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A Process to Aid Investment In Manufacturing Technology Within Aerospace

SUPERVISOR: Dr. CHARLES E.R. WAINWRIGHT

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Abstract

The work presented in this thesis is a culmination of a collaborative venture between Matra BAe Dynamics and The Department of Enterprise Integration at Cranfield University. Initially the thesis examines the Engineering Doctorate philosophy, before describing the collaborator's history and the background to the decision to formulate a structured process to aid investment in manufacturing technology.

The findings of an extensive literature review are described accompanied by the results of two supporting industrial studies initiated to complement the theoretical work. The literature review and studies revealed a concern about the degree of planning conducted prior to the adoption of manufacturing technology and how insufficient planning can have a negative impact on the implementation of the chosen investment. Further investigation highlighted an awareness of this being the problem within industry, yet it also revealed a lack of time and resources to take corrective action.

The thesis then extends to the development of a process model constructed using the findings from the literature review and the industrial studies. The process model presents a structured process for investing in manufacturing technology consisting of a series of activities designed to guide managers through the planning and implementation stages of an investment. A third stage is proposed consisting of activities designed to encourage planning for future investments using the results from past investments as guides. Following a review of possible techniques for developing a process aid from the process model, HTML was selected and, based on a series of established requirements, a process aid was constructed.

An industrial case study was undertaken to validate the process model and prove that the process is robust. Finally, recommendations for future work are presented and proposals for future developments are outlined.

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The author wishes to acknowledge the following people for their help and assistance throughout this research project.

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To all of my friends, past and present, I wish you all the greatest success in your lives and sincerely hope we achieve all that we deserve. I would like to thank my friend Louise Buckley, with whom I have shared so much and whose friendship I will always value and cherish. I also want to extend my deepest appreciation to Mark England for not only opening up his life and home, but for the love and laughter he continuously provides.

Finally, to my parents and my sister who continue to show me unquestioning love and support, I have you to thank for everything and this achievement is as much yours as it is mine.

Author Profile

The author attended Leeds Metropolitan University in 1991, graduating in 1994 with 2:1 (Honours) in Manufacturing Systems Engineering.

After a brief period of work with British Gas, she accepted a place on the Computer Integrated Manufacturing Masters Programme at the Department of Enterprise Integration (formerly Computer Integrated Manufacturing – CIM) at Cranfield University. An integral part of this course was the project work. The author was involved in a group project, comprising five members, and completed an individual project, both with great success. The group project was initiated to complement the European Union (EU) funded AMBITE (Advanced Manufacturing Business Implementation Tool for Europe) research project which was ongoing within the University at the time. The focus of the group project was the link between business and manufacturing strategy development within small to medium sized enterprises (SME's). To support this research a mini-project was conducted within a local SME. The results of this project were well received and commended by the company, and eventually documented within the MSc group thesis. To further satisfy the requirements of the MSc programme, the author commenced an individual project supported by the Engineering and Physical Sciences Research Council (EPSRC – formerly SERC). This project focused on the extent to which academic research supports the needs of industry engaged in environmental production. The results of this project were published in the international journal *Design Studies, vol.99.*

In 1996, the author commenced an Engineering Doctorate (EngD) within the Department of Enterprise Integration. The author was initially involved in the Masters of Business Administration (MBA) programme at Cranfield School of Management. The remainder of the project focused on industrially relevant research within the collaborating company, Matra British Aerospace Dynamics. This thesis is a documentation of the author's research.

Research Papers

The following papers have been published as a direct result of this research:

1. Argument, L.J., Wainwright, C.E.R. and Reynolds, K.A., (1998).
   "A Process to Aid Information Systems Integration".
   3rd International Conference on the Dynamics of Strategy, University of Surrey, UK, pp 397 – 406.

2. Argument, L.J. and Wainwright, C.E.R., (1998).
   "Virtual Vertical Integration As A Strategy for Manufacture".
   Advances in Manufacturing Technology XII, Proceedings 14th National Conference on Manufacturing Research, Derby, UK, pp 295 – 301, ISBN 1 86058 172 2.

3. Argument, L.J. and Wainwright, C.E.R., (1998).
   "Decision Aids for Strategic Virtual Vertical Integration".
   Proceedings 6th Annual High Technology Small Firms Conference, University Twente, Enschede, The Netherlands, pp 403 – 415.

4. Argument, L.J. and Wainwright, C.E.R., (1999).
   "Virtual Manufacturing: A Strategy for Agility".
   Proceedings of the Institute of Mechanical Engineers, 15th International Conference on Computer Aided Production Engineering, University of Durham, UK.

5. Argument, L.J. and Wainwright, C.E.R., (1999).
   "Information System Justification for Virtual Manufacturing".
   Proceedings 9th Business Information Management Conference.

6. Argument, L.J., Wainwright, C.E.R. and Winchester, M., (1999).
   "Justifying New Manufacturing Technology in the Twenty First Century".
   Advances in Manufacturing Technology XIII, Proceedings 15th National Conference on Manufacturing Research, University of Bath, UK, pp 307 – 311, ISBN 1 86058 2273.

Submitted for Publication:

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   "Developing a Process to Aid Information Systems Integration".
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Chapter 1 Introduction to the Research Project

Abstract

This thesis presents the research conducted by the author under Cranfield University's Engineering Doctorate (EngD) Programme. The research was supported by British Aerospace Systems and the project commenced in 1996. This introductory Chapter discusses the background to the Engineering Doctorate programme, and the philosophy of the Engineering Doctorate. Historical information about the industrial collaborator is also contained in this Chapter, as are details of the research process adopted by the author. An outline of the Engineering Doctorate thesis is presented as a conclusion to this first Chapter.

1.0 The Engineering Doctorate Programme

Within British Universities a Doctor of Philosophy is awarded for a high level of very focussed research. In recent years concern has been expressed that whilst the research conducted within British Universities is of a high calibre the usefulness and relevance to industry of some of the narrowly defined projects is debateable. Conventional research projects are often criticised as being too specialised to meet ever changing industrial needs.

In the late 1980's The Engineering and Physical Sciences and Research Council (EPSRC), formerly the Science and Engineering Research Council (SERC), established a working party to research the PhD and other post-graduate training in the UK in order to understand the relevance of such schemes for satisfying industrial problems (Anon.,

2000)[1]. The conclusion of this report was the recommendation that a new research programme be developed which should be dedicated to nurturing a broader range of skills in those candidates undertaking doctoral research. As a result of this report EPSRC established the Engineering Doctorate Programme which now runs at several universities around the UK, of which Cranfield University is one.

The pilot scheme for the Engineering Doctorate (EngD) commenced in 1992 with a total of thirty research engineers involved. The researchers were placed in participating universities in Manchester (UMIST – The University of Manchester Institute of Science and Technology), Warwick (Warwick University), and Wales (University College Swansea, the University of Wales). Cranfield University and Brunel University joined the scheme the following year, and the number of researchers at each university increased from ten to fifteen.

The aim of the Engineering Doctorate Programme is to provide each candidate with up to four years research time during which the researcher may choose to conduct their work within the collaborating company itself. The candidate is also expected to attend taught management-related courses and other courses relevant to their research. This combination of taught and industrially based research deviates from the traditional approach to research where a student can spend the majority of their research time conducting laboratory experiments and reading supporting theoretical material. The Engineering Doctorate allows the researcher greater interaction with their sponsoring company, and as a result of this assists the development of skills that are of particular

[1] Appendix A.

relevance to that industry. The taught management courses assist in the development of skills that are relevant to industry as a whole.

A number of recommendations were outlined in the SERC working party report (SERC, 1990; Reynolds, 1997). However, the universities participating in the Engineering Doctorate scheme were allowed to follow their own interpretations of these recommendations. Doctoral students are usually assessed by a thesis which the student must defend in a viva voce examination. Cranfield University followed the example set by UMIST and kept this approach as the primary means of assessment for Engineering Doctorate students. The researchers are also assessed on the work completed for the taught aspect of the EngD course and this assessment continues throughout the research period.

To honour the SERC commitment to review the Engineering Doctorate a panel was established by the EPSRC in 1997 to review the progress of the EngD scheme. The panel visited the participating universities gathering information from people directly involved with the EngD scheme. Other researchers not involved in the EngD scheme were also contacted. It was agreed that the Engineering Doctorate is a significant addition to UK research qualifications, the reason for this being the applied nature of the research and the focus on the relationship between the researcher and the collaborating company. The links between the participating universities and the collaborating industries was also found to be strengthened through the Engineering Doctorate scheme. The panel found that allowing the participating universities to manage their own EngD programmes enhanced the overall success of the EngD scheme and improved the

relations between themselves and the collaborating companies. The four years duration of the EngD was also considered necessary to allow the researcher to establish a relationship with the collaborator.

The panel recommended that the number of studentships be increased from a total of 75 to 125 researchers per academic year. It was also recommended that the number of participating universities be increased up to fifteen. To summarise, the review panel considered the Engineering Doctorate a success in achieving high quality academic research and providing skilled individuals that are more useful to industry. Hence, the recommendations to increase the number of researchers and participating universities.

1.1 Introduction to the History of the UK Aerospace Industry

Under the Engineering Doctorate Programme at Cranfield University, researchers conduct their project in collaboration with an industrial sponsor. This project was conducted in collaboration with Matra British Aerospace Dynamics (MBD) based in Stevenage in the UK. British Aerospace was formed in 1977 and since its formation it has undergone a number of organisational and cultural changes of which the joint venture between British Aerospace and Matra was a result. Matra British Aerospace Dynamics is an established guided weapons company employing over 6000 personnel over sites in the UK and France. It has an annual turnover of over £1 billion and has over 40 customers in five continents, (Anon., 1999).[2]

[2] Appendix B.

British Aerospace was a nationalised corporation formed through the merger of the British Aircraft Corporation (BAC), Hawker Siddeley Aviation (HSA), Hawker Siddeley Dynamics (HSD) and Scottish Aviation. In 1996 a joint venture was formed between British Aerospace plc and Largardere Group SA and was named Matra British Aerospace Dynamics. In 1999 British Aerospace Systems (BAE Systems) was formed through an amalgamation of British Aerospace and Marconi Electronic Systems (Anon., 2000)[3]. In terms of size and enhanced capability BAE Systems is now in an even greater position to support its global defence and aerospace customers. BAE Systems still has a 50% ownership of MBD.

1.1.1 History of the UK Aerospace Industry

The aerospace and aviation industries are undoubtedly products of the twentieth century. The aviation industry was already coming into being by the end of the First World War and by the end of the Second World War there were twenty seven British airframe companies, and eight British aircraft engine manufacturers (Gardner, 1981). During these years the major components of early aircraft designs were the airframe and the engine to power the frame. Four of the airframe units were members of the Hawker Siddeley Group, and competition was fierce against other members of the group for design work. The period between the end of the First World War and the beginning of the Second World War saw many changes being made in civil aviation and overall aircraft development. As far as technology was concerned, most of the aircraft developed during this period depended on similar developments in aeronautical and mechanical science, and it was not until the Second World War that greater

[3] Appendix C.

technological advances were made with regards to radar and other electronic systems (Hayward, 1994). These technological developments were the first signs of the changes that were about to hit the aviation industry.

Towards the end of the 1940's it was becoming increasingly obvious to the major players in the aviation industry that there were simply too many airframe and engine design and manufacturing companies. The Second World War had seen the introduction of increasingly complex mechanics and electronics. The atom bomb was now in existence and missiles and other guided weapons were being developed that would require specific airframe design changes to accommodate them. The companies responsible for the design and manufacture of the airframes and engines were aware of a lack of resources and capabilities to keep up with these new requirements. The government - the industry's biggest customer - was beginning to recognise the need to have a solid defence base and during the early 1950's began encouraging the aircraft companies to become involved in guided weapon design and manufacture.

Out of the many airframe and aero-engine designers and manufacturers some of the main names approached by the government were The Bristol Aeroplane Company Ltd, English Electric, and Vickers. The government's plan was to reduce the fragmentation in the aviation industry and have a small number of designated companies to handle their orders. The Korean War commenced in 1950 and countries around the world began to re-arm themselves in fear of a third world war. It was during this period that the term "weapons system" - denoting a need to design and develop a complete technology package – became common parlance (Hayward, 1994). During the early

1950's there were high growth rates in the number of employees in what was rapidly becoming a recognisable defence industry, thanks to the development of increasingly sophisticated fighter aircraft. Both The Bristol Aeroplane Company and English Electric set up guided weapon departments. The Bristol Aeroplane Company based their weapons department in Filton, near Bristol, whilst English Electric based theirs in Luton. English Electric requested permission to expand their site at Luton, though their request was rejected. In 1953 the decision was taken to re-locate part of their business in a new town named Stevenage in the UK (Adams, 1976; Reynolds, 1997). English Electric continued defence research at their Luton site, whilst production was located in other English Electric sites around the UK. Development and engineering began at the Stevenage site of English Electric in 1955 and continued there for some time. Competition between the guided weapons departments of English Electric and The Bristol Aeroplane Company was fierce and rivalry had been prevalent since the government had taken the decision to rationalise the aviation industry through mergers.

During the late 1950's there were a number of military project cancellations and eventually in 1957 a Defence White Paper, The Duncan Sands paper, was administered to the aircraft industry which shook it to the core (Hayward, 1994). Duncan Sands, a Member of Parliament in Mr. Harold Macmillan's government, had been given unlimited powers to change the size and shape of the armed services and their equipment and supply. The paper pointed out that there was a very definite limit to the effort which the UK could afford to devote to defence and hence the defence focus would be thermo-nuclear, phasing out manned combat aircraft, and replacing them with missiles (Hayward, 1994). At this point there was very little left to the British airframe

industry, and one may argue that the Sands paper had a detrimental effect on British military aviation.

The Hawker Siddeley Group, Vickers, English Electric and The Bristol Aeroplane Company were the main companies in the government's plans for re-organising the aviation industry. Rumours were abound of mergers during the period between 1958 and 1959. In 1960 the British Aircraft Corporation (BAC) was formed consisting of The Bristol Aeroplane Company, English Electric and Vickers. Hunting Aircraft Ltd also became a part of the British Aircraft Corporation. Work then began on establishing the reputation of the British Aircraft Corporation.

In 1960 the British Aircraft Corporation had two projects underway, these being projects PT428 and Blue Water. PT428 was a low-level anti-aircraft system (Hayward, 1994). Blue Water was a tactical mobile system with a nuclear warhead and a range of up to seventy miles. In February 1962 PT428 was cancelled as the specification was considered too sophisticated and ambitious for the contemporary technology (Reynolds, 1997; Adams, 1976). This project eventually gave way to the Rapier missile which was more successful than its predecessor. The Blue Water project was cancelled in August 1962 and, coupled with the cancellation of project PT428, the consequences were felt throughout the British Aircraft Corporation.

During this period of uncertainty there were redundancies at English Electric and all guided weapon system activities were moved to Stevenage on the closure of the Luton site. English Electric had learned that it was incredibly risky to commit themselves to a

single project or customer and as a result of this they adopted a new approach to contracting whereby they set out to attract overseas custom. In 1963 the Guided Weapons Division of the British Aircraft Corporation was formed and the Bristol Aeroplane Company and English Electric found themselves united in the development of the Rapier contract. In 1964 half of the Rapier contract was moved to Bristol (the launcher and the fire unit) while the missile was developed at the more modern site at Stevenage. Rapier was an important project for the BAC and its technological brilliance gained the Rapier project a Queen's award for technological innovation (Hayward, 1994). Throughout the 1960's BAC consolidated its industrial connections overseas and became involved in a number of satellite programmes as well as guided weapon system development.

In 1965 it was recommended in a government report that Hawker Siddeley Aviation and the British Aircraft Corporation merge, bringing with this merger a form of public ownership (Hayward, 1994). In 1971 the Confederation of Shipbuilding and Engineering Unions passed a resolution calling for the nationalisation of the aircraft industry (Reynolds, 1997). This was the year that also saw the bankruptcy of Rolls Royce and a rise in the costs of the government's civil aviation programmes including Concorde. 1974 saw the election of a Labour government, a government in full support of the nationalisation of the aircraft industry and a change in the strategic direction of aerospace and aircraft projects. The British Aircraft Corporation, Hawker Siddeley Aviation, Hawker Siddeley Dynamics, and Scottish Aviation were finally merged in 1977 to form British Aerospace , a nationalised organisation.

British Aerospace (BAe) began establishing its organisational structure from the moment it was nationalised and by 1978 there were two groups comprising British Aerospace, namely the Aircraft Group and the Dynamics Group. These two main groups were also split into separate divisions which were located at various factories around the UK. The Dynamics Group comprised of a division spread over sites at Stevenage and Bristol, and a division spread over sites at Hatfield and Lostock. The Hatfield site once housed De Havilland Propellers, and the Lostock site was once home to Hawker Siddeley Dynamics.

In 1979 the Conservative Party came into power and began moves to privatise many of the nationalised industries. The re-organisation of British Aerospace continued in the early 1980's when the Dynamics Group was subject to further changes. Sites at Stevenage, Bristol and Hatfield were re-organised to serve particular armed forces customers: Stevenage became the Army Weapons Division, Bristol the Naval Weapons Division, Hatfield the Air Weapons Division, and Site B (also at Stevenage) became the Spares and Communications Division (Reynolds, 1997). A British Aerospace Act was passed by the Conservative Government in 1980 and this led to British Aerospace being re-named British Aerospace Limited in November 1980. By May 1985 British Aerospace was fully privatised.

The restructuring continued in the 1980's when the Dynamics Group was disbanded. In 1986 the individual Dynamics divisions were given autonomy until further restructuring in 1988 when the individual divisions were merged to form a single Dynamics Division. The headquarters of this newly rationalised Dynamics Division was based in Stevenage.

This restructuring greatly affected the number of employees in the Dynamics Division which fell from approximately 19,000 in 1988 to around 2,800 in 1996. The total number of employees in British Aerospace Defence, the parent organisation, fell from over 60,000 in 1988 to roughly 30,800 in 1996. In 1989 the Dynamics Division experienced further restructuring and the division was split into three main sites based at Stevenage, Lostock, and Bristol. Research and Development continued at Stevenage whilst electronic and software design was conducted at Bristol.

The global restructuring that had taken place in the defence industry during the 1980's and early 1990's resulted in an industry that was highly competitive and suffering from over-capacity. In the words of Sir Richard Evans, the then Chief Executive of British Aerospace (and now Chairman) the company had lost its self-respect and its pride, and they came very close to loosing the legacy that had been left to them by the pioneers of the UK aerospace industry (Evans and Price, 1999). Under the guidance of Sir Richard Evans, British Aerospace embarked upon BenchmarkBAe, a five year effort to change the culture within British Aerospace and make it a world leader in defence (Evans and Price, 1999). A number of joint ventures and mergers were to play an enormous part in this change programme and the 1996 merger between Matra and British Aerospace Dynamics was typical.

In May 1996 British Aerospace plc and Largardere Groupe SA agreed terms for the formation of a joint venture in guided weapons, guided weapon systems and related

activities which resulted in the formation of Matra BAe Dynamics (Anon., 1999).[4] By 1997 Matra BAe Dynamics was the largest guided weapons organisation in Europe.

In 1997 Dynamics employed just over 6,000 personnel on seven sites distributed in France and the UK. Dynamics retained the sites at Stevenage, Lostock, and Bristol while research and development, production and integration, electronics, and testing were moved to sites in France.

In October 1997 British Aerospace and Largardere agreed an extension to their equally owned Matra BAe Dynamics guided weapons joint venture by the acquisition of a 30% interest in the German guided weapons business LFK, a subsidiary of Daimler Benz Aerospace. This represented a further step towards the consolidation of the guided weapons business in Europe and it was hoped that the move would enhance the European guided weapons industry through shared marketing of an integrated product range (Anon., 1998; 1999).[5, 6]

Throughout 1998 there were calls throughout Europe for a unified aerospace industry. Western governments were facing a single currency and it was becoming increasingly apparent that European integration would have to be extended to the aerospace and defence industries if Europe was ever to mimic the economies of scale generated by the US defence industry.

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[4] Appendix B.
[5] Appendix D.
[6] Appendix E.

In 1998 UKAMS, the company responsible for the development and initial production of the UK variant of the PAAMS (Principal Anti Air Missile System) project for the Common New Generation Frigate, became a wholly owned subsidiary of Matra BAe Dynamics UK. This followed an agreement signed between Matra BAe Dynamics, British Aerospace plc, and GEC-Marconi, formerly UKAMS shareholders. The agreement gave Matra BAe Dynamics the prime contractor role for the UK variant of the project, helping also to satisfy a government Strategic Defence Review which called for an improved area air defence for the Royal Navy (Anon., 1999).[7]

In 1999 Aerospatiale Matra, British Aerospace and Finmeccanica signed a Heads of Agreement which established a joint venture in missiles and missile systems. Partnerships were set to develop around Alenia Marconi Systems (AMS) which was the result of a joint venture agreed between Marconi Electronic Systems and Alenia Difesa. They specialised in land based and naval radar, command and control systems, missiles and simulation. The new European Group is expected to be in receipt of over £1.5 billion (Euro 2.5 billion), and will employ over 10,000 people in Italy, the UK and France. The group will also have a 30% shareholding in LFK, the main German guided weapons business which is currently owned by Matra BAe Dynamics. Their aim is to have a complete range of land and sea based surface to air systems as well as air launched and anti-ship weapons for world wide customers. This will position the group as the prime contractor or main partner in all European missile programmes.

[7] Appendix F.

In 1999 British Aerospace and GEC agreed to create a global aerospace and defence company by merging British Aerospace with GEC's Marconi Electronic Systems business. This move, together with the move to create a European missile and missile system joint venture represented a further consolidation of the European aerospace and defence industries and was a direct answer to the increasing number of calls for a unified European aerospace industry (Anon., 1999).[8]

These constant changes have encouraged the uptake of a variety of research projects by MBD, a number of which have been in collaboration with Cranfield University. In order to consolidate its position within the European Defence Industry, and ultimately to compete globally, research projects, such as the author's, have focused on areas highlighted by MBD as requiring attention. The changing nature of the European and Global and defence industries will require its players to be informed and flexible to adapt to further changes and exploit emerging opportunities. Key to making MBD a successful partner in defence will be the technologies it employs and the degree of success it achieves in their implementation. It will become increasingly important that the process by which investments are acquired is consistent, to ensure that the right technologies are selected and implemented with maximum ease. The author's research project was initiated in response to this.

1.1.2 Matra BAE Dynamics Product Listings

The following tables detail a range of products offered by Matra BAE Dynamics. These tables are derived from the BAE Systems, The Facts (1999).

[8] Appendix G.

Product	*Type*
ASRAAM	Short range air-to-air
ALARM	Air launched anti-radiation missile
MAGIC 2 MK 2	Dogfight missile with infrared Seeker
MICA	An interception, combat and self defence Missile
METEOR	Beyond visual range air-to-air missile
MISTRAL ATAM	Self defence and combat system for helicopters, based on the MISTRAL
STORM SHADOW/SCALP EG	Conventionally armed stand-off missile: Air-to-ground long-range missile

Table 1.1: Matra BAE Dynamics Air Weapons

Product	*Type*
RAPIER FSC	Surface-to-air defence system
JERNAS	Advanced air defence system based on RAPIER FSC
RAPIER B1X	Air defence system offering existing B1X users the chance to upgrade
MISTRAL	Low-altitude air defence missile
MISTRAL MANPADS AND MCP	A two-load man-portable air defence weapon system with a single MISTRAL ready-to-fire missile
NATO SHORAD/VSHORAD	The requirement for a future NATO short range/very short range air defence system

Table 1.2: Matra BAE Dynamics Air Defence Systems

Product	*Type*
VERTICAL LAUNCH SEAWOLF	Rapid reaction, ship-borne, close-area defence system
SEAWOLF	Conventional launch SEAWOLF is a ship based close area defence system
SEA SKUA	All weather, day/night, lightweight anti-ship missile system
SIGMA	Combined gun/missile stabilised naval mounting. Anti-air.
PAAMS	Principal anti-air missile system for use with new generation frigates
OTOMAT	Very long-range surface-to-surface or coastal defence system
MILAS	Surface ship anti-submarine torpedo carrier missile derived from OTOMAT
SIMBAD	Air defence, twin launcher with two ready-to-fire MISTRAL missiles

Table 1.3: Matra BAE Dynamics Naval Systems

Product	*Type*
MEDIUM RANGE TRIGAT	Anti-tank infantry missile system
LONG RANGE TRIGAT	Helicopter or vehicle launched anti-tank missile system
KESTREL	Proposal for UK next generation light anti-armour weapon requirement

Table 1.4: Matra BAE Dynamics Anti-Armour Defence Systems

Product	*Type*
ICMS/SPIRALE	The decoying and missiles warning system which is totally integrated into the airframe and the aircraft system
MILDS	Missile launch detector system
SAPHIR	Decoying self-protection system for helicopters

Table 1.5: Matra BAE Dynamics Countermeasures

Product	*Type*
TUCAN	User friendly multi-mission UAV system
BREVEL	Real-time observation and target localisation system

Table 1.6: Matra BAE Dynamics Unmanned Aerial Vehicles

1.2 Outline of the Collaborative Project

During the 1990's British Aerospace Dynamics experienced severe competition from other defence companies and as a result of this they began to seek ways of securing a financially viable and competitively stable future. Fixed price contracts had superseded the cost-plus policies and this was leading towards a change in the nature of the relationship that existed between the Ministry of Defence and British Aerospace Dynamics. The Ministry of Defence, British Aerospace's primary UK customer, was advocating multi-national missile development programmes in order to spread project cost and risk, and the focus for design, development and manufacturing was on achieving low unit costs while maintaining a manufacturing base capable of meeting demands in times of conflict.

By 1996 when the merger between BAe Dynamics and the Largardere Group SA occurred, British Aerospace was already undergoing a major cultural change. The joint venture between BAe Dynamics and the Largaredere Group was part of this cultural shift. In line with the rest of the British Aerospace organisation Matra BAe Dynamics began to focus their attention on achieving sustainable competitive advantage in the 21st Century.

Achieving sustainable competitive advantage is a real challenge for modern organisations, not least those operating within the defence market. Dynamic global competition, the move out of mass production into mass customisation, and the unending quest to lower operating costs and improve efficiency compelled Matra BAe Dynamics to further examine their processes and seek ways to effectively manage their operations.

Virtual Vertical Integration (VVI) is a term used by the collaborator to define a concept that is based on the principles of the virtual organisation. Within a virtual organisation partnerships are formed with organisations for the purpose of acquiring skills and technology in order to exploit market opportunities. It has been argued that organisations wishing to remain competitive should adopt a more proactive approach to change and this includes their approach to technology investments. British Aerospace had embarked upon their own company-wide change management programme, namely "BenchmarkBAe"[9], and it was suggested by Matra BAe Dynamics that a large research project be initiated to investigate the feasibility of virtual vertical integration as an approach to their business operations in the 21st century.

Hence, this research project commenced initially with an investigation into virtual vertical integration examining the principles of this and its relation to contemporary manufacturing techniques and philosophies. Contemporary manufacturing must encompass customer focus, enhanced competitiveness, and change management. Greater emphasis is placed on open information exchange and a culture of change and

[9] Benchmark BAe was a five year culture-change project initiated within British Aerospace.

organisational learning is required for customer expectations to be achieved. To implement VVI requires the organisation to focus upon core elements of the business. As a consequence, the scope of the research project was concentrated to focus on the process of acquiring and implementing the core technology necessary in order to achieve sustainable competitive success. It was suggested that the benefits of virtual vertical integration would be more easily realised through a greater awareness of how to identify and implement core technologies.

Advanced manufacturing technology (AMT) has been described as a group of integrated hardware based and software based technologies which, when properly implemented, can improve the operating efficiency and effectiveness of adopting firms (Udo and Ehie, 1996). There has been a great deal of argument in academic literature relating to perceived and real benefits arising from investing in AMT. Perceived benefits are those benefits estimated to be effected by a technology investment and real benefits are those benefits which improve operating performance and create vital business opportunites.

Capturing such benefits has become a concern for Matra BAe Dynamics. Research has indicated that sufficient attention needs to be focussed on the early stages of planning for technology investment if problems are to be minimised in the implementation stage. Research has shown that technology based programmes appear to be the greatest source of productivity improvement (Harvey, 1990; Noori and Gillen, 1995) but if they are not managed properly in the early planning stages then many technology investment projects fail in the delivery of the benefits anticipated by investors. This research

project was initiated to investigate the process of investing in manufacturing technology and to examine the stages of such a process, with a view to using the information to reduce the number of problems associated with technology implementation within a VVI framework.

1.2.1 Research Objectives

Recent literature (Voss, 1986, 1988 and 1992; Macdougal, 1997) has identified a need for further research into the planning stage of the manufacturing technology investment process. It is argued that further research is necessary to understand more wholly the manufacturing technology investment process, and to understand the contribution that effective planning makes towards successful technology implementation. This research attempts:

- To address the need for a greater understanding of the technology investment process by investigating the whole process within the collaborating company;
- To breakdown the process of investing in manufacturing technology into key stages and to analyse these in detail;
- To detail the process of acquiring and implementing manufacturing technology and to build a model of this;
- To develop a process aid which may be employed within the collaborating company to aid consistency in the investment process.

The process aid has the potential to be generic and applicable within any manufacturing industry although it has been constructed using information from the aerospace sector.

1.2.2 Research Value

The aim of this research project was the development of a process aid that may be used to assist engineering managers in the manufacturing technology investment process. The Engineering Doctorate philosophy is to provide practical assistance to those responsible for the management of an engineering organisation, and ultimately to provide a contribution to knowledge. The results of this research project must contribute to, and increase the existing knowledge of manufacturing technology investment. The foundations of virtual vertical integration are laid in the process of acquiring the necessary technologies and from a greater understanding of the process of investing in manufacturing technology should emerge a knowledge of how to best select and implement manufacturing technologies with a view to creating a virtually vertically integrated organisation.

1.2.3 Research Methodology

The nature of research is to seek answers to problems that remain unanswered or unchallenged, and to validate any results obtained. It has been argued that conventional laboratory-derived research styles seek to minimise the degree of involvement between the researcher and the researched in the interests of objectivity. Here, instead of promoting change, the task of conventional pure scientific research is to describe, understand, and explain – not to promote change. It was Kurt Lewin who coined the phrase *action research* and this involves a spiral of cycles of planning, acting, observing and reflecting (Robson, 1993). The ethos of the Engineering Doctorate research programme is to take 'real' industrial problems and seek solutions to these by synthesising both academic and industrially based research. The research problem is

outlined, and the researcher plans how to best seek answers to this research problem using available industrial and academic resources. Once a plan is derived and the research problem defined, the researcher then applies theories and employs a variety of approaches to derive information pertaining to the research problem. Once information is obtained the researcher may then apply the knowledge obtained in order to address the research problem. Any solutions presented must be validated and areas requiring further research must be noted. On this basis, Engineering Doctorate research could be classed as action research.

