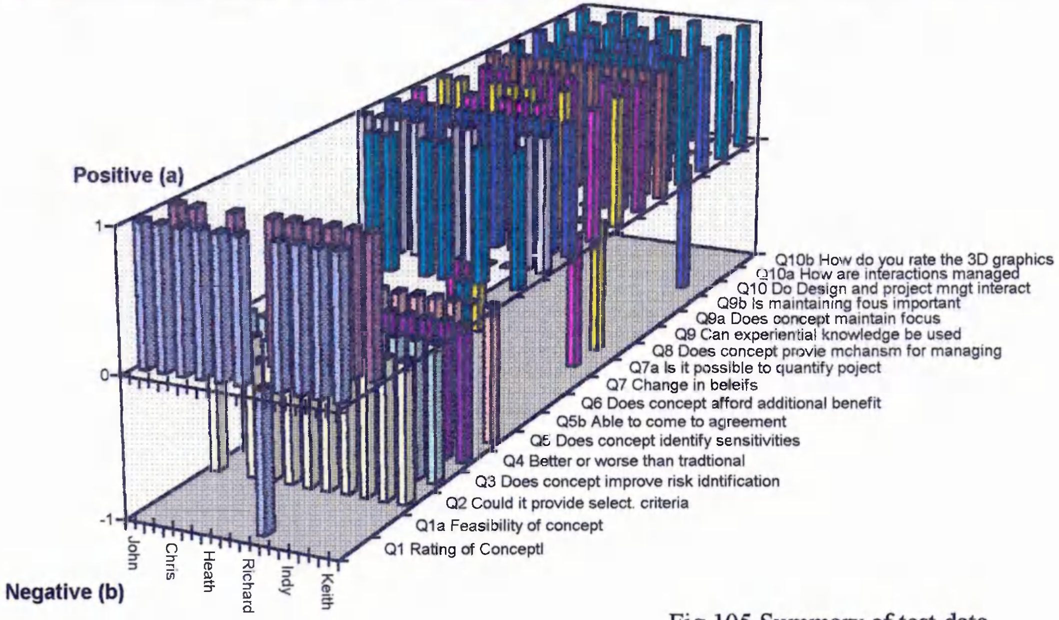


Fig 105 Summary of test data

APPENDIX J

A Guidelines for Project management and engineering design reviews The guidelines for the reviews require that the following considerations are made :-

A	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks Identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid plant	Risks identified	Cost implication	Design Implications
a	Flow sheet review B								
b	P&ID review C								
c	Site layout review D								
d	Equipment layout review E								
e	Electrical power review F								
f	Control Philosophy review G								
g	Piping review H								
h	Cable routing review								
i	Other								

Table 21

APPENDIX J

<u>B Guidelines for Flow sheet review</u> The conserv procedures for undertaking a flow sheet review have been indicated in the item reference, the subsequent effect on the two projects has been indicated in the table :-
For simplification the folowing legend has been used: U=Unable to evaluate H =High M=Medium L=low N=Non

B	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
a	Project Scope	Partially defined	H	H	H	Phase 1 well defined, Phase 2 Undefined	H	U	U
b	Source of Technology	Known Chemical processes	M	M	M	Well established from suppliers	M	M	L
c	Technical risks	Process not fully developed	H	H	H	SO3 Technical committee	M	M	L
d	Research and trial data	Unknown	U	U	U	Storage conditions known	M	M	L
e	Validity of data	Unknown	U	U	U	Data considered to be well validated	M	M	M
f	Understanding of Chemistry	Chemistry believed to be known and proven	M	M	M	Chemistry of fuming acid storage known	H	M	M
g	Main Plant Item Inventory	Brief inventory available of only MPI's	L	L	M	Inventory of storage vessels and pumps	L	L	L
h	Control Philosophy	Unknown	H	M	H	Unknown	H	M	H
I	Commissioning Shutdown	Assumed to be similar to existing processes	M	L	L	Procedure to be developed	M	M	M
j	Emissions inventory	Assumed to be similar to existing processes	M	M	M	Release of fuming acid a major concern	H	H	H
k	Installed stand by plant	Batch processing therefore no standby	N	N	N	No standby plant required	N	N	L
l	Plant availability/utility	Pilot plant therefore low utilisation	L	L	L	Plant in full service 24 hrs/day	H	H	M
m									
n									
o									
p									
q									
r									

<u>Table 22</u>

APPENDIX J

C Guidelines for P&ID review The guidelines for the P&ID review require that a specific procedure is followed similar to a Hazop in which the review considers Efficiency, Reliability and Safety issues by using a set of key Guidewords. The table below is a summarised version of what the concept would produce :-

C	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
a	Efficiency (Plant items)	Unknown	U	U	U	Unknown	U	U	U
b	Efficiency (Pipework)	Unknown	U	U	U	Unknown	U	U	U
c	Efficiency (Relief streams)	Unknown	U	U	U	Unknown	U	U	U
d	Efficiency (Inst. systems)	Unknown	U	U	U	Unknown	U	U	U
e	Efficiency (Electrical)	Unknown	U	U	U	Unknown	U	U	U
f	Efficiency (Isol, vent drain)	Unknown	U	U	U	Unknown	U	U	U
g	Reliability (Plant items)	Unknown	U	U	U	Unknown	U	U	U
h	Reliability (Pipework)	Unknown	U	U	U	Unknown	U	U	U
I	Reliability (Relief streams)	Unknown	U	U	U	Unknown	U	U	U
j	Reliability (Inst. systems)	Unknown	U	U	U	Unknown	U	U	U
k	Reliability (Electrical)	Unknown	U	U	U	Unknown	U	U	U
l	Reliability (Isol, vent drain)	Unknown	U	U	U	Unknown	U	U	U
m	Safety (Plant Items)	Unknown	U	U	U	Unknown	U	U	U
n	Safety (Pipework)	Unknown	U	U	U	Unknown	U	U	U
o	Safety (Relief streams)	Unknown	U	U	U	Unknown	U	U	U
p	Safety (Instrmnt systems)	Unknown	U	U	U	Unknown	U	U	U
q	Safety (Electrical equip.)	Unknown	U	U	U	Unknown	U	U	U
r	Safety (Isolation vent drain)	Unknown	U	U	U	Unknown	U	U	U

Table 23

APPENDIX J

D Guidelines for site layout

The conserv procedures for undertaking a site layout review have been indicated in the item reference, the subsequent effect on the two projects has been indicated in the table :-For simplification the folowing legend has been used: U=Unable to evaluate H =High M=Medium L=low N=Non

D	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
a	Interface with existing site	Location interfaces with existing site	L	L	L	Location of Phase 1 items locates well	L	M	M
b	Interface with other proposed developments	No known proposed works is planned for the identified location	N	N	N	Proposed location of Bulk acid storage tank farm would integrate well with existing	L	M	M
c	Site safety constraints	The proposed location does not appear to have any safety constraints	N	L	L	Proximity to existing effluent drain in the event of an acid spill is a known constraint	H	L	M
d	Effect on the environment	The proposed layout has no adverse effect on the environment	N	N	L	Bulk acid or Oleum release has major consequences on environment	H	H	H
e	Availability of Site services	The location is suitable for the provision of site services	L	L	L	Proposed bulk storage location is close to available services and utilities	L	L	M
f	Site geological considerations	Conditions in the immediate area need to be reconfirmed	H	M	M	Nominated site for Bulk storage is at South end of site in close proximity to canal.	M	M	M
g	Civil considerations	The ground bearing and the static loading conditions are to be quantified	M	M	M	Location is adjacent to disused roadway and ground conditions are likely to be good	M	L	L
h	Construction access	Access for construction is good	L	L	L	Proposed Site is readily accessible	L	L	L
I	Transport of process matls	Roadway needs improving	L	M	M	Roadway to site is good roadway from site will need to be made good	L	M	M
j	Location of main buildings	The main buildings shed 46 are close to the new plant (3-4 metres)	L	L	L	Location from main buildings is over 20m and therefore an improvement on existing	M	M	M
k	Road system	The road access is incomplete and will require some 50 meters of making up	M	M	M	Tanker loading bay and Road way will need to be developed	M	M	M
l	Plant Emergency provisions	Fire fighting capability will be required at the plant to contain and control (Solvents)	M	M	H	Emergency services to control fire and spillages have good access	H	M	H
m	Vehicle parking, loading and unloading	The roadway alongside the West of the building could be extended to provide loading and unloading	L	L	L	A special purpose tanker loading facility will be an integral part of the plant design	M	M	M
n	Plant Offices and amenities	Ground floor office and provision for ablutions made has been included	L	M	L	No plant offices or amenities are required at the Bulk storage facility	L	L	L
o	Main cable and piping routes	The main cable and piping routes have not been identified. It is assumed there will be a need for pipe bridges	M	M	M	The main cable and piping routes to and from the Bulk acid tank farm shall be via overhead gantry	M	M	M
p	Location of control room	Identified on drawing	H	M	H	Not Applicable	N	N	N
q	Separation distances from hazardous areas	Solvents may need to be stored separately once process has been described	H	L	M	Plant location is sufficient distance from known hazardous areas ecxept DMS store	M	M	L
r	Fences	Finished product storage area may need fence	M	M	M	Tanks shall be bunded not fenced	H	M	L

Table 24

APPENDIX J

E Guidelines for Plant and equipment layout review The conserv procedures for undertaking a plant and equipment review have been indicated in the item reference, the subsequent effect on the two projects has been indicated in the table :- legend used: U=Unable to evaluate H =High M=Medium L=low N=Non

E	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
a	Relation to agreed site layout	Orientation and location of loading and off loading facilities and location of external services building	L	L	L	Location of Phase 1 items locates well	L	M	M
b	Separation distances for hazardous areas	Building Classification Zone 1 Area designation and classification needed	N	N	N	Proposed location of Bulk acid storage tank farm would integrate well with existing	L	M	M
c	Control Room location	Is control room area classification agreed ? No of operators using room ?	N	L	L	Proximity to existing effluent drain in the event of an acid spill is a known constraint	H	L	M
d	Storage	Can we estimate the likely on plant storage areas	N	N	L	Bulk acid or Oleum release has major consequences on environment	H	H	H
e	Services	service corridor and provisionally estimate of running loads for support structure	L	L	L	Proposed bulk storage location is close to available services and utilities	L	L	M
f	Effluent treatment provisions	local retention facility to pre treat spillages prior to discharging ? (Solvent rich liquids)	H	M	M	Nominated site for Bulk storage is at South end of site in close proximity to canal.	M	M	M
g	Preferred economic equipment location	The Main Plant Items are in the process of being identified abortive design effort possible	M	M	M	Location is adjacent to disused roadway and ground conditions are likely to be good	M	L	L
h	Floor levels internal access and escape	No comments	L	L	L	Proposed Site is readily accessible	L	L	L
I	In plant maintenance areas	Are any additional lifting or runway beams considered necessary at this time	L	M	M	Roadway to site is good roadway from site will need to be made good	L	M	M
j	Air Conditioning and Ventilation	Building will be naturally ventilated with local fume extraction. control rooms / offices to be A/C	L	L	L	Location from main buildings is over 20m and therefore an improvement on existing	M	M	M
k	Selection of packaged plant units	No comment	M	M	M	Tanker loading bay and Road way will need to be developed	M	M	M
l	Provision for future expansion	The assumed future expansion of the pilot plant shall be due North	M	M	H	Emergency services to control fire and spillages have good access	H	M	H
m	Access for emergency services	No comment	L	L	L	A special purpose tanker loading facility will be an integral part of the plant design	M	M	M
n	Flow of process materials through the plant	The likely quantities and details of in flow materials would be useful when designing the plant layout especially whether drummed,	L	M	L	No plant offices or amenities are required at the Bulk storage facility	L	L	L
o	Flow of process materials	assumed that materials will normally flow by gravity or under slight Nitrogen pressure	M	M	M	The main cable and piping routes to and	M	M	M
p	Access for construction	No comments	H	M	H	Not Applicable	N	N	N
q	Provision for removal of items for maintenance	See earlier comments re lifting and runway beams	H	L	M	Plant location is sufficient distance from known hazardous areas except DMS store	M	M	L
r			M	M	M	Tanks shall be bunded not fenced	H	M	L

Table 25

APPENDIX J

F Guidelines for Electrical power distribution review The conserv procedures for undertaking a plant and equipment review have been indicated in the item reference, the subsequent effect on the two projects has been indicated in the table :- legend used: U=Unable to evaluate H =High M=Medium L=low N=Non

F	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
a	Availability of supply								
b	Reliability of supply								
c	Connected load								
d	Normal running load								
e	Maximum demand								
f	nature of load								
g	Power factor								
h	Fault levels and protection								
I	Voltage overload								
j	Area classification								
k	Earthing								

Table 26

APPENDIX J

G Guidelines for Control philosophy review :- (ConSERV process breaks control into 4 groups) legend used: U= Unable to evaluate H =High M =Medium L= low N =Non

G	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
1	**Process Operations**								
a	level and degree of automation	The complex nature of automating multi purpose processes suggests low level				High level of automation for bulk acid storage facility			
b	Control of start up/shutdown phases	Insufficient data available to identify specific needs				Plant designed for continual operation, start -up shutdown procedures maintenance only			
c	Operator Interface displays location and type	Plant area classification Zone 1 therefore displays on plant to be rated accordingly				Batch recognition (bar code) tank volume measurement, tanker tare weights possibly			
d	Advanced process control requirements	Non known				Non known			
e	Data logging, and batch records requirements	Assumed that they will be required indeterminate at present				data logging of deliveries, batches received sampling etc. required			
2	**System Considerations**								
a	Centralised or Distributed Control system	Local PLC located in control room				Bulk Acid inventories required at Plant 45 and main office building			
b	Future process changes or add on requirements	allow considerable flexibility as pilot plant will require experimentation				Non required			
c	Quality procedures and test procedures required	System will be controlling potentially dangerous process chemistry				System will control potentially hazardous materials.			
3	**Installation**								
a	Area classification and types of protection	Zone 1 area classification. Plant detection and protection for gas presence, heat rise.				Area classification not yet determined			
b	Environmental considerations, dust dirt solvents etc.	Solvent and acid presence suggests IP66 instrument ratings				Equipment used on the plant will be outdoors in a chemically charged area			
c	Provision of reliable supplies to controls air-power-UPS	Critical process control systems may require UPS see Hazop studies for details				Batch metering of acids into tanks may require UPS			
d	Materials of construction of control equipment / panels	Plastic coated Pressed steel or acid resist plastic materials preferred				Acid resistant plastics or stainless housings will be required			
4	**Process Safety**								
a	Main process hazard, rate of temp rise. Detection system.	Hazards identified from Hazard studies				Hazrds identified from hazard studies but will include presence of acids in bunds.			
b	Process dynamics rates of response	Early detection of gas presence runaway processes and high level conditions required				Early detection of leakages and or spillages essential			
c	Required speed of response from operator or system	Rapid response required for abnormal and emergency conditions				Rapid response required for abnormal and emergency conditions			
d	Required Integrity or reliability of trips and alarms	Very high level of system integrity required with regular maintenance, cleaning regime				Very high level of system integrity required for contents and spillage detection			
e	Modes of failure and test criteria for failures	Generally fail safe / fail close conditions will be used				Fail safe conditions required to prevent unnecessary losses of acid			
f	Standby and backup needs	Standby system for control power required				Standby system not required			