The aim of this research project was to model the process of investing in manufacturing technology and produce a tool to assist with the investment process. Surveys were conducted in order to identify and detail the key stages of the investment process. The surveys were also conducted to identify the concerns of those in aerospace with their investment process. A process aid was then developed for assisting the process of investing in manufacturing technology. It is hoped that this tool will aid consistency in the process of acquiring and implementing manufacturing technology. The ultimate aim of the project was to understand the process of investing in manufacturing technology and provide a valid contribution to a body of knowledge that may help to close the gap that is perceived to exist between expected investment performance and actual investment performance.

A central theme of the Engineering Doctorate programme is to provide practical assistance to industry and to address problems that have been identified by the

collaborating companies. The following research methodology was adopted by the author in order to satisfy requirements of the Engineering Doctorate programme:

- Phase 1: A literature review for identifying the process of investing, and implementing manufacturing technology within the context of VVI. The literature review focuses on the process of investing in manufacturing technology, the problems associated with this process, how research has attempted to overcome these problems, and managing investments in manufacturing technology;
- Phase 2: A survey of aerospace/defence suppliers and a survey of British Aerospace and Matra BAe Dynamics personnel to gather data for building a conceptual model of the technology investment process;
- Phase 3: The development of a theoretical process model for representing the activities in the manufacturing technology investment process;
- Phase 4: To make the process model operational to assist in the process of investing in manufacturing technology;
- Phase 5: Validation of the model through a case study within the collaborating company;
- Phase 6: Identification of limitations of the model and the process in order to propose areas for future research.

1.2.4 Thesis Structure

The structure of this thesis corresponds to the research methodology outlined in section 1.2.3. An investigation of virtual vertical integration was performed initially to begin

the thesis and provide a background to the research. Details of this are outlined in Chapter 2.

- Chapter 2 details the literature review which examines existing knowledge pertaining to investing in manufacturing technology. A review of investment appraisal techniques is presented and modern frameworks for assisting the investment process are examined. Other reviews of appropriate literature are also presented in Chapter 2. This Chapter corresponds with Phase 1 of the research methodology.
- Chapter 3 reflects the work conducted during the data gathering phase of the research. This Chapter is constructed to represent the information gained from a postal survey initiated by the author investigating manufacturing technology investments. The work corresponds to Phase 2 of the research methodology.
- Chapter 4 corresponds to Phase 3 of the research methodology, presenting work from an interview-based survey. This work is fundamental to the development of the process model.
- The proposed process model is presented and discussed in Chapter 5 in relation to information gathered during Phase 2 of the research.
- Chapter 6 discusses the method chosen for transforming the process model into a process aid. This Chapter corresponds with Phase 4 of the research methodology.

The process model is a theoretical representation of the stages of the investment process as identified through the surveys in Phase 2 of the research methodology. The model represents the definable stages of the process and also the variables affecting the outcomes of each stage. The data contained in this model was then

used to construct the process aid for assisting investments in manufacturing technology.

- Chapter 7 details the validation of the process model and process aid through case studies within the collaborating company. This corresponds with Phase 5 of the research methodology. Conclusions are presented within Chapter 8 and limitations are acknowledged, accompanied by suggestions for future research. The research structure is illustrated in **Figure 1.1.**

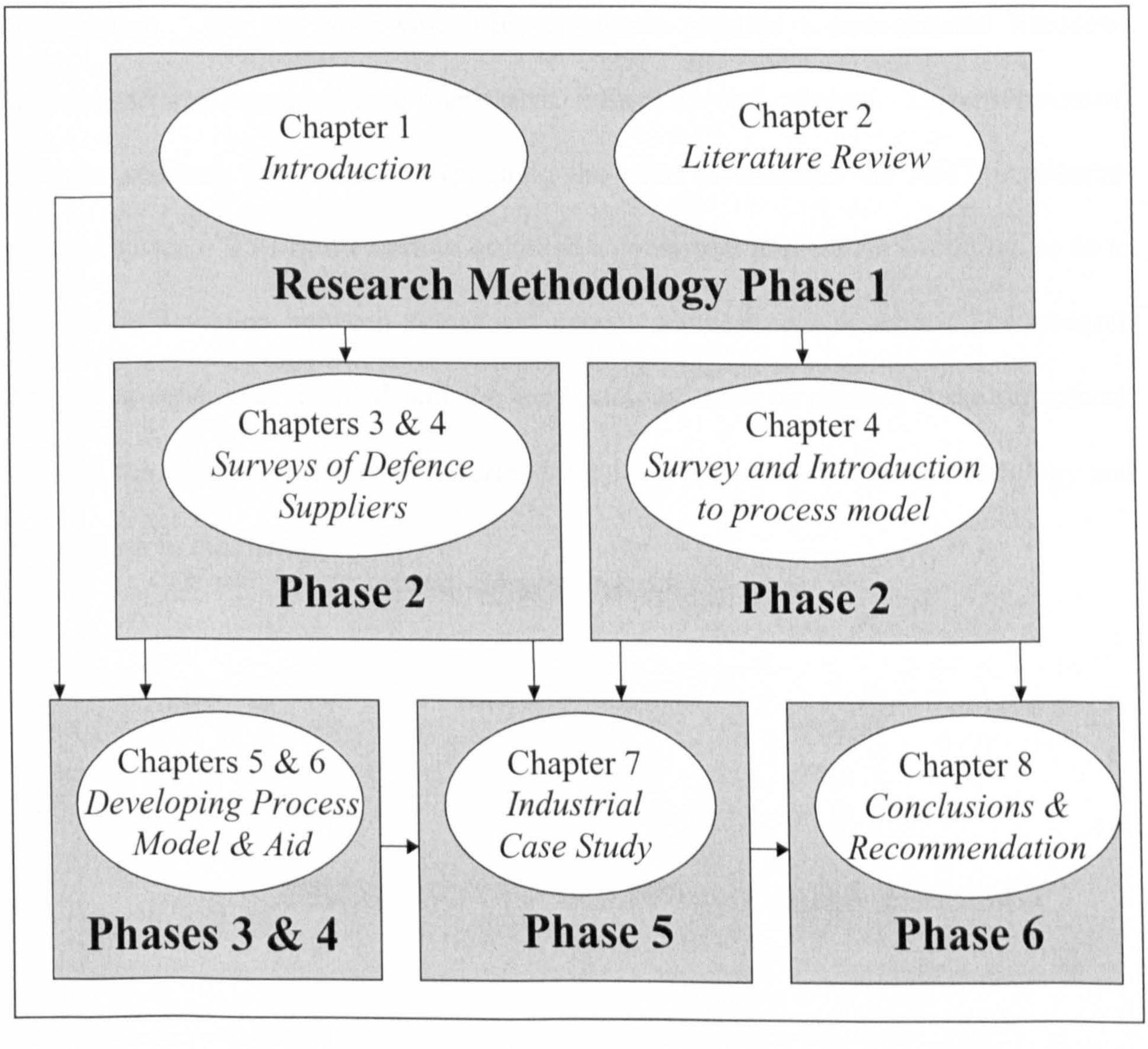


Figure 1.1: The Thesis Structure

1.3 Chapter Summary

This Chapter initially examined the philosophy surrounding the Engineering Doctorate and emphasised its relevance to industry. The collaborating company was introduced and the chronological history of the company was examined. The collaborating company has experienced perpetual change and consolidation in order to remain competitive. The background information detailed the change from fragmented organisations with single business goals, to a nationalised aerospace and defence organisation. We are now witnessing the move towards a consolidated European defence industry encompassing many sites, influences and cultures. This environment puts the research into context, explaining the need to examine the AMT investment process within a VVI framework to establish a consistent process for investing, so as to reduce the deviation between actual and expected investment benefits. The research objectives were also detailed and the methodology used to achieve these objectives. Finally, the thesis structure was described detailing each stage of the methodology and its location in the thesis.

Chapter 2 Understanding the Process of Investing in Manufacturing Technology

Abstract

The primary aim of this research was to understand the process of investing in manufacturing technology and to use this understanding to develop a tool to assist the investment process. In accordance with the first phase of the research methodology, available sources were analysed to build an understanding of the main research areas connected with investing in manufacturing technology. The literature review was used primarily to focus on the areas of investment research that would emphasise the research problem, and to highlight other areas requiring further attention. The results of the literature review are presented in this Chapter. The Chapter closes with a summary of the literature review.

2.0 The Focus of the Literature Review

An integral part of any research project is the literature review, the purpose of which is to explore issues pertaining to the research topic. For the purpose of understanding the terminology relating to investing in manufacturing technology a literature review was conducted, the results of which are detailed in this Chapter.

Voss (1986) identified a need for further research into the investment appraisal stage of the process of investing in manufacturing technology in order to fully understand the whole technology investment and implementation processes. Decisions and actions taken in the appraisal stage of the investment appraisal process can greatly affect the

overall performance of an investment. Hence it is of vital importance that the correct decisions and actions are taken to minimise problems that may occur in the later stages of the investment process. For the purpose of the research the following main research topics are analysed within this Chapter. These are identified as follows:

1. The Relationship Between Strategy and Decision Making;
2. The Short Term Nature of Investments;
3. Decision Making;
4. Financial Appraisal;
5. Strategic Appraisal;
6. Recent Developments in Appraisal Methods
7. Performance Measurements;
8. Implementation and Management of Manufacturing Technology Investments.

An analysis of each research topic is contained within this Chapter and the relationship between the research topic and the research area is detailed.

2.1 Problem Statement

There are many issues surrounding the investment process for manufacturing technology. In this Chapter, these issues are identified and clarified and a detailed analysis of related literature is presented. Also, in this Chapter a definition of manufacturing technology is presented and examples of manufacturing technology are described. The phrase "investment process" is defined and discussed leading into a description of what occurs throughout the whole process. It is important to outline what

occurs when a company wishes to invest in manufacturing technology and hence becomes absorbed in this process.

Another issue that is addressed in this Chapter is that of benefits arising from an investment in manufacturing technology. Investments must be beneficial to a company in some way otherwise there would be no point in considering the investment in the first place. The notion of tangible and intangible benefits has been discussed by Meredith and Suresh (1986). Tangible benefits are those that are easily quantifiable and identifiable. Intangible benefits may be difficult to quantify in investment appraisal as it is not always possible to predict when or where these benefits will be felt. The benefits that arise from an investment in manufacturing technology have also been referred to as direct and indirect benefits, and financial and non-financial benefits.

The argument follows that if a distinction can be made between the benefits that arise from an investment then different evaluation methods may need to be employed in order to account for the different effects that will be felt. For example, it may be unnecessary to employ a mathematical model to account for the rise in employee satisfaction as a result of investing in new production tooling. The rise in employee satisfaction can be detected in any number of ways yet it is often not always possible to account for such benefits using quantitative methods.

Primrose (1991) argued that all benefits must be quantified and that managers should consider all possible effects of investing in manufacturing technology. Other researchers have concluded that a distinction must be made between tangible and

intangible benefits because without this distinction then companies will carry on evaluating investments using the same methods without considering new, possibly more effective methods of evaluation. Issues concerning tangible and intangible benefits are discussed in this Chapter.

The methods employed by managers for appraising investments are also examined in this Chapter. Small and Chen (1997) argued that while mathematical models may provide accurate results regarding profit and payback, they are not suitable for determining non-financial effects. A further argument concerning the use of mathematical models for appraising investments in manufacturing technology is that they focus on the short term results delivered through the investments, failing to highlight long term, strategic and monetary benefits. This issue is also addressed in this Chapter.

When implementing manufacturing technology an organisation is putting into effect the technology they have chosen to invest in, for example, a design department using a CAD system for designing components. However, there are a number of issues which contribute to a successful implementation of a technology investment and this section of the thesis examines the factors that affect the implementation of manufacturing technology.

For all the money spent by companies there often remains a persistent gap between the expected and actual performance of a manufacturing technology investment. This is troublesome for managers considering that the cost of investments often rise into

millions. Researchers have often tried to address this issue with varying results but it none the less remains a pertinent area for research considering the changing nature of manufacturing.

Researchers have identified a number of problems with investing in manufacturing technology. Examples of these are (Chan, Chan, Mak and Tang, 1999):

- Inadequate post-implementation tracking procedures and contingency plans;
- Insufficient organisational and operational planning prior to adoption;
- Faulty execution of the implementation process;
- Improper adoption of the conventional costing systems in reflecting the actual costs.

It is common for managers who are experienced in making investment decisions to have a "gut feel" about how successful an investment project will be. This intuition is often the basis for an investment decision and managers should learn to recognise their immediate feelings about an investment. All investments have pros and cons and often intuitive feelings can be good indicators of an investment's potential when comparing the merits of investment choices.

However, considering how important the cost is to a company of making an investment decision it would be unwise for the decision maker to solely base their investment decision on intuition alone. Hence, other appraisal methods have been researched to assist managers in the investment decision. Strategic appraisal methods are a group of methods that have been researched and developed to be employed by managers when

evaluating investment choices. Examples of these methods are also discussed in this Chapter.

2.2 Mass Production to Mass Customisation

History has shown us that businesses throughout the past 100 years have survived by mass producing and mass standardising. Standardising is a term used to denote standardised taste, standardised design, and standardised products that could be mass produced and mass distributed (Lampel and Mintzberg, 1996). This paradigm of mass production saw companies around the world reap the benefits that arose from the enormous wealth that was generated during this period. However, as factories became geared up to producing large volumes of low variety and low cost products, they became inflexible and lost the capability to respond to rapid shifts in market conditions (Kidd, 1997). For instance, the traditional mass-producing company could be described as being bureaucratic and hierarchical. Workers operated within an environment characterised by low costs, and standard goods and services, and they generally performed narrowly defined, repetitious tasks (Pine, Victor, and Boynton, 1993).

However, Lampel and Mintzberg (1996) and Goldman and Nagel (1995) argued that the period of mass production was coming to an end and that a new approach to manufacturing was emerging. This new approach to manufacturing was being driven by increasing levels of competition and the need to be able to satisfy the fickle demands of increasingly assertive customers. This approach became known as mass customisation, and was said to be characterised by the ability to rapidly respond to changing market preferences and the continuous introduction of innovative technology

(Alford, Sackett and Nelder, 2000). According to Pine *et al* (1993) mass customisation calls for flexibility and quick responsiveness. In an ever-changing environment, people, processes, units, and technology reconfigure to give customers exactly what they want. The results of mass customisation are low cost, high quality, customised goods and services (Pine *et al,* 1993).

As companies began to embrace mass customisation it became apparent that, as a strategy to manufacturing, mass customisation was proving to be expensive, not to mention difficult to apply without an understanding of the customer base and their needs. Furthermore, it began to emerge that mass customisation was not a "catch-all" strategy that could be easily adopted and applied without fundamental changes to organisational structures, values, management roles and systems, learning methods, and ways of relating to customers (Pine, Victor and Boynton, 1993). This led scholars to discuss strategies for mass customisation with the emphasis on making mass customisation work for individual companies.

Gilmore and Pine (1997) identified four faces of customisation and argued that when designing or redesigning a product, process, or business unit, managers should examine each of the approaches for possible insights into how best to serve their customers. These approaches are summarised below:

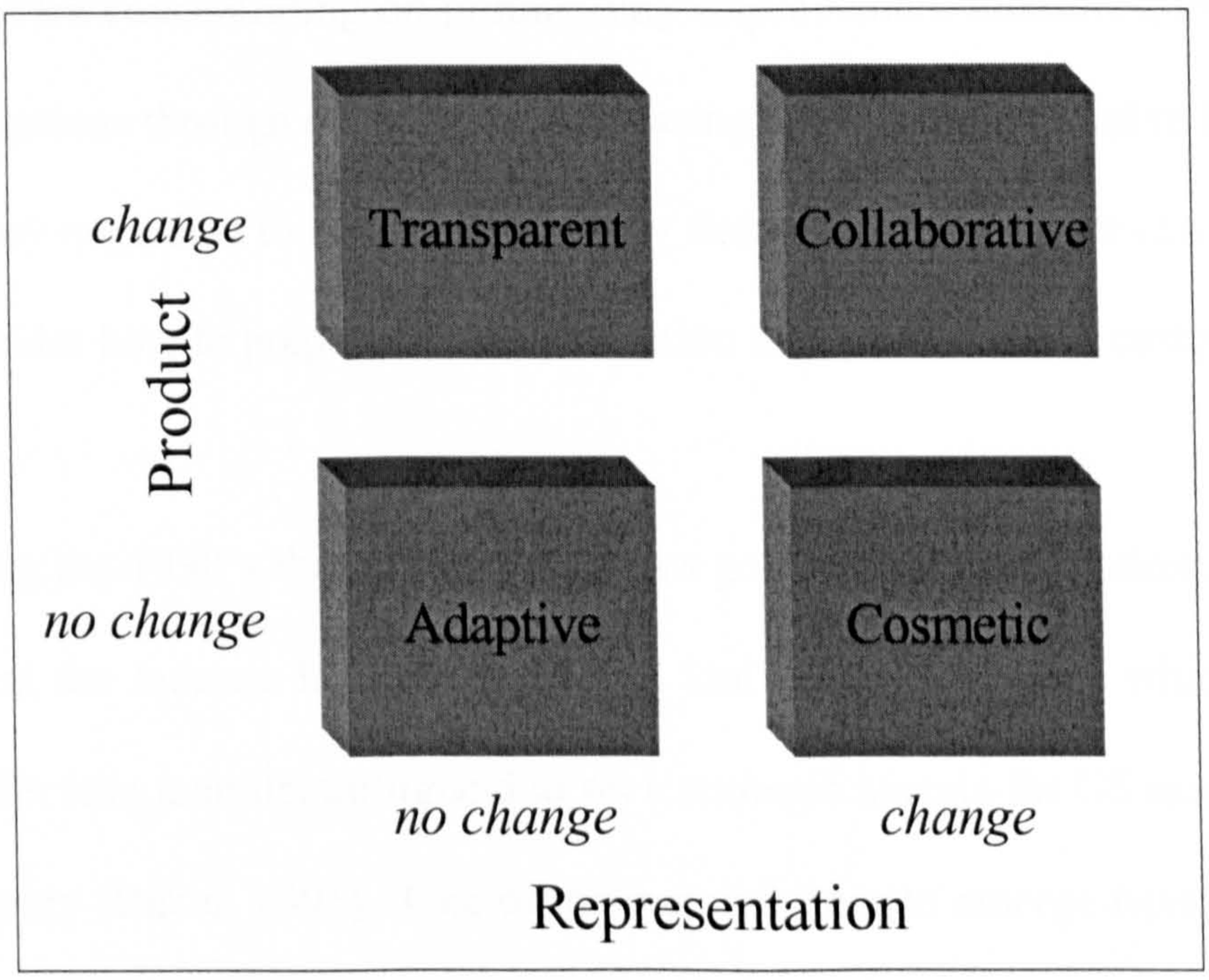
- Collaborative approach - where the companies consult with their customers to ensure that they offer the exact customised product to suit the customer's needs;

- Adaptive approach – where companies offer a standard product that may be customised, should they require it, by the customer;
- Cosmetic approach – where a company will offer a standard product but it will be presented differently depending on the customers requests;
- Transparent approach – where companies provide individual customers with unique goods or services without letting them know that those products or services have been customised for them.

Figure 2.1 illustrates the four approaches to customisation as outlined by Gilmore and Pine (1983) and further solidifies the argument that customers can no longer be grouped into easily defined market groups. The four approaches to customisation allow companies to identify the dimensions along which their customers differ in their needs. However, altering the product itself is only a part of customisation and in order to become adept customisers companies should customise the representation of the product and should learn that the key to effective customisation is to do so only when and where it counts. Lampel and Mintzberg (1996) called this *customising customisation.*

With regards to investing in manufacturing technology, Pine *et al* (1993) discuss manufacturing technology as a key component of achieving successful mass customisation. They argue that companies must first turn their key processes into modules, identifying the key stages and activities in each. They will then need to create an architecture for linking these modules that will allow them to use the best combination or sequence of activities to tailor products or services. The emphasis moves from using process improvement measures to prevent failure within a process to

developing and enhancing the capability of a sequence of processes to ensure that customer requirements are met. They argue that technology should be employed across all the processes, not just as a means for production but for linking all processes and people.



Source: Gilmore and Pine (1997), *p. 95.*

Figure 2.1: The Four Approaches To Mass Customisation

2.3 Agile Manufacturing

Traditionally large companies have been most comfortable in the position of supplying high volumes and low variety, but trends show that this approach is disappearing as more customers demand more choice (Esmail and Saggu, 1996). Mass customisation is said to be upon us (Esmail and Saggu, 1996) and the force that is driving this paradigm shift is customer choice. Choice will become the new dimension in which companies will seek to achieve sustainable competitive advantage.

During the 1990's much research focussed on strategies for manufacturing in the 21st century, with efforts being both academic and industry led. Companies and researchers alike began to take a more proactive approach to research focussing on preparing manufacturing organisations to be competitive in 21st century markets. However, whilst companies were concentrating on productivity improvement measures, and revitalising their organisations through downsizing, increasing stock turnover, and reducing work in progress, they neglected to consider fully how fickle consumer tastes can be, and hence did not consider how to prepare their organisation to cope with mass customisation.

It was during the 1990's that the United States government commissioned an industry-led survey at the Iacocca Institute of Lehigh University to explore what the next step might be after lean manufacturing and to set a strategic agenda for US manufacturers for the 21st century (Baker, 1996). One of the major themes to emerge from this study was agility.

In the UK, the Centre for the Exploitation of Science and Technology (CEST) has developed a definition of agility (Esmail and Saggu, 1996):

> *"The agile enterprise executes a continuous, rapid and adaptable response to unpredictable market threats and opportunities."*

Noaker (1994) also proposed a definition of agility:

> *"The measure of a manufacturer's ability to react to sudden, unpredictable change in customer demand for its products and services and make a profit."*

In agile manufacturing, the aim is to combine the organisation, people, and technology into an integrated and co-ordinated whole (Kidd, 1997). It is a continual process of managed change, continually adapting internal operations and external relationships, to identify and ultimately satisfy new customer opportunities. The concept of agile manufacturing is built around the synthesis of a number of enterprises that each have some core skills or competencies brought to a joint venturing operation, based on using each partner's facilities and resources (Kidd, 1997). Therefore, agility is about having the ability to react to unforseen change, and the agile enterprise should be seen as a set of value adding processes and capabilities, rather than a structure of functional units (Campbell, 1998).

The Lehigh study identifies four dimensions of agile competition, and within these dimensions agile enterprises can be competitive on the following levels (Goldman *et al*, 1995):

- Marketing: to sell individualised combinations of products and services;
- Production: to manufacture goods and to provide services to customer order in arbitrary lot sizes;
- Design: to have a holistic methodology for design that integrates the supplier, production processes, business processes and the product's use and eventual disposal;
- Organisation: to have the ability to effectively employ all resources regardless of location;

- Management: a less controlling approach to management, to create trust, and to encourage and motivate;
- People: to have a knowledgeable and skilled workforce that are adaptable and innovative.

Goldman *et al* (1995) argue that as these new patterns of agile competition emerge the implications for how companies and people need to change in order to be able to prosper in the new environment will be far reaching. Four dimensions of agility were outlined by the Lehigh study and these are as follows (Baker, 1996):

1. Enriching the customer;
2. Co-operating to enhance competitiveness;
3. Organising to master change;
4. Leveraging the impact of people and information.

Goldman *et al* (1995) argue that these four dimensions can be described as competitive spaces in which companies can position themselves to create and exploit customer opportunities. However, if agile manufacturing is to be successful companies must abandon their bad practices, and certainly learn equal lessons from any failures or successes.

2.4 The Virtual Organisation

It has been argued that there is a difference between flexibility and agility and in order for an organisation to be agile, there must first be a degree of flexibility within their

structures and processes. Although the concept of agile manufacturing might seem revolutionary it is a natural evolutionary progression of other business concepts, such as lean and flexible manufacturing (Ross, 1994).

Flexible manufacturing was a concept that emerged in the 1970's and evolved as a means to satisfy customer requirements within an uncertain market environment. Flexibility has been defined by Voss (1992) as:

> *"...the ability to respond effectively to changing circumstances...it should be considered as an interface between the causes of change and the means of response, both of which are monitored by the steps in the manufacturing strategy framework."*

Baker (1996) argues that agile manufacturing differs from flexible manufacturing in that flexibility is applied at operational levels, to describe the state of manufacturing processes and sub-processes, and other resources. If an organisation is agile then all their processes, resources, and strategies at all levels are flexible and re-configurable.

At the heart of an agile manufacturing organisation is a team of companies that will optimise itself for an instant opportunity. Since the early 1990's business organisations, telecommunications companies, and on-line service providers have realised the potential to use global information networks to communicate internally and externally with suppliers, partners, and customers. This prompted some scholars and business people alike to suggest that the ultimate expression of the business organisation and the use of IT in a business context may be the virtual organisation (Campbell, 1998).

There have been numerous attempts at defining virtual organisation. Ward (1997) illustrates that:

> *"...it might be a single room from which administration and manufacturing are outsourced, a single facility with a mobile workforce of road warriors or some other combination of resources."*

Ross (1994) describes a virtual organisation as:

> *"...a temporary, inter-company organisation working as an entity to achieve a specific purpose."*

Byrne (1993) argues that in the concept's purest form, when a company links with others to form a virtual organisation it will be stripped to its essence. It will contribute only what it regards as its core competencies, denoting that individual company's key capabilities. Campbell (1998) argues that as a description of organisational activity, as opposed to a new organisational model, the phrase virtual organisation already describes the behaviour of many successful business organisations. Byrne (1993) supports this argument by claiming that within industries as diverse as film making and construction, companies have come together for years for specific projects, only to dissolve when the project is over.

Constituent elements of the virtual organisation include focussing on core value-adding processes, and working with external partners to bring products and services to the market place. Campbell argues that a number of organisations have improved their

flexibility, and have strengthened their structures through strategic alliances and business relationships, for the purpose of efficient response to market demand. Byrne (1993) notes that the virtual corporation will demand a different set of skills from all managers, and that they'll have to learn to negotiate "win-win" deals for all involved, finding the right partners with compatible goals and values to provide the virtual organisation with the necessary degree of freedom and control. Chesbrough and Teece (1996) argue that the appeal of the virtual organisation lies in our belief that flexibility is good. However, they also argue that companies pursuing the virtual organisation, and rushing to form alliances instead of nurturing and guarding their own capabilities may be risking their future. Byrne (1993) continues this argument stating that the more companies become entangled with others, the more chances there will be for them to stumble. Besides the technological hurdles of information highways and networks of partners that will make the virtual organisation a reality, Byrne also argues that the concept poses new challenges for management. Before companies can more routinely engage in collaboration, they must build a high level of trust in each other. Goldman and Nagel (1993) argue that as trust is formed and secured between agile companies, they are then in a position to form virtual organisations.

Technology is also playing a vital role in the development of agile, and ultimately virtual organisations. Goldman and Nagel (1993) note that the optimal utilisation of technologies that significantly alter the character of production processes may require significant changes in an organisation's managerial values, in its internal culture, even in its organisational structure. They also note that attempting to integrate new technologies, whether they are new manufacturing technology investments or

technologies acquired through an alliance with another company, can certainly have an incredible impact on an organisation's effectiveness. Hamilton (1997) argues that technology is both a driver and an enabler of globalisation, as companies seek to capture the full value of advanced products and services in broader markets. It also follows that as technology drives globalisation, so globalisation influences technological development as organisations require increasingly sophisticated technologies in order to achieve sustainable competitive advantage. Managers must make technology an integral part of their strategic thinking and decision making. There are a number of common obstacles that companies must overcome in their quest to integrate technology and strategy, and managers can experience great difficulty in planning to accommodate the rapid advances that continue to take place within technology research and development. It is the managers of an organisation who need to make the decisions about the kind of technical expertise they wish to posses, and also managers who decide what technologies to acquire, and when and where these should be employed within their company.

2.5 Technology Integration in BAE Systems

According to Iansiti and West (1997) technology integration is the approach that companies use to choose and refine the technologies employed in a new product, process or service. They agree that it is important for a company to have access to good research but argue if a company selects technologies that do not work well together then all kinds of problems can ensue. An effective technology integration process starts in the earliest phases of a research and development project and provides a road map for all design, engineering, and manufacturing activities. Companies who are most adept at

choosing technologies are likely to improve their long term competitive advantage. BAE Systems have recognised this and taken action in order to generate, capture and exploit new technological opportunities.

BAE Systems recognise that innovation and technology are a core competitive arena (Evans and Price, 1999) and have thus developed a senior management forum for visioning salient trends and likely impacts on products, processes and competitive positions. They use the forum to consider the possible business impact of numerous geopolitical and technological paradigm shifts, and as a result of this are fostering intellectual vision with regards to technologies.

When considering investing in manufacturing technology, BAE Systems are aware they will need to keep abreast of technological developments and learn which technologies will give them a significant competitive advantage. They will have to decide the best means for acquiring technology, whether it is best to rely on their own technology research and development base, to acquire technologies through strategic alliances, or to make straightforward investments from external vendors. They must have a firm understanding of their key processes and capabilities and make decisions based on the extent to which the technology they acquire will positively affect their key capabilities and process efficiency. It is important when making investments that BAE Systems are aware of the skills and areas in which they want to excel in the future, and acquire technology with a view to supporting their goals and objectives.

2.6 The Relationship Between Strategy and Investment Decision Making

A strategy is a plan outlining goals and objectives. The means for achieving goals and objectives should be outlined in a strategy, as should the time allocated for achieving the specified goals and objectives. Many definitions of strategy exist and many of these stem from an initial definition by Chandler (1962):

> *"Strategy is the determination of the basic long-term goals and objectives of an enterprise, and the adaptation of courses of action and the allocation of resources necessary for carrying out these goals."*

A definition has been proposed for manufacturing strategy (Wainwright, 1993):

> *"A manufacturing strategy is defined by a pattern of decisions, both structural and infrastructural, which determine the capability of a manufacturing system and specify how it will operate in order to meet a set of manufacturing objectives which are consistent with the overall business objectives."*

As a strategic objective, the decision to invest in manufacturing technology may help a company achieve other strategic objectives. For this reason decision makers need to consider their business and manufacturing strategies when investing in manufacturing technology.

A strategy is implemented through various development programmes and projects. It has been argued that in order to implement a strategy properly, each technology investment project must either be in accordance with the current manufacturing and/or

business strategy or be intended to change the existing strategies. This can be problematic when planning and implementing manufacturing technology (Pirttila and Sandstrom, 1995). Traditional quantitative appraisal methods tend to focus on the short term monetary returns that an investment project yields. Financial considerations should, of course, be of paramount importance when making an investment decision but it has been argued that companies should also consider the effect an investment will have on realising other manufacturing and business objectives outlined in their strategies

With regards to strategy, strategic planning must be considered at all levels throughout an organisation's hierarchy to ensure that all objectives, business and manufacturing oriented are supported. Strategies operate on different levels within an organisation (Wilson, 1995; Jones and Lee, (1998):

- Corporate strategy which deals with the allocation of resources amongst various businesses or divisions of an organisation;
- Business strategy which deals with the question, at a divisional or business unit level, of competitive positioning;
- Functional strategy which deals with the actions of specific functional departments.

There are two key aspects of strategy development – process and content. Focussing concern on the process of strategy development allows organisations to understand how their strategies are shaped through their organisational processes. It is through these processes that technology investment projects are identified, developed, justified and

approved. The content of a strategy refers to the goals and objectives a company wishes to achieve. The company should set its competitive priorities and then outline the means by which it hopes to realise these.

The most important elements of the content of the manufacturing strategy can be expressed in two categories (Pirttila and Sandstrom, 1995):

- Competitive priorities based on organisational and/or business unit goals;
- Decisions that are of long term importance in the manufacturing function.

As there are different levels of strategy constructed by managers at differing levels in an organisation, one may assume that the content of strategy varies in relation to the nature of its strategic priorities. A study conducted in the mid 1990's (Jones and Lee, 1998) concluded that relating strategic considerations to the financial appraisal process could enhance the success of technology implementation, the reason for this being that the decision makers had been careful to outline specific strategic objectives for their investment. A further point raised through the Jones and Lee study (1998) is that often those involved in the implementation of an investment have a different understanding of the company's strategies. Personnel on the "shop floor" may have a greater awareness of the functional strategy and little or no awareness of the business strategy. This effects the investment decision as those personnel involved in the implementation on a day to day basis may have specific intentions for the investment compared to those outlined by personnel involved at a less functional level. This raises the point that an investment can have a number of effects on the many different levels that exist within a

company. It is for this reason that personnel from all levels should be involved in the investment decision.

2.7 The Short Term Nature of Investment Decisions

There has been much discussion of the tendency for managers to appraise investments with the focus on maximising short term financial returns. Ultimately an organisation will hope to increase profit through their investments, and hence it is necessary to judge an investment on the extent to which it will contribute in the long and short term to the organisation's cash flows and profit levels. However, it may not be enough for managers to select an investment on the basis of short term financial returns.

Many reasons have been highlighted to suggest why managers should adopt a less short term approach to investment appraisal. Firstly, such a short term approach to investment appraisal may lead to a loss of market opportunities as a result of managers' poor perceptions of their company's capabilities. Also, modern technologies are becoming increasingly sophisticated and it may take longer for both financial and non-financial benefits to be realised.

Further criticism has been directed towards the level of investment achieved by companies. Short termism has been described as a culture of low levels of investment, and a desire for easy financial returns (Wilkes, Samuels and Greenfield, 1996). Managers are under increasing pressure to prove their worth by raising profits and it is due to this that there is greater emphasis on short term financial results. It has also been suggested that managers are reluctant to invest and take the risks that are associated

with investing (Lefley and Sarkis, 1997). As a result of this companies may start lagging behind their foreign competitors in acquiring sophisticated technologies.

Furthermore, methods for investment appraisal have also come under scrutiny in the argument about short termism. Traditional quantitative methods may not be suitable for appraising sophisticated modern technologies and fully representing the longer term benefits that may arise. It is argued that modern technologies have many strategic benefits which may not be realised in the short term. As Meredith and Suresh argue (1986) the basic problem is that many of the advantages of modern technologies lie in more nebulous, "strategic" areas such as shorter lead times, simpler scheduling, and more consistent quality.

Managers have typically appraised investments with a view to increasing cash flows, raising profit, increasing capacity and cutting costs. Quantitative appraisal methods may be suitable for providing accurate results with regards to all of the above but may not account for what have been named "strategic", indirect, or intangible benefits. Furthermore, managers may not understand how to account for intangible benefits or perhaps may not believe it is necessary to account for benefits that are not financial in nature. The outcome of this is that researchers have begun to focus their attention on identifying appraisal methods that are appropriate for identifying intangible and strategic benefits.

2.8 Decision Making

Early literature argued that capital budgeting theory was progressively seeking to improve techniques for the appraisal of capital projects (King, 1975). Regarding the appraisal of investments, managers were informed they should consider the effect that technology implementation can have on their company systems and processes in the appraisal process. With regards to the progress of capital budgeting it was argued that corporate management should strive to develop a process of decision making which in the end allows them to approve the majority of capital investment proposals (King, 1975). This argument offers support to this research project in that it calls for focus on the process of capital budgeting, and the development of this process in order to allow management to make more informed decisions.

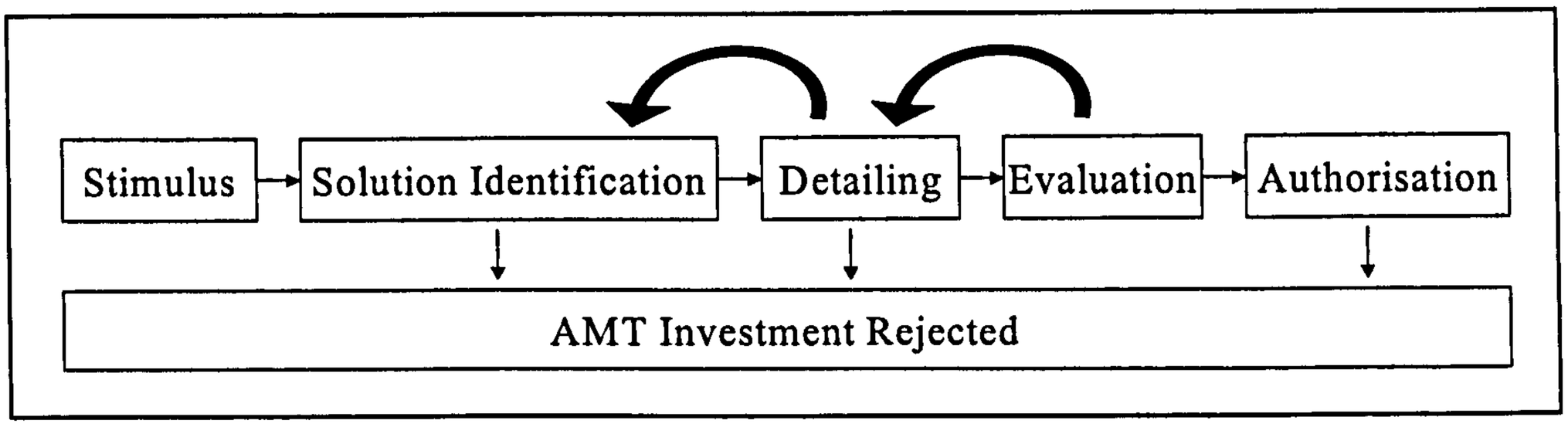
There have also been calls for corporate management to develop the process of capital budgeting so that ultimately the investment process will reflect the corporate strategy. Fuelled by the changing business environment and the move out of mass production into mass customisation, there has been even greater focus on the need to appraise investments in relation to corporate strategic objectives.

There have been many changes in manufacturing with regards to the working philosophy. The adoption of "process-based" management rather than "function-based" management has meant that the role of some managers has changed. From the time when a customer outlines their requirements, right through to the final delivery of the product, managers are required to guide this sequence of processes. This change in philosophy, as well as the cultural changes in management style, requires the

application of tools for managing the process. It is the application of these manufacturing derived process management tools which provides the need for, and focus of, much research at present (Morris, Rogerson and Jared, 1998).

Technology has become increasingly complex over the years and technological advances are expected to continue for many years to come. If strategic and financial gains are to be reaped through technology investments then the process for investing should be so that the problems associated with technology implementation are minimised. The resources committed to technology investments in terms of time, money, coupled with the importance of the actions taken throughout the process, establish technology investment decisions as strategic in nature (Kumar, Murphy and Loo, 1996).

A survey was conducted in the mid 1990's (Kumar, Murphy and Loo, 1996) which focussed on the decision process for investing in manufacturing technology. From their sample firms they discovered that all technology investment decisions begin with the identification of an opportunity, and end with the authorisation or rejection of the proposed investment. It is necessary to note at this point that the research only concentrated on the initial stage of the decision process, a stage concerned primarily with choosing the most suitable technology to purchase. Using management decision making literature and results from the survey a framework was constructed representing the entire technology decision process. This framework is shown in **Figure 2.2.**



Source: Kumar *et al* (1996), *figure 1.*

Figure 2.2: Model of the AMT Investment Decision Process

This is a general model to represent the decision making process in companies investing in manufacturing technology. The model is divided into five main stages and these stages have sub-components and activities. Kumar *et al* (1996) also note that the decision process is not linear in nature and that the decision makers may return to the *detailing* and the *evaluation* stages if the outcomes of these are not satisfactory.

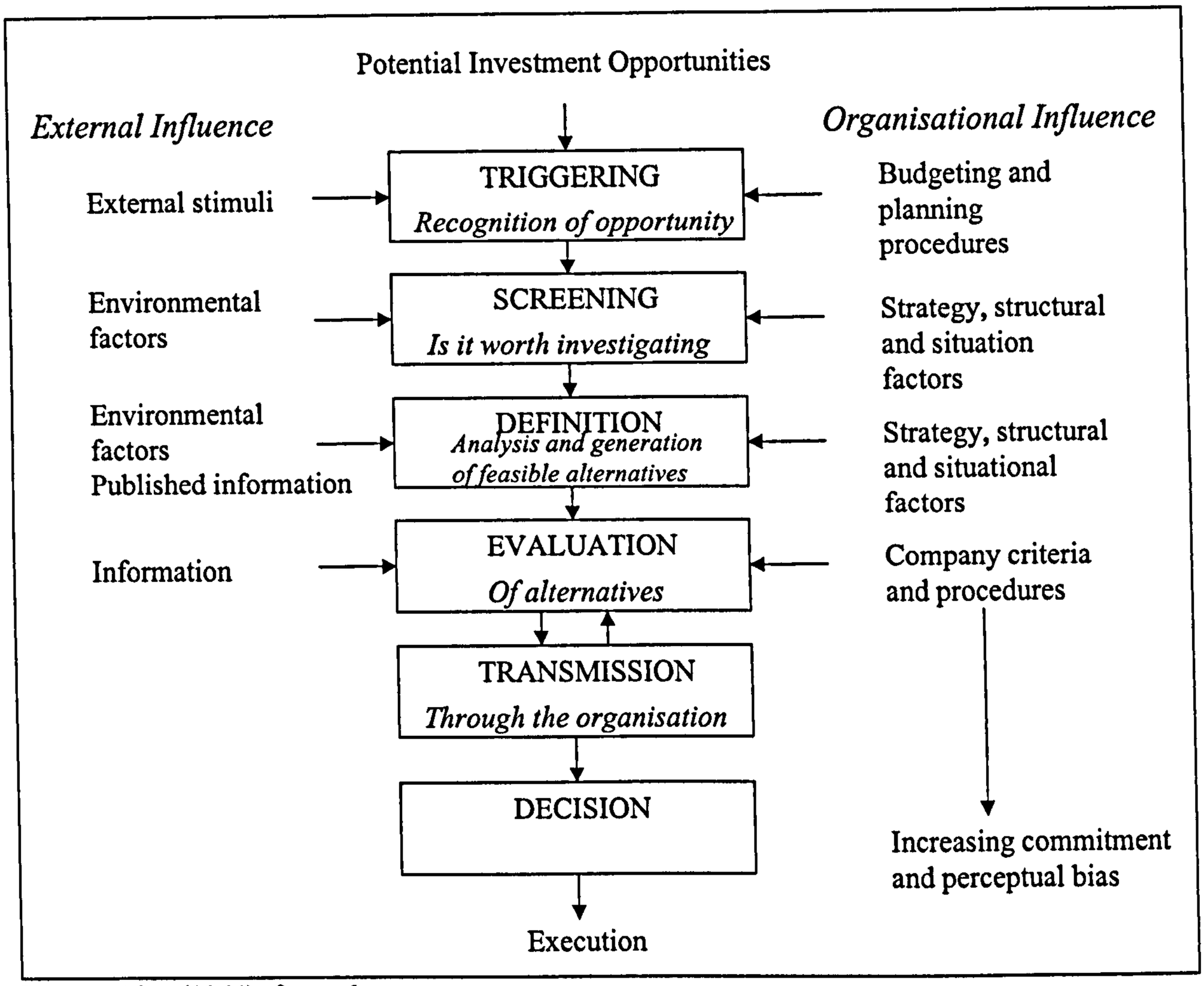
This model is similar in many ways to a model developed by King (1975). Both models were developed after extensive research within a number of companies. The King model has six stages and the first stage – *Triggering* – denotes the recognition of an opportunity. The first stage in **Figure 2.2** (Investment Decision Process) is called the *Stimulus* stage and it is at this stage that potential ideas, or investment choices, are introduced into the process. The following two stages in this decision model – *Solution Identification* and *Detailing* - can be likened to the *Screening* and *Definition* stages in King decision model. In the model in **Figure 2.3** these stages are concerned with recognising a problem, outlining possible solutions, and then gathering sufficient information about these solutions to be able to make a shortlist of potential investment choices. The *Screening* stage in the King model represents the activities concerned with collecting information, and identifying factors which may or may not influence a

decision. The *Definition* stage is concerned with investigating the information gathered during the *Screening* stage and "entails imaginative search for possible forms of the investment which meet the needs identified" in the *Screening* stage.

Both models contain *Evaluation* stages where alternatives are assessed and ultimately a decision is made and an investment is accepted or rejected. However, King mentions that this stage *"typically.....will include the collection of further information and the quantification of previously qualitative judgements."* There is no indication that purely qualitative methods were employed in the *Evaluation* stage and one may assume from this statement that it was necessary to quantify the qualitative factors in order for a choice to be made. With regards to **Figure 2.2** (Kumar *et al,* (1996) it was noted that this stage comprised of qualitative and quantitative appraisal methods.

The final stage in the King model is the *Transmission* stage, and it is at this stage that any investment choices are communicated to necessary personnel. The *Decision* stage is the point at which an investment choice is made and the necessary funding is arranged. In **Figure 2.2** the final stage is called the *Authorisation* stage. At this stage information is prepared for the decision makers and the investment choice is either approved or rejected.

The King model was developed to represent the process of decision making, a process which is said to consist of choices. These choices are then evaluated through their possible consequences. This model is shown in **Figure 2.3.**



Source: King (1974), *figure 1.*

Figure 2.3: The Decision Making Process

King refers to this model as an *idealisation.* Not all information and data pertaining to the process of decision making can be contained in such a model hence King concludes it is for this reason that further research into the process of decision making, and decision making in investment appraisal, is necessary. In other words, further research is always necessary to assist decision makers with their task of choosing the most appropriate investment. To summarise:

> *"Good capital investment decision making is seen as synonymous with good evaluation."*

2.9 Selecting The Most Appropriate Appraisal Method

When speaking of investment appraisal Primrose (1991) argued that it must not be treated as giving a yes/no verdict. It is a technique which is only an aid to management decision making but, as such, it has to be used as an integral part of the process of selecting investments. The profitability of an investment is only one of the criteria to be considered. Primrose (1991) also argued that once the nature and reasons for investment appraisal have been correctly identified, it is possible to look at the problems faced by companies when trying to appraise manufacturing technology.

Primrose argues there are two types of problems relating to the appraisal of manufacturing technology investment choices. The first is the technical problem of using investment appraisal techniques, while the other is the conceptual belief that many of the benefits of manufacturing technology are intangible and cannot be quantified in financial terms. Problems can arise from the appraisal process in that it must be concerned with identifying changes in cash flow and measuring any cash savings that arise from the investment (Primrose and Leonard, 1987). Hence, by using financial appraisal methods it is possible to account for financial benefits associated with an investment but not so easy to account for non-financial benefits. Meredith and Suresh (1986) also argue that there are some investment situations where financial appraisal methods are more suitable yet there will be other situations where it may be necessary to employ other appraisal methods whether these be analytical, strategic, or a combination of methods.

Finnie (1988) also suggests that the problem lies in the effectiveness of the conduct of financial appraisals. This argument is also supported by Meredith and Suresh (1986) who argue that managerial attitudes and policies can create problems in the investment appraisal process. Middaugh and Cowen (1987) argue that an overemphasis on short-term results and an overly conservative attitude towards risk can have a profound impact on the financial appraisal of manufacturing technology investment projects. As a result managers may under-invest which may in the future put them in an unfavourable competitive position in comparison to more innovative competitors.

Finnie (1988) also outlines "problems" associated with the financial appraisal of manufacturing technology investment choices. Finnie suggests an education problem, this being that the accountants who provide the financial information for the evaluation need to be made aware of the equipment's special characteristics. This also applies to the managers who will assess the information. Secondly, Finnie also argues that it is not always possible to account for special characteristics of the equipment under evaluation hence other appraisal methods are required.

Furthermore, it is possible for managers to underestimate the effect an investment in manufacturing technology can have on their present systems and processes. Large scale investments can have a substantial impact across the whole company (Pike, Sharp and Price, 1989) and it is important that managers consider this effect when appraising potential investment choices. Meredith and Suresh (1987) also argue that the impact of more sophisticated manufacturing technologies is often far more significant than expected and can create problems for managers trying to justify an investment and

assess its benefits. Lefley (1994) continues this argument by suggesting that if managers have a greater understanding of the risks associated with an investment decision then they will be in a better position to appreciate the full implications of their decision.

Despite the belief that financial appraisal techniques are becoming redundant for appraising modern technologies Kaplan (1986) suggests that managers should persevere even if they are experiencing problems in their application. One way of overcoming this problem is not just to rely on faith alone, but to become more familiar with the special attributes of sophisticated technologies. However, this may be difficult for companies with little or no experience of large investment projects. Also, companies must learn to differentiate between overcoming problems associated with investing in manufacturing technology and learning to live with any difficulties arising from such investments.

Lefley (1994) adds another dimension to the argument regarding the suitability of financial appraisal methods. He argues that basic methods such as IRR (Internal Rate of Return), NPV (Net Present Value) and Payback suffer from a basic inadequacy in that they ignore, or are incapable of taking into account, management's flexibility to revise its original strategy if future events are not as originally predicted at the outset. Lefley also refers to intangible benefits as "real options" and argues that it is important for managers to realise that these options have a value which should be taken into account when technology investment choices are being proposed. Examples of options are:

- The option to make follow-on investments if the immediate investment succeeds;
- The option to abandon a project;
- The option to wait and learn before investing;
- The option to reduce the size of the initial project.

Lefley goes on to argue that this "option theory" approach to manufacturing technology investments has important implications in that if the option value is not taken into account in the initial appraisal of technology investment proposals, then the company may reject an investment which may have otherwise proved profitable and/or less risky in the long term. Managers may find it difficult placing a value on an option or using current option valuation models but Lefley argues that it is important that managers are aware that options and opportunities can be created through manufacturing technology investments. Putterill *et al* (1996) also argue that there are always going to be a number of elements associated with the manufacturing technology investment process which require greater attention. The challenge for managers is to ensure that each receives attention and that organisational arrangements are in place to aid the implementation of the technology and to help achieve synthesis. Furthermore, it has also been argued that no investment process is likely to produce outstanding results without the appropriate organisational attitude, and progress towards a learning organisation (Putterill *et al,* 1996).

2.9.1 Financial Appraisal

Discounted cash flow techniques are often referred to in relation to manufacturing technology investments. NPV (Net Present Value) and IRR (Internal Rate of Return)

are the principal techniques used in discounted cash flow calculations. Research conducted by Pike (1982) suggested that the IRR method, although less extensively used than payback, is the most popular primary DCF appraisal technique. NPV was shown to be a less popular appraisal method, although Pike suggests this clashed with literature at the time which claimed NPV to be a very popular method for investment appraisal. Lefley (1994) noted also the use of DCF techniques for appraising manufacturing technology investments but argued the decline in their use since research conducted in the 1980's.

According to Sangster (1993) these techniques are more time consuming and, therefore, more costly to use than the other principal techniques – ARR (Accounting Rate of Return) and Payback. Pike (1982) suggests that managers are attracted to Payback as it is a relatively simple technique to use and understand. A later study conducted by Lefley (1994) also revealed Payback to be a highly popular method for investment appraisal. With ARR, Pike suggests that managers are attracted to this method because it relates the project's return to the return on the business as a whole.

Kaplan (1986) entered the debate about DCF techniques suggesting that the DCF approach most often goes wrong when companies set arbitrarily high hurdle[1] rates (Brealey, Myers and Marcus, 1991) for appraising new investment projects. This continues an argument proposed by Pike (1982) who suggested that setting high hurdle rates for investment projects can lead to missed opportunities for growth, while an understating of these rates may result in the acceptance of non-profitable projects.

[1] The hurdle rate is the required rate of return for a capital investment project.

Kaplan also suggests that companies should use a discount rate (the discount rate being the rate of interest used in calculating the present value of investment projects) that is based on the project's opportunity cost of capital (that is, the return available in the capital markets for investments of the same risk). Finnie (1988) argues that it is common for companies to seek projects which have short payback periods over projects with defferred pay-offs. He argues that the criticism to be considered is that the use of DCF techniques is to bias financial evaluations in favour of expenditures which promise rapid pay-offs and against expenditures with longer pay-offs, such as investments in manufacturing technology.

However, Myddelton (1995) argues that even where one of the DCF techniques appears to show that a project is worthwhile it is still important for managers to take further measures to prove to themselves that an investment project is worthwhile. With regards to risk and accounting for risk in DCF calculations, Chan (1996) argues that companies make many common errors. Using an excessively high discount rate is one error, yet a further error can occur when managers use nominal interest rates to discount future cash flows, but make no adjustment for inflation in the cash flow. Support is offered to this by Wilkes *et al* (1996) who argue that research has revealed that the breadth of outlook by companies varies and this can influence how managers view the significance of inflation and interest rates.

2.9.2 Strategic Appraisal

The process of appraising investments in manufacturing technology is one that is influenced by a number of factors. The methods employed by decision makers to

appraise investments will vary from company to company, investment choices will range from stand alone machines to large-scale fully integrated systems, and the culture of the company and the personalities of the decision makers will also have some effect on the process. All in all, these factors go towards making the process of investment decision making complicated and subjective. Stainer *et al* (1996) divided these influencing factors into *internal* and *external factors.* These internal and external factors are shown in **Table 2.1**.

As manufacturing technologies become more sophisticated, and business operations become more globally focussed, managers will need to conduct their investment appraisal process with their company strategies in mind. The common argument with regards to investing in manufacturing technology would appear to be the use of quantitative methods for appraising investments. Traditionally, manufacturing technology has been justified using traditional evaluation methods such as payback, internal rate of return, etc. but with the changing business environment, and the emergence of agility, researchers have argued that financial methods alone are not enough for justifying technologies.

Furthermore, financial methods must be used correctly otherwise the results of using these methods may be inaccurate. The results of using such methods may be manipulated to place the investment in a more favourable light to enable managers to sell the investment to their peers. Meredith and Suresh (1986) argue that new manufacturing technologies could be considered to span a continuum in terms of level of integration. This continuum is detailed in **Figure 2.4**.

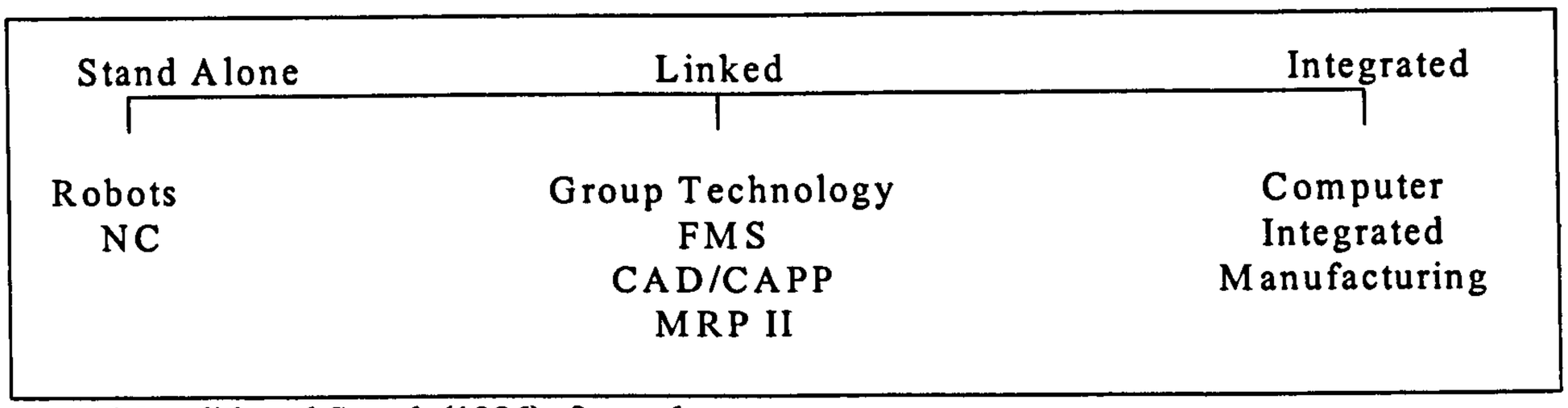
Internal Factors	*External Factors*
Methods used to assess manufacturing technology investments	Financial environment
Nature of corporate governance	Behaviour of competitors
Culture of the organisation	Fiscal and regulatory framework
Level of technological confidence	

Source: derived from Stainer *et al,* (1996).

Table 2.1: Internal and External Factors Influencing Manufacturing Technology Investment Decisions

It is argued that these manufacturing technologies possess certain characteristics that make their justification through appraisal more complex. These technologies are more flexible and it has been argued that it is difficult to quantify the benefits that are offered by flexible technologies and systems. Furthermore, it has also been argued that due to the increased sophistication, and often cost, of these technologies the risks involved in acquiring such technologies are raised. Managers may have difficulty trying to quantify the risks not only involved during an investment's implementation, but also the risk to the company's supporting infrastructure that may have been changed substantially to accommodate the investment.

Small and Chen (1997) noted the growing consensus towards the use of strategic and financial appraisal methods for evaluating manufacturing technology investment proposals. They also agreed that a key issue when considering investment proposals is to determine the variables that should be used to measure the performance of the system.



Source: Meredith and Suresh (1986), *figure 1.*

Figure 2.4: The Advanced Manufacturing Technology Continuum

By understanding the key areas the company wishes to improve upon, the decision makers can set reasonable performance measures for an investment which are attainable and preferably in alignment with business and/or manufacturing strategies.

Meredith and Suresh (1986) noted three justification categories and these are shown in **Table 2.2**. These justification categories represent the divisions in literature with regard to investment appraisal techniques for manufacturing technologies. The authors argue that these three categories of "justification" techniques correspond to the technologies listed in **Figure 2.4**. However, more recent arguments have focussed on the need to use a combination of these appraisal techniques with research being initiated to develop suitable hybrid models, such as weighted scoring models (Small and Chen, 1997) which allow decision makers to assign values to each tangible and intangible factor under consideration.

With regards to strategic investment appraisal Primrose (1991) argued that if strategic benefits are not quantified in the appraisal, they will appear as unexplained variances not attributable to the project through accountancy reports. Also, research conducted by Small and Chen (1997) suggests that there are significant tangible and intangible

benefits to be gained from implementing manufacturing technologies and that failure to account for all benefits is detrimental to the decision making process, whether the project is accepted or not. Hrebiniak and Joyce (1984) (Voss, 1986) proposed a general model for the implementation of strategy. This model is illustrated in **Figure 2.5**.

Economic Approaches	*Analytical Approaches*	*Strategic Approaches*
Payback	Value Analysis	Technical Importance
Return on Investment (ROI)	Portfolio Analysis	Business Objectives
Internal Rate of Return (IRR)	Risk Analysis	Competitive Advantage
Net Present Value (NPV)		Research and Development

Source: derived from Meredith and Suresh (1986).

Table 2.2: Classification of Justification Methodologies

Voss believed this model could be tailored to the context of Advanced Manufacturing Technology. He proposed his own model based on the Hrebiniak and Joyce model as a framework for the strategic implementation of advanced manufacturing technology. This model is shown in **Figure 2.6**. Voss argued that it is vital to give proper consideration to implementation and a strategic input is needed if the full potential of the technology is to be realised. However, the results of the Small and Chen study suggests that decision makers are not using sophisticated methods designed by researchers to assist with strategic investment appraisal. It may be that companies do not have the time to use such models and that often they are too complex to be applied (Nair, 1995).

Making a decision to invest in manufacturing technology can be fraught with difficulties. Often managers may have a number of technology investment choices from

which to choose, and it is time consuming having to determine which investments offer the most financial and non-financial benefits.