Table 27

APPENDIX J

<u>H Guidelines for Piping review</u> :- (ConSERV reviews piping design against safety/ engineering) legend used: U= Unable to evaluate H =High M =Medium L= low N =Non

H	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant	Risk identified	Cost implication	Design Implications
a	Consistency and accuracy with approved P&ID	No approved P & ID available	H	H	H	No approved P & ID available	H	H	M
b	Design and operating conditions	Insufficient information available	H	H	H	Detailed information required	H	H	M
c	Piping specifications and materials of construction	Company piping standards available	L	L	L	Company piping standards available	M	M	M
d	Possible leakage, its effects on people, plant or environment	Proposed pipe rack for utilities and services has been nominated	L	M	M	Pipe route for bulk acids has been nominated with self drain back to tanks	L	M	M
e	Provision for and the need to undertake flexibility analysis	Main plant Item list includes centrifuge therefore flexibility analysis required	H	H	M	Flexibilty analysis required for pipe runs as SG of acids is 2	H	H	M
f	Need to provide clearance access to remove blockages	Insufficient information available to determine whether rodding facilities needed	L	M	L	Pipework to be fully welded to avoid flange leaks, high grade acids should have no dirt	L	M	L
g	Support of pipework specially each side of valves	No piping GA to check	L	M	L	No piping GA to check	L	M	L
h	Access to valves and provision for fitting/maintaining valves	No piping GA to check	L	M	L	SO3 Technical committee has standards on preferred access design	L	M	L
i	Slopes falls and drainage requirements of pipework	No piping details or isometrics	L	M	M	Self draining pipe system required	L	M	M
j	Insullation and identification of pipework	very important to clearly identify pipework in a pilot plant	H	H	L	very important to clearly identify pipework connections on bulk acid compound	H	H	L

Table 28

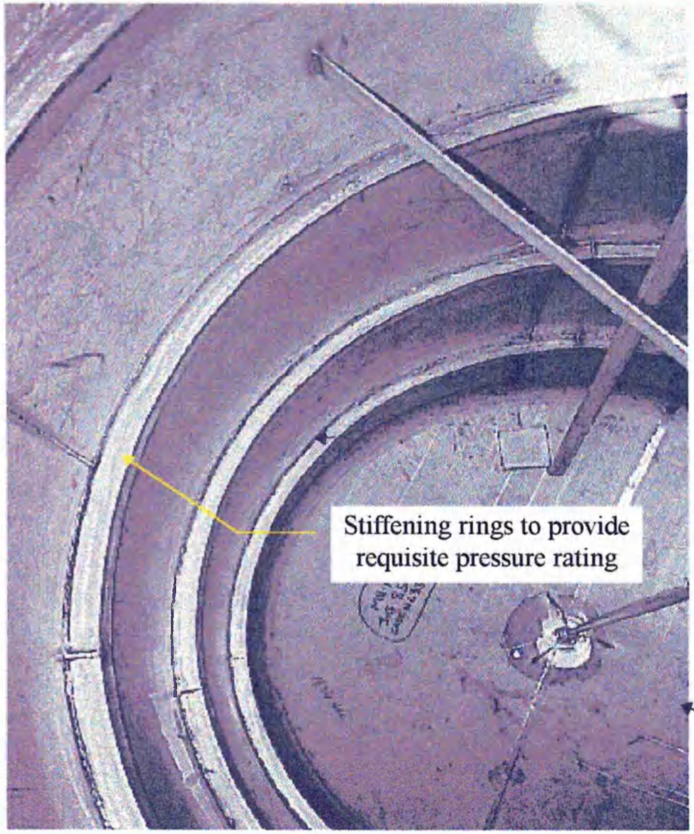
APPENDIX J

I Guidelines for Cable routing review The ConSERV procedures for undertaking the cable routing :- legend used: U=Unable to evaluate H =High M=Medium L=low N=Non

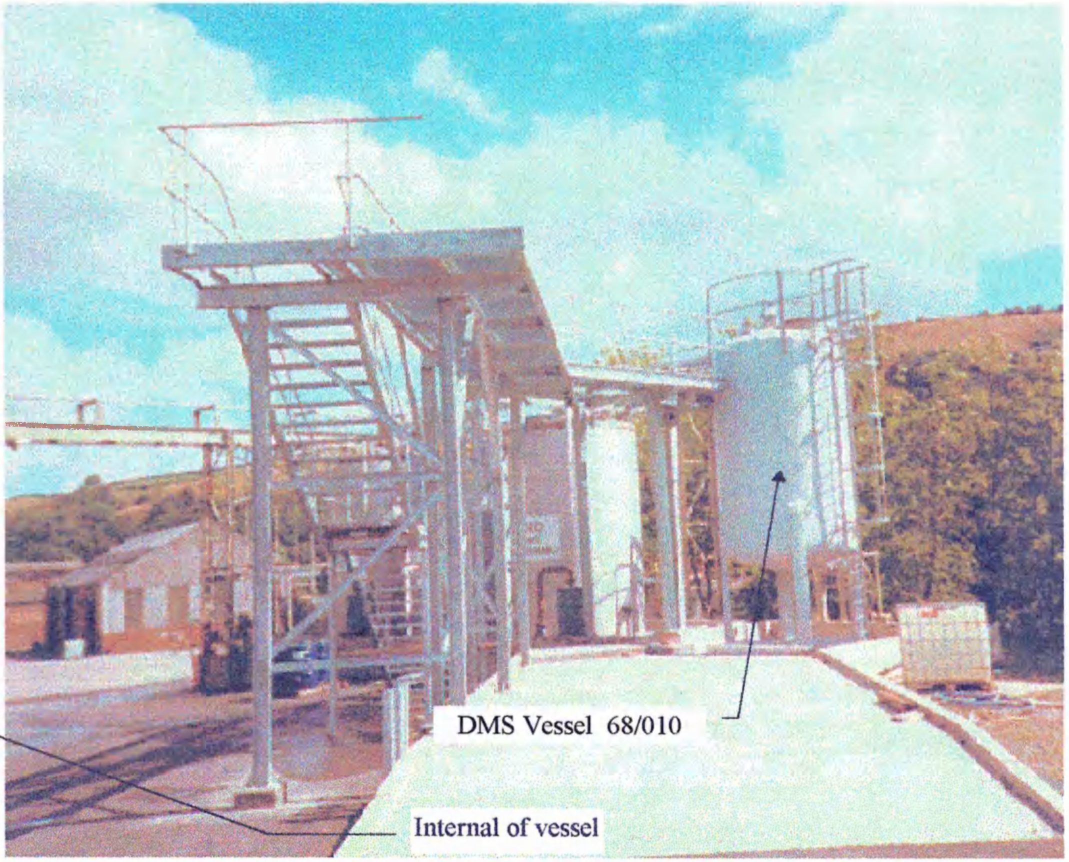
E	Item Reference	Effects and impact on Test Case 1 Pilot Plant	Risks identified	Cost Implications	Design implications	Effects and impact on Test case 2 Bulk acid and Oleum distribution plant Phase 1	Risk identified	Cost implication	Design Implications
a	The segregation of instrument and electric cables	No cable schedule to assess need to segregate	M	M	L	No cable schedule to assess	U	U	L
b	The segregation of intrinsically safe circuit cables	No cable schedule to assess need to segregate	M	M	L	No cable schedule to assess	U	U	L
c	The allocation of intrinsically safe JB's	Intrinsically safe Junction boxes and cable glands and entries will be necessary	H	H	M	Intrinsically safe JB's are unnecessary	N	N	N
d	The routing of cables in the control room (underfloor)	Cables will be run under false floor unless otherwise stated	M	L	L	No Control room or computer interface	N	N	N
e	The routing of cables away from known potential fire hazards	Cable schedule and location diagram for main plant items required	H	H	L	Close Proximity of proposed acid store to nearest known flammable materials DMS	H	H	M
f	The routing of cables away from potentially harmfull spillages	Approved Layout of plant GA showing services and cable routes required	H	H	L	Chemically spillage a highly possible event on acid tanker bays	H	H	M
g	The separation of cables associated with duty/stdby	Approved Layout of plant GA showing services and cable routes required	M	H	L	A duty / stand by system likely on the bulk acid plant	M	H	L
h	The routing of cables to prevent mechanical damage	Approved Layout of plant GA showing services and cable routes required	M	M	L	Cables likely to be fed over gantry should be kept away from sides of gantry	M	M	M
I	The routing of cables associated with fire protection and alarms	Pyrotechnic cable may be needed for alarming plant area and control room	M	M	L	Dedicated cable tray will be included in the design for fire protection cabling	M	M	L
j	The routing of cables for high integrity trip systems	Route for Cable trays carrying high integrity trip cables to be approved	M	H	L	Dedicated cable tray will be included in the design for fire protection cabling	M	H	L
k	The routing of cables associated with fire detection and alarm	Location of detection heads and design to be agreed i.e. Temp rise or VESDA	H	H	M	Dedicated cable tray will be included in the design for fire detection cabling	H	M	L
l	The provision for spare cable ways and pits	Pilot plant therefore allow two extra pairs.	M	M	L	Spare cable ways for further plant expansion	L	L	L
m	The separate routing of dual data highway cables	Data highway cabling to be routed off cable tray	M	L	L	Dedicated cable tray required for data highway cabling	M	L	L
n	The potential for interference with pipe routes and access	Approved Layout of plant GA showing services and cable routes required	M	M	M	No details of cable tray or pipework	U	U	U
o	The termination and glanding of cables into JB's and panels	All cable ducting entering the process plant to be glanded with solvent resist materials	H	H	M	Termination and junction boxes to be specified for chemically charged area	M	M	H
p	Identification of underground cables and draw pits	Routes to be identified	M	M	L	Location of underground cabling and draw pits to be identified in case of acid leak	H	H	L

Table 29

APPENDIX J



P 13 Internal photograph of DMS storage vessel



P 14 DMS Installation

Chapter X

"I hear and I forget, I see and I remember, I do and I understand."
Confucious[1]

10.0 SUMMARY, CONTRIBUTION TO KNOWLEDGE AND BEYOND

10.1 Introduction and Summary

10.1.1 Introduction

The previous Chapter presented the findings from the testing procedures applied to the ConSERV concept. It was demonstrated that the concept appears to have real benefit in assisting project engineers and project managers to identify and quantify project risks, and the necessary man-hours required to manage them. In this final Chapter, the author recounts the *raison d'être* underlying the work imbued in this document, and how the more recent project management issues, particularly those raised at the APM[1] 25th Anniversary conference, can be related to the concept.

The Chapter details those areas in which the research effort makes a significant contribution to knowledge, specifically those pertaining to the management of major, multidisciplinary engineering capital projects currently being undertaken in the Chemical and processing industry.

The Chapter alludes to a number of recommendations on those areas of the concept that may be worth considering for future development, and possible methods by which they may be progressed.

Chapter X also outlines the potential benefits of a fully developed system and how such a system may be used as a comprehensive integrated project management methodology in the next Millennium.

The concluding remarks made in this Chapter incorporate the key issues raised at the APM[1] 25th Anniversary conference held at UMIST 13 June 97, in which the future direction of the profession of project management was reviewed and discussed.

[1] Association for Project Managers

10.1.2 Summary of Thesis

This Ph.D. has been submitted in 4 parts.

Part 1 Introduction, case studies and justification. which comprises 4 Chapters.

Chapter I outlined the structure of the PhD and provided an insight into the business of project management. Chapter II addressed the more general and historical aspects of project management and provided an overview of the knowledge domains pertinent to project management. Chapter III introduced the case studies and the subsequent findings from the industrial research, whilst Chapter IV provided a description of the justification and methods employed in undertaking this research.

Part 2 Development of the Concept, consists of 3 Chapters.

Chapter V The development of the *project management* element, and Chapter VI The development of the *Engineering Design* element of the ConSERV concept were both structured using a risk identification approach in which the key success factors were identified using a question and answer routine. Chapter VII described the 3D model and how it is used as an information transfer technique within a project group.

Part 3 Software Development comprising of a single Chapter.

Chapter VIII which described the system architecture and further details of the demonstrator programs.

Part 4 Results and Summary of the Research

The final section of the Ph.D. includes two Chapters. Chapter IX which addressed the testing procedures, the evaluation and validation of the tests, and this, Chapter X, which summarises the content of the PhD, the contribution made to knowledge, and the future prospects.

10.1.3 Background

The previous nine chapters have described the background, justification and basis for undertaking this research. The various failure mechanisms for both project management and engineering design have been discussed with arguments being supported by industrial case studies. From the research findings the traditional *engineering design* and *project management* techniques were considered to be inconsistent with the demands likely to be placed on management systems in the next Millennium.

It was argued that *engineering design* and *project management* are inextricably linked and are therefore unable to be managed effectively in isolation of each other.

As a consequence it was contested that a methodology capable of integrating the two technologies is now required.

It was also argued that traditional management techniques were dated and afforded little in the way of decision support for the engineers and project managers.

The submission contended that it is possible to develop a comprehensive engineering design and project management technique, ConSERV, which uses a knowledge based approach in order to better understand and manage projects. As we have seen the concept is used to identify the key project dimensions which are subsequently used in conjunction with expertise, (knowledge rules) to determine the main risk issues associated with the project being managed.

It is the authors view that over the life cycle of any given project a number of unplanned and unforeseen events will occur. These events will have an impact on the project that will need engineering man-hours in order to address them. The time spent on attending to these issues will be directly proportional to the rate, frequency and time at which they occur. Both *Chapman*[2] and *Harrington*[3] recognised the cost implications of addressing risk issues late into the project design phase.

On those projects in which the level of planning and detail has been inadequate there is a high probability that the man-hours scheduled for the project will be exceeded. These are *known* project management problems, the hitherto *unknown* issues were how to effectively reduce, minimise or ultimately, eliminate them.

10.2 Detailed Contribution to Knowledge

10.2.1 A New concept

In the introductory Chapter section 1.6 it was stated that the most useful contribution to knowledge was in: "taking heuristic and experiential project management knowledge into an area where it can be more easily structured and accessed".
It is, perhaps, easier to describe the contribution to knowledge made by this research, by comparing how it fits with what is already known in project management and engineering design. This is shown in Fig 106 below.