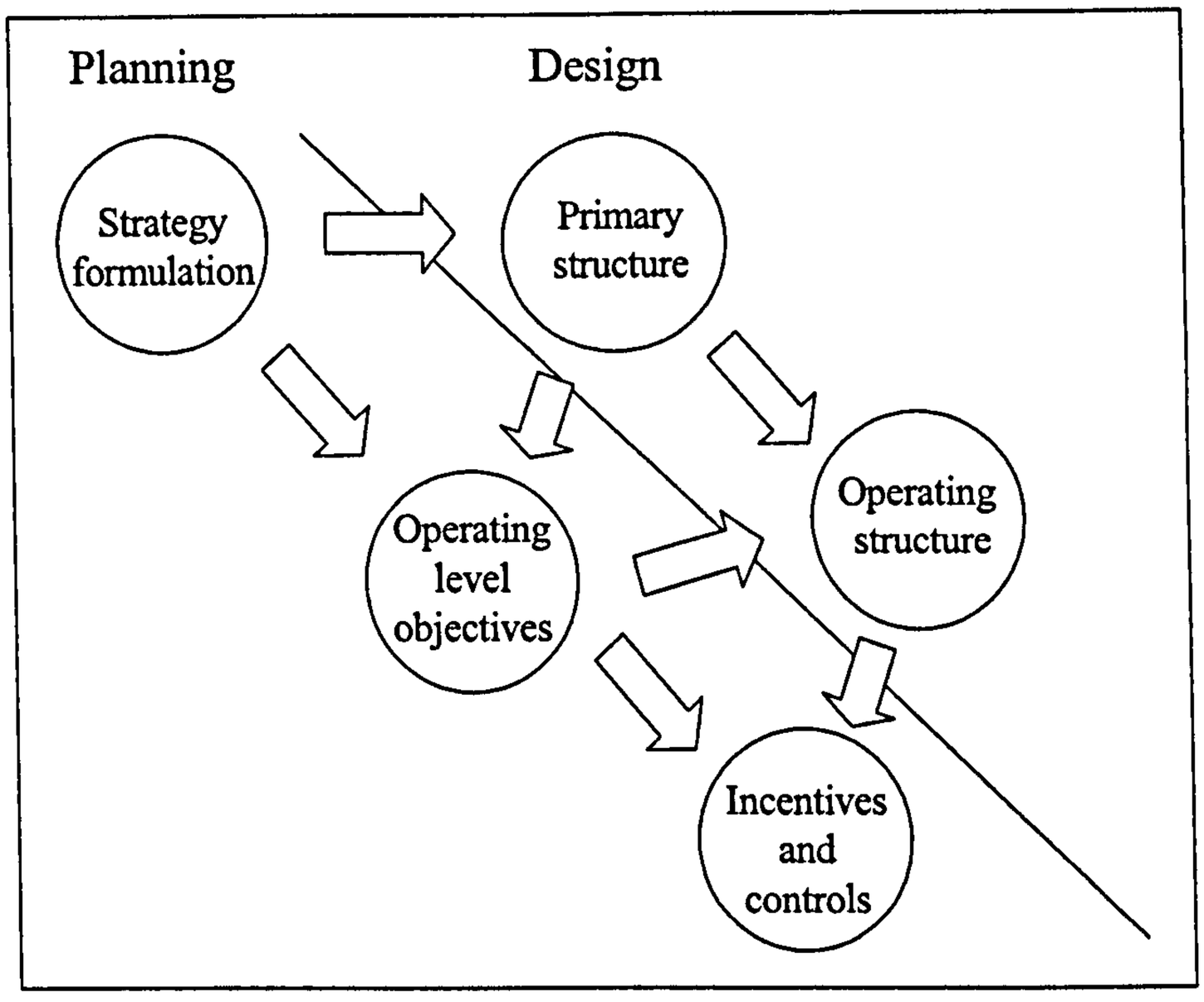
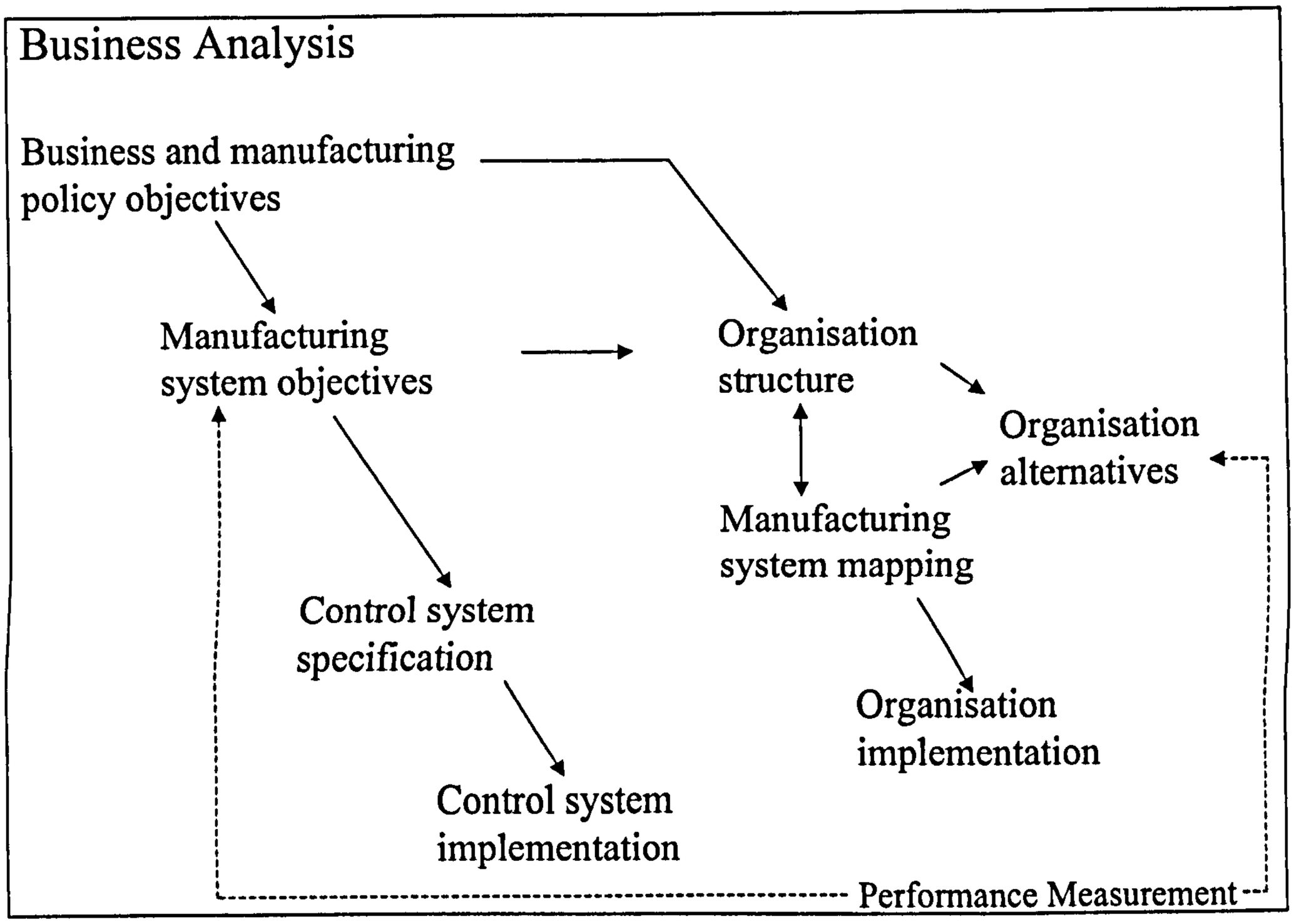


Figure 2.5: Outline of the Framework for Implementation

2.9.3 Recent Developments in Investment Appraisal

A variety of techniques have been used over the years for best determining the most suitable choice of investment yet it has been argued that it is possible for managers to overlook the impact investment choices will have on their core business processes and systems. As yet, it would appear that no one tool can allow managers to fully appraise an investment, taking into consideration all financial and non-financial benefits that may be realised, and the impact the investment will have on the company, and its processes as a whole.



Source: Voss (1986), *figure 3.*

Figure 2.6: General Methodology for Organisation and Control of Manufacturing Technology

Angelis and Lee (1996) discussed the use of Activity Based Costing (ABC) concepts in the appraisal process for manufacturing technology investments. In more recent years ABC has been used to determine the cost of products based on a managerial analysis of core product processes and activities. ABC costing can be effective in that it allows management to establish priorities, and if it leads to more accurate costs then it is argued that better decisions should follow (Myddelton, 1995). Angelis and Lee developed a methodology that may be used by managers when considering technology investment choices. Their methodology incorporates ABC principles which allow them to focus on how an investment contributes towards cost savings over their business activities. The methodology ties investment decisions to ABC concepts using what is known as the Analytical Hierarchy Process (AHP). Their methodology can also be used

to assess how the investment will affect the performance of core activities. This focus on the activities allows the managers to follow how the investment will ultimately support the company's strategic goals.

The AHP was developed in 1980 by Saaty to structure complex, multi-attribute problems (Angelis and Lee, 1996). Since its development, it has become absorbed into research conducted in the quest to develop industrially useful strategic appraisal methods. As an approach for decision analysis it is useful, structuring decisions into a hierarchy of elements. This approach then establishes shares of influences, or relative weights, among the elements through a sequential process of pairwise comparisons. The pairwise comparisons are based on judgements about the relative differences among comparable elements (Mohanty and Deshmukh, 1998). The relative weights are combined to derive a single overall rating for each decision alternative (Chan, Chan, Mak and Tang, 1999).

Chan *et al* (1999) propose a model for manufacturing technology appraisal which integrates strategic, economic, and analytical appraisal techniques for quantifying tangible and intangible benefits. The model incorporates a manufacturing strategy map which shows the interdependence between the decision areas and the manufacturing outputs within the company. The analytical hierarchy approach is also incorporated to allow for an analysis of the non-financial aspects of the investment choice, and to allow these to be weighted and compared. A mathematical, namely the state-price net present value (SP-NPV) tool, is incorporated to calculate financial data which is incorporated into the analytical hierarchy assessment.

The state-price net present value tool was born out of developments in finance theory, and was developed simultaneously by Banz and Miller, and Breeden and Litzenberger in 1978 (Chan *et al,* 1999; Krinsky and Miltenburg, 1991). It is relatively easy to understand and use, no estimate of the discount rate is needed, and data requirements are small. Chan *et al* (1999) argue that in comparison to the NPV method, the SP-NPV deals with uncertainty by adding more terms to the present value calculation. The cash flows are weighted across both time and uncertain states, rather than just across time.

Presley *et al* (1995) developed a business case tool for the strategic justification of manufacturing technologies. Their tool was developed in response to their perceived shortcomings of traditional appraisal techniques. The SJET (Strategic Justification for Enterprise Technologies) tool uses a range of techniques and methods which are integrated into a comprehensive methodology and deployment toolset. The deployment tools consist of a workbook and a supporting software decision support system.

2.9.4 Performance Measures

More recent research has focussed on integrating management accounting and investment appraisal for manufacturing technology. However, it is important to remember that there are many factors that can influence the use of traditional and modern appraisal techniques, for instance, managerial experience, company size, culture, and operating environment. Not all companies will adopt uniform approaches to investment appraisal, and what works for one company may not for another.

Clarke (1995) notes one of the main criticisms of accounting is that the information and data it provides are too narrow for strategic decision making, and that many earlier arguments for traditional investment appraisal (accounting) methods do not account for less financially oriented investment benefits. Clarke also suggests that investment appraisal should focus less on the cost savings arising from an investment and more on the strategic benefits that may be generated. This, in turn, gives rise to the need for non-financial measures of performance to enable a company to monitor its progress towards achieving non-financial goals.

Slagmulder and Bruggeman (1992) also noted the increasing dissatisfaction with traditional investment appraisal techniques and argued that improving management accounting procedures would go one step further towards more effective investment decision making. Tayles and Walley (1997) also followed this argument suggesting that companies should evaluate and appraise their strategies if they wish to set specific costing and performance measures. They argue that strategy development begins with the definition of the organisation's objectives in terms of growth, profit, return on investment and other relevant criteria. In turn, these objectives should influence the development of other strategies and be aligned with, and support top level strategies. The link between performance measures and the business and/or manufacturing strategies is important. This link can be very effective in monitoring and controlling the performance of manufacturing technology investments.

It has been suggested (Tayles and Walley, 1997) that deriving performance measures from a company's costing system, e.g. from cost drivers is effective for monitoring a

company's technology investments. They go on to argue that costing systems need to be compatible with the characteristics of the manufacturing system, because they must assist in the measurement and control of operations. Ultimately, it is argued that it is useful to design a company accounting system that reflects in some way the company's manufacturing and business strategies. For a management accounting system to be effective, accountants need to evaluate their company's strategies and take these into account when assessing their accounting systems. By following this approach it is argued that some companies may find it easier in adjusting to internal changes, such as an investment in manufacturing technology, and external changes.

Managers and decision makers are always going to be interested in and motivated by investments which generate positive cash flows, and ultimately contribute towards increased long term profit. Clarke (1995) argues that there needs to be a greater emphasis on which aspects of performance measurement need to be captured by management accounting systems. With regards to investments in manufacturing technology this increased emphasis is highly important for companies. Achieving a greater understanding of how to measure performance and how to best achieve such measures (and move towards achieving overall company goals) should assist companies in their decision to adopt new technologies or adapt old technologies.

2.10 Implementation and Management of Technology Investments

Introducing technology investments into a company can present all kinds of challenges to managers. Many of these challenges will need to be overcome if the investment is to be introduced and then implemented efficiently and effectively. There are many

reasons why a company should wish to invest in manufacturing technology. Small (1998) argues that the prime motivation for the installation of manufacturing technologies is to improve manufacturing and/or business operations and consequently to improve company competitiveness. Amoako-Gyampah and Maffei (Small, 1998) suggest three major objectives for the adoption of manufacturing technology, these being:

1. Modernisation – a commitment to the factory of the future;
2. Marketing – emphasising superior products with high quality and relatively low costs;
3. Operating - to meet technical and operating needs that are not adequately addressed by the company's existing technologies.

Primrose (1991) suggested that managers outline what they want to achieve through their investment, and what they require from the implementation before they attempt to choose an investment. However, the adoption of manufacturing technology depends on many factors in order for it run smoothly. Beatty (1990) suggests that managers adhere to three main paths to aid the smooth absorption of a manufacturing technology investment.

These are as follows:

- Ensuring that a capable investment project champion (or leader) directs the implementation effort;

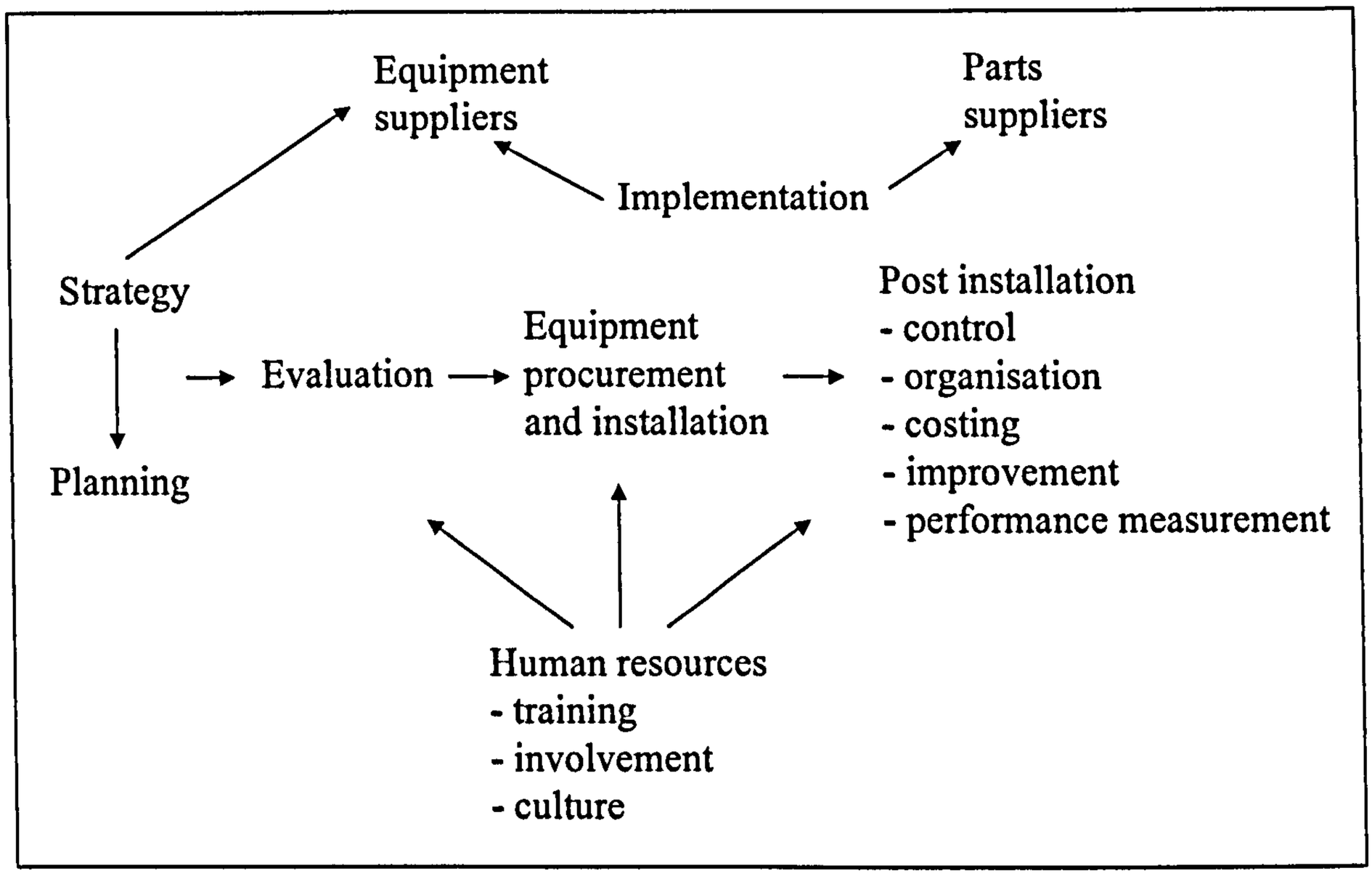
- That systems are integrated;
- The right mix of teams is used for organisational integration.

Leonard-Barton *et al* (1985) also outlined the challenges that managers must face when considering how to best introduce a manufacturing technology investment:

- Early involvement of the technology supplier in the process to inform users;
- Organising the infrastructure to receive the investment;
- Choosing the most suitable site for housing the investment;
- The need for one person to champion the investment;
- Providing training for those users who need it and providing information about the investment to overcome resistance to change;
- Setting long term goals, as the investment may take time to reach projected targets.

Voss (1988) argues that too many managers believe they have successfully adopted manufacturing technology when the investment is technically performing correctly. However, Voss goes on to argue that getting the technology to work is just one step towards successful manufacturing technology adoption. Full success can only be realised if performance measures are being matched, the desired benefits are achieved and competitiveness is increased. A process model for managing manufacturing technology is also proposed by Voss (1986) and this is shown in **Figure 2.7.**

The model emphasises stages in the process of managing manufacturing technology and key elements that have been the subject of much academic research over the years. This is a very brief outline of the process of managing advanced manufacturing technology as no model can include all pertinent information



Source: Voss (1986) (a), *figure 1.*

Figure 2.7: Managing Manufacturing Technology: A Process Model

2.11 Chapter Summary

This Chapter has examined the issues relating to investing in manufacturing technology. A problem statement was presented, outlining these issues and how they are interrelated. The relationship between strategy and investment decision making was discussed to show the importance of relating investment decisions to functional and business level strategies so that investments ultimately support the company goals.

There has been much discussion of the problems with investing in manufacturing technologies. When making decisions based on financial calculations it has been

argued that managers are inclined to favour appraisal results that show financial returns in the short term. There are problems associated with this in that it takes time for an investment to be successful not just in financial terms but in strategic terms. Managers may reject an investment proposal that, in time, may be highly beneficial to their operations based on inadequate short term financial returns. Furthermore, it has been argued that managers become unwilling to invest because they fear investing in technologies that may take years to be financially and strategically beneficial. This leads to the argument that more strategic investment appraisal methods are required to enable managers to fully appraise an investment proposal so that more intangible benefits are quantified, not just the tangible benefits.

When developing methods for use within companies for the strategic appraisal of manufacturing technologies, researchers should consider the complexity of their method. Further research is required to develop models that may be easily employed within companies for assessing the strategic benefits of manufacturing technology investments. While there are substantial benefits to be gained from investing in manufacturing technology it is important that managers are fully aware of what they want to achieve from an investment, strategically and financially, and that their investment projects are managed to allow for all benefits to be realised.

Chapter 3 A Current Perspective on Investment Appraisal: postal survey results

Abstract

The previous Chapter examined literature surrounding the process of investing and implementing manufacturing technologies. However, a requirement of the Engineering Doctorate programme is that the research conducted must be of relevance to industry. To satisfy this requirement it was necessary to conduct a survey of a selection of companies to offer support to issues raised in the literature review. The results of the survey are detailed in this Chapter. Prior to conducting the survey it was necessary to gain an understanding of how the nature of manufacturing has changed over the years and to speculate how these changes will affect the way in which companies acquire manufacturing technologies in the 21st century. A review of these changes is presented and the results of the survey follow.

3.0 Introduction to the Postal Survey

The literature review, details of which are contained in Chapter 2, reveals that there is great concern about how to qualitatively and quantitatively appraise manufacturing technology investments considering the changing nature of manufacturing. The argument that manufacturing is experiencing a paradigm shift from mass production to mass customisation further compounds problems for companies wishing to invest in manufacturing technologies, as mass customisation introduces the need for agile production processes and resources.

BAE Systems are aware of how the nature of conducting business is changing. As Evans and Price (1999) argue, without partnership skills, defence and aerospace companies do not get a seat at the bargaining table. They also believe in the inevitability of more prevalent joint venturing in the future European and global market for defence equipment. The merger in 1996 of British Aerospace plc and Largardere Group SA, to create Matra British Aerospace Dynamics, was yet another addition to a long list of organisational and cultural changes that have taken place since the formation of British Aerospace in 1977. Their £7.8 billion merger with Marconi Electronics further signalled the new BAE Systems change in approach towards achieving a consolidated defence industry through strategic alliances.

However, there are serious implications for companies considering forming alliances with regards to acquiring technology. As Matra British Aerospace Dynamics learned, merging with another company can raise a number of problems with regards to integrating and introducing new investments. The joining companies may have incompatible technologies and systems, and there will undoubtedly exist anomalies in management styles and culture. A few examples of the kind of issues facing companies entering into alliances relate to technology research, technology development practices, and technology investment policies and objectives. For companies not engaging in this collaborative behaviour the process of investing in manufacturing technology is still fraught with problems. Hence, further research was necessary to investigate the investment practices of companies considering how the global nature of manufacturing is changing.

3.1 Developing the Survey

In order to understand how modern companies are making technology investments whilst adjusting to the evolution of manufacturing and emergence of mass customisation, it was necessary to survey a selection of companies. 150 companies were selected from the Edinburgh Engineering Virtual Library (EEVL) database and were taken from a list of suppliers to the defence market sector. As the sponsoring company, BAE Systems, is a defence company it was decided to limit the survey to the defence sector. This was the only parameter used in the selection process. As the author had no specific contact names within the companies, the questionnaire was addressed to the Managers of the companies, following the author's assumption that a member of senior management would be in a position to answer some, if not all of the questions. The questionnaire was designed to be simple and easy to complete, and was also designed so that all responses would be valid.

In the second Chapter of this thesis eight main research areas were identified and these were:

1. The Relationship Between Strategy and Decision Making;
2. The Short Term Nature of Investments;
3. Decision Making;
4. Financial Appraisal;
5. Strategic Appraisal;
6. Recent Developments in Appraisal Methods
7. Performance Measurements;

8. Implementation and Management of Manufacturing Technology Investments.

The survey was initiated to study manufacturing technology investment practices in the defence sector and to provide information to support the five main research areas. It was important, therefore, that the main research objectives and the objectives of the survey were aligned.

The survey had a number of objectives:

- To identify what competitive strengths are pursued by modern defence companies;
- To understand what motivates or influences their decisions to invest in manufacturing technologies;
- To understand their processes for investing in manufacturing technology;
- To identify manufacturing technologies currently employed within defence companies.

The literature review revealed that decisions and actions taken in the appraisal stage of the investment appraisal process greatly affect the overall performance of an investment. Theoretically speaking, the investment decision process can be broken into three main stages: pre-implementation, implementation, and post implementation. In reality, decisions are constantly being made throughout the whole life-cycle of this process and if misinformed decisions are made in the early planning stage of the investment decision process then this can contribute to poor investment performance. In other words, the investment is unlikely to meet the performance measures and

financial targets established by managers. Hence, the survey was designed to elicit responses relating to the investment decision process and capture knowledge pertaining to this. Once the questionnaires had been designed and finalised they were then posted to the companies taken from the defence company database.

Using data from similar surveys conducted (Kumar *et al*, 1996 and Slagmulder *et al*, 1995) a questionnaire was constructed and sent out to the chosen companies. This questionnaire is contained in Appendix H. A common difficulty encountered when constructing questionnaires for data capture is deciding what questions to ask, in order to elicit the required responses, to be able to proceed with the investigation of a research problem. For this reason, a list of objectives were outlined prior to enable the questionnaire to be designed with these objectives in mind. Once these objectives were outlined, a set of questions was established. The questions were phrased to prevent confusion for the respondent.

Furthermore, it was also important to decide the type of data required from the respondent. For instance, qualitative data may be more useful that quantitative for some research, and sometimes a combination of both qualitative and quantitative responses is required. The questionnaire was designed to allow respondents to tick answers or use worded answers where required. Deciphering questionnaire responses can be difficult as the data provided by questionnaire based surveys are subjective, and based on the respondent's experiences, perceptions and values. It was important to take this into account when designing the questionnaire to prevent problems occurring during data analysis.

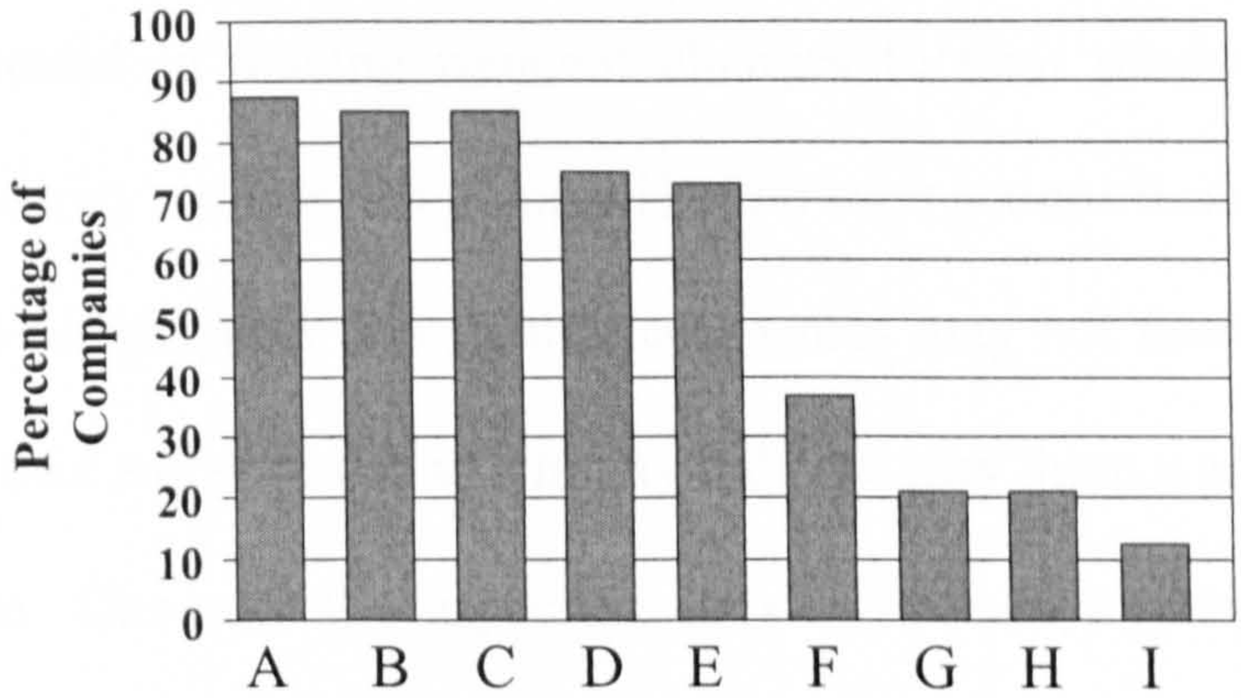
As a guide to constructing the questionnaire two surveys conducted in the mid-1990's were used. Both of these surveys focussed on the investment decision process and how this process is managed within modern companies. The earlier survey conducted by Slagmulder *et al* (1995) focussed on the capital budgeting practices of companies with regards to manufacturing technologies and how they control their major investments in such technologies. The study conducted by Kumar *et al* (1996) was initiated to analyse the decision processes within companies wishing to invest in manufacturing technologies. The latter study also presents a model of the investment decision process. This is illustrated in Chapter 2 in **Figure 2.2**. A survey conducted by researchers (Argument *et al*, 1995) at the Department of Enterprise Integration (formerly the CIM Institute) in Cranfield University was also consulted for designing a suitable questionnaire.

3.2 Postal Survey Results

From the 150 companies who were contacted in the postal survey, 57 returned the questionnaire completed. The Companies were asked to discuss what competitive strengths they wish to pursue **(Q3. What competitive strengths are pursued by your company?)**. The results of this are shown in **Figure 3.1**. This question was designed to allow companies to tick as many answers as necessary. The most popular response to this question was *to offer consistent quality* with 87.5% of the responding companies selecting this. Other popular responses to this question were *to make profits in price competitive markets* with 85% of respondents selecting this. There was also an 85% response rate to the answer *to make dependable delivery promises.* Least popular

responses were *to make rapid product mix changes* (21%), *to make rapid design changes* (21%), and *to make rapid volume changes* (12.5%).

Competitive strengths pursued by responding companies



A) To offer consistent quality
B) To make profits in price competitive markets
C) To make dependable delivery promises
D) To provide effective customer service
E) To provide fast deliveries to customers
F) To offer a broad product line
G) To make rapid product mix changes
H) To make rapid design changes
I) To make rapid volume changes

Figure 3.1: Competitive Strengths Pursued by Responding Companies

From responses to this question one may deduce that companies are committed to delivering quality products and services to their customers, and realise the importance of assuring timely deliveries. Quality, however, is intangible in nature and is very much subject to how an individual perceives quality. Quality may be said to be the degree of excellence possessed by something, and one individual's perception of quality may differ from another. If companies are committed to offering consistent quality one may assume that they are taking an active interest in how their customers perceive quality and acting accordingly to deliver it. From this one may also assume that companies are investing in manufacturing technologies with a view to delivering quality products and services and it may be said that by investing in manufacturing

technologies they are assisting the pursuit to offer consistent quality as a competitve strength.