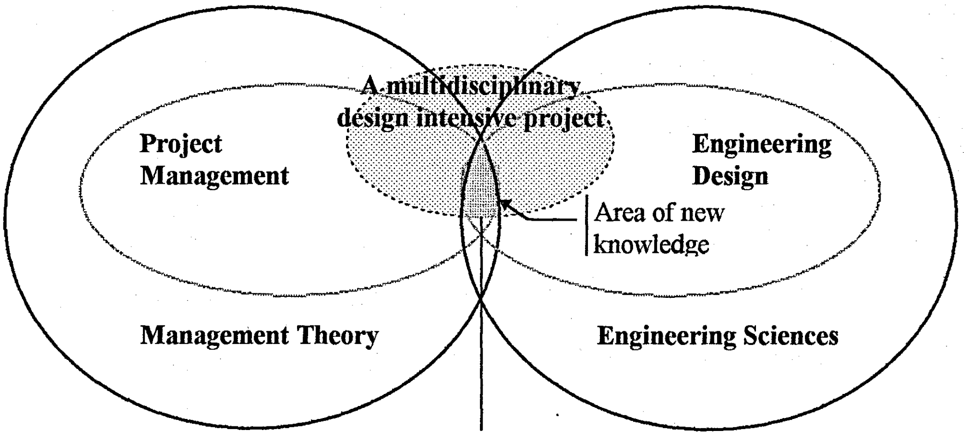


Fig 106 Diagramatic representation of knowledge

As illustrated above, both Project Management and Engineering Design can be viewed as sub sets of the more general and traditional *Management theory* and *Engineering Sciences*, indeed in most academic institutions they are taught as such. E.g. Cranfield School of Management offers "Project Management" as an MSc. whilst the engineering sciences are taught through the respective Schools of Engineering. This division between the two domains, Management and Engineering, extends into the industry, in the form of the *Engineering and Engineering design* functions, and the *Production and Project management* functions.

Knowing how to effectively integrate these two rather esoteric functions within the framework of a real project is recognised as being a major problem area.
The concept described in this submission is being proposed as a new methodology that enables this interface to be integrated and managed, and is therefore submitted as being new knowledge.

10.2.2 The Area of new knowledge

The area of new knowledge shown in Fig 107 could be viewed as the addition of a small slice within three specific knowledge domains.

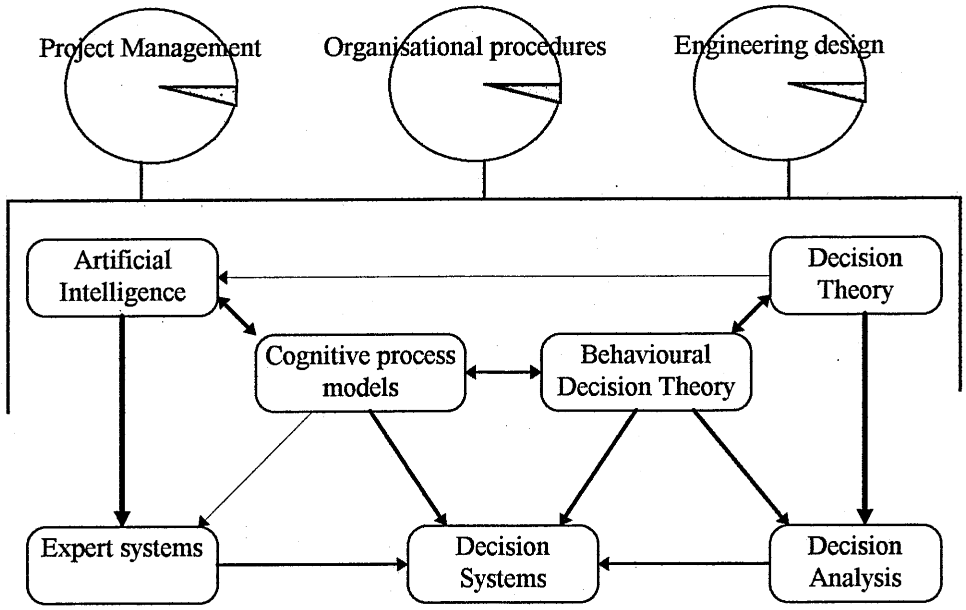


Fig 107 Classical methods to represent uncertain knowledge

Due to the uncertain nature of the individual knowledge, each domain will in turn incorporate some aspect of the classical methods of reasoning behaviour and the representation of the uncertain knowledge as shown above.

It is suggested that this research has increased the level of knowledge and understanding of the **application** of the classical reasoning theories in a **project management** environment.

Unfortunately the validity of this claim can only be established by measuring the success rate of projects using the ConSERV concept against identical projects being managed at the same time, with the same team, using traditional methods.

Such an experiment would require that the test project would have to be allowed to fail whilst information that may prevent the failure would have to be withheld simply to prove the point. If, however such a test were undertaken and a discernible difference was observed, then one could argue that the improved success rate would be attributable to the fact that the system user is apparently better informed about how to manage projects more successfully. i.e. By using the new management process.

10.3 Limitations of the concept

10.3.1 Limitations in the project management domain

The ConSERV technique is based upon developing a close working relationship between the project manager, the design team and the 'expert system'.

The system is therefore limited to some extent by the validity of the information provided by the user. The major limitations concerning the acceptance of any 'expert system' is in being able to provide the user/s with a sufficient number of detailed explanations to afford confidence in the 'recommendations' and advice provided by the system.

The research has been undertaken primarily in the Chemical industry and has been mainly concerned with relatively small £5-10 M value projects.

It is recognised that the techniques used in the management of larger greenfield LSTK[1] projects may be somewhat different and possibly inappropriate for the application of the ConSERV concept as it presently stands. It is also recognised that the type of system proposed in this submission may not be entirely applicable to the management of projects being undertaken in other industries.

The limitations of the demonstrator have already been identified.

10.3.2 Limitations of the Engineering Design domain

As was stated at the outset Section 1.1.1 "The very nature of project management and engineering design requires both an holistic and in depth view, and any research will therefore be wide ranging and broad based". In being broad based it is very difficult to focus on any one specific design problem that may develop over the life cycle of a given project. In this respect the concept is limited, however if we accept that recognising the likelihood of the problem emerging is as important as solving the problem then the concept is only as limited as the knowledge base and systems and the machines processing capability.

---

[1] Lump sum Turn key

10.4 Potential Benefits

10.4.1 Training benefits

A fully developed version of the concept would afford major benefits to the Association of Project Managers as a method for assessing individuals skill levels and evaluating individuals performances. This could be easily achieved by presenting project engineers and managers, with a number of hypothetical project scenarios as described in Appendix E5.

The project parameters and risks could be 'simulated' using the concept and the responses provided by the individuals could be evaluated against the "knowledge based rules" employed by the simulator. *Wateridge*[4] identified the need for a better method of training project managers, specifically the transfer of new techniques and experiential knowledge between managers.

10.4.2 Modelling benefits

The fully developed system, will be capable of providing the user with a number of modelling options in which 'predictable' project outcomes can be generated.

E.g. Committing resources to undertake work required to meet the project needs but not identified at the outset. The choices include: i/ *'not to do the work'* the consequences of which are that the project end date slips, or ii/ *'to undertake the work'* the consequences of which are a potential overspend on man-hours, or iii/ *to subcontract* the work resulting an overspend on the budget. It would be possible to simulate the three scenarios using the concept, but determining which of the three options provides the greatest benefit will depend upon the status of the key dimensions at the time of the evaluation. i.e. Project Focus.

10.4.3 Decision Aid

In a real world environment the fully operational system should be capable of allowing the user to test a number of project decision possibilities, and thereby build confidence in the outcome. Supporting the decision making process is seen as a major advantage provided by a well written 'expert system'. Of equal importance is the user feedback to advise the system as to whether or not the decision was sound. In this way the science of hindsight can actually be incorporated into the expert system in the form of additive knowledge rules that can be generated from scratch or adapted to suit the specific case.

10.5 Recommendations for further Development

10.5.1 Addressing the limitations

The limitation of providing detailed explanations of the systems reasoning methods can hopefully be addressed by further development of the system software.

The work undertaken to date is still largely incomplete as there are an almost infinite number of possibilities that can emerge during the life cycle of a major capital project. Each problem solving routine is unique and depends upon the availability of *temporal* knowledge and the status of *project specific* conditions at the time.

The research effort required to analyse every decision making scenario over the many stages of numerous live projects would be unrealistic, as the data obtained would describe a set of world events that may include a number of unsafe or flawed human decision making processes that may involve irrationality.

In order to build a really useful KB project management system the researcher would need to capture, isolate and identify the flawed process in order to provide an acceptable explanation when providing the user with an alternative solution.

One area worthy of further research would be to devise some technique that would allow the concept to be developed more quickly, possibly by brainstorming specific scenarios at various stages during the project life.

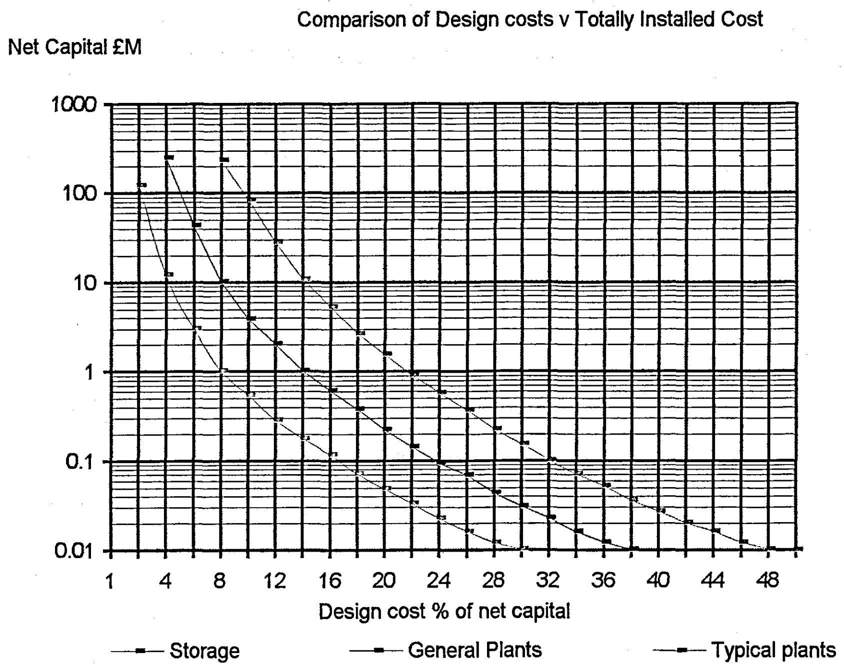


Fig 108 Graph of design costs v Project Capital

10.5.2 Justification

The costs of undertaking further developmental work has to be measured against the perceived benefits afforded by the system. It is the authors' view that due to the enormity of the annual costs of mismanaged projects undertaken in the UK Chemical industry alone, even the smallest savings would easily justify the research effort.

In the Process Industry, the Engineering and Engineering Design costs are often measured as a percentage of the Total Installed Costs (TIC), sometimes the Total Commissioned Costs (TCC). Ref. Fig 108 p 193. Clearly each project is unique and the balance of the engineering costs will vary widely from project to project.

From the research studies typical figures for the Engineering and Design elements were estimated as:

* Feasibility Design 1%-2%

* Front End Design 5%-15%

* Detailed Design 15%-25% (Including Front end design)

* Construction Management 2.5%-6%

These figures are consistent with those suggested by *Hackney*[5] and *Sweeting*[6].

As can be seen up to one third of the totally installed costs could be spent on the engineering and design costs incurred on a major capital project. This figure is likely to be far greater on the more design intensive projects such as R&D.

For a relatively small annual spend of £12 M it is likely that between £3-4 M will be spent on the engineering and engineering design and construction management costs. Assuming that 'on average' projects are 10-15% overspent[1] *Morris and Hough*[7] then a potential savings of around £ 0.5 M per project per annum could be achieved.

---

[1] Overspent as distinct from undervalued

The justification for this research is two fold,

i/ Direct saving on man-hours expended by minimising lost time in communication and information flow.

ii/ Indirect cost saving as a result of preventing abortive use of man-hours in the design process.

iii/ Time savings resulting from reductions in the transfer of design critical data.

iv/ Savings resulting from the rework of design errors.

Clearly the final objective is a fully operational product that can guarantee some form of cost benefit to the management of any major capital project. The research to date has provided a reasonably sound platform on which to develop such a product.

10.5.2 Main areas for further Research

The author recognises that the work is incomplete and that other areas in need of further research include :-

i/ A more thorough analysis of the incidence and real costs of project failure, both at a National and global scale in order to confirm the widely held views.

ii/ Confirmation at a National level that the eight live project examples submitted in this document are representative of the majority of projects being managed in the Chemical, Petrochemical and Pharmaceutical industries.

iii/ A follow up investigative study on practising project managers, possibly through the APM to reconfirm the analysis and substantiate the assumptions and findings.

iv/ More rigorous testing and enhancements of the concept on a wider population.

v/ The inclusion of additional knowledge based rules in identifying the covert risks

vi/ The application of the "Guidelines" provided in Appendices H and J to form a second level of *project data* acquisition software to incorporate the "Engineering Risks" into the systems *project* knowledge base.

vii/ The application of the "Hazop" data obtained from the H & O studies as shown in Appendix K into a third level of *project data* risk abstraction.

10.5.3 Development possibilities

It should be relatively easy to apply a number of very basic front end rules to the information provided in the first stage of the ConSERV process A1 Fig. 24 p 77, that will allow the system to determine whether or not the project includes the basic requirements to warrant being undertaken in the first place.

E.g. *<project value[1]>* * *0.33* = Total engineering costs [Eng. cost $_{\text{total}}$]

From national statistics average hourly rate for engineers working in processing industry (across all engineering disciplines, age and experiences) = £23

Eng. cost $_{\text{total}}$ * 0.0435 = Total man-hours [Eng. Man-hrs. $_{\text{total}}$]

i.e. For a £3M project £1M will be spent on engineering which buys 43,478 man-hours or 1144 man weeks, which translates into 25 man-years (allowing statutory holidays).

By comparing the project duration input, and the WBS of the program, it is possible to challenge the validity of the user input.

? can <25 man-years> be managed in <12 month> .

In the same way the project deliverables (documents) can be estimated against the project budget.

E.g. From the research data it was found that for a £3M spend one could expect some:

650 drawings, 200 purchase orders and 2,000 vendor documents.

From the project identification data the system would be able to challenge such issues as:

? can <12> documents be generated and managed per day with/without a QS.