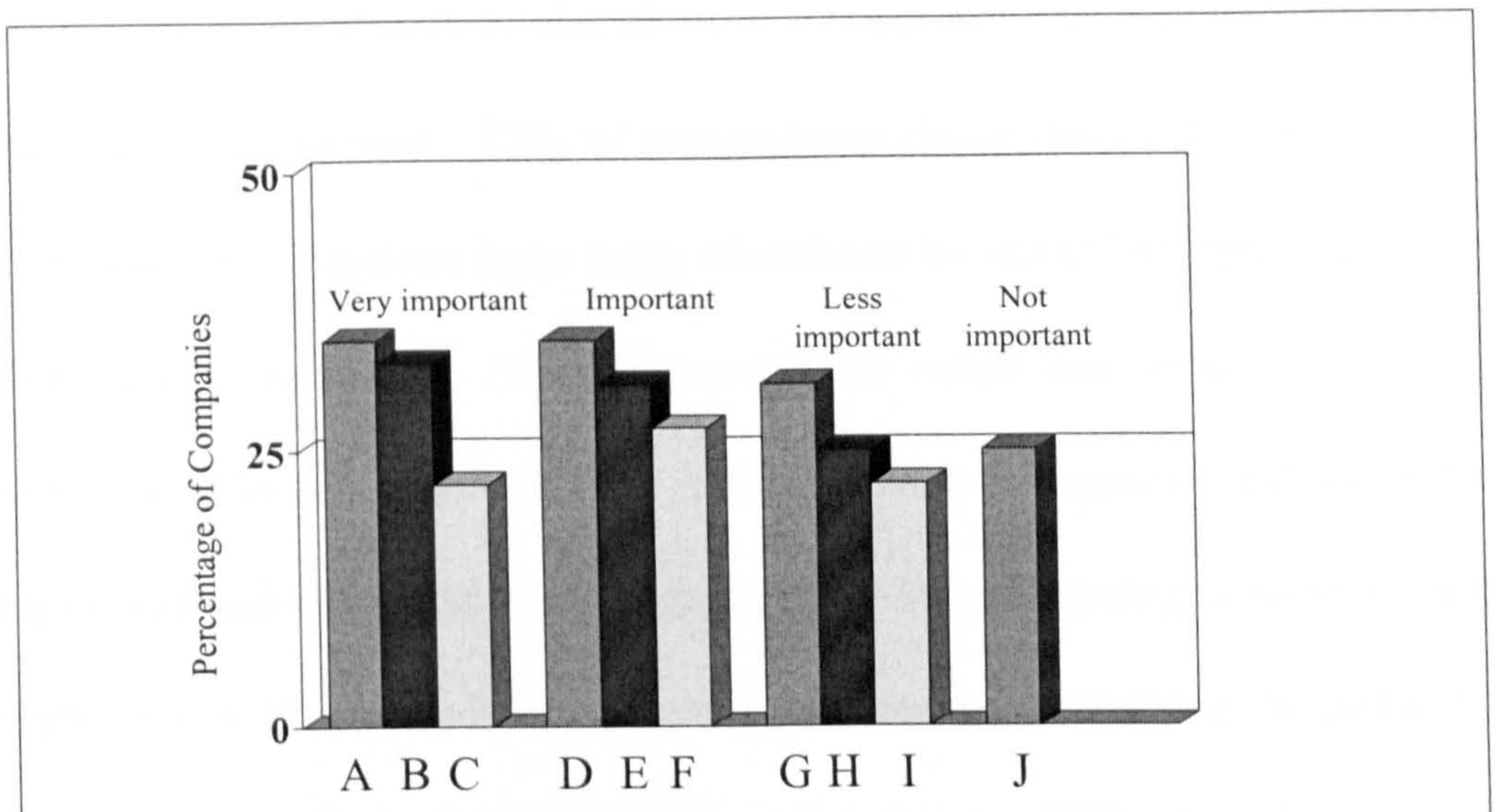
However, the lack of responses to other answer choices would indicate that companies are less interested in making frequent changes to their product mixes and product volumes. One may assume that companies find such actions time consuming and costly and hence do not perform this. Other companies may not need to drastically change their product mix and volume, which may indicate why there was a low response to this answer choice. One may also argue that they do not adopt such practices as they wish to adopt a more customised approach to production, preferring to focus more on the individual needs of customers as opposed to offering as much variety as possible. However, a lack of response to *to make rapid design changes* indicates a lack of interest in offering varied product or service design. One may argue that some companies do not need to offer frequent design changes. Other companies may find it a costly practice, whilst others may find it time consuming.

Companies invest in manufacturing technology for a number of reasons and the survey provided an opportunity to explore these. It is possible that changing manufacturing conditions will affect manufacturing technology investment decisions but this may not always be the case, and for this reason it was important to understand why companies make such investment decisions. The chosen companies were given a selection of possible answers to a question, prompting them to discuss what factors influenced their manufacturing technology investment decisions (**Q4. What factors influenced your manufacturing technology investment decisions?**). The question was designed to

enable the respondents to rate the importance of various factors using a scale starting with ratings from 1 for *Not Important* through to 5 for *Very Important.* As with the previous question, the respondents could select as many responses as necessary although they had to indicate the degree of importance for each chosen response. The results of this question are illustrated in **Figure 3.2.**

35% of respondents noted that *Increasing pressure on costs* was a *Very Important* factor. 33% of companies chose *New trends in market/customer demand,* indicating that this was also *Very Important* whilst 35% of respondents declared an *Important* factor when making manufacturing technology decisions. 31% of companies said *To pursue a technological development strategy* was an *Important* factor when making manufacturing technology investment decisions, as was *Time-based competition* with 27% of respondents selecting this response.

This question prompted companies to discuss how their manufacturing technology investment decisions are influenced. Responses to this question indicate that companies are concerned about the pressure on costs and how to adapt to changing consumer demands. It is interesting to learn that 31% of the responding companies are interested in pursuing a technological development strategy and their pursuit of such a strategy influences their decisions to invest.



A) Increasing competitive pressure on costs
B/D) New trends in market/customer demand
C) Increasing product complexity
E) To pursue a technological development strategy
F) Time-based competition
G) New manufacturing technology became available
H) Competitors made similar investments/Strategy of product differentiation
I/J) Product(s) not design for manufacture

Figure 3.2: Factors Influencing Manufacturing Technology Investment Decisions

From this one may conclude that these companies are focussing on their technology base and how to develop this in the future to best cope with the demands that will arise. One may also conclude from this that these companies must be engaging in some degree of planning for technology introduction. Their interest in pursuing a strategy would indicate that they are interested in organising their process of technology development and to organise this process a plan, or strategy is necessary.

The author was interested to learn how manufacturing technology investment decisions are initiated. Hence, a question was designed to prompt companies to elaborate upon this[1]. As with previous questions the respondents were allowed to select as many responses as necessary. 85% of companies chose to describe their decisions to invest as

Opportunity, meaning that their decisions to invest were initiated to improve a stable manufacturing environment. 27% of respondents chose *Problem*, indicating that some of their investment decisions have been stimulated by manufacturing inefficiencies not requiring immediate action. 12% of respondents noted that some of their investment decisions were *Crisis,* indicating that some of their investment decisions have been initiated to respond to intense manufacturing problems requiring immediate action. An *Other* response was included in the list of choices for companies wishing to provide further information about their investment decisions. 27% of companies chose this particular response to describe their investment decisions, with responses including "to strategically position the company to enter new markets", "for growth", "to reduce costs", and "to meet the long term strategy of the company."

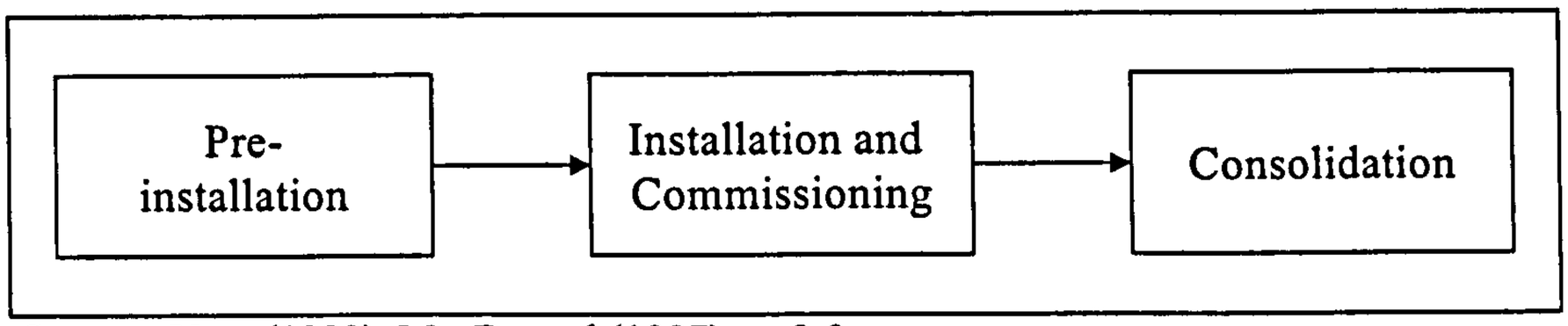
Kumar *et al, (1996)* also used this question in their survey conducted in the early 1990's analysing manufacturing technology. Their survey revealed a range of external and internal stimuli propelling companies to make opportunity, problem or crisis decisions. Often companies make a combination of investment decisions in response to stimuli. Their survey revealed that 41% of respondents made *Problem* investment decisions, whilst 27% made *Opportunity* investment decisions. No *Crisis* investment decisions were made, whilst 32% made *Opportunity/Problem* investment decisions. Kumar, et al argue that the lack of *Crisis* investment decisions is due to the inherent characteristics of manufacturing technology, implying that the level of planning required to introduce manufacturing technology into a company is too great for crises requiring immediate action. The greatest number of responses in both the author's

[1] Please see **Q5.** in the questionnaire contained in Appendix H.

study and the Kumar study were for *Opportunity* and *Problem* investment decisions. One may assume, therefore, that companies are investing in manufacturing technologies to improve their manufacturing environment and prepare it for future manufacturing success.

One may also assume that because companies are investing in manufacturing technologies they are aware that these technologies may be exploited in order to improve their manufacturing processes and hence increase their chances of gaining future competitive advantage. One may also conclude that the lack of responses to *Crisis* investment decisions indicates that companies have an awareness that manufacturing technologies are not instantly applicable in crisis situations and require planning prior to their introduction and implementation. If companies are formally planning for manufacturing technology investments one may also assume that they are doing so with a view to achieving strategic objectives. This also adds support to a previous question asking companies to discuss how their manufacturing technology investment decision is influenced. 31% of the responding companies indicated they were interested in pursuing a technology development strategy, which implies a desire to achieve strategic goals through the application of manufacturing technologies.

Voss (1992) suggested that the implementation process for manufacturing technology consisted of three main parts. This Implementation Process model is illustrated in **Figure 3.3**. The first stage was named *Pre-installation,* the second was named *Installation and Commissioning,* and the third was named *Consolidation.*



Source: Voss (1992); MacDougal (1997), *p. 3-9.*

Figure 3.3: Implementation Process

The decision to invest ends the *pre-installation* stage, whilst technology *Installation* begins the second stage. It is during this stage that the technology will achieve, to some degree, any performance measures targets set. The third stage, *Consolidation,* is for adapting the technology or the process should improvements or adjustments be required. Voss (1988) argued that companies often believe they have successfully implemented new manufacturing technologies when they have eliminated problems from the process and the investment is working technically. Voss argues that this is only part of the process of managing a successful manufacturing technology investment project, and for an investment to be truly successful the benefits expected must have been fully realised, and realised in the market place through increased competitiveness.

It has been argued that without sufficient planning in the early stages of the manufacturing technology investment process the investment may experience problems during the implementation stage and ultimately fail to reach the investor's original expectations. However, if problems do occur with an investment then it is essential that managers understand why the problems have occurred and how further problems can be prevented in the future by incorporating what they have learned from the investment into the planning stages of future investments.

It is for this reason that the author designed a question to prompt the respondents to discuss their use of post-implementation reviews **(Q7. Do you undertake post-implementation reviews of new manufacturing technology investments?)**. A post-implementation review may be said to consist of a number of smaller stages during which data taken from earlier performance reviews, and any other data gathered relating to the planning and implementation stages is assessed and documented. The purpose of this is to highlight how the investment performed in relation to any original expectations, performance measures and strategic goals, and to suggest areas for improvement for future investment projects.

An interesting point to note is that there is no definition as to when the implementation stage ends and post-implementation begins. The same can be said for the pre-implementation stage in that it has no defined beginning or end. One may argue that this reflects industrial practice where there are no definable boundaries between set, definable process stages. Therefore, one may also argue that when one stage ends and another begins is subject to an individual's understanding of the investment process and, in practice, these stages are seamless.

67% of respondents noted that their companies conducted post-implementation reviews for all of their technology investments. However, one may assume that not all the responding companies are conducting their post-implementation review as a continuous improvement measure, although this may be the case for some of the participating companies.

23% of respondents said their companies conducted post-implementation reviews for some of their investment projects, whilst 10% of the participating companies said they did not conduct post-implementation reviews. It is important to note that some of the participants may not have had a clear understanding of the phrase "post-implementation review" and this may have affected their answer. The author assumed that the respondents would have their own perception, if any, of what constitutes a post-implementation review for a manufacturing technology investment, and so was interested to learn these.

The use of reviews at any stage of the investment's life-cycle is important as it allows for knowledge capture and for tracking the extent to which investments meet performance targets. However, a review process should be planned and the results of a review documented. All personnel involved in the review should be aware of its purpose and should be fully briefed of this.

The survey by Slagmulder *et al* (1995) revealed that companies were carrying out post-implementation reviews for *some* of their investment projects. It is interesting to learn that in the Slagmulder survey 32.5% of companies did not carry out post-implementation reviews in comparison with 10% of companies in the author's survey. One may assume when conducting surveys such as this that the respondents will have their own perception of what a question requires of them, and will also answer the questions in such a way as to show their company in a most favourable light. Hence, the way in which a respondent approaches a questionnaire and responds to it is very

much subject to their understanding of the content of the questionnaire and their opinion of the value of academic surveys.

Companies were asked to select from three choices the kind of performance measurement system used by their company to evaluate their management **(Q8.)**[2]. Research has argued that the pressure of management to produce short-term results has often meant that companies have overlooked the long term benefits of manufacturing technology in favour of positive short-term financial returns. It has been argued that this has led to the slow adoption of manufacturing technologies by companies in the UK as managers focus less on the long term benefits and more on initial returns (Lefley and Sarkis 1997).

It has been implied through research that traditional quantitative appraisal techniques, whilst adequate for providing data pertaining to short term financial returns, are not suitable for companies wishing to appraise potential investment projects whose benefits are often realised after a longer period of time. This has led to further research to develop appraisal techniques to assess the strategic and financial long term benefits that are said to arise from implementing manufacturing technologies.

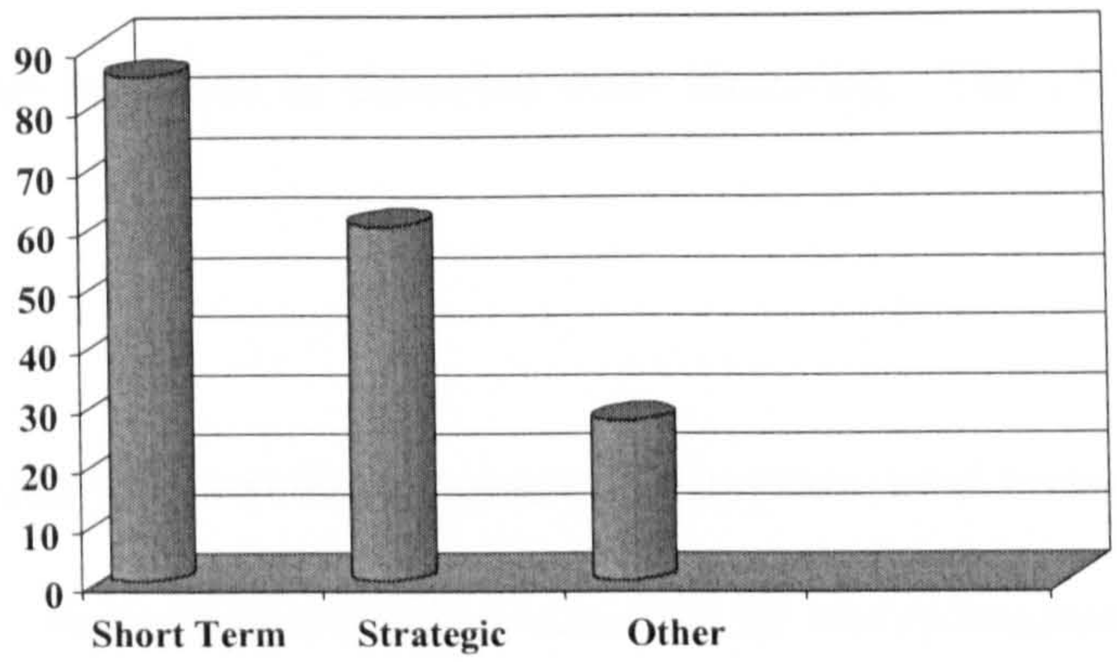
85% of respondents said their companies use *Short-term financial performance* as a management measurement system, with 60% of companies stating *Strategic performance* as a management measurement system. 27% of respondents chose the

[2] The choices included *short-term financial performance, strategic performance,* and *other.*

Other category to answer this question. The following are examples of management measurement systems given by respondents:

- Weekly reviews with management attending;
- Five year business plans;
- Balanced scorecards;
- Medium/long term financial performance;
- Level of growth;
- General discussions;
- Sets of non-financial measures are reviewed and measured parallel to the financial measures;
- Long term trends which have resulted in increased performance both in profitability and value for money to customers.

The chart in **Figure 3.4** illustrates the results to this question. Researchers have argued that whilst most companies will always be interested to learn how financially viable their investments will be in the first few months and years of life, by doing so they may be neglecting to focus on the long term benefits that are derived from the application of manufacturing technologies. It is natural for companies to be concerned with an investment's short term financial returns especially considering they cite *to remain competitive* and *to reduce costs* as major influences on their decisions to invest in manufacturing technologies.



85% of companies use *Short Term Financial Performance* for performance measurement
60% of companies use *Strategic Performance* for performance measurement
27% of companies selected the *Other* category for performance measurement

Figure 3.4: Management Performance Measurement Systems

Results to this question indicate that the majority of the responding companies use *short term financial management,* with this selection achieving an 85% response rate. This question relates to management performance measurement systems and not whether management use short term financial performance as an indictor of investment success. It is not possible to conclude that companies are solely assessing their investment performance on the degree to which they provide substantial short term financial returns. However, if companies are assessing their management using the measure of short term financial returns then one would assume that managers will make decisions based on the extent to which the consequences of such decisions will raise their short term financial returns.

Companies were also asked to describe the *conception, initiation* and *final authorisation* of an investment project **(Q12.)**. The purpose of this question was to elicit information about the manufacturing technology investment decision process and

how investment decisions are initiated within a company. Respondents were able to select more than one response to describe their situation. The results to this question are as follows:

- 44% of companies selected the response *Conception and initiation at a lower level in the company; Formal approval or rejection by top management;*
- 43% of companies selected the response *Investment was a top-down corporate policy;*
- 27% of companies selected the response *Conception at a lower level in the company: Proposal gathers support as it is passed up through the company; Final authorisation is by top management and is more a formality.*

From this one may conclude that within the responding companies it is the managers who control the decision to invest, although some of the respondents agreed that it was not always managers who proposed an investment choice.

Technology acquisition is a complicated process and this is often complicated further by the decision to select a suitable vendor from which to purchase manufacturing technologies. Vendor selection decisions are typically multi-objective in nature (Weber, Current and Desai, 1998) and in the case of some technology investments the vendor will need to be more fully integrated into certain stages of the process to ensure the investment is correctly installed and implemented. In order to explore the extent to which companies integrate their technology suppliers into their investment process a

question was designed to investigate this. Respondents were asked to discuss if their technology implementation process is:

- conducted entirely by suppliers;
- conducted by suppliers and in-house staff;
- conducted by in-house staff alone.

89% of respondents said their investment implementation was conducted by the suppliers and in-house staff, whilst 4% of companies said it was conducted entirely by the suppliers. 19% of companies said their in-house staff alone conducted the implementation of their investments.

From a final question prompting the respondents to discuss which personnel are involved in the investment decision, one may conclude from that a combination of personnel from a range of departments are involved in the investment decision, including engineering, sales, finance and managerial personnel. Respondents also indicated that their company directors are also involved in the investment decision.

The literature review has revealed that appraising manufacturing technologies on this basis of financial returns alone neglects to consider the strategic benefits that arise from such technologies in the longer term. Often, companies do not have the time or the expertise to fully appraise manufacturing technologies for their short and long term financial and strategic benefits and hence focus solely on the financial gains an investment will bring. Whilst it is important to understand how an investment will

perform financially (considering the substantial cost and risk to a company of investing in such technologies) it is also important to understand the effects an investment will have on the strategic performance of a company. Once these are understood, a company can then begin to harness all the benefits derived from their technologies, not just the financial.

To conclude, the literature review revealed that companies are appraising manufacturing technology investments on their short term financial returns, yet should also be focusing on the strategic benefits that are realised through long term implementation of manufacturing technologies. The review also revealed criticisms of current strategic appraisal techniques, arguing that they are difficult to apply within an industrial environment. It would appear from the author's study that some of the responding companies are conducting management appraisals based on short term financial performance and strategic performance.

3.3 Chapter Summary

This Chapter has discussed the concepts of mass customisation and agile manufacturing and how the adoption of such approaches to manufacturing will change the way in which business is conducted in the 21st century. The virtual organisation has also been discussed as an organisational model for conducting 21st century business activities and how manufacturing technologies will play an increasing part in realising this, agility and mass customisation.

The results of the author's survey have also been discussed. 150 companies from the defence sector were contacted to participate in a survey relating to investing in manufacturing technology. The results of this survey have been detailed and discussed, and from these results one may conclude that whilst companies are making investments in manufacturing technologies they may be continuing to appraise these investments on the basis of the short term financial returns they provide.

Chapter 4 A Current Perspective on Investment Appraisal: interview survey results

Abstract

The postal survey revealed a number of issues relating to investment in manufacturing technology within defence companies. The interview questionnaire was constructed to derive information that would complement and build upon the data gathered from the first stage of the data collection process (the literature review and the postal survey). Whilst this survey was useful as an introduction to the data collection process, further data were required to model the investment decision process. A survey was subsequently initiated to gather more detailed data pertaining to the manufacturing technology investment process. This Chapter introduces the survey and includes a discussion of the results. The Chapter closes with a summary of its contents.

4.0 The Purpose of the Interview Survey

The survey was initiated for a number of reasons:

- To complement data derived from the postal survey;
- The data from the postal survey, whilst useful, was insufficient to develop a process model and user process guide;
- To research in greater detail the manufacturing technology investment process.

The author concluded that a further study be initiated, one with a greater degree of focus on the actual investment process and, in particular, one that would provide data about the process within the collaborating company.

The literature review revealed a concern for the methods by which technologies are evaluated within some companies. Researchers (Wilkes, Samuels and Greenfield, 1996; Lefley and Sarkis, 1997; Meredith and Suresh, 1986) discussed the "short term" approach adopted by managers when appraising investments. The argument was proposed that focusing solely on the short term financial returns means that long term investment benefits may be overlooked in favour of quick profits. Whilst financial success is crucial to any company, the importance of assessing the long term effects of technology investments has been stressed and this was discussed in Chapter 2.

Considering the extent to which the European defence industry is engaged in consolidation, one assumes that those involved are working to long term strategies for financial and strategic success. Hence, it is important for the collaborator that their technology investment strategies reflect and support their overall business objectives. To sustain their competitive advantage, investments should be chosen that not only fit the purpose and fulfil financial requirements, but aid the achievement of long term business goals. The technology investment process should be consistent and allow for the right technology to be chosen and implemented to satisfy the goals set for it by the collaborator. In reality, the process of investment is likely to be haphazard, certain elements will be present in this process that can be organised and controlled to provide a degree of consistency. The author was interested in learning about the elements that,

without control, can lead to problems throughout the process and maybe failings in an investment project.

With this in mind, the survey would be designed to extract information about the elements and activities that constitute the process of investing in manufacturing technology, and what may be changed in order to achieve investment success.

4.1 Introduction to the Interview Survey

The purpose of the postal survey was to gather information on investment practices within the companies. This survey revealed that companies are investing in manufacturing technologies for a variety of reasons. It also revealed that the majority of investment decisions were taken to improve the manufacturing environment. One may argue that this illustrates an awareness of the benefits that may be gleaned through a technology investment. The postal survey was useful as an investigation of manufacturing technology adoption within modern defence companies. It highlighted the reasons companies invest in manufacturing technologies and provided a brief outline of how manufacturing technologies are introduced into companies.

The literature review revealed that the investment decision process can be said to consist of three main stages. Voss (1992) illustrated these stages in his Process of Implementation Model, these being the *Pre-installation* stage, the *Installation and Commissioning* stage, and the *Consolidation* stage. The author adopted and adapted this model for the purpose of the interview-based study, assigning different names to the three main stages. For the purpose of the interview study the stages became the Pre-

Implementation stage *(Pre-installation)*, the Implementation *(Installation and Commissioning)*, and the Post-Implementation *(Consolidation)* stage. The questionnaire was constructed so as to derive information about these three stages. Questions were designed to prompt discussion about the activities that constitute each stage of the process and what, if anything, could be incorporated into these to aid technology investment success. The interview questionnaire is contained in Appendix I.

4.2 Designing the Questionnaire

The questionnaire was based upon the Voss (1992) Process of Implementation Model and was designed to be used to interview either a member of management, or senior management, or a staff member with detailed knowledge of the investment practices within their company. The author adapted the Voss model by re-naming the individual stages. Questions within each section would enable discussion about the activities at each stage of the process.

The first section of the questionnaire was titled *Current use of manufacturing technology.* This section was designed to elicit responses pertaining to the present employment of manufacturing technologies within the participating companies. This section was intended to be an introduction to the survey; to ease the interviewee into the situation. The second section, titled *Budgeting Process* was constructed to enable the interviewee to discuss what occurs during the company's manufacturing technology appraisal process. This section of the questionnaire relates to the first stage of the Process of Implementation model (Voss, 1992), the stage at which initial actions are

taken to justify possible manufacturing technology investment projects. The questions were designed to focus on the activities at this stage.

The third section of the questionnaire is titled *Manufacturing technology implementation process* and relates to the second stage in the Voss model. It is at this stage in the process that the chosen investment project is introduced into the company and employed within the capacity it was designed for. The questions in this section were designed to prompt the interviewee to discuss what occurs prior to, and during an investment implementation. Other questions in this stage were concerned with the problems encountered during this phase of the investment process and how these are addressed.

The fourth stage, titled *Post-implementation process,* relates to the third and final stage of the model, with questions designed to elicit responses about what occurs once the initial investment has been made and the implementation is underway. This section of the questionnaire was concerned with deriving information about how companies monitor the progress of their investments and the use of performance measurement data. The literature review illustrated a concern for the way in which technology investments are evaluated, and that a number of investments in manufacturing technology can fail to satisfy managers' performance expectations if managers neglect to consider all the effects of their preferred investment choice. It has been suggested that the use of traditional financial appraisal methods do not provide managers with a full justification of all the benefits associated with a manufacturing technology investment.

Hence, if an investment fails to deliver the expected returns in the short term, it may be considered a failure, ignoring the possibility that exceptional returns may be realised in the future. This implies that some managers have failed to investigate further than the short term financial benefits derived from the adoption of manufacturing technologies and neglected to account for the long term effects that manufacturing technology may have on company structure and processes. The final section of the questionnaire, titled *Decision aid* was designed to elicit responses about the need for a guide or tool to assist managers in the process of investing in manufacturing technology.

4.3 Pilot Study

Once the questionnaire was constructed it was necessary to conduct a pilot review with the collaborating company to ensure the questionnaire style and content were satisfactory. An initial questionnaire was prepared and presented to the sponsors. Changes were suggested and the questionnaire was amended to incorporate these. An updated copy of the questionnaire was presented to the sponsors and an interview date was arranged.

When conducting interviews it is not always possible to manually record the discussion. Often, information can be misheard, misinterpreted or overlooked, and for this reason the author chose to use a dicta-phone, when allowed by the sponsors, to ensure most of the interview was recorded. Where possible, the author chose to manually record the interview. The pilot study was completed in 90 minutes and the interviewee responded to all the questions. Few criticisms were raised. Further improvements for the questionnaire were suggested and noted.

4.4 An Outline of The Survey

For many years there have been strong links between Cranfield University and BAE Systems. A wide variety of research projects have been sponsored by the company thus forging even stronger links for the future. A "link office" exists at the university for the purpose of fostering the relationship between the University, its researchers and BAE Systems. The author contacted this office and was provided with a selection of possible interviewees. The author then contacted the suggested personnel and interviews were arranged.

Interviews were eventually conducted at the following sites within BAE Systems:

- Woodford Aerodrome – Regional Aircraft;
- Headquarters, Farnborough;
- Matra British Aerospace Dynamics – Guided weapon systems;
- Salmesbury – Airbus

BAE Systems describes itself as a *Prime contractor and systems integrator.....in the air, land, and sea defence markets sectors* (BAE Systems, 1999). At these individual sites a whole range of complex activities are conducted and the author was interested in learning about the activities at each site that lead to the adoption of manufacturing technologies.

The interviews were conducted in the manner established during the pilot study. For confidentiality reasons the interviewees can not be named. However, all interviewees

held management positions within the companies, with some having experience of investment practices at a number of BAE Systems sites. The interviewees were presented with the questionnaire and allowed to peruse the content. Once they were comfortable with the situation and aware of what was required of them the interview commenced. The interviewees were not obliged to answer all of the questions but were pressed for answers when difficulties arose. As all of the interviews were conducted using a dicta-phone, on completion of the survey it was necessary to transcribe the interview data to allow for future analysis. The interview results are contained in Appendix J.

4.5 Results Analysis

The aim of the research was to use available sources to understand the process of investing in manufacturing technology and, based on research data, build a process aid to assist managers in their investment decision. Once the information had been gathered through the interviews an analysis was conducted. There were several objectives for the analysis of the interview data:

- To develop a method that would ultimately allow the research objectives to be achieved;
- To develop a method for analysing data that would be non-subjective, yet not discount any individual's opinion;
- To develop a method so that as much data about the investment process could be retrieved with ease;

- To develop a method that would capture the greatest amount of relevant information about the investment process to enable the construction of the process model and process aid.

The author considered using hypotheses to analyse the data but on reviewing the interview scripts noticed the interviewees had raised many similar points. The most suitable analysis method would allow for the capture of all these points. Hence, the use of hypotheses was rejected in favour of using a key word search. A key word search was favoured by the author for effectively capturing the many issues raised by the interviewees. The interviewees had alerted the author to many issues that they considered had a positive and negative effect on the investment process, i.e. created an environment for a smooth or problematic technology implementation. This data would then be used to construct a process model and a process, aid thus satisfying the research objectives.

4.5.1 Performance measures

One question asked about the use of performance measures, to which all interviewees responded claiming their units within BAE Systems use performance measures. Such performance measures are used to measure process improvements. However, it was noted that due to the time it takes for some of the products to be completed it is difficult to track the extent to which investments are meeting the original performance measures outlined for them. All interviewees recognised the importance of using performance measures for their investments as a means of tracking progress and controlling it. As one interviewee claimed, *"It is important to look at investments that have a positive*

effect on company operations". They also stressed that performance measures are important as a base to work from when initiating new improvement measures and investment projects. Quoting from one interview, *"If any of the key performance indicators can be changed positively through an investment then this is key to the company"*. Another interviewee stated that *"Measures are the basis for any investment and it is important to outline areas in which to excel.....Investments should be purchased with these in mind"*.

4.5.2 The Issue of Implementation

One issue that was raised during the interviews was that concerning the beginning and end of an investment's implementation phase. MacDougal (1997) noted the importance of effective management during the implementation stage and argued that effective implementation raised the chance of implementation success and the success of the investment project overall. Other studies have argued that for this stage to be successful and minus the setbacks that normally accompany this process there has to be thorough planning prior to implementation. One interviewee suggested that implementation begins once an investment idea is proposed. It was also suggested that implementation begins once the decision to invest has been made and the necessary preparations are underway.

4.5.3 Reasons for Investing

Cutting costs was cited as a reason for investing. To quote one interviewee, *"Unit production cost is a key measure and if a particular type of technology will reduce this then it will be purchased"*. Whilst investment cost was cited as being an important

factor when selecting a suitable investment, it is also important to understand the costs associated with an investment, such as maintenance costs. As one interviewee stated, *"Understanding where the costs lie is important"*, although it was noted that people do not always understand the costs associated with an investment project. Increasing competitive pressure on costs was the main reason for making investments.

4.5.4 The Importance of the Business Case

The interviewees discussed the purpose of the business cases for outlining all the necessary information connected with an investment proposal. A business case is a detailed justification of a proposed investment project. Quoting from one interview script, *"Time should be spent conducting a full justification of an investment choice.....How successful the justification process is depends on the quality of information available and how this information is used."* Once a business case is prepared it is submitted to the necessary board of managers for approval. To quote one interviewee's summary of a business case, such a proposal includes, *"the technical benefits of pursuing an investment, how the investment fits with the strategic direction of the company, the financial returns and if the investment is a necessity"*.

Manufacturing technologies can be incredibly expensive to purchase despite the benefits that may ultimately arise, and some technological systems cost millions to install, implement and maintain. There are different management levels within BAE Systems to which business cases for investments have to be submitted. Depending on the cost of the investment, the business case is submitted for approval from the appropriate personnel and approved or rejected. To quote an interviewee, *"it is important that this*

review...(submitting a business case to higher level management review committees)...*is conducted because the lower level managers might not have the understanding about the strategic direction of the company as a whole as the senior managers"*. The interviewees stressed the importance of the business case for proposing an investment project. As one interviewee stated, *"It is important to construct a business case in relation to what the business needs in terms of technology and what the drivers are in terms of performance."*

4.5.5 Value Management

Another interviewee stressed the importance of conducting a *"thorough investigation of possible investment choices"* before selecting an appropriate project. Quoting another, *"It is important to look at investments that have a positive effect on the company's operations"*. All of the interviewees discussed the importance of value management. One interviewee discussed the importance of value plans saying *"they are important as they outline the measures for an investment"*. Another stated *that "it is useful to understand where value exists in the business and maximise this through investments"*. A value plan may also show the alignment of *"the present needs of the company with any emerging needs"*.

4.5.6 Issues and Influences

In the words of one interviewee, *"The whole of the investment process is influenced by a variety of issues"* and coupled with data from the postal survey one may summarise these with ease. To quote one interviewee, *"What the customer wants is a major influence"* on choice of investment. Another discussed, *"the need for an investment*

and the level of risk associated with an investment" as being considerable influences on their investment decision. *"The capability of the company to satisfy shareholders"* was cited by another interviewee as an important influence. In agreement with this, another interviewee stated, *"It is important not to forget shareholder value and that any benefits realised from an investment will directly or indirectly affect shareholder satisfaction".*

The survey has also revealed that the degree to which an investment will reduce costs influences investment choice as much as the cost of the manufacturing technology itself. As one interviewee declared, *"Payback is a key measure in terms of investment. We are interested in cutting costs hence it is important to know when our investments will start paying for themselves".* The business case is what it used to sell an investment in order to gain funds, but as one interviewee stated, *"decisions are then concerned with how to allocate the money available in alignment with the strategic direction of the company".* However, this is not always an easy decision as *"Different investment choices will have different effects".*

Furthermore, competitor behaviour can affect an investment decision. To quote one interviewee, *"An understanding of what competitors are doing is also important as it may be dangerous to become involved in something that is ongoing within a bigger competitor".* The issue of maintenance and technological support was raised by one interviewee who stated that *"some investments require maintenance from an external company and if this company is poor at their job and unreliable then this can cause severe problems during implementation".*

All interviewees agreed that with regard to manufacturing technology investments it can be difficult making a selection that will satisfy everyone. As one interviewee stated, *"There is often a conflict between what different people want.....accountants may have a different idea about what the company needs compared to more technologically minded personnel"*. Further problems can also occur when *"Trying to balance the budget and satisfying peoples expectations"*. Another interviewee noted that it can be problematic to have people within the company *"influenced by their own perception of what they should be doing.....sometimes strategic intents are not explicitly mentioned"*. To overcome this problem, all of the interviewees suggested that there should be no more than the necessary personnel involved in an investment decision. All agreed that a surplus of people in the investment decision can be detrimental to this process. It is simply not possible to satisfy everyone and have *"user buy-in"*. As one interviewee stated, *"User buy-in can make all the difference between a successful project and a failing project"*.

The survey also revealed the importance of communication between people during the investment process. The interviewees were in agreement that encouraging people to be more trustworthy and communicate issues is a problem. To quote one interviewee, *"There has to be communication.....People must be involved from the beginning and have an idea of the risks involved"*. The same interviewee stressed the importance of people *"sharing risks"* to prevent one person having to accept blame for a project's failings. This was also reflected in another interview: *"If a person takes ownership for an investment it is always good that they see it through until the end.....people have a habit of enjoying when an investment is performing successfully and neglecting when*

the investment is under-performing". The importance of communication is stressed by one interviewee who states, *"Problems arise because the investment is brought into the business with most people being unsure of the effect it will have"*. One interviewee claims *"The best examples of investments generally involve a great deal of communication between the necessary personnel beforehand"*.

There is always a certain degree of risk associated with investment projects and, to account for this, calculations can be performed when justifying investments that allow for differences in risk. Investing as a process is fraught with risks and it has been argued in the past that the risk associated with investing discourages the adoption of manufacturing technologies. The interviewees discussed risk management and how risk must be managed effectively to gain a greater control over the process. As one interviewee stated, " *It is important to outline the risks associated with an investment because once you know these you can act accordingly early to minimise these"*. With regards to the calculations to account for risk, another interviewee stated, *"it may be a good idea to adjust the hurdle rate used* (for assessing risk associated with investment projects) *to account for the fact that investments yield benefits in the long term."* One interviewee claimed that risk is a serious problem which *"increases with lack of understanding"*. The same interviewee believes that risk management *"should identify problems early as problems can often be related to poor initial planning"*.

4.5.7 Reviews

As one interviewee stated, *"Reviews are very important to understand the progress of the investment"* though it would appear from the survey that few reviews are conducted

in the investment process. All interviewees believe in the use of reviews as tools for learning about and understanding their investment process. To quote one interviewee, *"A post-implementation review should be like a continuous improvement process and assist learning"*. They all agreed that their review processes should be robust and, on the whole, their own review processes were *"weak"*. To quote one interviewee, *"The review process is weak and the weakness lies in not learning from the mistakes that have been made and understanding what went wrong"*. The same interviewee suggested that, *"Maybe more lateral thought is required about investing and how to improve the process"*. Furthermore, the issue of how to use review data to the advantage of the company was also raised by the interviewees. As one interviewee stated, *"It can be difficult understanding how to use the information that comes from a.....learning review"*. Continuing in this theme, another interviewee noted the difference between data and information, stating, *"As far as data concerning investments, there are an abundance of data but no information. Data have to be organised into something usable to assist the learning process"*.

The interviewees agreed that while reviews are useful for assessing the progress of an investment, it can be difficult measuring how much people are learning. To quote one interviewee, *"In terms of the lessons learnt from investments we are weak and tend not to look at the bigger picture"*. It is not possible to examine people on their skills and knowledge regarding investments, and as one interviewee stated, *"It is not easy to say when people have learned sufficient to be able to make positive changes"*.

With regards to the timing of reviews one interviewee claimed they conducted reviews regularly, *"but final audits are conducted six to twelve months after an investment"*. Another interviewee claimed they conducted reviews *"about 1-2 years after an investment being live.....it often depends on the size and nature of the investment"*. One interviewee claimed that they conducted quarterly reviews, stating, *"Reviews are very important to understand the progress of the investmemt*.....and.....*to improve the process and reduce risk"*. Another interviewee claimed they did not conduct post-implementation reviews, stating, "*if anything is documented about the performance of an investment once the implementation is over then it is very little"*. The same interviewee raised an important point with regards to the use of post-implementation reviews stating, *"If there are no documented results about the performance of an investment then there is nothing to refer to when selecting new investments"*. This suggests that if little is documented about the performance of an investment then people will have nothing to refer to to help them learn from the implementation and make the right decisions in the future. However, as one interviewee stated with regards to conducting reviews, *"time is crucial and people don't often have the time to spare for such tasks"*. This view was supported by another interviewee who claimed, *"People don't often have the time to devote to understanding why something wasn't as successful as originally expected"*.

4.6 Points For Improving The Process

As Leonard-Barton and Krauss (1985) said,

"Introducing technological change into an organisation presents a different set of challenges to management than does the work of competent project administration."

The results of this survey without question support the above statement, and have certainly proved that introducing manufacturing technologies into a company involves a great deal more than appraising the investment choice and installing it. Beatty (1990) likened investing in manufacturing technology to *"setting out upon a journey in a foreign land without a map and without speaking the native langauge"*. Beatty also suggested three *"paths"* for arriving at the final destination of successful manufacturing technology implementation, these being:

1. A capable champion to direct the implementation effort;
2. Systems integration;
3. The right mix of teams.

Through extensive research Beatty found that the presence of the above three factors considerably affected the degree to which organisational objectives for manufacturing technologies were achieved. Starting with the first factor – a capable champion to direct the implementation effort – the interviewees participating in this survey agreed with the need for a strong person to guide an investment and oversee its progress. One interviewee discussed the need for *"a project manager.....to monitor the whole project and its progress"*. Another stated, *"that if someone proposes an investment then they should take responsibility for seeing the whole project through, especially when problems occur"*.

The issue of top-management commitment was also raised in the survey, with one interviewee stressing the importance of *"top management buy-in"*. The survey also highlighted problems associated with staff mobility and how this affects the progress of an investment. The interviewees were in agreement that if one person is assigned the role of project manager, or champion, they should ensure their commitment to the project at all times, good and bad, and should they ever leave their position then whoever is responsible for taking over their role should be thoroughly versed in the job responsibilities.

With regards to the second factor – systems integration – the survey did not reveal anything regarding systems integration. However, concerning human systems the importance of communication and encouraging a sense of shared risk was discussed by the interviewees. Regarding data and its availability, the interviewees were in agreement that data is of little use unless converted into a usable form that is easy to understand and informative. They were also in agreement that information regarding the investment should be communicated to all investment stakeholders to reduce the level of risk and prevent misunderstandings.

With regards to the third and final factor – the right mix of teams – one interviewee claimed, *"Teamwork is another key factor in ensuring the success of an investment"*. The other interviewees agreed that teamwork was one of the key issues in the success of a manufacturing technology investment. They were also in agreement on the involvement of necessary personnel in the investment decision from a variety of key functions, e.g. accounts and engineering, and that once a group of stakeholders had been

gathered they should be made privy to all information regarding the investment. The interviewees suggested that an informed team led by a committed project leader was key to investment project success.

To summarise, the survey has revealed the following as being influential in the success of a manufacturing technology investment project:

- Establish a review procedure and adhere to this;
- Try to keep to one project leader and have senior management backing;
- Conduct a thorough justification of all possible investment projects;
- Organise maintenance and technological support from the outset;
- Involve all stakeholders, or necessary personnel, as early as possible in the investment process;
- Encourage stakeholders to communicate their desires and preferences for investment choice;
- Encourage all personnel involved to have commitment to, and a sense of sharing in the project;
- Frequently communicate the progress of the investment;
- All problems associated with the investment should be communicated as soon as they arise;
- Outline as many risks as possible to the project;
- Plan for risk and make preparations to accommodate problems, should they occur;
- A clear understanding of the effects an investment will have, and communication of this;

- An organised and thorough business case.

Voss (1988) proposed two levels of success by which an investment in manufacturing technology should be judged:

- Technical success;
- Realisation of benefits (business success).

Voss also proposed a number of factors that, when present, positively influence the technical and business success of manufacturing technology investments. Table 4.1 illustrates further the factors that contribute towards greater *technical* and *business* success.

Technical Success	Business Success
Top management support	Linking manufacturing technology to manufacturing policies
Links with suppliers	The way manufacturing is managed
Cross functional implementation teams	Managing to realise the benefits: A) Planning and budgeting; B) Measurement and control; C) Managing new technology as a learning process.
Planning	Taking an integrated approach
Workforce involvement and human factors	Changing the organisation
Skills and training	
Keeping management informed	

Source: derived from Voss (1988).

Table 4.1: Factors Influencing Technical and Business Success of Manufacturing Technology Investments

Voss (1992) further outlined factors which should be present in the three stages of the implementation process for a manufacturing technology implementation to be a success. These are illustrated in Table 4.2.

Pre-installation (Planning and Design)	Installation and Commissioning	Consolidation
Identifying and forecasting capabilities of the technology Strategy-Business and technical objectives for process technology Broadly based evaluation team and implementation champion Matching complexity of technology to the firm's ability to handle fit Long-term evaluation of the full system, not short-term evaluation of parts of it	Broadly based project team Effective support from the supplier Implementation champion Managing industrial relations Training and availability of skills	Keeping teams in place after commissioning Mutual adaptation of organisation and technology Appropriate managerial control

Source: MacDougal (1997), *Table 3-2;* Voss (1992), *p. 42.*

Table 4.2: Factors Influencing Implementation Success/Failure

4.7 Factors Contributing To A Good Investment Project

The survey also revealed a number of factors that are key to the success of the manufacturing technology implementation process. One interviewee summarised a *"good"* investment process as one where *"you know how much you want to spend, you have an investment in mind, you can justify it* (the investment), *and you know to whom to justify the investment."*

One of the first things to decide with regards to an investment in manufacturing technology is if the technology is an essential item. As one interviewee stated, *"if it is not* (an essential item) *it may be difficult trying to develop a business case for it"*. So from this one may deduce that it is important to have a firm reason to invest otherwise money may not be assigned to a business case that cannot be fully justified. The interviewees also stressed the importance of involving all the necessary personnel from the beginning of the process and informing them of the progress of the investment from initial idea proposal to selection and installation.

The importance of communication was also stressed by the interviewees, and communicating the need for the investment was also highlighted as being important. Furthermore, the interviewees stressed the importance of investigating the supply chain to assess the extent to which any suppliers can accommodate and support the major or minor changes that may take place as a result of the investment.

"A thorough investigation of all investment choices" must be conducted to ensure that the most suitable and appropriate technology is selected for investment. It is interesting to note that whilst companies select their manufacturing technologies with a view to cutting and minimising costs, they suggest that a successful investment project will have been thoroughly assessed and evaluated for both its financial and strategic benefits. From this one may suggest that assessing an investment project on the basis of the extent to which it will provide cost savings is not a thorough investment appraisal. One may also suggest that this supports the argument that a portion of manufacturing technology investments fail to achieve managers' expectations because only financial

appraisals are conducted, and managers neglect to consider the longer term strategic benefits.

If one wishes to propose an investment then its acceptance or rejection will be based on the information contained within the business case, and any other relevant information. *"Gut feel"* often tells a manager if an investment will be a sound decision, but if one requires more specific information on which to base an investment decision then a business case is of vital importance. The business case must be thorough and contain all the data and information pertaining to the investment. One interviewee suggested all investment choices be thoroughly investigated to ensure the right investment is selected. There are many reasons why a company might chose a particular investment over another but an investment should be selected on the extent to which it will help the company achieve the goals it has outlined, preferably strategic and financial.

Once this *"right"* investment is chosen a business case must be prepared detailing the justification and other data that may sell the investment to the necessary personnel. As investments costing over a certain amount of money are referred to a more senior management panel for review, the business cases should be tailored to best present the data to the particular review board. The business case must detail a plan for technology implementation, and also provide details of how the technology supplier will be supported and maintained throughout its life. It is important that the business case shows how the investment fits financial and strategic objectives, and a payment plan must also be detailed. The preparation and submission of the business case are probably the last steps in the first phase of the manufacturing technology investment process. If

the business case is rejected then the personnel involved must reconsider the business case and their proposed investment. If the business case is accepted the personnel involved in designing and preparing the department(s), or functions, for the technology installation can continue with their activities in anticipation of the arrival of the technology.

4.8 Preparations For the Process Aid

Once an analysis of the interview responses had been conducted it was then necessary to take this information and construct a list of issues that should be reflected in the process aid. These issues are listed in Table 4.3. The purpose of the process aid will be to provide a framework that can guide users through the process of investing in manufacturing technology. The author has concluded from the interviews that whilst the participants understand what is necessary to make a good investment process, they do not have the time to devote to researching their process and addressing the problems that arise. The author suggests that key to investment success is the degree of control which is exercised over the process, especially control over those elements that can positively and negatively affect progress. Hence, the author has used the interview information and devised a list comprising further factors for consideration in the process aid. At each stage of the investment process (based on Voss' interpretation – The Process of Implementation) particular issues will have to be addressed and, using the information from the interviews, the author has compiled in Table 4.3 the factors that must be considered at each stage of the process.

In Chapter 2 there is discussion of *external and internal factors* (see Table 2.1). These factors can greatly affect the investment process and must be considered when making investment decisions. Under the heading External Factors, a list is also included that will eventually be used in the construction of the process aid.

The following factors are in no particular order. They are factors that affect the investment decision and for this reason will be represented in the process aid.

Pre-Implementation Stage	**Implementation Stage**	**Implementation Review/Knowledge capture Stages**
What does the business require in technologies	Deciding to run with an investment	Who to involve
What business areas require improvement	Preparing the area/site for locating the investment	When to conduct review
What are the key technology areas	Whom to prepare for receiving the investment	How to record data/performance measure data
What to invest in	To which business case to allocate finance	Reassessing maintenance plan
Purpose of investment	Establishing a review procedure	Reassessing training requirements
When to submit proposal of investment	When to review	Consolidating review procedure
When to submit business case	Who should be involved in the review	Compile document detailing review outcomes and learning points
Fitting the investment to the business drivers	Action to be taken should investment not achieve performance measures	To whom to issue review document
Fitting the investment to the strategic objectives of the company	What does the business require in technologies	What data should be included in the review document
To whom to give the finance	Assessing needs for future investments/other technologies	
What performance measures should be used		
When to invest		
Calculating risk associated with project		

Risk management planning		
When to have decision gates		
Who will control/have ownership of the project		
Who will use the investment		
When it will be used		
Who to involve		
When to review		
To match investment objectives with business objectives		
De-commissioning plan		
Which technology vendor		
Matching emerging needs to technology needs of the company		
Who will conduct maintenance		
Level of training required		
Check health and safety implications		
Who to train		
What decisions must be made at these points		
Spending available for addressing problems		
Which investment adds value to the business		
On what basis to select the best investment		
Final investment choice		

Table 4.3: Factors Affecting Manufacturing Technology Investments

4.9 External and Internal Factors

The following are a selection of factors taken from the interviews that have an effect on, or stimulate in some way, the manufacturing technology investment process. It is important to note these factors, namely External and Internal Factors, as they will have

some bearing on the degree to which certain issues have an effect on, or are controlled and managed, throughout the investment process. It is important that decision makers are aware of these factors and the extent to which they influence manufacturing technology investment decisions. These factors will also be included in the process aid.

External Factors	Internal Factors
Competitors behaviour	Who has requested finance for investing
Mergers/acquisitions within the industry	Who agrees the level of spending available
Availability of vendors	Company strategies
Capability within supply chain	Number of business cases for review
Customer demands	Business value drivers
Capability of maintenance company/ies	Review board
	Is there a budget available to spend
	Splitting the budget
	Existence of a review process
	Level of technological confidence
	Nature of corporate governance
	Methods for evaluating investments
	Culture of organisation
	Organisation technology development strategy

Table 4.4: External and Internal Factors Highlighted by the Interviews

4.10 Chapter Summary

This Chapter discusses the design of a survey to investigate the process of investing in manufacturing technology in aerospace. The purpose of the study is highlighted, followed by the design of a specific questionnaire for use in the survey. It was decided to conduct interviews within the collaborating company. In total five interviews were conducted with personnel from various sites within BAE Systems. A pilot study was conducted initially, the results of which are also contained in this Chapter, prior to the main survey. The interviews alerted the author to many issues, many of which had been

encountered in the literature review and the postal survey. These issues are documented in a results section in this Chapter. The actual interview scripts are provided at the end of the thesis in Appendix J.

Chapter 5 Developing the Process Model

Abstract

Once the data had been gathered and analysed, it was necessary to use the information derived to construct a model of the manufacturing technology investment decision process. In order for a process aid to be built to assist the process of investing in manufacturing technology the interviews had to be analysed together with information from the postal survey and the literature review. This had to be conducted in such a way as to derive the most important points raised by the interviewees relating to the manufacturing technology investment process. This Chapter discusses a variety of modelling techniques and the selection of an appropriate technique for modelling the manufacturing technology investment decision process. The Chapter closes with a description of the process framework and conclusions.

5.0 The Purpose of Modelling

Wainwright (1993) proposed a definition of a model:

> *"A representation of a real system which can be manipulated to reveal the consequences of particular decisions more readily, or more cheaply, and with less risk than for direct manipulation".*

Modelling therefore provides a framework in which complex problems may be dealt with more easily. A variety of modelling techniques exist each of which are appropriate

for a specific application. Baines (1994) identified the major types of modelling techniques and produced a taxonomy which is summarised in **Table 5.1.**

MAIN CLASS	SUB CLASS	DEFINITION
Physical	Replication	A spatial transform of an original physical object in which the dimensionality of the modelling is retained in the replica.
	Quasi replica	A physical model in which one or more of the dimensions of the physical object are missing or modified
	Analog	A model which bears no direct resemblance to the modelled phenomena.
Symbolic	Schematic	A graphical representation of a system using symbols.
	Simulation	A model of the behaviour of a system, defining in detail how various components interact with each other.
	Mathematical	Explicit analytical formulae describing known relationships.

Source: Argument *et al,* (1996), *Table 5.1;* Baines (1994).

Table 5.1: Taxonomy of Model Types

Throughout the 1980's and 1990's significant effort was applied to research and develop methods for capturing, controlling and managing knowledge and information resources. This was driven by the awareness that the ability to successfully manipulate data and information could give rise to lucrative economic and strategic benefits for those with the power. It was becoming increasingly apparent that one of the keys to attaining sustainable competitive advantage was information management.

5.1 Modelling Techniques

There are a variety of modelling techniques in existence, each with its own unique structure and purpose. Alternative modelling techniques are important as not all are

suitable for particular circumstances. However used, combined or singular, they all provide a greater understanding of the process, or system, being analysed. **Figure 5.1** shows a hierarchy of typical modelling techniques applied in industry.

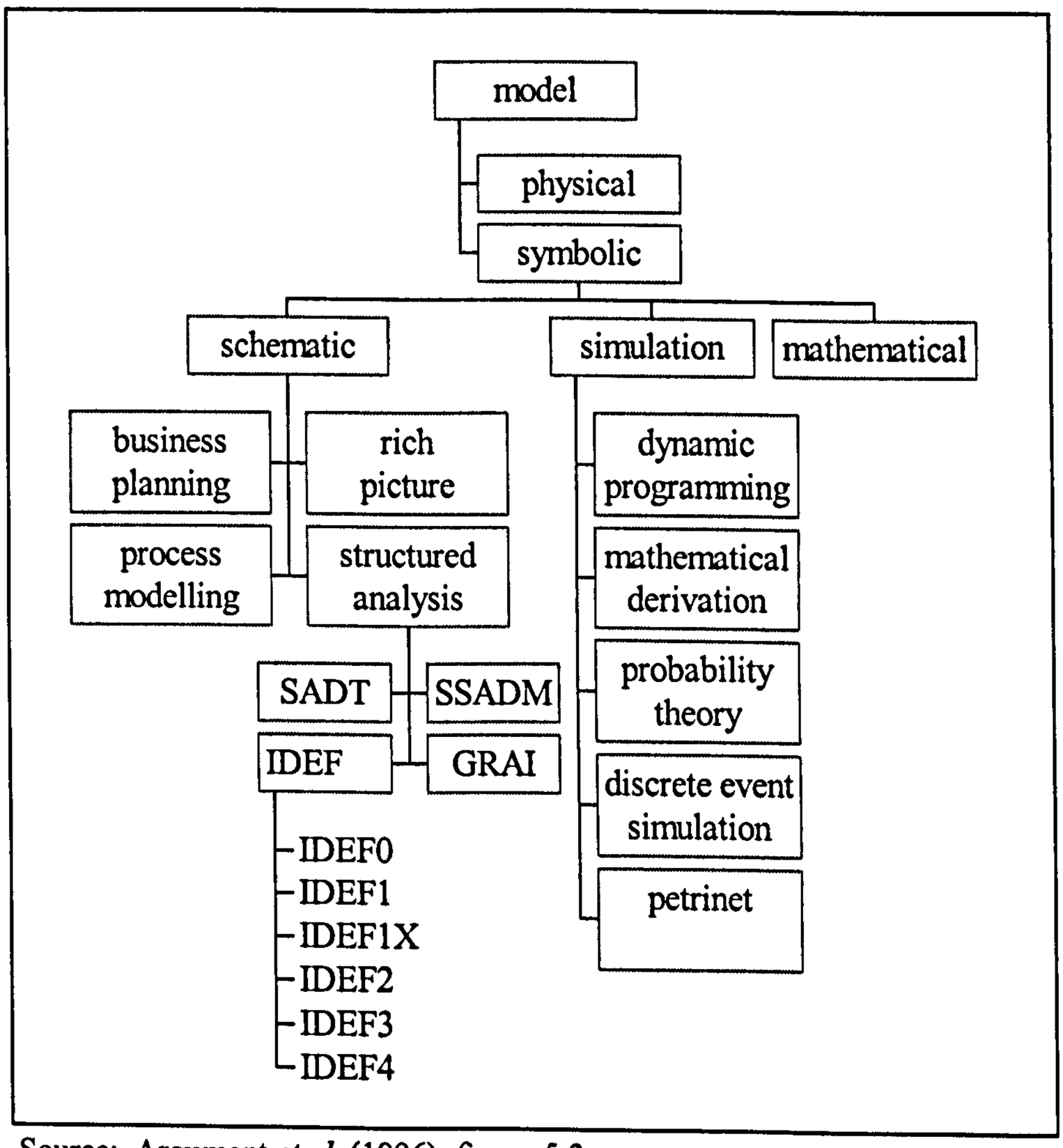
Wainwright and Thethi (1997) note that symbolic modelling methods are used to describe a particular situation, and can be categorised into schematic, simulation, and mathematical types. Schematic models are used to model the activities in a system; simulation models model time dependent systems; mathematical models are used to interpret a given situation.

In order to model a process such as the manufacturing technology process a number of modelling techniques would have to be researched. In the family of structured analysis techniques, several techniques would be applicable, most notably IDEF. For the author, this was the most obvious choice for reasons of familiarity and ease of use. However, prior to selecting one of these techniques for application, it was necessary to conduct a study to assess the suitability of these techniques for modelling the investment process. Relevant sources were researched to provide the theoretical background to IDEF0, and pilot studies were conducted to eliminate less appropriate techniques. The details of this follow.

5.1.1 IDEF Modelling

In the US, the Air Force established a programme in the early 1980's, namely the IICE (Information Integration for Concurrent Engineering) programme, and committed themselves to the further development of technologies for manipulating and exploiting

knowledge and information resources. The IICE programme was chartered with developing the theoretical foundations, methods, and tools to successfully evolve toward an information-integrated enterprise. Another US Air Force programme, namely ICAM (Integrated Computer-Aided Manufacturing), gave birth in the 1980's to the first ICAM Definition, or IDEF, methods. IDEF, or Integration Definition, methods have been continually developed to produce a family of mutually-supportive methods for enterprise integration (Mayer *et al,* 1995). The relationship of the IDEF techniques to other modelling techniques may be observed by the modelling hierarchy (Argument *et al,* 1996) shown in **Figure 5.1.**



Source: Argument *et al,* (1996), *figure 5.2.*

Figure 5.1: Hierarchy of Modelling Techniques

Mayer *et al,* (1995) argue that the IDEF family of modelling techniques are developed in such a way as to strike a balance between special-purpose techniques, which are limited to specific problem types, and super techniques which attempt to include everything. This balance is maintained by providing explicit mechanisms for integrating the results of individual techniques within the IDEF family.

5.1.2 The IDEF family

IDEF originally comprised a number of different tools as outlined in **Table 5.2.**

•	IDEF0	Function modelling – Activity centred analysis
•	IDEF1	Information modelling – Information centred analysis
•	IDEF1X	Semantic data modelling – Logical database design
•	IDEF2	System dynamics modelling – Simulation model specification
•	IDEF3	Process description capture – Process centred analysis
•	IDEF4	Object – State description capture – Object centred analysis/object; Oriented design

Source: Argument *et al,* (1996), *figure 5.2.*

Table 5.2: The IDEF Family

This family of four was eventually built upon and now contains many IDEF modelling methods, each with their own individual purpose. Wainwright (1993) proposed a summary of IDEF techniques describing the IDEF family as a graphical modelling system containing its own rules of syntax, construction, validation, and referencing. The summary is as follows:

- IDEF0 – for modelling the structural relationship of the functions of a manufacturing system and of the data which inter relate those functions;

- IDEF1 – for modelling the structural relationship of the data needed to support the functions of a manufacturing system An advantage of IDEF1 is its usefulness for the design of integrated databases. IDEF1 is criticised for not defining interfunctional entities;
- IDEF2 – for modelling the dynamic behaviour of functions and information within a manufacturing system. IDEF2 is criticised for lacking the capability to illustrate control aspect of systems;
- IDEF3 – for capturing descriptions of sequences of activities;
- IDEF4 – Object state description capture;
- IDEF 5 – Ontology description capture;
- IDĖF6 – Design rationale capture;
- IDEF7 – Information system audit method;
- IDEF8 – Human system interaction modelling;
- IDEF9 – Business constraint driven modelling;
- IDEF10 – Implementation architecture modelling;
- IDEF11 – Information artefact modelling;
- IDEF12 – Organisation modelling;
- IDEF13 – 3-Schema mapping;
- IDEF14 – Network design.

5.1.2.1 IDEF0

IDEF0 was designed for activity modelling, and can represent the objects that move between activities. It is a "top-down" approach, where the highest level of a system is represented by a single box. It is applied to classify schematically the structural

relationships between functions and entities in order to make it easy to understand the detailed working of a complex system. By using IDEF0 the system being modelled can be viewed as a collection of diagrams, with the ability to view activities within activities through the use of decomposition. As shown in **Figure 5.2** the box has an *input* which is transformed into an *output*, under the influence of the *control* and *mechanism*.