By incorporating Electronic Document Management software it should also be possible to actually check whether or not the documents were being generated and managed as advised. The rate of document generation could now be seen as the 'rate determining step' for satisfying one of the main project success criteria.

By relating the production of deliverables with multidisicplinary design critical data flow the rate of progress for the generation of documents can be produced using the 3D visualisation technique.

---

[1] Project value is totally installed cost

10.5.4 Contractual Implications

The selection of the form of contract, i.e. lump sum or reimbursable is strongly influenced by the specific issues of the nature of the project.

Fixed price lump sum contracts (FPLS) have a number of key points that need to be made clear at the outset of the award of a major contract.

i/ A highly defined project scope, able to be accurately defined and specified.

ii/ Sufficient time to process the contract award process.

iii/ Appreciation of the implications in changing scope.

A reimbursable contract is more flexible and releases the contractor from many of the risk elements associated with the design and process performance.

Reimbursable contracts should ensure that:

i/ The design does not need to be fully detailed/

ii/ Purchaser can have an on going input and review alternative design solutions

iii/ Programme can be shortened by design development

iv/ Risk items (for contractor) are minimised.

There are a number of variations that can be applied to the standard forms of contract, e.g. Reimbursable with target man-hours. I. Chem. E. Green Book. MF1, JTC. Green book design and manage contract, etc. Each type of contract can include various forms of incentive/damage schemes, such as liquidated and consequential damages.

The whole purpose of the contract is to provide a framework in which the respective parties can work together towards the common goal, namely:

i/ Completion of project to budget (or under)

ii/ Completion of project to planned time-scale

iii/ Share the rewards if objectives i/ and ii/ are satisfied.

Table III of the Green book compares Lump sum with wholly reimbursable contracts Ref. Appendix K2. Again there is considerable scope for further research concerning the application of knowledge rules to the project specific data to advise the user on the most appropriate form of contract. E.g.

? If <project=Time> and <WBS<3> and <project focus<50>then recommend wholly reimbursable type of contract.

10.6 Concluding Remarks

10.6.1 Recap

The history of both Knowledge based software and modern day Project management theory is relatively new. The APM was founded only 25 years ago and knowledge based technology has only really matured over the past decade. It is difficult to comprehend the overwhelming influence that each technology has had on its respective industry and profession. The merger of *knowledge based technology* into the *art* and *science* of project management is, in the authors' view, simply a matter of time. During the course of this dissertation a number of limitations associated with the use of existing tools and traditional management techniques has been identified from a number of industrial studies. The main contributing factors to project failure on multidisicplinary projects was identified as being the flow and approval of design critical information within the project group. Underestimating man-hours and the pressures of trying to complete projects to unrealistic programmes was seen as being a major cause of design omissions. The concept proposed in this submission is submitted for consideration as an alternative project management technique intended to address a number of the failure mechanisms identified by applying some level of expertise to the issues.

It is the authors' opinion that a *knowledge based* approach to solving the complex issues of multidisciplinary design intensive projects is the most likely way ahead, and once a suitable model has been developed, the justification accepted, and a strategic fit found then it is likely that the next generation of project management software will incorporate KB Technology.

10.6.2 The future for Project Management

As we move towards the second Millennium the future for the human species appears to be both threatening and challenging. The global problems will inevitably be faced by engineers and scientists, whose thoughts and ideas shall need to be translated into ecological solutions by managers of *change*. In Chapter II it was suggested that "project management is not for the faint hearted", this sentiment remains as true today as it was at the turn of the Century, with one possible accretion, the global and ecological stakes are far greater. In order to do justice to the challenges ahead we shall need the best tools and technological developments available, this may possibly include techniques that have not yet been conceived.

During the 25th Anniversary conference of the APM, the vice president *P. Morris* advised that :-

"The conference builds off an attempt made by the Association during the last few months to define **best practice** and **emerging trends** in several important areas - *Risk management, procurement, programme management*, and three less familiar areas, *systems engineering, design management* and *concurrent engineering*".

The culmination of the conference was a paper delivered by *D Johnson* of BT Research Ltd. entitled "Managing by Pictures", in which a tantalising glimpse of a highly sophisticated IT future, as perceived by BT, was projected. In this new order it would seem that central to the future of Project management is the need for a system that embraces the core issues of *Risk management, Concurrent engineering, Engineering design management* and the *interactive 3D* communication facilities afforded by today's *IT.*

This description would seem to be well suited, if indeed not written for, the type of project management philosophy submitted in this dissertation, namely:

ConSERV. A **Con**current **S**imultaneous **E**ngineering **R**esource **V**iew.

10.6.2 References

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APPENDIX K

APPENDIX K

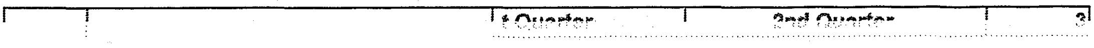
COMPARISON BETWEEN LUMP SUM AND
REIMBURSABLE CONTRACTS
CONFIRMATION FROM THE APM
SUPPORTING LETTER FROM UWE BRISTOL
COPY OF LETTER FROM 14TH WORLD CONGRESS
ORGANISERS
INSTRUCTIONS ON USE OF DEMONSTRATOR

SUBJECT INDEX

7.4 ConSERV 3D model

7.4.1 Limitations of 2D representation

It can be seen that the 2D representation of engineering and engineering design activities is a very limited method of representing the multidisciplinary effects of the flow of design data between disciplines. In a 2D environment the point of concurrence and release of design data for use by others are key milestones that are difficult to visualise using the 2D techniques.



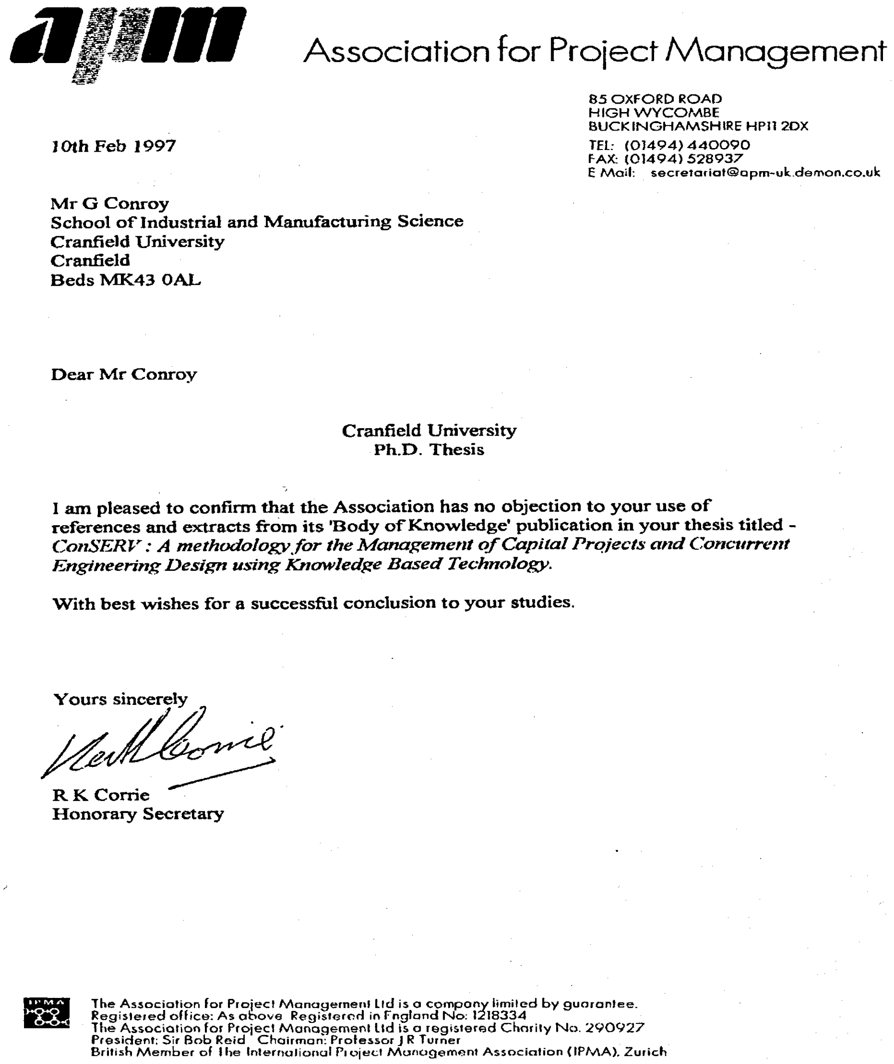
APPENDIX K

COMPARISON BETWEEN LUMP SUM AND REIMBURSABLE CONTRACTS

Lump sum	***Wholly reimbursable***
Project definition required in enquiry	Minimum-sufficient to enable Contractor to check the resources needed.
Advantages (1) Purchaser knows his expenditure commitment. (2) Responsibility for the project is vested in a single body (Contractor) (3) Allows fullest competition between Contractors	***Advantages*** (1) Requires minimum enquiry definition (2) Shortest possible bid time (few days) (3) Complete flexibility-Purchaser participation entirely practicable. (4) Purchaser/Contractor conflict of interest is minimised. (5) Purchaser has control over costs incurred (6) Purchaser can assess Contractor's rates (7) Purchaser can use Contractor to evaluate alternative schemes (8) Purchaser can terminate at will without incurring substantial costs
Disadvantages (1) Purchaser / Contractor interests are more divergent than other forms of contract. (2) Long bidding time is required (2-4 months), also long enquiry preparation time. (3) Crucial process design phase compressed into very short period. (4) Lack of flexibility - changes are difficult / expensive (5) Purchaser participation in project is difficult. (6) Cost to purchaser may be unnecessarily high (7) Emphasis on low bid price may result in an unsatisfactory plant	***Disadvantages*** (1) Contractor has no monetary incentive to minimise cost to purchaser. (2) Purchaser has no assurance of final cost. (3) Purchaser has to check and verify Contractor's man-hour and expense record. (4) Bid evaluation may be difficult (5) Contractor competition is only on a very small part of total cost. (6) Contractor has no monetary incentive to achieve early competition unless covered by special conditions
Typical Applications (1) When competing contractors offer proprietary processess and technology. (2) When purchaser provides Contractor with front end engineering packages and detailed specifications (3) When purchaser's rule require it.	***Typical Applications*** (1) When project cannot be defined in detail at the start e.g. major revamp of existing facilities, feedstock (or capacity, etc) not yet fixed. (2) When Purchaser wishes to participate extensively in the design, e.g. a development project, especially one dependent on Purchaser know how (3) When confidentiality considerations preclude the issue of detailed enquiry specifications to Contractors (4) When a very short program is required. (5) When Purchaser considers Contractor's contingencies (e.g. for escalation) are likely to be excessive (6) When Contractors are not prepared to take lump sum contract (e.g. very large contracts, periods of high escalation, times of high inflation)
Comments (1) Complete project definition is essential. (2) Contractor's bidding costs are very high. Purchaser should minimise contracting industry bidding overheads(and thus plant costs) by (a) Not inviting bids until there is a high probability of the project proceeding. (b) limiting the number of bidders. (c) pre-qualifying each bidder so that he will not be rejected later on grounds known to the Purchaser before the enquiry is issued, and (d) consider reimbursing pre-qualified unsuccessful bidders for their costs of bid preparation.	***Comments*** (1) The most flexible type of contract, allowing a very rapid start. (2) Flexibility may encourage Purchaser to introduce design change, resulting in increased cost and longer programme. (3) Contractor's profit / loss is limited. (4) Conversion of all or part of contract (e.g.) lump sum basis during the project is possible when scope of work becomes fully defined.

Fig 109 Comparison of Lump sum v Wholly reimbursable contract

APPENDIX K



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10th Feb 1997

Mr G Conroy
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Dear Mr Conroy

Cranfield University
Ph.D. Thesis

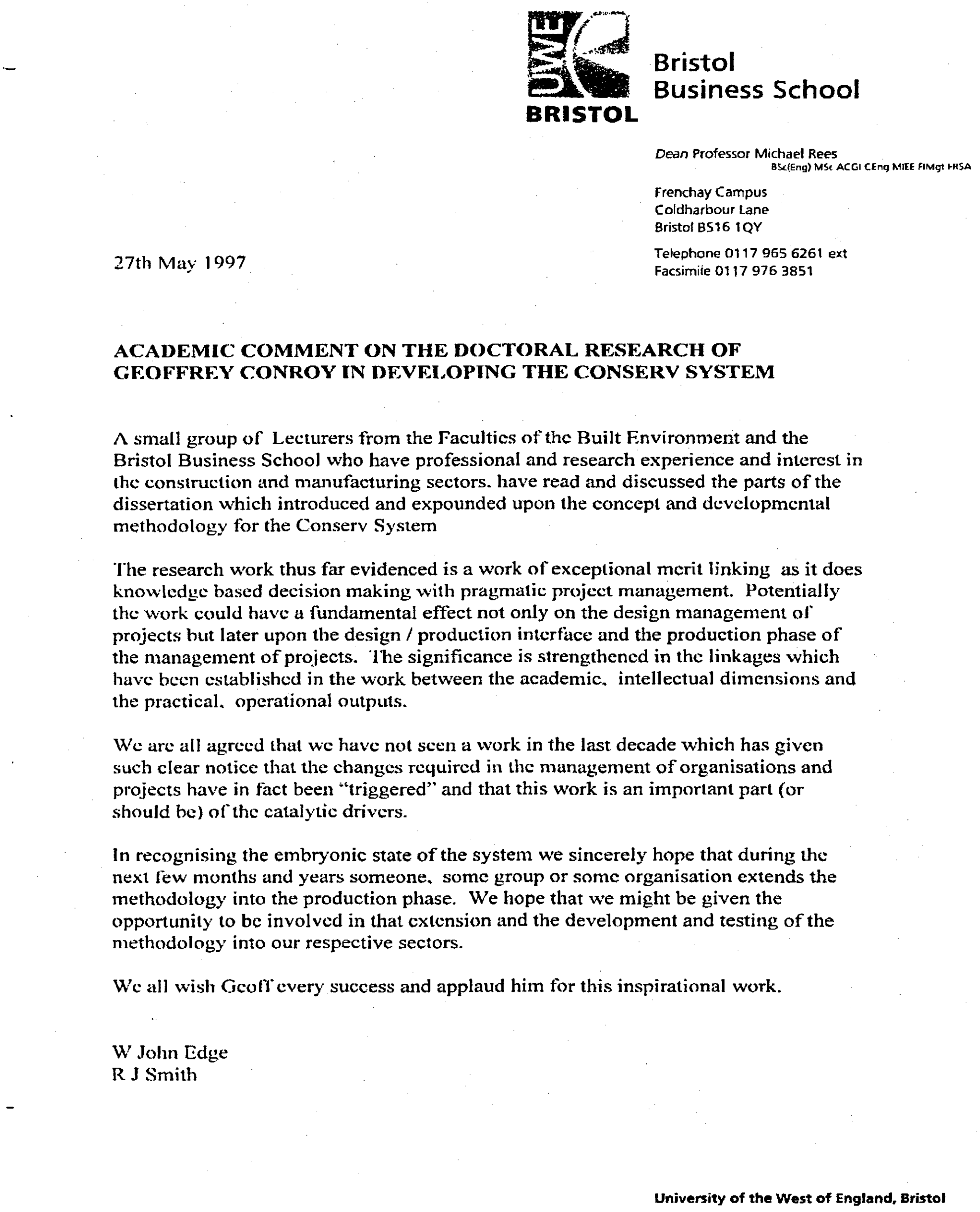
I am pleased to confirm that the Association has no objection to your use of references and extracts from its 'Body of Knowledge' publication in your thesis titled - *ConSERV : A methodology for the Management of Capital Projects and Concurrent Engineering Design using Knowledge Based Technology.*

With best wishes for a successful conclusion to your studies.

Yours sincerely

R K Corrie
Honorary Secretary

APPENDIX K



BRISTOL
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27th May 1997

ACADEMIC COMMENT ON THE DOCTORAL RESEARCH OF GEOFFREY CONROY IN DEVELOPING THE CONSERV SYSTEM

A small group of Lecturers from the Faculties of the Built Environment and the Bristol Business School who have professional and research experience and interest in the construction and manufacturing sectors. have read and discussed the parts of the dissertation which introduced and expounded upon the concept and developmental methodology for the Conserv System

The research work thus far evidenced is a work of exceptional merit linking as it does knowledge based decision making with pragmatic project management. Potentially the work could have a fundamental effect not only on the design management of projects but later upon the design / production interface and the production phase of the management of projects. The significance is strengthened in the linkages which have been established in the work between the academic, intellectual dimensions and the practical, operational outputs.

We are all agreed that we have not seen a work in the last decade which has given such clear notice that the changes required in the management of organisations and projects have in fact been "triggered" and that this work is an important part (or should be) of the catalytic drivers.

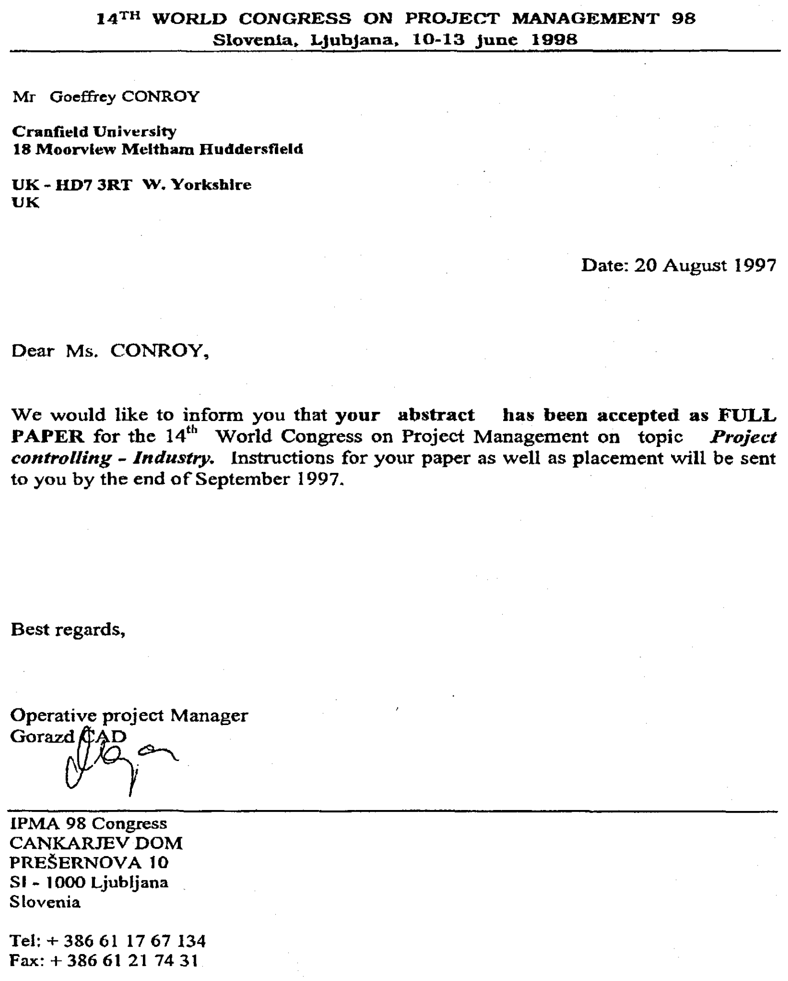
In recognising the embryonic state of the system we sincerely hope that during the next few months and years someone, some group or some organisation extends the methodology into the production phase. We hope that we might be given the opportunity to be involved in that extension and the development and testing of the methodology into our respective sectors.

We all wish Geoff every success and applaud him for this inspirational work.

W John Edge
R J Smith

University of the West of England, Bristol

APPENDIX K



14TH WORLD CONGRESS ON PROJECT MANAGEMENT 98
Slovenia, Ljubjana, 10-13 June 1998

Mr Goeffrey CONROY

Cranfield University
18 Moorview Meltham Huddersfield

UK - HD7 3RT W. Yorkshire
UK

Date: 20 August 1997

Dear Ms. CONROY,

We would like to inform you that **your abstract has been accepted as FULL PAPER** for the 14th World Congress on Project Management on topic ***Project controlling - Industry.*** Instructions for your paper as well as placement will be sent to you by the end of September 1997.

Best regards,

Operative project Manager
Gorazd CAD

IPMA 98 Congress
CANKARJEV DOM
PREŠERNOVA 10
SI - 1000 Ljubljana
Slovenia

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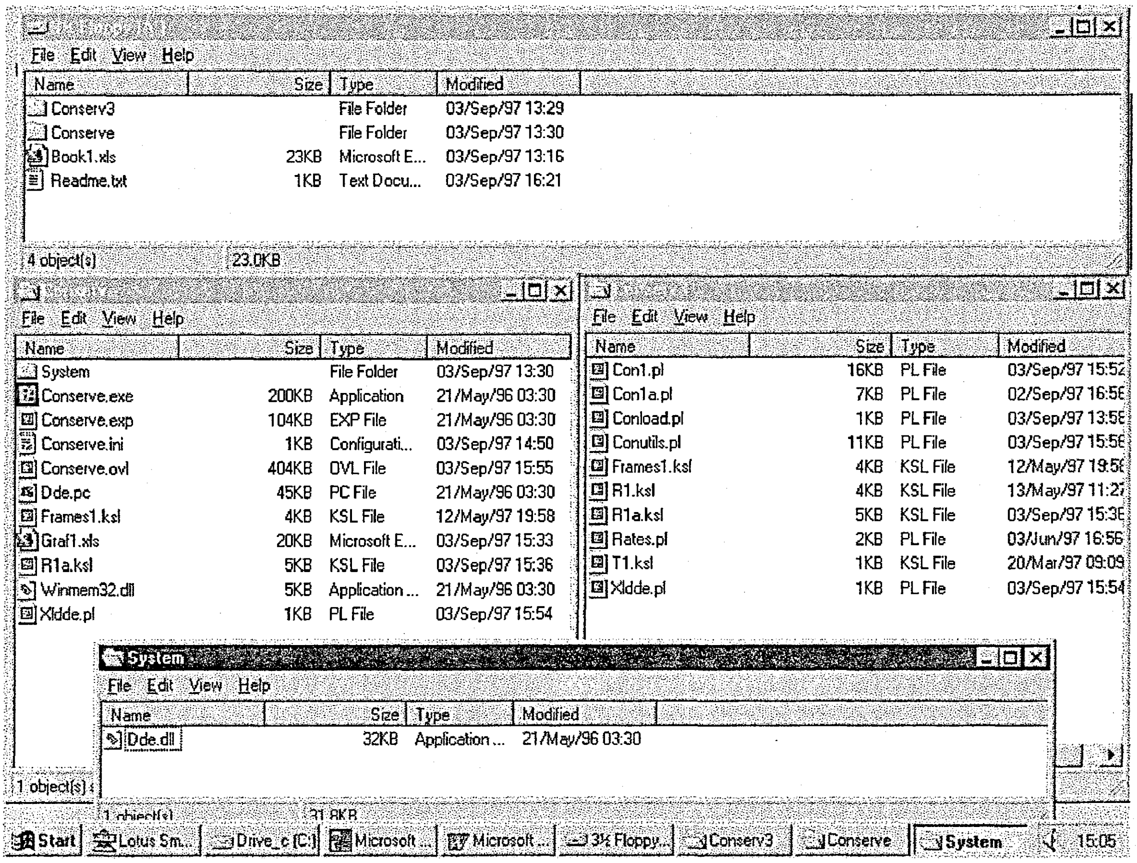
APPENDIX K

INSTRUCTIONS ON USE OF DEMONSTRATOR 'A'

The demonstrator disc supplied with this submission has been developed to assist the reader what the ConSERV concept is being developed to achieve. The disc has been checked for known viruses and contains only those files and sub directories required for running the application. Namely:



Name	Size	Type	Modified
Conserv3		File Folder	03/Sep/97 13:29
Conserve		File Folder	03/Sep/97 13:30
Book1.xls	23KB	Microsoft E...	03/Sep/97 13:16
Readme.txt	1KB	Text Docu...	03/Sep/97 16:21

4 object(s) 23.0KB

Name	Size	Type	Modified
System		File Folder	03/Sep/97 13:30
Conserve.exe	200KB	Application	21/May/96 03:30
Conserve.exp	104KB	EXP File	21/May/96 03:30
Conserve.ini	1KB	Configurati...	03/Sep/97 14:50
Conserve.ovl	404KB	OVL File	03/Sep/97 15:55
Dde.pc	45KB	PC File	21/May/96 03:30
Frames1.ksl	4KB	KSL File	12/May/97 19:58
Graf1.xls	20KB	Microsoft E...	03/Sep/97 15:33
R1a.ksl	5KB	KSL File	03/Sep/97 15:36
Winmem32.dll	5KB	Application ...	21/May/96 03:30
Xldde.pl	1KB	PL File	03/Sep/97 15:54

1 object(s)

Name	Size	Type	Modified
Con1.pl	16KB	PL File	03/Sep/97 15:52
Con1a.pl	7KB	PL File	02/Sep/97 16:5
Conload.pl	1KB	PL File	03/Sep/97 13:5
Conutils.pl	11KB	PL File	03/Sep/97 15:5
Frames1.ksl	4KB	KSL File	12/May/97 19:5
R1.ksl	4KB	KSL File	13/May/97 11:2
R1a.ksl	5KB	KSL File	03/Sep/97 15:3
Rates.pl	2KB	PL File	03/Jun/97 16:56
T1.ksl	1KB	KSL File	20/Mar/97 09:09
Xldde.pl	1KB	PL File	03/Sep/97 15:54

System

Name	Size	Type	Modified
Dde.dll	32KB	Application ...	21/May/96 03:30

1 object(s) 31.8KB

The demonstration can be run from the floppy 'A' drive or it can be installed on the C drive. The software runs on Windows 95 and contains a DLL file which generates the graph in EXCEL. A readme text file has been included to provide details and explanations of how the system functions.

APPENDIX K

SUBJECT INDEX

APPENDIX L

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Filename      : CONUTILS.pl
%   Author        : M.Pappas/G Conroy
%   Original date : Jan 1997
%
%   This is the Utilities file for the ConServe system.
%    All date routines should use 4 char. year format - 01/01/1997
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
:- dynamic( s_data/2 ).

release :- wflag(1), wait(0), ! .

starter :-
        wshow( 0, 3 ),
        wtext( (0,0), `ConSERVE` ),
        sttbox('',  -1),
        ensure_loaded( xldde ),
        reconsult_rules( r1a) ,
        reconsult_rules( frames1 ),
        ctl3d(1),
        % pre_runs,
        wtext( (1,1), `` ),
        repeat,
          advice,
        fail .


advice :-
        restart,
        conres,
        con1a, disp_inp1,
        con1b, disp_inp1,
        con1c, disp_inp1,
        calc_success_criteria_values,
         disp_inp2,
        fc( budget,L ),
         disp_advice,
         update_XL,
        repeat,
           release,
           retract( conres( refresh ) ), ! .

my_abort :- halt .


s_data(0,0).

calc_days( First_str,  Last_str,  Diff ) :-
   d_date_convert( First_str , (A/B)/C )   ,
   d_date_convert( Last_str  , (X/Y)/Z )   ,
   calc_diff( A/B/C , X/Y/Z , Diff) , ! .

d_date_convert( Str,  DD/MM/YY  ) :-
   atmbyt(Str, [A,B,_,D,E,_,G,H,I,J]),
   name(DD, [A,B]),
   name(MM, [D,E]),
```

```
   name(YY, [G,H,I,J]).

date_convert( Str,  DD/MM/YY  ) :-
   atmbyt(Str, [A,B,_,D,E,_,G,H,I,J]),
   name(DD, [A,B]),
   name(MM, [D,E]),
   name(YY, [G,H,I,J]) .

calc_diff( D1/M1/Y1,  D2/M2/Y2, TOTAL) :-  ! ,

   jul_date(D1,M1,Y1,T1)  ,
   jul_date(D2,M2,Y2,T2)  ,

   TY is ((Y2-Y1) * 365) + 1 ,

   TOTAL is TY + T2 - T1 , ! .

jul_date( Day, Mnth, Year, Tot_days) :-
    jul_days(Mnth, Tot)  ,
    Tot_days is Tot+Day .

jul_days( 1,0).
jul_days( 2,31).
jul_days( 3,59).
jul_days( 4,90).
jul_days( 5,120).
jul_days( 6,151).
jul_days( 7,181).
jul_days( 8,212).
jul_days( 9,243).
jul_days(10,273).
jul_days(11,304).
jul_days(12,334).



pname( NUM, ATOM ) :-
        name( NUM, LIST ),
        atmbyt( ATOM, LIST ), ! .




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


roundup(NUM1, ROUND) :-
        NUM2 is ( (NUM1 * 100 )+ 0.5 )//1,
        ROUND is NUM2/100 .