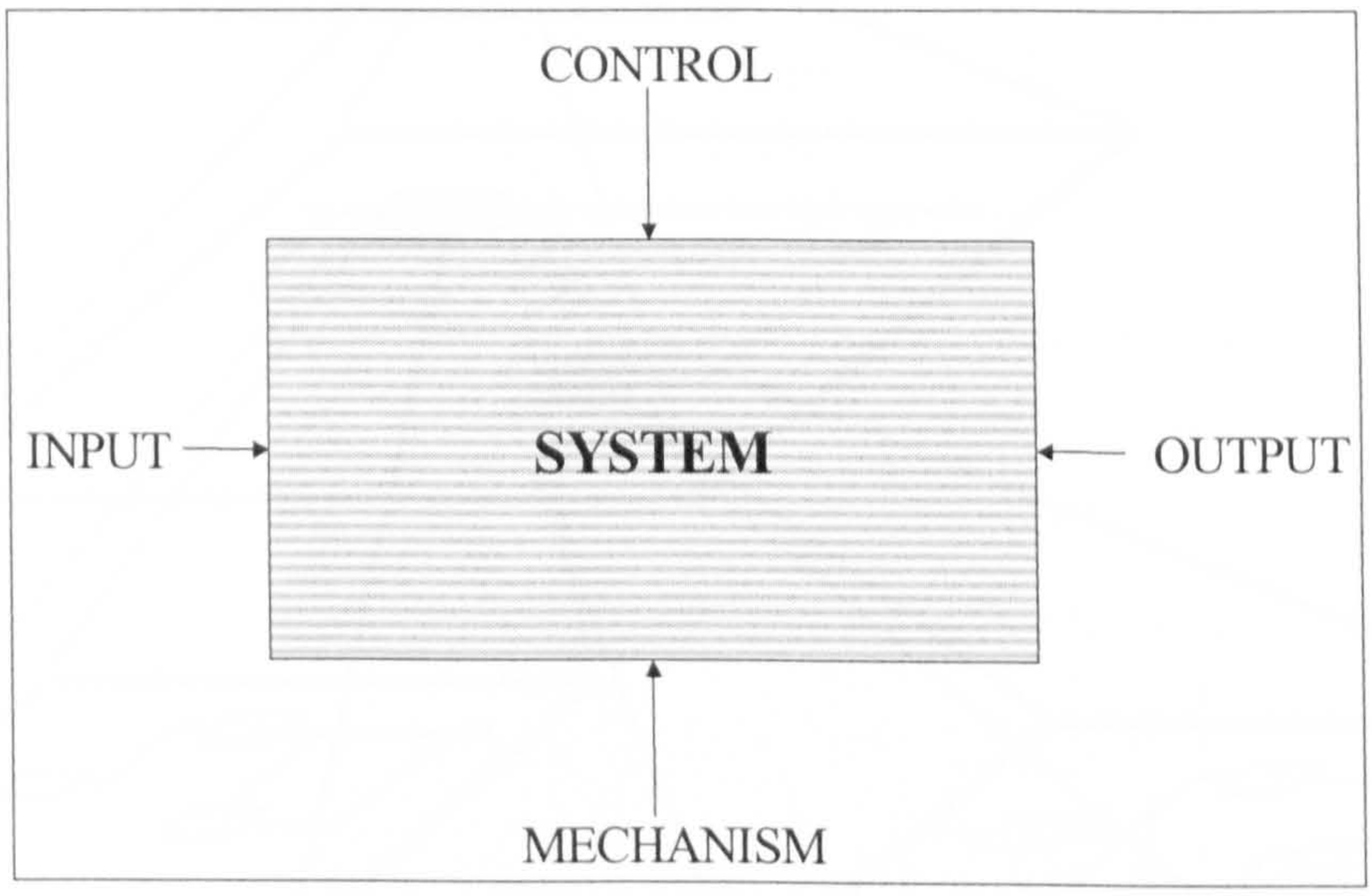
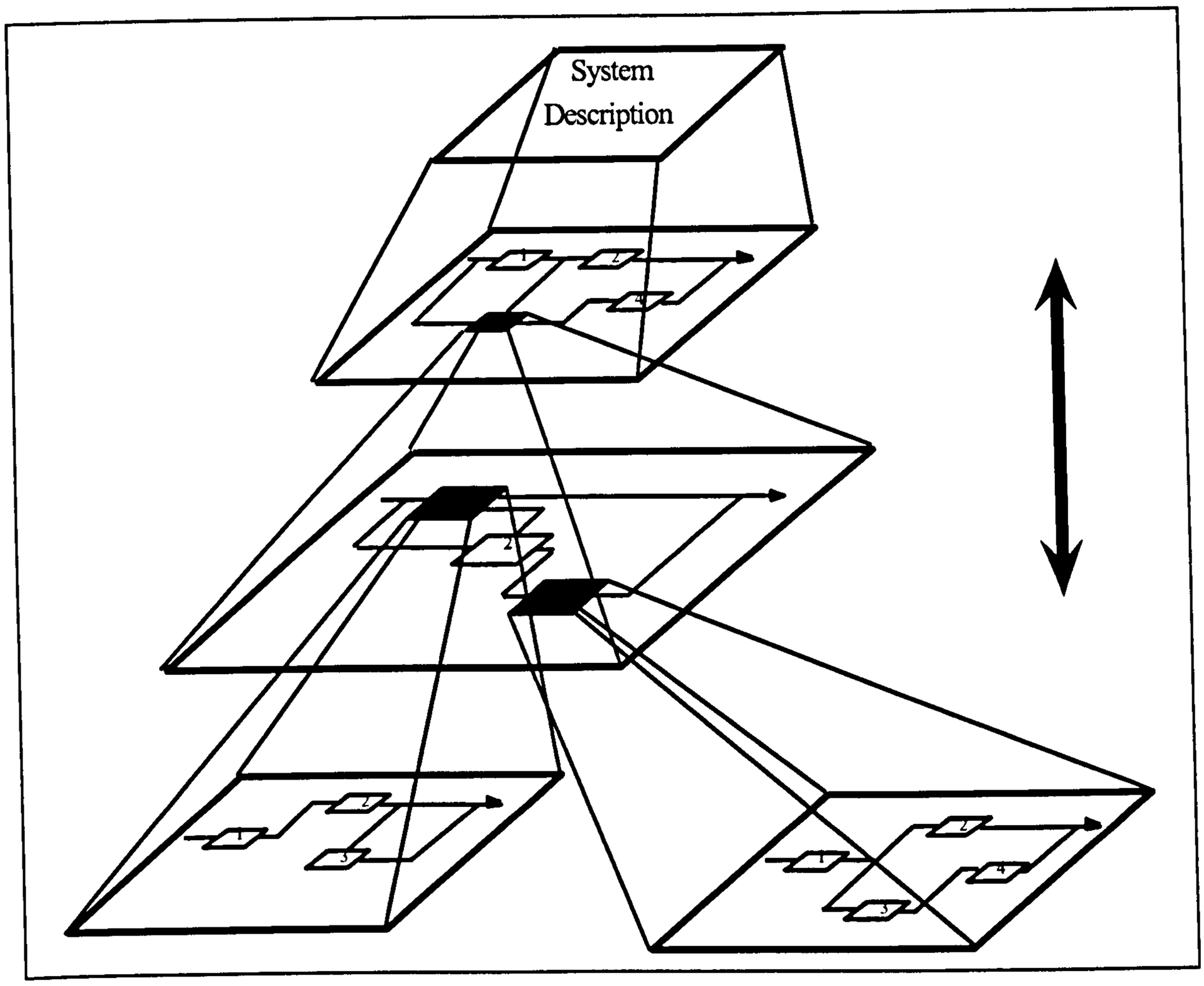


Figure 5.2: Example of an IDEF0 Box

A typical IDEF0 diagram will comprise many levels each conveying information about the process. A multi-layered IDEF0 diagram is shown in **Figure 5.3.**

5.1.2.2 IDEF3

IDEF3 is part of the IDEF family of modelling techniques and was developed to capture descriptions of sequences of activities within real-world systems. IDEF3 focuses on the relations between processes within a system, the objects involved in the processes, and the object state changes within the system. Mayer *et al,* (1995) describe the primary goal of IDEF3 as to provide a structured method by which a domain expert can express knowledge about the operation of a particular system or organisation.



Source: Wainwright, 2001.

Figure 5.3: A Multi-Layered IDEF0 Diagram

5.2 Selecting An Appropriate Method

The research objectives are outlined in Chapter 1 as follows:

- To address the need for a greater understanding of the technology investment process by investigating the whole process within the collaborating company;
- To breakdown the process of investing in manufacturing technology into key stages and to analyse these in detail;
- To detail the process acquiring and implementing manufacturing technology and to model this;

- To develop a generic tool which may be employed within the collaborating company to aid consistency in the investment process.

Hence, to satisfy the research objectives the author concluded a need for a modelling technique that would enable a thorough representation of the activities and elements that constitute the manufacturing technology investment process. Furthermore, the author required a modelling technique that would be relatively easy to use, and one that would present data clearly. Through the use of the chosen modelling technique the author would graphically represent the constituent parts of the process and, using literature review and survey data, produce a full model incorporating suggestions for improving the process. Once this model was produced, the structure would be used as a basis for the design and development of the investment process aid, for use within the collaborating company.

One of main reasons for using a structured modelling technique is that they organise often complex data into an easily readable form, enabling clarity and understanding. One of the main research objectives outlined in Chapter 1 is to produce a process aid to enable consistency and control in the investment process. However, it would not be possible to create a process aid without having constructed, or represented, the process itself first. Hence, the author undertook to model the process of investing using data from the literature review and data from the postal and interview surveys.

The author considered using the GRAI modelling method yet it was found to be unsuitable for the task of modelling the activities of the investment process. The author

initially selected IDEF0 for modelling the investment process. IDEF0 was chosen as the author was familiar with the IDEF0 logic and software, and favoured the use of decomposition for representing activities in detail. A pilot study in IDEF0 was conducted, the results of which are contained in Appendix K. Once modelling was underway the author experienced difficulty in representing the many activities and elements of the process using the IDEF0 logic. Using the chosen modelling method it was not possible to include all the necessary activities to enable a full representation of the investment process. Hence, IDEF0 was rejected as a modelling method

5.2.1 The Selection of IDEF3

After the rejection of IDEF0, IDEF3 was selected as a modelling method for the task of representing the investment process. The use of IDEF3 would enable the representation of any number of activities (without constraints), and would also allow for the inclusion of unlimited information about the process itself and any other factors involved, such as resources. Activities can be broken down, or decomposed, using IDEF3 to reveal their constituent activities. There are no limitations as to the number of activities, or decomposed activities, that may be contained within the process under representation. Furthermore, should there be any changes to particular elements within the process, these changes may also be represented using IDEF3. A pilot study was conducted using the chosen modelling technique. This was found to be so successful that the pilot study was withheld as an element within the holistic model subsequently developed.

5.3 Process Model Construction

With regards to the construction of the process model, there were a number of objectives:

- To create an accurate model of the investment process within aerospace (i.e. a model that contains all the major activities that lead to technology adoption and implementation);
- To use data from the literature review and the postal and interview surveys to create a full investment process;
- To create a process that is not only accurate, but incorporates the author's research and suggestions for improving the process.
- To create a model upon which a practical process aid may be based.

It was decided to base the process model around the same stages used as bases for the interview survey questionnaire. Hence, the process model would consist of three main stages in the following order:

1. Pre-implementation;
2. Implementation;
3. Post-implementation.

These stages are linked in the process model to form the whole process of investing. As discussed in previous Chapters, these stages are essentially the components of the Voss (1992) Process of Implementation Model shown in **Figure 3.1** in Chapter 3. For the

purpose of this study, the author renamed the stages and used these as the basis for the interview survey. It was decided that the process model should also be based on these three stages, and would be built using the information derived from the literature review and the surveys. By using these three stages, a degree of organisation was imposed on the model.

The following are brief descriptions of what occurs during the three main stages:

Pre-implementation

This stage encompasses planning, evaluation and the eventual selection of an investment. The literature review and the surveys revealed that extensive planning is required prior to an investment to ensure that whilst a range of investment choices are being analysed, preparations are underway to enable the final investment choice to be eased into the company with the minimum problems. This is the stage at which the groundwork is laid for a successful or problematic investment and all action taken should be tracked and documented.

Implementation

It is at this stage that the investment choice is brought into the company and into operation. All the preparations made in the earlier "Pre-implementation" stage will guide the investment through this stage. The investment will experience a pilot run which is an initial run to introduce the technology to the stakeholders and operators. The purpose of this pilot run is to understand how the technology operates, to enable operators to familiarise themselves with the technology, and to highlight possible

problem areas. If problems are discovered then corrective action should be taken. Reviews should be prevalent during this stage or, at least, a system by which the progress of the investment is monitored and documented. It is important that progress during this stage is tracked and documented.

Post-implementation

This is the stage at which the investment process is reaching its end of life. This is the stage at which the progress of the investment is assessed and all the information associated with the investment is compiled into a report. It is likely at this stage that replacement, or new, investments are being reviewed and evaluated and, as always, managers will be hoping that their investment choice will be relatively trouble-free. At this stage, it will be useful to take the information gained from previous investments, and use it as a measure for continuous improvement.

In order to construct the process model the author preferred to use PromSim Modelling software. The complete process model is contained in Appendix L

As outlined in Chapter 4, there are a number of factors that should be present throughout the investment process to aid technical and business success. Voss (1988) revealed that an investment must be judged on these two levels of technical and business success before it can be considered a success. He also proposed several factors that contribute towards the technical and business success of an investment. These factors are outlined in Chapter 4 in **Table 4.1** and **Table 4.2.** Through the surveys, a

number of factors were revealed that may have a positive influence on the progress of a technology investment.

These are as follows:

- Establish a review procedure and adhere to this;
- Try to keep to one project leader;
- Conduct a thorough justification of all possible investment projects;
- Organise maintenance and technological support from the outset;
- Involve all stakeholders, or necessary personnel, as early as possible in the investment process;
- Encourage stakeholders to communicate their desires and preferences for investment choice;
- Encourage all personnel involved to have commitment to, and a sense of sharing in the project;
- Frequently communicate the progress of the investment;
- All problems associated with the investment should be communicated as soon as they arise;
- Outline as many risks as possible to the project;
- Plan for risk and make preparations to accommodate problems, should they occur;
- Senior management backing;
- A clear understanding of the effects an investment will have, and communication of this;
- An organised and thorough business case.

For this reason, the author wanted to include these factors in the process model and process aid. Many of these factors can be considered as planning, or preparatory factors and, hence, should precede factors such as those regarding monitoring and communicating investment implementation progress. The author concluded the majority of these factors should be included in this first stage of the process. It was decided to begin the pre-implementation model with a number of planning procedures and end this stage with the decision to invest. Activities in between these introductory and end activities would be concerned with the evaluation of investment choices and preparations of personnel and the operating environment.

5.3.1 Activities, Sub-Activities and Parents

Throughout the process model the author has named the individual stages *activities*. Each activity is a point in the process that must occur before the process can continue. Some of the activities are decomposed to show more detail action, the reason for this being that some of the activities contain a number of what the author has named *sub-activities*. These are basically the activities that constitute another main process flow activity, but are often too numerous to include in the main process flow. These sub-activities are therefore the constituent activities of what the author has named the *parent* activity (the decomposed activity). Where necessary, further decomposition exists where sub-activities have been further broken down to reflect their constituent sub-activities.

The process flow begins and progresses through the main activities, moving through the sub-activity processes when indicated. At several points in the process *junctions* exist,

which are a feature of the IDEF3 methodology, and they are used to indicate when multiple activities occur. The purpose of junctions is to indicate the order and timing of the different activities. Whilst the main process flow represents the sequential flow of activities, the sub-activities contained within a decomposition may or may not occur simultaneously. Furthermore, whilst all of the activities within some sub-activities must occur, in some cases the process may need only to flow through one or two possible sub-activities for the whole main flow to continue. Junctions are used in these instances to reflect the necessary process flow through sub-activities. It is important to note that whilst there are three identifiable "main stages" within the process, they are linked and thus constitute the whole process of investing in manufacturing technology. This is illustrated in **Figure 5.4.**

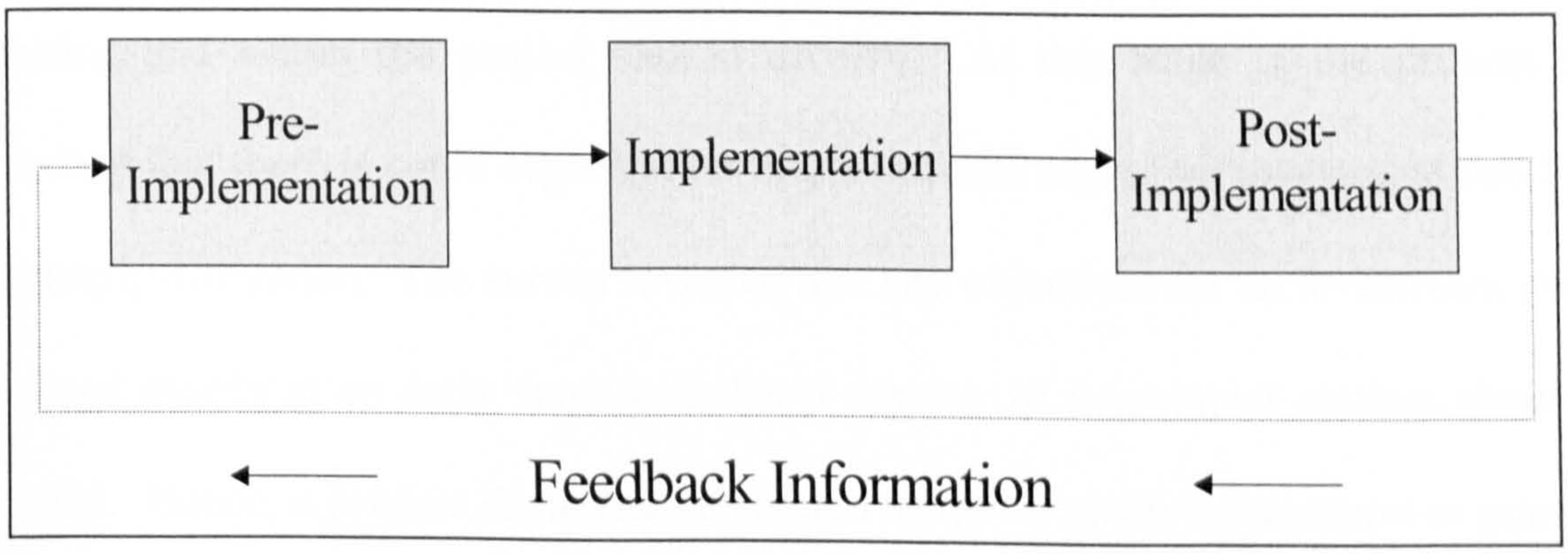


Figure 5.4: Process Model Overview

5.3.2 The Pre-Implementation Stage Activity Flow

The process begins with the activity ***Initial Investigation of Investment Need.*** This is the point at which the company is aware of the need for an investment. There may not be a flurry of activity at this point, hence no decomposition is required, and it is likely that an idea has been discussed or one is in mind. Many investment projects are purchased to replace older technology so the lead is often there within a company.

There is no one person in the company responsible for generating investment ideas. Ideas tend to emerge as opposed to being generated. This activity is also used at the end of the Post-Implementation stage to illustrate the cyclical nature of the investment process. The Post-Implementation stage ends with a review of the business case that has been developed in the Pre-Implementation stage. Using information from this review, the company can then begin to investigate new investment ideas, thus linking the whole process and beginning the cycle of investment again.

The process flow moves onto the next activity, a decomposed activity named ***Create Project Document 1.*** This sequence is detailed in **Figure 5.5.** This activity is broken into a number of sub-activities, the product being a document detailing reasons for investing and whom the project should involve. At this stage in the process it is important that there is some organisation to the introduction of an investment need, and not simply discussion. The survey revealed that any objectives for an investment should be stated clearly at an early stage and that a number of investment choices should be outlined. Hence, a ***project document*** is created to list as much information as possible. It is important that the requirements for any possible investment are also stated clearly in the project document (1). From an early stage, personnel should be aware of the reasons why a company is choosing to invest in manufacturing technology, whether this be replacement technology or otherwise. Also, any strategic objectives should be outline at this stage, together with the costs associated with the investment suggestions.

Following this stage there is a sequence of activities involving the distribution of the ***project document.*** It is at this stage that the document will be delivered to the necessary

management and personnel for their perusal. The sequence has been created to allow for the acceptance or rejection of the project document. If the document is accepted, the process flow moves to the next activity; if the document is rejected it is then referred to the decomposed activity ***Create Project Document 1.*** This is important as there may be aspects of the document, or the proposals contained within it, that are not possible to fulfil and they should be revised and re-submitted. However, if the project document is accepted then the process flow will continue to the next activity, ***Generate Investment Ideas.***

This activity, ***Generate Investment Ideas,*** involves a more thorough investigation of the possible investment choices proposed in ***Project Document 1.*** This investigation should involve an investigation of possible suppliers, prices involved, delivery arrangements, risks associated with the investment, maintenance arrangements, and operating procedures. It is key at this point that any investigation is conducted with the contents of ***project document 1*** in mind. This document should be the guide for action at this stage. During this stage it is likely that the project team will examine as many investment choices as is necessary. For instance, they may need only to examine three or four different choices. At each level within the company the number of investments projects under investigation will vary, and there are few that finally make it for approval at, and above, management board level. Once this stage has been completed and personnel are satisfied they have a satisfactory list of investment choices, they then progress to the next activities, ***List Possible Investment Ideas,*** and ***Create Project Document 2.***

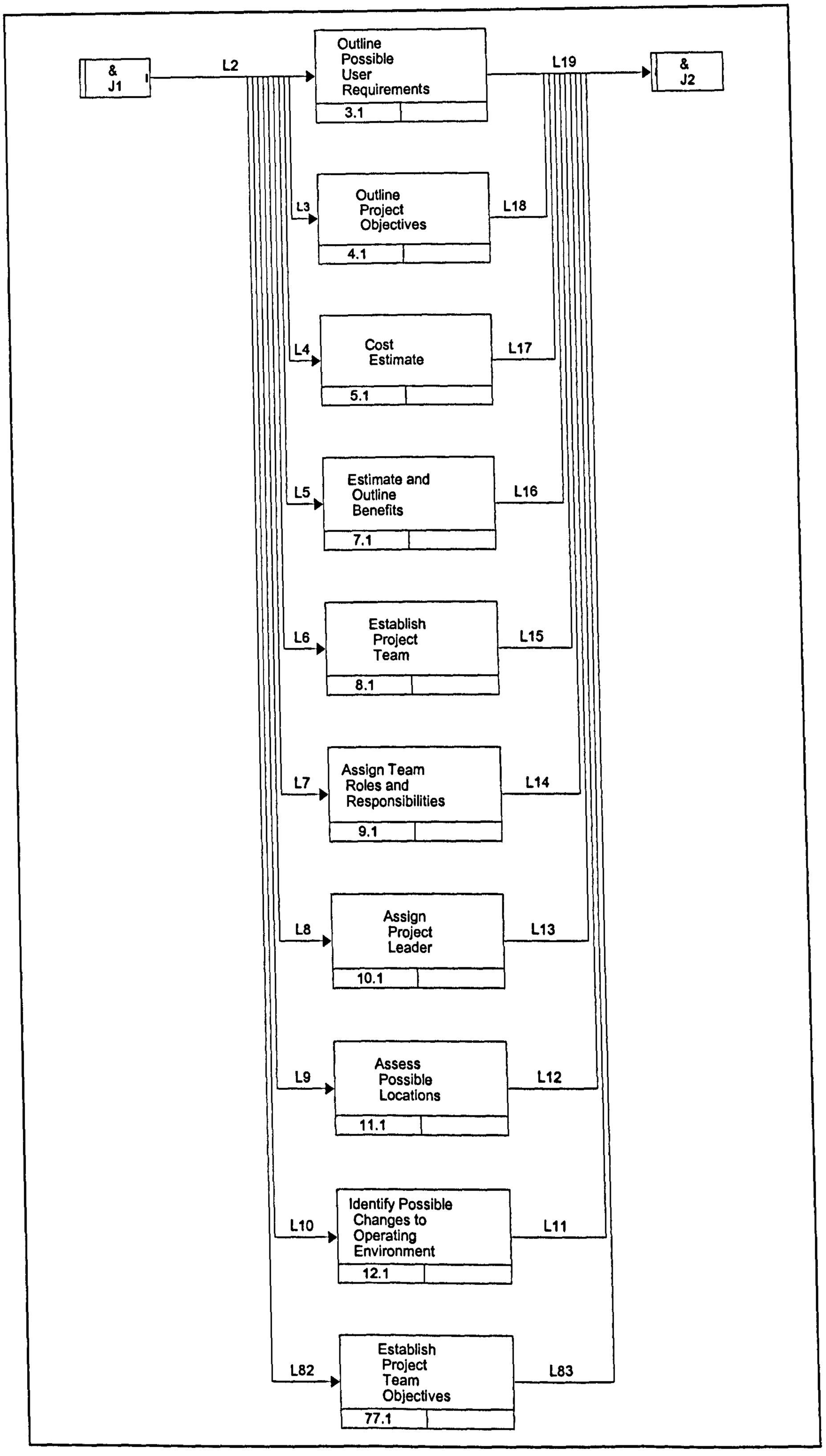


Figure 5.5: Decomposed Activity – Create Project Document 1

Any suitable investment choices are listed in the activity ***List Possible Investment Ideas.*** This list is then used in the following activity, ***Create Project Document 2,*** a decomposed activity which involves the creation of a detailed document. This sequence of activities is shown in **Figure 5.6.**

Project Document (2) contains information about the investment choices and the effect they will have on the company. The document will contain information about budgets available for spending and the costs involved with each choice. Again, this sequence of events may lead to either an acceptance or a rejection of the document. If the document is rejected, the process moves back to the activity ***Generate Investment Ideas.*** If the document is accepted, the process flow moves onto the next activity, ***Investigate Suitable Vendors.***

In this activity, ***Investigate Suitable Vendors,*** a thorough investigation of potential vendors will be conducted. It may be that the company already has dealings with a particular vendor and understands them. In this case, the company will want to learn more about the particular type of technology they are interested in and the maintenance and support they offer once the technology is in operation. Important points to consider when selecting vendors is the technical capability they offer and the extent to which they understand the companies technical and business requirements. The vendor must be able to support the implementation. The company will need to discuss their requirements with possible vendors and establish links with them for further consultations. The outcome of this activity is a selection of possible vendors, which,

together with other vendor information, is compiled into a document in the next stage, ***Compile Vendor Document.***

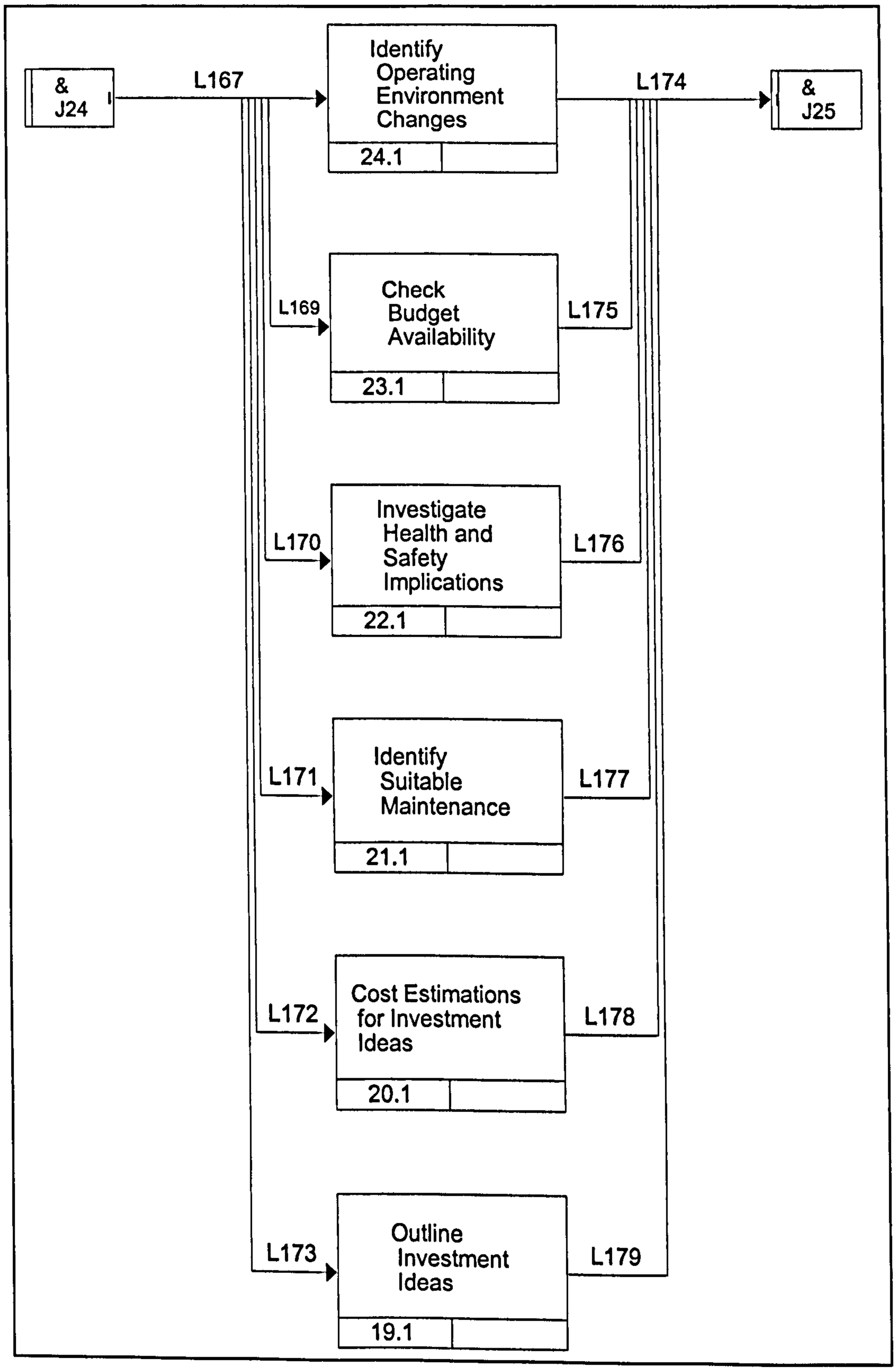


Figure 5.6: Decomposed Activity – Create Project Document 2

Following this activity is a familiar sequence of events involving the acceptance or rejection of the vendor document. If the document is rejected, the process is led back to the activity ***Investigate Suitable Vendors.*** If the document is accepted the process moves onto the next activity, ***Prepare Tender.***

A sequence of activities occurs during which information about the company's investment requirements is prepared and submitted to the chosen vendors. This sequence begins with ***Prepare Tender.*** The tender is prepared around the technical requirements of the company. These are outlined and the selection will be based on the degree to which the vendor can satisfy these. The vendor most likely to succeed will be one based on their understanding of the company's technical and business requirements, the degree to which they can support the technology implementation, and cost. The vendor must place effort into building the confidence of those they wish to sell to. The following activity is ***Review Submissions,*** an activity during which the company's project team review the information provided by the vendors about the technology they offer. Some of these offers will be unacceptable, hence the following activity, ***Organise Returned Tenders,*** when the viable tenders are reviewed. Once the tenders have been organised, the project team then choose the most viable, (activity ***Select a Tender Submission)***, based on a series of quantitative and qualitative evaluations. This activity is decomposed and is detailed in **Figure 5.7.**

Once the evaluation has been conducted, the results are then documented in the following activity, ***Document Evaluation Results.*** These results are then used in the next activity, which is ***Create Business Case.*** This activity is decomposed into

constituent sub-activities. The business case is important as it is upon the information contained within it that the appropriate management committee approve or reject it.