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

get_radio_sel( WIN, [ ] , [] , `` ) .
get_radio_sel( WIN, [ O1 | _ ] , [B1 | _ ] , O1 ) :-

CONUTILS.PL - 14:20:42 - Mon 15 Sep 1997 - Page 002
```

APPENDIX L

```
        wbtnsel( (WIN, B1), STATE ),
        STATE  == 1, ! .
get_radio_sel( WIN, [ _ | OPTS ] , [ _ | BUTS] , SEL ) :- ! ,
        get_radio_sel( WIN, OPTS ,  BUTS , SEL ) .



fill_list_box( WIN, ITEMS ) :-
        forall( member( I, ITEMS ), ( stratm( S_I, I ), wlbxadd( WIN, -1,



get_box_sel(  ID,  S ) :-
        get_contents( ID, LIST ),
        length( LIST, LEN ),
        NEW is LEN - 1 ,
        reverse( LIST, REV_LIST ),
        get_box_sel_name( ID, NEW, REV_LIST, S  ), ! .

get_box_sel( _, [''] ).

get_box_sel_name( ID, NEXT, [] , []  )   .

get_box_sel_name( ID, NEW, [SEL | REVS] , [A_SEL|SELS]  ) :-
        wlbxsel( ID, NEW, STATE ),
        STATE == 1,
        NEXT is NEW - 1,
        stratm( SEL, A_SEL ), !,
        get_box_sel_name( ID, NEXT, REVS , SELS  )   .

get_box_sel_name( ID, NEW,  [_ | REVS] , SELS  ) :-
        NEXT is NEW - 1, !,
        get_box_sel_name( ID, NEXT, REVS , SELS  )   .



get_contents( WIN, LIST ) :-
        get_conts( WIN,  0, LIST ).



get_conts( WIN, NUM, [VAL | REST] ) :-
        wlbxget( WIN, NUM, VAL ),
        NEXT is NUM + 1,
        get_conts( WIN, NEXT, REST ).

get_conts( WIN, NUM, [] ) .


empty_list_box( WIN ) :-
        wlbxdel( WIN, 0 ),
        empty_list_box(WIN ).
empty_list_box( _ ).


get_data( _, _, [], [] ).
```

```
get_data( number, WIN, [N|REST], [NUM|PREV] ) :-
        wtext( (WIN,N), STR), ! ,
        ( STR =`` -> NUM = 0 ; number_string( NUM, STR)),
        get_data( number, WIN, REST, PREV).

get_data( text, WIN, [N|REST], [ATM|PREV] ) :-
        wtext( (WIN,N), STR), ! ,
        stratm( ATM, STR),
        get_data( text, WIN, REST, PREV).



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
user_message(TITLE, TEXT ) :-
  wdcreate(ud1,TITLE,30,50,500,200,[ws_caption,dlg_modalframe]),
  wccreate((ud1,1000),static,TEXT,5,5,490,180,[ws_child,ws_visible,ss_left
  wccreate((ud1,100),button,`OK`,10,140,100,30,[ws_child,ws_visible,ws_tab
        call_dialog( ud1, ok ).

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


update_frame( _, [], [] ).
update_frame( FRAME, [S|SLOTS], [V|VALUES] ) :-
        new_value( @(S, FRAME), V ), ! ,
        update_frame( FRAME, SLOTS, VALUES ).

/*
new_slot( A,B,C ) :-
        write( A ), write( ' ~I' ), write(C), nl.
*/



p_rel( obr, overt_budget_risk, total_overt_budget_risk ) .      % , `What
p_rel( ocs, overt_cont_sat,    total_overt_cont_sat ) .                 %,
p_rel( op,  overt_meet_prog,   total_overt_meet_prog ) .                %,
p_rel( ocls,overt_client_sat,  total_overt_client_sat ) .       %, `What d
p_rel( oe,  overt_pmf_eff,     total_overt_pmf_eff ) .          %, `What d



get_template('overt budget risk',      obr).
get_template('overt contractor satisfaction',ocs ).
get_template('overt program',   op).
get_template('overt client sat', ocls ).
get_template('overt pmf effectiveness', oe ).


concat( CRIT, OUT ) :-
        cat( [CRIT, '_', elements_change], OUT, _ ).

% convert( , CON ) :-


%%%%%%%%%%% %%%%%%%%%%% %%%%%%%%%%% %%%%%%%%%%% %%%%%%%%%%% %%%%%%%%%%%

CONUTILS.PL - 14:20:42 - Mon 15 Sep 1997 - Page 004
```

```
disp_inp1 :-
        wtext((conres, 800), `` ),
        wedttxt((conres, 800), `USER INPUT DATA` ), wnl, wnl,
        forall( isa_slot( A,project,B ), (wwrite(A), wwrite('  '), wwrite(
        wnl, wnl.


disp_inp2 :-
        wedttxt((conres, 800), `OVERT RISK TOTALS` ), wnl, wnl,
        forall( p_rel( A,B,C),
                ( (isa_slot( C,_,VAL ); VAL = 0 ),
                  wwrite(C), wwrite('  '), wwrite( VAL ), wnl)),
        wnl, wnl.


disp_advice :-
        isa_slot( total_covert_budget_risk, project, VAL ),
        wnl,
        wwrite( `On the basis of your data input about the project, the to
        wwrite( VAL ), wnl, wnl, ! .

%%%%%%%%%% %%%%%%%%%% %%%%%%%%%% %%%%%%%%%% %%%%%%%%%% %%%%%%%%%%

wnl :- wedttxt((conres, 800), `~M~J`), ! .
wwrite(T) :-
        convert(T,S ),
        wedttxt((conres,800), S ), ! .

convert([],_).
convert( [ H|T ], _ ) :-
        wwrite(H),wwrite(`, `),
        convert(T,_) .

convert( T, S ) :-
        atom( T ),
        stratm( S, T ), ! .
convert( T, S ) :-
        number( T ),
        number_string( T, S ), ! .
convert( T,T ).



writeit(TEXT) :- write(TEXT),nl.

fc(R1, R2) :-
        forward_chain( fcfs, true, fail, once, R1, R2 ) .



quest(CRITERIA, ELEMENT, SLOT, FRAME, OUT ) :-
        release,
        WIN = q1,
        template( CRITERIA, [LIST], _),
        make_title( LIST, TITLE ),
        stratm( TEXT, ELEMENT ),
```

```
        (retract( s_data( WIN,_ )) ; true ),
  wdcreate(WIN, TITLE, 30,200,300,200,[dlg_ownedbyprolog,ws_sysmenu,ws_cap

  wccreate((WIN,1000),static,`What do you perceive the OVERT risk associat
  wccreate((WIN,1001),static, TEXT,     10,50,100,30,[ws_child,ws_visible,

  wccreate((WIN, 800),editor, ``,       120,50,50,20,[ws_child,ws_visible,

 wccreate((WIN,1102),button,``,         5,130,290,45,[ws_child,bs_groupbox
 wccreate((WIN,1),button,`OK`,  200,140,90,30,[ws_child,ws_visible,ws_tabs

        window_handler( WIN, q1_h ),
        show_dialog( WIN ),
        repeat,
                release,
                s_data( WIN, OUT ),
        wclose( WIN ),
        new_slot( SLOT, FRAME, OUT ), ! .


q1_h( (q1,1), msg_button, _, _ ) :-
        release,
        wtext( (q1, 800), T ),
        number_string( N, T ),
        assert( s_data( q1, N ) ).

make_title( [], '' ).
make_title( [H|T], TITLE ) :-
        make_title(T, SOFAR ),
        cat( [H,' ', SOFAR], TITLE,_), ! .

%%%%%%%%%%%% %%%%%%%%%%%% %%%%%%%%%%%% %%%%%%%%%%%% %%%%%%%%%%%% %%%%

pnl :- wedttxt((conconfm, 805), `~M~J`), ! .
pwrite(T) :-
        convert(T,S ),
        wedttxt((conconfm,805), S ), ! .


show_project :-
        isa_slot( industry,project, IND ),
        isa_slot( town,project, TOWN ),
        isa_slot( country,project, COUNT ),
        pwrite( `The project being undertaken is in the `), pwrite( IND ),
        pwrite( ` industry, and is located in `), pwrite(TOWN), pwrite(',

        pnl,    isa_slot( elements,project, ELEMS ),
        isa_slot( impacts,project, IMP ),
        (IMP = yes -> IMPACT = `does` ; IMPACT = `does not`),
        pwrite( `It is a `), pwrite( ELEMS),
        pwrite( ` project which `), pwrite( IMPACT), pwrite(' involve othe

        pnl,    isa_slot( finance  ,project, FIN ),
        isa_slot( budget  ,project, BUD ),
        pwrite(`The Project which is being financed by the `), pwrite(FIN)
        pwrite(` has a sanctioned budget of £M`), pwrite(BUD), pwrite(` +-
```

```
        pnl,    isa_slot( process, project, PROC ),
        isa_slot( plant_items, project, ITEMS ),
        pwrite(`The key process invloved is `), pwrite(PROC),
        pwrite(` and includes `),
        showproj( ITEMS),

        pnl,    isa_slot( focus, project, FOCUS ),
        pwrite(`The project focus at the time of evaluation is `), pwrite(

        pnl,    isa_slot( mix, project, RESC ),
        pwrite(`The project rescources are `), pwrite( RESC ),pwrite(` sta

        pnl,    isa_slot( duration, project, DUR ),
        isa_slot( work_breakdown, project, LEV ),
        pwrite(`The planned duration of the project is `), pwrite( DUR),
        pwrite(` months, based on a level `), pwrite(LEV), pwrite(` WBS.`)

        pnl,    isa_slot( end_date_confidence, project, CONF ),
        isa_slot( penalties, project, PEN ),
        ( PEN = no -> DAM = `not` ; DAM = `` ),
        pwrite(`The confidence level in meeting the end date is classed as
        pwrite(`.  Liquidate damages are `), pwrite(DAM), pwrite(` involve

        pnl,    isa_slot( procedures, project, PROCS ),
        proj_pocs(PROCS, SPORCS ),
        HAS = ``, CERT = ``,
        pwrite(`The procedures that shall be followed on this project are
        pwrite(`The project manager has `), pwrite( HAS ), pwrite(`been as
        pwrite( CERT), pwrite(`certified by the APM.`) .



proj_pocs( 'Company Procedures', `the client organisations QA procedures.`
proj_pocs('British Standards',`British Stanards.`).
proj_pocs('USA Standards',`USA Standards.`).


showproj([] ).
showproj([I] ):-
        stratm(S,I), pwrite( S), pwrite(` systems. `),!.
showproj([I|T] ):-
        stratm(S,I), pwrite( S), pwrite(`, `),!,
        showproj(T ).


get_strings( FRAME, [], [] ) .
get_strings( FRAME, [S1| SREST], [OUT1|VREST] ) :-
        (isa_slot( S1, FRAME, V1 ) ; V1 = 0 ), write( V1), nl,
        number_string( V1, OUT1 ), !,
        get_strings( FRAME, SREST, VREST ) .
```

APPENDIX L

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Filename       : BADUTILS.pl
%   Author         : M.Pappas/G Conroy
%   Original date  : Jan 1997
%
%   This is the Utilities file for the Bad Advice system.
%    All date routines should use 4 char. year format - 01/01/1997
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
:- dynamic( s_data/2 ).

release :- wflag(1), wait(0), ! .

starter :-ctl3d,
        con1a, con1b, con1c,
        calc_success_criteria_values,
        fc( budget ),
        getb(O), halt .

my_abort :- halt .


s_data(0,0).

calc_days( First_str,  Last_str,  Diff ) :-
   d_date_convert( First_str , (A/B)/C )  ,
   d_date_convert( Last_str  , (X/Y)/Z )  ,
   calc_diff( A/B/C , X/Y/Z , Diff) , ! .

d_date_convert( Str,  DD/MM/YY  ) :-
   atmbyt(Str, [A,B,_,D,E,_,G,H,I,J]),
   name(DD, [A,B]),
   name(MM, [D,E]),
   name(YY, [G,H,I,J]).

date_convert( Str,  DD/MM/YY  ) :-
   atmbyt(Str, [A,B,_,D,E,_,G,H,I,J]),
   name(DD, [A,B]),
   name(MM, [D,E]),
   name(YY, [G,H,I,J]) .

calc_diff( D1/M1/Y1,  D2/M2/Y2, TOTAL) :-  ! ,

   jul_date(D1,M1,Y1,T1)  ,
   jul_date(D2,M2,Y2,T2)  ,

   TY is ((Y2-Y1) * 365) + 1 ,

   TOTAL is TY + T2 - T1 , ! .

jul_date( Day, Mnth, Year, Tot_days) :-
    jul_days(Mnth, Tot)   ,
    Tot_days is Tot+Day .

jul_days( 1,0).
jul_days( 2,31).
jul_days( 3,59).

CONUTILS.PL - 13:56:10 - Mon 15 Sep 1997 - Page 001
```

```
jul_days( 4,90).
jul_days( 5,120).
jul_days( 6,151).
jul_days( 7,181).
jul_days( 8,212).
jul_days( 9,243).
jul_days(10,273).
jul_days(11,304).
jul_days(12,334).



pname( NUM, ATOM ) :-
        name( NUM, LIST ),
        atmbyt( ATOM, LIST ), ! .




%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


roundup(NUM1, ROUND) :-
        NUM2 is ( (NUM1 * 100 )+ 0.5 )//1,
        ROUND is NUM2/100 .



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

get_radio_sel( WIN, [ ] , [] , `` ) .
get_radio_sel( WIN, [ O1 | _ ] , [B1 | _ ] , O1 ) :-
        wbtnsel( (WIN, B1), STATE ),
        STATE  == 1, ! .
get_radio_sel( WIN, [ _ | OPTS ] , [ _ | BUTS] , SEL ) :- ! ,
        get_radio_sel( WIN, OPTS ,  BUTS , SEL ) .



fill_list_box( WIN, ITEMS ) :-
        forall( member( I, ITEMS ), ( stratm( S_I, I ), wlbxadd( WIN, -1,



get_box_sel(  ID,  S ) :-
        get_contents( ID, LIST ),
        length( LIST, LEN ),
        NEW is LEN - 1 ,
        reverse( LIST, REV_LIST ),
        get_box_sel_name( ID, NEW, REV_LIST, S  ), ! .

get_box_sel( _, [''] ).

get_box_sel_name( ID, NEXT, [] , []  )  .

get_box_sel_name( ID, NEW, [SEL | REVS] , [A_SEL|SELS]  ) :-

CONUTILS.PL - 13:56:10 - Mon 15 Sep 1997 - Page 002
```

```
        wlbxsel( ID, NEW, STATE ),
        STATE == 1,
        NEXT is NEW - 1,
        stratm( SEL, A_SEL ), !,
        get_box_sel_name( ID, NEXT, REVS , SELS  )  .

get_box_sel_name( ID, NEW,   [_ | REVS] , SELS   ) :-
        NEXT is NEW - 1, !,
        get_box_sel_name( ID, NEXT, REVS , SELS  )  .



get_contents( WIN, LIST ) :-
        get_conts( WIN,  0, LIST ).



get_conts( WIN, NUM, [VAL | REST] ) :-
        wlbxget( WIN, NUM, VAL ),
        NEXT is NUM + 1,
        get_conts( WIN, NEXT, REST ).

get_conts( WIN, NUM, [] ) .


empty_list_box( WIN ) :-
        wlbxdel( WIN, 0 ),
        empty_list_box(WIN ).
empty_list_box( _ ).

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
user_message(TITLE, TEXT ) :-
  wdcreate(ud1,TITLE,30,50,500,200,[ws_caption,dlg_modalframe]),
  wccreate((ud1,1000),static,TEXT,5,5,490,180,[ws_child,ws_visible,ss_left
  wccreate((ud1,100),button,`OK`,10,140,100,30,[ws_child,ws_visible,ws_tab
        call_dialog( ud1, ok ).

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


update_frame( _, [], [] ).
update_frame( FRAME, [S|SLOTS], [V|VALUES] ) :-
        new_value( @(S, FRAME), V ), ! ,
        update_frame( FRAME, SLOTS, VALUES ).

/*
new_slot( A,B,C ) :-
        write( A ), write( ' ~I' ), write(C), nl.
*/



p_rel( obr, overt_budget_risk, total_overt_budget_risk ) .      % , `What
p_rel( ocs, overt_cont_sat, total_overt_cont_sat ) .            %, `What d
p_rel( op,  overt_meet_prog, total_overt_meet_prog ) .          %, `What d
p_rel( ocls, overt_client_sat, total_overt_client_sat ) .       %, `What d

CONUTILS.PL - 13:56:10 - Mon 15 Sep 1997 - Page 003
```

```
p_rel( oe,  overt_pmf_eff,    total_overt_pmf_eff ) .           %, `What d

report :-nl,nl,
forall( isa_slot( A,project,B ), (write(A), write('  '), write( B ),nl)).


writeit(TEXT) :- write(TEXT),nl.
fc(R1, R2) :-
        forward_chain( fcfs, true, fail, once, R1, R2 ) .



quest(CRITERIA, ELEMENT, SLOT, FRAME, OUT ) :-
        release,
        WIN = q1,
        template( CRITERIA, [LIST], _),
        make_title( LIST, TITLE ),
        stratm( TEXT, ELEMENT ),
        (retract( s_data( WIN,_ )) ; true ),
  wdcreate(WIN, TITLE, 30,30,300,200,[dlg_ownedbyprolog,ws_sysmenu,ws_capt

  wccreate((WIN,1000),static,`What do you perceive the OVERT risk associat
  wccreate((WIN,1001),static, TEXT,     10,50,100,30,[ws_child,ws_visible,

  wccreate((WIN, 800),editor, ``,       120,50,50,20,[ws_child,ws_visible,

 wccreate((WIN,1102),button,``,         5,130,290,45,[ws_child,bs_groupbox
 wccreate((WIN,1),button,`OK`,  200,140,90,30,[ws_child,ws_visible,ws_tabs

        window_handler( WIN, q1_h ),
        show_dialog( WIN ),
        repeat,
                release,
                s_data( WIN, OUT ),
        wclose( WIN ),
        new_slot( SLOT, FRAME, OUT ), ! .


q1_h( (q1,1), msg_button, _, _ ) :-
        release,
        wtext( (q1, 800), T ),
        number_string( N, T ),
        assert( s_data( q1, N ) ).

make_title( [], '' ).
make_title( [H|T], TITLE ) :-
        make_title(T, SOFAR ),
        cat( [H,' ', SOFAR], TITLE,_), ! .
```

APPENDIX L

```
pro_list( [ con1, con1a, conutils] ).
ksl_list( [ 'r1a.ksl', 'frames1.ksl'] ).

l1 :- system_menu(_,file,close_all).

l2 :-
        pro_list( LIST ),
        open_files( LIST, 50, 50 ),
        ksl_list( KSL ),
        reconrules( KSL, 150, 50 ),   ! .

open_files( [ ], X, Y ).
open_files( [F | REST], X, Y ) :-
        cat( ['c:\conserve\con03sep\', F], FILE,_ ),
        system_menu(_,file,open(FILE,X, Y, 500, 500)),
        ensure_loaded( FILE),
        X1 is X + 20, Y1 is Y + 20 , ! ,
        open_files( REST, X1, Y1 ) .


reconrules( [ ], X, Y ).
reconrules( [F | REST], X, Y ) :-
        cat( ['c:\conserve\con03sep\', F], FILE,_ ),
        system_menu(_,file,open(FILE,X, Y, 500, 500)),
        reconsult_rules( FILE ),
        X1 is X + 20, Y1 is Y + 20 , ! ,
        reconrules( REST, X1, Y1 ) .



close_files( [ ] ).
close_files( [ F| REST] ) :-
        cat( ['C:\aamickp\badadv\', F], FILE,_ ),
        cat( [FILE, '.PL'], FULL,_),
        abolish_files( FULL ), wclose( FULL),
        close_files( REST ) .
```

APPENDIX L

```
con1a :- release,
        WIN = con1a,
        (retract( s_data( con1a,_ )) ; true ),
  wdcreate(WIN,`ConSERVE`,30,30,500,400,[dlg_ownedbyprolog,ws_sysmenu,ws_c

  wccreate((WIN,1000),static,`The answers to the following 10 questions wi
                                         10,10,480,30,[ws_child,ws_visible
  wccreate((WIN,1001),static,`1. Type of industry ?`,20,50,120,15,      [w
  wccreate((WIN,501),combobox,``,        120,50,100,100,        [ws_child,

  wccreate((WIN,1002),static,`2. International location ?`,250,50,120,15,
  wccreate((WIN,502),combobox,``,        380,50,100,100,        [ws_child,

  wccreate((WIN,1003),static,`3a. What are the main project elements ?`,20
  wccreate((WIN,503),combobox,``,        220,100,140,50,        [ws_child,
  wccreate((WIN,10031),static,`3b. Are there any 'other project' impacts ?
  wccreate((WIN,205),button,`yes`,      250,130,50,15,[ws_child,ws_visible
  wccreate((WIN,206),button,`no`,       300,130,80,15,[ws_child,ws_visible

  wccreate((WIN,10032),static,`3c. Who is financing the project ?`,     40
  wccreate((WIN,50311),combobox,``,     220, 155,140,50,[ws_child,ws_visib

  wccreate((WIN,10033),static,`3d. What is the contract type ?`,        40
  wccreate((WIN,50312),combobox,``,220, 180,140,50,[ws_child,ws_visible, w

  wccreate((WIN,1004),static,`4. What is the main process involved ?`,20,2
  wccreate((WIN,504),combobox,``,        220,220,100,80,        [ws_child,
  wccreate((WIN,10041),static,``,       40,245,180,30,          [ws_child,

  wccreate((WIN,10034),static,`4b. Are there any 'long lead' items ?`,  40
  wccreate((WIN,207),button,`yes`,      250,300,50,15,[ws_child,ws_visible
  wccreate((WIN,208),button,`no`,       300,300,80,15,[ws_child,ws_visible


 wccreate((WIN,1102),button,``,5,330,490,45,[ws_child,bs_groupbox,ws_visib
 wccreate((WIN,101),button,`Exit`,10,340,90,30,[ws_child,ws_visible,ws_tab
 wccreate((WIN,100),button,`Next`,400,340,90,30,[ws_child,ws_visible,ws_ta

        fill_list_box( (WIN,501), ['Chemical','Petrochemical', 'Pharmaceut
        fill_list_box( (WIN,502), ['North America', 'Asia/Far East','Europ
        fill_list_box( (WIN,503), ['Design only', 'Design and Construction
        fill_list_box( (WIN,50311), ['Business Group','External Source'] )
        fill_list_box( (WIN,50312), ['Lump Sum','Reimbursable','Joint Vent
        fill_list_box( (WIN,504), ['Digestion','Blending','Mixing'] ),
        wlbxsel( (WIN, 501), 0, 1 ),
        wlbxsel( (WIN, 502), 0, 1 ),
        wlbxsel( (WIN, 503), 0, 1 ),
        wlbxsel( (WIN, 50311), 0, 1 ),
        wlbxsel( (WIN, 50312), 0, 1 ),
        wlbxsel( (WIN, 504), 0, 1 ),

        wccreate((WIN,5021),combobox,``, 380,75,100,100,[ws_child,ws_tabst
        wccreate((WIN,50211),combobox,``,380,100,100,100,[ws_child,ws_tabs
        wenable((WIN,5021), 0), wenable((WIN,50211), 0),
```

```
        wccreate((WIN,5041),listbox,``, 220,245,140,50,[ws_child,ws_vscrol
        wenable( (WIN, 5041), 0 ),

        window_handler( WIN, con1a_h ),
        show_dialog( con1a ),
        repeat,
                release,
                s_data( con1a, _ ),
        wclose( con1a ).



con1a_h((con1a, 100), msg_button, A, B ) :-
        release,
        get_box_sel( (con1a, 501),   [INDUSTRY] ),
        get_box_sel( (con1a, 502),   [CONTINENT] ),
        get_box_sel( (con1a, 5021),  [COUNTRY] ),
        get_box_sel( (con1a, 50211), [TOWN] ),
        get_box_sel( (con1a, 503),   [ELEMENTS] ),
        get_radio_sel( con1a,  [yes, no], [205, 206], IMPACTS ),
        get_box_sel( (con1a, 50311), [FINANCE] ),
        get_box_sel( (con1a, 504),   [PROCESSES] ),
        get_box_sel( (con1a, 5041),  PLANT_ITEMS ),
        release,
        update_frame( project,
                [industry, continent, country, town, elements, impacts, fi
                [INDUSTRY, CONTINENT, COUNTRY, TOWN, ELEMENTS, IMPACTS, FI
        assert( s_data( con1a, [INDUSTRY, CONTINENT, COUNTRY, TOWN, ELEMEN


con1a_h((con1a, 101), msg_button, A, B ) :-
        wclose( con1a ), my_abort.

con1a_h((con1a, 502), msg_select, A, B ) :-
        release,
        get_box_sel( (con1a, 502 ), [ SEL ] ),
        release,
        data( (con1a, 502), SEL, LIST ),
        release,
        wshow((con1a,5021), 1 ),
        release,
        wenable((con1a,5021), 1), !,
        release,
        fill_list_box( (con1a,5021), LIST ),
        release,
        wlbxsel( (con1a, 5021), 0, 1 ),
        release .


con1a_h((con1a, 5021), msg_select, A, B ) :-
        release,
        get_box_sel( (con1a, 5021 ), [ SEL ] ),
        data( (con1a, 5021), SEL, LIST ),
        wenable((con1a, 50211), 1), !,
        wshow((con1a,50211), 1 ),
        fill_list_box( (con1a,50211), LIST ),
```

```
        wlbxsel( (con1a, 50211), 0, 1 ),
        release .


con1a_h((con1a, 504), msg_select, A, B ) :-
        release,
        get_box_sel( (con1a, 504 ), [ SEL ] ),
        data( (con1a, 504), SEL, QUEST,  LIST ),
        wtext((con1a, 10041), QUEST ),
        wshow((con1a,5041), 1 ),
        wenable((con1a,5041), 1), !,
        fill_list_box( (con1a,5041), LIST ),
        release.


con1a_h((con1a, 504), msg_select, A, B ) :-
        release,
        wshow((con1a,5041), 0 ),
        wtext((con1a,10041), `` ),
        release, !.


data( (con1a,502), 'Europe', ['COUNTRY', 'UK','Ireland','France','Belgium'
data( (con1a, 5021), 'UK',['TOWN','Huddersfield','Oxford','Blackpool']).
data( (con1a, 504), 'Mixing', `4b. What are the main plant items involved

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

APPENDIX L

```
con1b :-
       release,
       WIN = con1b,
       (retract( s_data(con1b, _ ) ); true ) ,
  wdcreate(WIN,`ConSERVE`,30,30,500,400,[dlg_ownedbyprolog,ws_sysmenu,ws_c

  wccreate((WIN,1005),static,`5. What are the project interfaces ?`,20,20,
  wccreate((WIN,505),combobox,``,       230,20,200,100, [ws_child,ws_visib
  wccreate((WIN,10051),static,``,       40,50,180,30,[ws_child,ws_visible,
  wccreate((WIN,205),button,`yes`,      250,50,50,15,[ws_child, ws_group,
  wccreate((WIN,206),button,`no`,       300,50,80,15,[ws_child, bs_autorad

  wccreate((WIN,1006),static,`6. What is the project capital value ?`   ,2
  wccreate((WIN, 802),editor,``,                   230,100,50,20,[ws_child
  wccreate((WIN,10061),static,`MILLIONS ~163`    ,  290,100,100,15,[ws_chil

  wccreate((WIN,1003),static,`6b. What is the cost est. accuracy ?`,    30
  wccreate((WIN,503),combobox,``,       230,130,50,100, [ws_child,ws_visib



  wccreate((WIN,1007),static,`7. What is the project focus ?`   ,20,170,18
  wccreate((WIN,507),combobox,``,        230,170,70,60, [ws_child,ws_visib
  wccreate((WIN,10071),static,`driven`  ,310,170,80,15,[ws_child,ws_visibl


  wccreate((WIN,1011),static,`7a. Date of assessment`   ,60,200,120,15,[ws
  wccreate((WIN, 811),editor,``,                   230,200,100,20,[ws_chil

  wccreate((WIN,1012),static,`7b. last update`  ,60,220,100,15,[ws_child,w
  wccreate((WIN, 812),editor,``,                   230,220,100,20,[ws_chil



  wccreate((WIN,1008),static,`8. What is the resource mix ?`    ,20,250,18
  wccreate((WIN,508),combobox,``,        230,250,200,100,      [ws_child,

  wccreate((WIN,1010),static,`8b. What disciplines are involved ?`     ,2
  wccreate((WIN,510),combobox,``,        230,270,200,100,      [ws_child,


  wccreate((WIN,1009),static,`9. What is the duration of the project ?` ,2
  wccreate((WIN, 809),editor,``,                   230,310,50,20,[ws_child
  wccreate((WIN,10091),static,`MONTHS`  ,  290,310,100,15,[ws_child,ws_vis

  wccreate((WIN,1102),button,``,5,330,490,45,[ws_child,bs_groupbox,ws_visi
  wccreate((WIN,101),button,`Exit`,10,340,90,30,[ws_child,ws_visible,ws_ta
  wccreate((WIN,100),button,`Next`,400,340,90,30,[ws_child,ws_visible,ws_t

       fill_list_box( (WIN,505), ['New Greenfield','New Brownfield','Hybr
       fill_list_box( (WIN,507), ['Quality','Time','Cost'] ),
       fill_list_box( (WIN,503), ['50','30','20','10','5'] ),
       fill_list_box( (WIN,508), ['Outsource design work','Comb. In-house
       fill_list_box( (WIN,510), ['Mechanical','Electrical','Civil Engine
```

```
        wlbxsel( (WIN, 505), 0, 1 ),
        wlbxsel( (WIN, 507), 0, 1 ),
        wlbxsel( (WIN, 508), 0, 1 ),
        wlbxsel( (WIN, 503), 0, 1 ),wlbxsel( (WIN, 510), 0, 1 ),
        window_handler( WIN, con1b_h ),
        show_dialog( WIN ),
        repeat,
                release,
                s_data( con1b, _ ),
        wclose( con1b ).

con1b_h((con1b, 100), msg_button, A, B ) :-
        release,
        get_box_sel( (con1b, 505),   [INTERFACES] ),
        get_radio_sel( con1b,  [yes, no], [205, 206], MODIFICATIONS ),
        wtext( (con1b, 802),   VALUE ),
        number_string( NUM, VALUE ),
        get_value( capital, NUM, CAP_VALUE ),
        get_box_sel( (con1b, 507),  [FOCUS] ),
        get_box_sel( (con1b, 508), [MIX] ),
        wtext( (con1b, 809),   DURATION ),
        number_string( DUR, DURATION ),
        release,
        update_frame( project,
                [interfaces, modifications, cap_value, focus, mix, duratio
                [INTERFACES, MODIFICATIONS, CAP_VALUE, FOCUS, MIX, DUR, VA
        assert( s_data( con1b, [INTERFACES, MODIFICATIONS, CAP_VALUE, FOCU

get_value( capital, VALUE, very_high_cost_project ):- VALUE > 10 .
get_value( capital, VALUE, high_cost_project ):- VALUE > 2.9 .
get_value( capital, VALUE, medium_cost_project ):- VALUE > 0.25 .
get_value( capital, VALUE, low_cost_project ).




con1b_h((con1b, 101), msg_button, A, B ) :-
        wclose( con1b ), my_abort .



con1b_h((con1b, 505), msg_select, A, B ) :-
        release,
        get_box_sel( (con1b, 505 ), [ SEL ] ),
        data( (con1b, 505), SEL, QUEST ),
        wtext((con1b, 10051), QUEST ),
        wshow((con1b, 205), 1 ),
        wshow((con1b, 206), 1 ), !.

con1b_h((con1b, 505), msg_select, A, B ):-
        release,
        wtext((con1b, 10051), `` ),
        wshow((con1b, 205), 0 ),
        wshow((con1b, 206), 0 ), ! .

data( (con1b, 505), 'Hybrid', `5b. Are there any modifications to existing
```

APPENDIX L

```
data( (con1b, 505), 'New Brownfield', `5b. Are there any modifications to

%%%%%%%%%%%%%%% %%%%%%%%%%%%%%% %%%%%%%%%%%%%%% %%%%%%%%%%%%%%% %%%%%%
%%%%%%%%%%%%%%% %%%%%%%%%%%%%%% %%%%%%%%%%%%%%% %%%%%%%%%%%%%%% %%%%%%

con1c :-
        release,
        WIN = con1c,
        ( retract( s_data(con1c, _ ) ) ; true ),
  wdcreate(WIN,`ConSERVE`,30,30,500,400,[dlg_ownedbyprolog,ws_sysmenu,ws_c


  wccreate((WIN,1005),static,`9b1. What is the level of work breakdown ?`,
  wccreate((WIN, 400),combobox,``,                250,20,80,60,[ws_child,

  wccreate((WIN,1006),static,`9b2. What is the present confidence in meeti
  wccreate((WIN,202),button,`low`,      250,60,60,15,[ws_child,ws_visible,
  wccreate((WIN,203),button,`medium`,   320,60,60,15,[ws_child,ws_visible,
  wccreate((WIN,204),button,`high`,     390,60,60,15,[ws_child,ws_visible,

  wccreate((WIN,1009),static,`9c. Are penalties involved ?`     ,20,100,20
  wccreate((WIN,200),button,`yes`,      250,100,60,15,[ws_child,ws_visible
  wccreate((WIN,201),button,`no`,       320,100,60,15,[ws_child,ws_visible

  wccreate((WIN,1007),static,`10a. Are there organisational precedures req
  wccreate((WIN,205),button,`yes`,      250,190,50,15,[ws_child,ws_visible
  wccreate((WIN,206),button,`no`,       320,190,50,15,[ws_child,ws_visible

  wccreate((WIN,1008),static,`10b. Which procedured are required ?`     ,2
  wccreate((WIN, 401),combobox,``,                230,230,150,70,      [w

%  wccreate((WIN,800),editor,``,       230,230,180,20,[ws_child,ws_tabsto

  wccreate((WIN,1010),static,`10c. What is the overall risk contingency ?`
  wccreate((WIN, 801),editor,``,               240,260,40,20,[ws_child,ws
  wccreate((WIN,1011),static,`%`,              290,260,20,15,[ws_child,ws

  wccreate((WIN,1102),button,``,5,330,490,45,[ws_child,bs_groupbox,ws_visi
  wccreate((WIN,101),button,`Exit`,10,340,90,30,[ws_child,ws_visible,ws_ta
  wccreate((WIN,100),button,`Next`,400,340,90,30,[ws_child,ws_visible,ws_t

        fill_list_box( (WIN,400), ['1','2','3','4','5'] ),
        wlbxsel( (WIN, 400), 0, 1 ),
        fill_list_box( (WIN,401), ['Company Procedures', 'Contractors Proc
        wlbxsel( (WIN, 401), 0, 1 ),
        window_handler( WIN, con1c_h ),
        show_dialog( WIN ),
        repeat,
                s_data( con1c, _ ),
        wclose( con1c ).


con1c_h((con1c, 100), msg_button, A, B ) :-
        release,
        get_box_sel( (con1c, 400),   [WORKBRKDWN] ),
        get_radio_sel( con1c,  [low, medium, high], [202, 203, 204], ENDAT

CON1.PL - 14:36:01 - Mon 15 Sep 1997 - Page 003
```

```
        get_radio_sel( con1c,  [yes, no], [200, 201], PENALTIES ),
        get_radio_sel( con1c,  [yes, no], [205,206],  ORGPROCSREQD ),
        get_box_sel( (con1c, 401), [PROCEDURES] ),
        wtext( (con1c, 801),   RISKCONT ),
        lookup( duration, project, DURATION ),
        get_value( confidence, [DURATION, WORKBRKDWN, ENDATECONF], CONFIDE
        get_value( contingency, [ORGPROCSREQD, PROCEDURES, RISKCONT], ORGA
        update_frame( project,
                [work_breakdown, end_date_confidence, penalties, organisat
                [WORKBRKDWN, ENDATECONF, PENALTIES, ORGPROCSREQD, PROCEDUR
        assert( s_data( con1c, [WORKBRKDWN, ENDATECONF, PENALTIES, ORGPROC


con1c_h( (con1c,205), msg_button, _, _ ) :-
        release,
        wshow((con1c,1008), 1 ),
        wshow((con1c,401), 1 ), ! .

con1c_h( (con1c,206), msg_button, _, _ ) :-
        release,
        wshow((con1c,1008), 0 ),
        wshow((con1c,401), 0 ), ! .

con1c_h( (con1c, 101), msg_button, _, _ ) :-
        wclose( con1c ), my_abort .


get_value( confidence, [DURATION, '3', high ], duration_confidence_high )
        DURATION > 11, DURATION < 19, ! .


get_value( contingency, [yes, 'Company Procedures', `0`], client_org_mediu

%%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%

conres :-
        release,
        WIN = conres,

  wdcreate(WIN,`ConSERVE REPORT`,30,300,500,220,[dlg_ownedbyprolog,ws_sysm

   wccreate((WIN, 800),editor,``,                  5,5,480,150,
        [ws_child,ws_visible,ws_tabstop,ws_border,es_left, es_multiline, e

  wccreate((WIN,1102),button,``,5,330,190,45,[ws_child,bs_groupbox,ws_visi
  wccreate((WIN,101),button,`Fresh`,10,165,90,30,[ws_child,ws_visible,ws_t
  wccreate((WIN,100),button,`Print`,400,165,90,30,[ws_child,ws_visible,ws_
        window_handler( WIN, conres_h ),
        show_dialog( WIN ), ! .


conres_h( (conres, 100), msg_button, _, _) :-
        user_message('SYSTEM MESSAGE', `Sorry this function is not yet ava

conres_h( (conres, 101), msg_button, _, _) :-
        assert( conres( refresh ) ),
```

```
        wclose( conres ), ! .

%%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%

con_confm :-
        WIN = conconfm,
        wdcreate(WIN,`ConSERVE`,30,30,500,400,[dlg_ownedbyprolog,ws_sysmen
        wccreate((WIN,1000),static,`Project Confirmation Screen`,       15

        wccreate((WIN,1101),button,``,3,18,490,70,[ws_child,bs_groupbox,ws

        wccreate((WIN,1001),static,`Project Title :`,   20,30,100,20,[ws_c
        wccreate((WIN,1002),static,`Project No :`,      260,30,100,20,[ws_
        wccreate((WIN,1003),static,`Assessed by :`,     20,60,100,20,[ws_c
        wccreate((WIN,1004),static,`Date :`,            260,60,100,20,[ws_
  wccreate((WIN, 801),editor,``,        90,30,150,20,[ws_child,ws_visible,
  wccreate((WIN, 802),editor,``,        330,30,150,20,[ws_child,ws_visible
  wccreate((WIN, 803),editor,``,        90,60,150,20,[ws_child,ws_visible,
  wccreate((WIN, 804),editor,``,        330,60,150,20,[ws_child,ws_visible

  wccreate((WIN, 805),editor,``,        10,100,480,230,[ws_child,ws_visibl


 wccreate((WIN,1102),button,``,5,330,490,45,[ws_child,bs_groupbox,ws_visib
 wccreate((WIN,101),button,`Accept`,10,340,90,30,[ws_child,ws_visible,ws_t
 wccreate((WIN,100),button,`Change`,400,340,90,30,[ws_child,ws_visible,ws_

        % show_project,
        show_dialog( WIN ), ! .

%%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%%%%%% %%%%%%%%%
con_wts :-

        release,
        WIN = conwt,
        ( retract( s_data(conwt, _ ) ) ; true ),
  wdcreate(WIN,`ConSERVE`,30,30,500,400,[dlg_ownedbyprolog,ws_sysmenu,ws_c

  wccreate((WIN,1005),static,`4. Weighting Factors for Success Criteria`,0

  wccreate((WIN,202), button,`Deliver Project on Budget`,25,40,150,15,[ws_
  wccreate((WIN, 802),editor,`0.00`,                     180,40,50,20,[ws_

  wccreate((WIN,203), button,`Contractor Satisfaction`,25,70,150,15,[ws_ch
  wccreate((WIN, 803),editor,`0.00`,                     180,70,50,20,[ws_

  wccreate((WIN,204), button,`Meeting Program`,         25,100,150,15,[ws_
  wccreate((WIN, 804),editor,`0.00`,                     180,100,50,20,[ws

  wccreate((WIN,205), button,`Client Satisfaction`,     25,130,150,15,[ws_
  wccreate((WIN, 805),editor,`0.00`,                     180,130,50,20,[ws

  wccreate((WIN,206), button,`Effectiveness of pms`,    25,160,150,15,[ws_
  wccreate((WIN, 806),editor,`0.00`,                     180,160,50,20,[ws

  wccreate((WIN,207), button,`Project team satisfaction`,       25,190,150
```

```
  wccreate((WIN, 807),editor,`0.00`,                      180,190,50,20,[ws

  wccreate((WIN,208), button,`Meet project quality needs`,       25,220,150
  wccreate((WIN, 808),editor,`0.00`,                      180,220,50,20,[ws

  wccreate((WIN,209), button,`Project group satisfaction`,       25,250,150
  wccreate((WIN, 809),editor,`0.00`,                      180,250,50,20,[ws

  wccreate((WIN,210), button,`Meet technical challenges`,        25,280,150
  wccreate((WIN, 810),editor,`0.00`,                      180,280,50,20,[ws

  wccreate((WIN,211), button,`Other`,   25,310,150,15,[ws_child, ws_visibl
  wccreate((WIN, 811),editor,`0.00`,                      180,310,50,20,[ws


  wccreate((WIN,1102),button,``,5,330,490,45,[ws_child,bs_groupbox,ws_visi
  wccreate((WIN,101),button,`Exit`,10,340,90,30,[ws_child,ws_visible,ws_ta
  wccreate((WIN,100),button,`Next`,400,340,90,30,[ws_child,ws_visible,ws_t

        window_handler( WIN, con_wt ),
        wenable( (WIN,802), 0),
        show_dialog( WIN ),
        repeat,
                s_data( con_wt, _ ),
        wclose( con_wt ).

% for each of the check boxes, either enables the text box or
% dissables it and deletes the existing text.
con_wt( (conwt, NUM), msg_button, _, _ ) :-
        member(NUM, [202,203,204,205,206,207,208,209,210,211] ),
        wbtnsel((conwt, NUM), S ),
        ENUM is NUM + 600,
        ( S = 1 -> wenable((conwt,ENUM), 1) ; (wenable((conwt,ENUM), 0),wt

con_wt( (conwt, 100), msg_button, _, _ ) :-
        get_data( number, conwt, [802,803,804,805,806,807,808,809,810,811]
        update_frame(   project,
                        [budget_wt, consat_wt, meetprog_wt, clientsat_wt,
                        WTS).
```

APPENDIX L

```
update_XL :-
        exec( 'c:\msoffice\excel\excel.exe', '\conserve\graf1.xls',L) ,

        get_strings( project,
        [total_overt_budget_risk, total_overt_cont_sat, total_overt_meet_p
        [OBR, OCS, OMP, OCLS, OPMF] ),
        get_strings( project,
        [total_covert_budget_risk, total_covert_cont_sat, total_covert_mee
        [CBR, CCS, CMP, CCLS, CPMF] ),

        cat( [        OBR, `~I`, CBR,
                `~M`, OCS, `~I`, CCS,
                `~M`, OMP, `~I`, CMP,
                `~M`, OCLS, `~I`,CCLS,
                `~M`, OPMF, `~I`,CPMF
             ], DATA, _ ),

        ensure_loaded( '\conserve\dde' ),
        dde_load,       release,
        dde_open(xl, excel, `graf1.xls`),       release,
        dde_poke(xl, 'r1c2:r5c3', DATA),        release .
```

XLDDE.PL - 14:51:37 - Mon 15 Sep 1997 - Page 001

SUBJECT INDEX