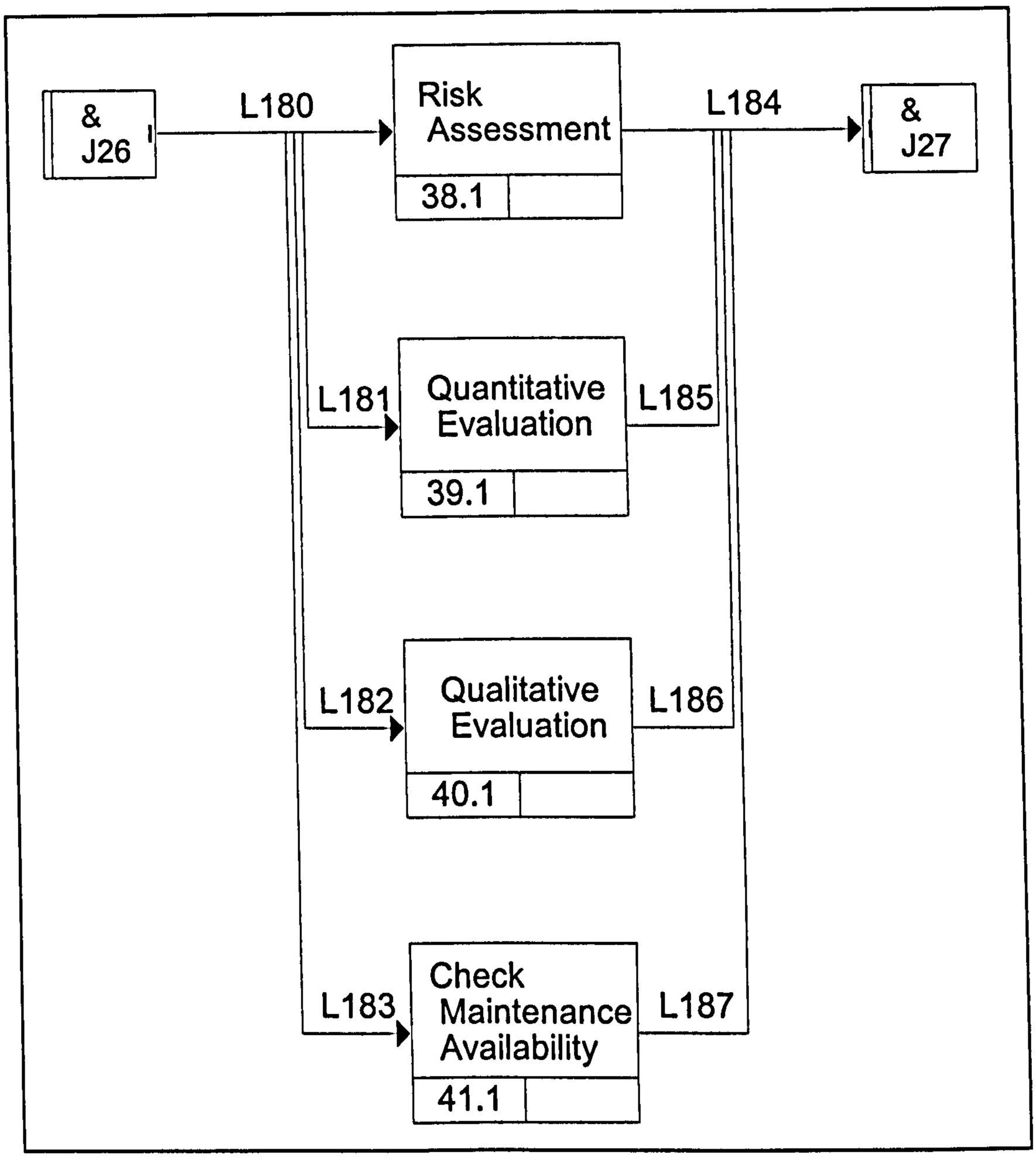


Figure 5.7: Decomposed Activity – Select A Tender Submission

Once the business case has been prepared, it is submitted to the appropriate management committee. Within BAE, depending on the cost of an investment, an investment proposal is reviewed by different managers. It is important that the business case is submitted to the appropriate committee for approval. The sequence of activities that follow ***Submit Business Case*** is illustrated in **Figure 5.8.** If an investment is

approved then the process flow continues to the next main stage of the process, *Implementation* and the activity ***Project Approved.*** If the investment is rejected, the process returns to the activity ***Create Business Case.***

5.3.3 The Implementation Stage Activity Flow

This stage of the process, namely *Implementation,* continues once the first stage, *Pre-Implementation,* has finished. The process begins with the activity ***Project Approved*** which is the point in the process at which the investment is accepted for purchase. Once the project has been approved, ***Training*** can begin. Once this activity is underway the project team can begin to ***Finalise Arrangements*** which is illustrated in **Figure 5.9.** This activity is decomposed into a sequence of activities through which a range of preparations are made for receiving the investment into the company.

The following activity is ***Document Arrangements.*** This activity has been included to enable arrangements to be traced. A sequence of meetings has been included in the process to enable discussion about arrangements. During the interviews, the importance of communication was stressed hence the inclusion of a series of meetings throughout the whole investment process.

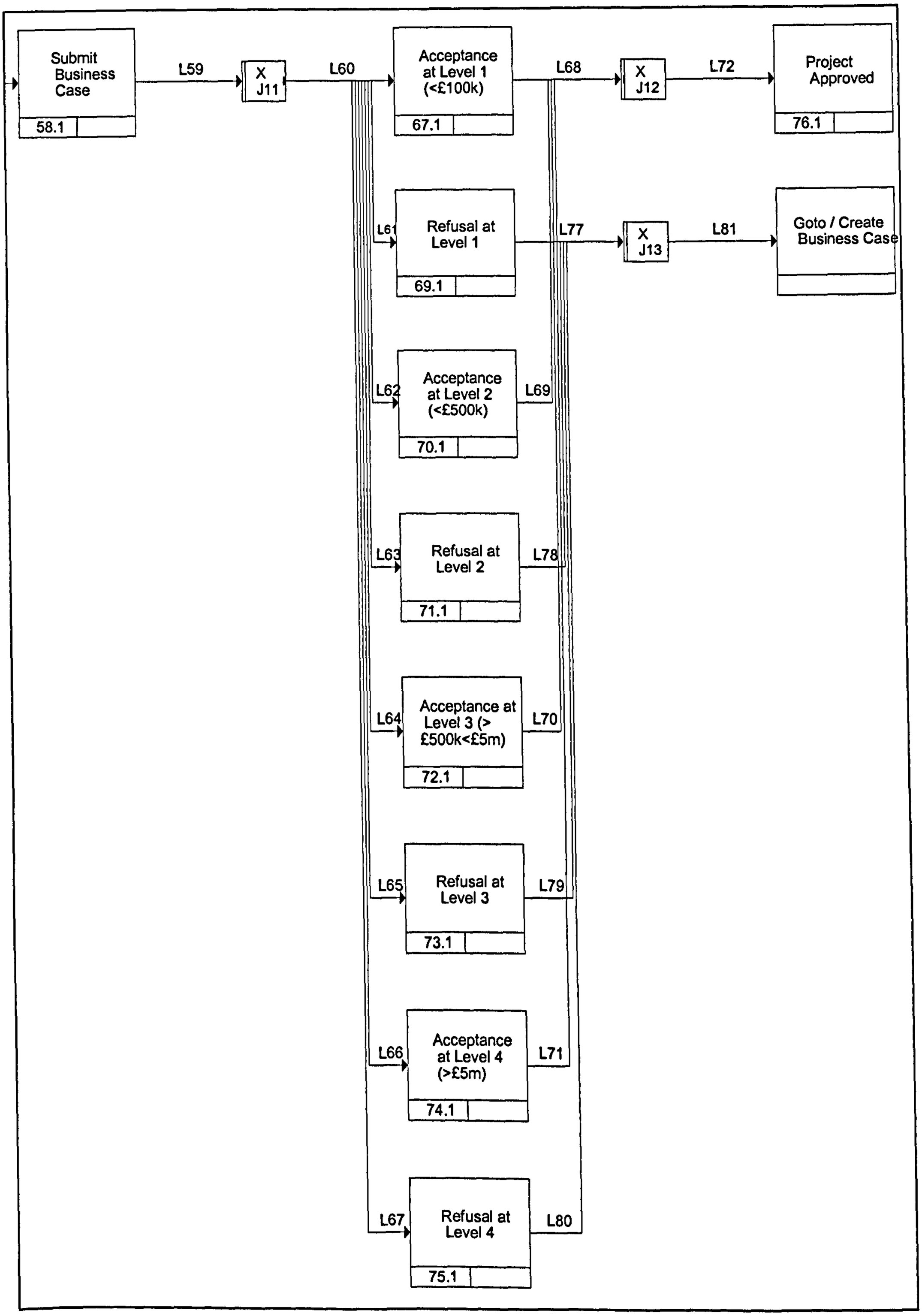


Figure 5.8: Sequence of Activities – Submit Business Case

Following progress meetings between the project team and management, an activity is included to allow changes to be made to the operating environment to receive the investment. These changes were outlined early on in the *Pre-Implementation* stage and are executed in the activity ***Make Operating Changes.*** Once these are complete the process moves onto the next stage, an activity named ***Prepare Location.*** This activity is included to allow for any final changes to be made to the area in which the investment will be located. Once this is completed a ***Final Check*** is conducted to ensure the operating environment and personnel are prepared for the delivery of the investment.

A further series of meetings is included after this activity to enable discussion between management and the project team. These meetings are to ensure readiness for the investment. Following these activities are ***Delivery*** and ***Installation.*** It is at this stage of the process that the new investment is introduced into the company, giving way to the next activity, ***Pilot Run.*** The activity ***Pilot Run*** contains two decomposed activities. The first decomposed activity is ***Test Run,*** an activity devoted to testing the investment. The way in which this is conducted will depend on the technology in which the company have invested. This activity is illustrated in **Figure 5.10.** The purpose of this activity is to use the investment for a period of time in which its progress can be measured against the original performance measures set by the project team (see activity ***Create Business Case).***

If there are any problems with the investment, they will be revealed to some degree at this stage, and the project team will have to correct these to ensure ill-effects are minimised.

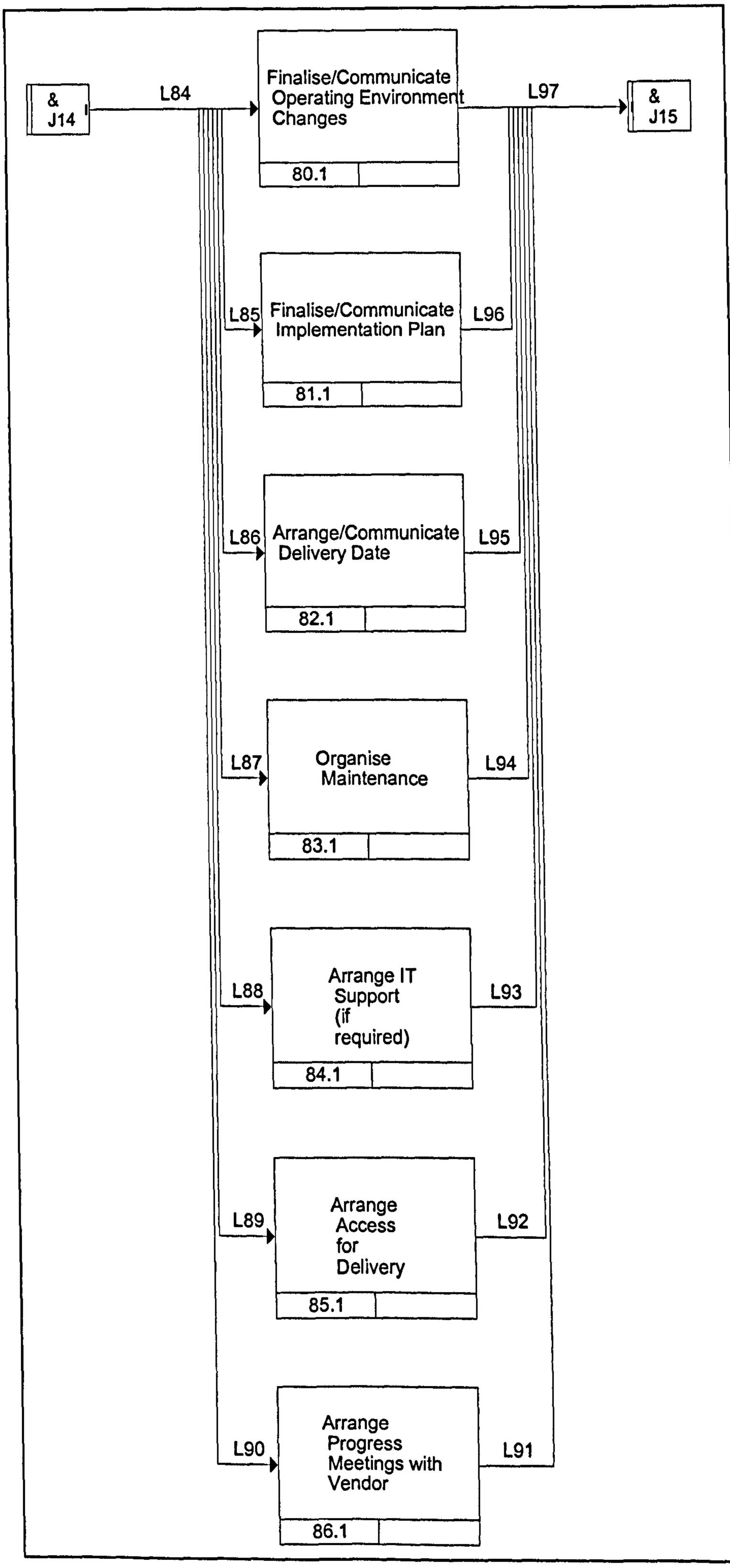


Figure 5.9: Decomposed Activity – Finalise Arrangements

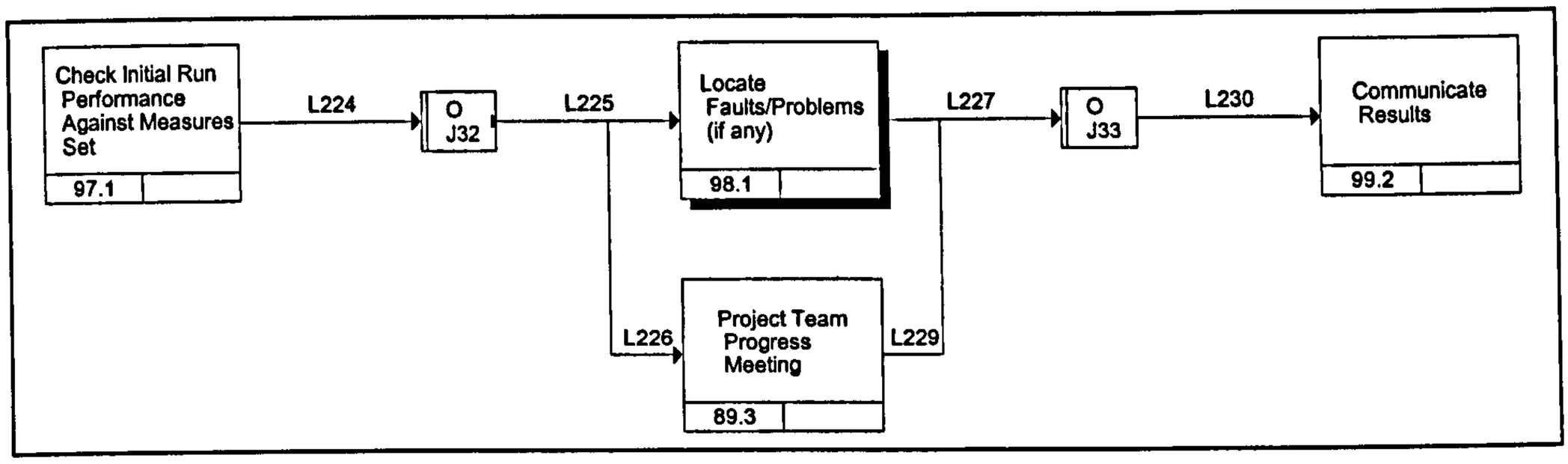


Figure 5.10: Decomposed Activity – Test Run

This can often be extremely costly, and if problems are not thoroughly addressed at this stage then they may be exacerbated at a later stage in the process by other factors. However, if the process is followed during the *Pre-Implementation* stage, and the project team have devised contingency plans, then investment problems in the *Implementation* stage should be minimal.

The activity ***Locate Faults*** is decomposed into a sequence of sub-activities. This sequence consists of a range of activities through which problems with an investment are addressed. Once the problems have been addressed, the process moves through the following activities, ***Project Team Progress Meeting,*** and ***Communicate Results.*** To enable continuous improvement measures, the result of the test run should be documented, hence the inclusion of the activity ***Document Results of Pilot Run.*** The results of the pilot run should be distributed to the management approval committee, to other management involved with the investment project, and to members of the project team. Following the distribution of the pilot run results, is the activity ***Run Investment to Standard.*** During this activity the investment is run as fully operational.

5.3.4 The Post-Implementation Stage Activity Flow

The activity flow in this stage begins with ***Assess Performance Against Measures Set.*** Earlier in the process, in the Pre-Implementation stage, an activity exists for establishing performance measures by which the progress of the investment can be monitored. It is important that this is closely monitored to enable the correction of deviations. This activity should be performed frequently throughout the process. When the investment is fully operational there should be continuous monitoring of performance targets. To account for this, a feedback loop is incorporated into the process to enable performance assessment, documentation, and then re-assessment.

Following the documentation of performance assessment results, a series of meetings (activities ***Project Team Progress Meeting*** and ***Management Progress Meeting***) are conducted to enable management and project team discussion about the findings of the performance assessment. Should corrective action be required to address any deviations that may have occurred, it should be conducted in the decomposed activity ***Make Adjustments.*** The purpose of this activity is to allow the project team to address the faults that have occurred with their investment. The process contains a set of activities that the project team can follow to action performance problems and devise further contingency plans. This set of activities contains a feedback loop to account for the discovery of further deviations in performance that may need corrective action. Once this has been completed it is likely the company are considering further investment. Hence, the inclusion of the activity ***Review Previous Business Case.*** It is important that the business case is consulted to enable a performance report to be compiled. The company will want to assess the performance of the investment against all the initial

planning. Once this is completed, the next activity in this stage of the Manufacturing Technology Investment Process is ***Compile Performance Report.*** At this stage the project team will have to document any results they have found throughout the performance measuring and adjustment activities. It is important that this is done to enable future investment planners to understand the performance and progress of past investment projects. This stage ends with the same activity that begins the whole process, ***Initial Investigation of Investment Need.*** This activity ties up the whole process and thus begins the investment process all over again, revealing the process to be cyclical in nature.

5.4 Chapter Summary

This Chapter discussed the development of the manufacturing technology investment process model. In order to produce the model a suitable modelling technique had to be selected. IDEF was identified as a possible modelling technique, and from the IDEF family IDEF3 was eventually chosen as the technique for developing a process model. The reasons for selecting IDEF3 were discussed, followed by a description of the process model construction. The process was constructed using findings from the literature review and the surveys. The data was analysed in order to produce a range of activities for the process. The process design was based upon the three main stages of Pre-Implementation, Implementation and Post-Implementation. The development of activities for each one of these stages was discussed, and then the final process is presented in Appendix L.

Chapter 6 Developing the Process Aid

Abstract

This chapter focuses on the development of the process aid, the framework of which is based on the data derived from the literature review and the surveys. Phase 4 of the research methodology began with the development of the process model, detailed in Chapter 5, and concludes with the completed process aid. The process model, whilst drawing on previous research for its base, was constructed to represent a number of elements that the authors' research had revealed to be essential to the success of a technology investment. To facilitate the practical application of the process model within an industrial context, a process aid was constructed consisting of a set of instructions to guide an investment project team through the whole process. Hypertext Markup Language (HTML) was used to operationalise the process model. The design of the process aid is discussed in this Chapter. The validity of HTML for this application is discussed, as is the relevance of the process aid to the collaborator's strategies for the future. The tool is intended for use by anyone involved with the project management of an investment.

6.0 An Introduction to The Process Aid

The Engineering Doctorate philosophy is to provide practical assistance to those responsible for the management of an engineering organisation, and ultimately to provide a contribution to knowledge.

The main aim of this Engineering Doctorate research project was outlined in Chapter 1 as follows:

- To develop a process aid that may be used to assist managers in the manufacturing technology investment process.

During the 1990's British Aerospace experienced a major cultural change, driven by severe competition from other defence companies and The Ministry of Defence requirements for missile development. The joint venture between BAe Dynamics and the Largardere Group, resulting in the formation of Matra BAe Dynamics (MBD), was part of this cultural shift. The company began earnestly focusing attention on achieving sustainable competitive advantage in the 21st century.

Cranfield University has established links with the aerospace industry and has collaborated with British Aerospace on a wide variety of pertinent research projects. In the 1990's Matra British Aerospace Dynamics became involved in several collaborative research projects with Cranfield University, of which this EngD project was one. Capturing the benefits of a manufacturing technology investment and managing these for a productive, and profitable future, has become a real concern for MBD. The literature review and surveys revealed a number of elements that contribute to the successful or poor performance of an investment, and it is these elements that must be managed throughout the process for benefits to be maximised. Hence, the focus of this research project on the process of investing in manufacturing technology, and the development of a process aid to guide engineering managers through this decision.

6.1 Operationalising the Process Model

Chapter 5 concentrated on the development of a manufacturing technology investment process model. This process model is a three stage representation of the process that leads to the acquisition and implementation of manufacturing technology. Voss proposed a three stage model, (the Process of Implementation Model detailed in Chapter 3) upon which the author has based the process model detailed in Chapter 5. However, the author has renamed the three stages and added constituent activities to each stage to represent a more industrially relevant process. As an academic exercise in organising and visually representing the research conducted thus far, the process model was valuable. To satisfy requirements of the EngD programme, and produce research pertinent to industry, this process model had to be transformed, or operationalised, to enable its use within the collaborating company.

6.1.1 Selecting An Appropriate Method

To satisfy the research objectives it was necessary to select an appropriate operationalising technique, or a technique for transforming the theoretical process model into a practical process aid to assist the manufacturing technology investment process. For this there had to be a number of options available for the task of operationalisation. Two possible options were highlighted as possible techniques for transforming the process model. These were:

- A paper based workbook;
- An electronic aid.

Each option has its own merits and drawbacks and these are briefly discussed. A paper-based workbook is a viable option. The advantages of constructing a paper-based workbook are as follows:

- Can be updated;
- No limitations on design or style (unless specified by user);
- Can incorporate diagrams, textual and mathematical data.

The disadvantages are as follows:

- Timely to construct and reproduce;
- Easy to misplace or lose;
- Easily defaced or destroyed;
- Not secure (can be transported outside of the company);
- Costly to reproduce.

The advantages of an electronic method are as follows:

- Easily adapted;
- Available to all who wish to use it;
- Conveys graphical, textual and mathematical data;
- Can incorporate sound if required;
- Interesting, colourful designs;
- Secure.

The disadvantages of an electronic method are as follows:

- Coded program may be difficult to maintain;
- May require an expert to make changes;
- Not always easy to understand;
- Training in use may be required;
- May be expensive to maintain if expert required.

6.1.1.1 Criteria For Selecting An Operationalising Technique

To enable the selection of the most appropriate technique for operationalising the process model, an analysis was performed using a validated decision making framework. This analysis was conducted using the Kepner-Tregoe (Kepner and Tregoe, 1981) framework for decision analysis. Using Kepner-Tregoe for decision making, a range of factors are highlighted from which the decision maker must decide which are *wants* and *musts*. The *want* factors are those factors which the decision maker would like to have in the outcome but does not necessarily need. The *must* factors are those which the decision maker absolutely must have in the outcome. Kepner-Tregoe is used to organise these *want* and *must* factors to enable the user to make an informed decision.

For this exercise, the author has chosen to adapt the Kepner-Tregoe exercise to focus on the *must* factors. **Table 6.1** illustrates the list of *must* factors. These were organised into three categories, each category representing a range of criteria that must be satisfied by the chosen technique. Once the *must* factors were outlined, they were organised into a table against which the technique options were matched. The purpose of this activity,

the results of which are illustrated in **Tables 6.2** and **6.3** was to decide which technique, taken from the range of technique options, was most suitable for operationalising the process model. This decision was based upon the appropriateness of the option for achieving the identified *must* factors.

Presentation Requirements	Collaborator Requirements
Clear	Simple
Concise	Accessible to all
Colourful	Easy to navigate
Informative	Informative
Adaptable	Easily integrated
Must be able to present complex data	Adaptable
	Easily maintained
	Secure

Table 6.1: "Must" Selection Criteria

Presentation Requirements

	Paper-based Workbook	Electronic
Clear	YES	YES
Concise	YES/NO	YES
Colourful	YES	YES
Informative	YES	YES
Adaptable	NO	YES
Portable	YES	YES
Incorporate diagrams	YES	YES
Present complex data in a readable form	YES	YES

Table 6.2: Kepner-Tregoe Analysis of *Musts* for Operationalising Technique

In **Tables 6.2** and **6.3** the *must* factors are arranged in the left-hand column of the tables, whilst the *Technique Options* are arranged along the top. Those *must* factors that are achievable through the use of the *Technique Options* are indicated by YES, and those

must factors that are not achievable through the use of the *Technique Options* are indicated by NO. It was decided to base the selection of the most appropriate technique on the total number of YES answers attained

Collaborator Requirements

	Paper-based Workbook	Electronic
Simple	YES	YES
Accessible to all	YES	YES
Easy to navigate	YES/NO	YES
Informative	YES	YES
Easily Integrated		YES
Adaptable	YES	YES
Easily maintained	NO	YES
Secure	NO	YES

Table 6.3: Kepner-Tregoe Analysis of *Musts* for Operationalising Technique

Once the analysis was complete, the number of YES answers were counted and totalled. The tables illustrate that the technique receiving the greatest number of YES answers for *must* factors was for an electronic technique. The objective now was to decide how to construct an electronic aid. The use of software coding, for example C++ or VisualBasic) was considered but it was decided that the construction of a program for assisting the investment process would provide insufficient flexibility. The author opted to use HyperText Markup Language (HTML) to translate the process model into a process aid. Furthermore, the use of HTML would allow the process aid to be transferred onto the company's intranet hence exposing the process aid to a greater number of personnel.

Once an appropriate technique had been selected, it was important to ensure that the *must* factors were satisfied through the design of the process aid. FrontPage, a program

for translating HTML into a readable format, was chosen as the medium for translating the process model into a usable process aid. FrontPage is discussed in the following section.

6.2 Developing the Process Aid Using HTML

The World Wide Web (WWW) is an internet service containing a wealth of information. When scientists were designing and developing the internet, one of the many problems they encountered was how to present data that could be easily written, accessed, and read by millions of potential users. They discovered that if they created a system that could mark, or code, data in some way then they would be able to fulfil their objectives. Eventually, scientists developed a system for tagging data. Tags are codes that show how data should be presented to the user. The tags ensure that data is presented in a particular way and the computer controls this to ensure the presentation is correct for the reader. Mark-up language must specify how text is presented. For example, if a sentence is to be presented in italics, then the language must specify this through the use of tags. The tagging technique was given the name HyperText Markup Language, or HTML as it is more commonly known. Typically, this language became well known the world over, and as a result of people using this language to present and share data, the World Wide Web was born.

The problem with early HTML was that as its popularity increased, so did the number of tags required to present data. As a result of this a more user-friendly version of HTML was developed called WYSIWYG, an acronym for What You See Is What You Get. The user simply enters whatever they want to appear on the screen and the

document displays the text entered. An example of a WYSIWYG program is Microsoft FrontPage, the software chosen for operationalising the process model. FrontPage is an example of software that translates HTML into a usable format. The advantage of using a program such as FrontPage is that there is no need to write data using tagging. The software performs this task to prevent the user from having to code the information themselves.

6.2.1 Defining the Process

The purpose of the process aid is to provide managers with a tool that will guide them through their investment process. The literature review and the surveys revealed that there are certain elements within the investment process that must be controlled for greater investment performance to be achieved. For example, it has been revealed that planning is key to the success of a manufacturing technology investment and without sufficient planning prior to implementation an investment can fail to perform as well as expected. It has also been revealed that whilst managers are aware of the planning and control that is required to ensure investment success, they argue lack of time and resources as reasons why they fail to address the issue of organising, controlling and tracking their investment process. Hence, this research project has been initiated to tackle this issue and develop a process aid that can be accessed by managers seeking the means to achieve a more structured approach to investing in manufacturing technology. By following a more structured approach to investing, one which guides the user through the whole process and highlights particular steps that must be followed to ensure problems are minimised, it is hoped that managers will experience greater success with their investment projects.

For the process to be considered robust it was necessary to perform a validation exercise in order to operationalise the process model to aid the planning and control of investments. Therefore, the author chose to develop a checklist against which the progress of an investment study could be matched. The process model requires that all the activities be completed. Following an analysis of the study, the checklist may be used to highlight activities that were or were not performed during the investment process. If a number of alternative investment options were being considered, the checklist should highlight the difference in performance, if any.

6.2.2 Developing the Checklist

Figure 6.1 illustrates the design of the checklist. There are three checklists, one for each stage of the manufacturing technology investment process. The first column in each checklist lists the activities that constitute the stage of the process under investigation. The following two columns are for indicating if the activity was performed in the analysis study.

Process Activity	Option	
	A	B
Activity 1	✗	✓

Figure 6.1: Checklist Design

Tables 6.4, 6.5 and **6.6** illustrate the checklists for the individual stages of the process model.

6.3 The Design of The Process Aid

The design of the process aid is largely based on the process model developed in Chapter 5, and the development was guided by the *must* factors identified earlier in this

Process Activity (Pre-Implementation)	Option A	Option B
Initial Investigation of Investment Need		
Outline User Requirements		
Outline Project Objectives		
Cost Estimate		
Estimate and Outline Benefits		
Establish Project Team		
Assign Team Roles and Responsibilities		
Assign Project Leader		
Assess Possible Locations		
Identify Possible Changes to Operating Environment		
Establish Project Team Objectives		
Compile Relevant Information		
Distribute Relevant Information		
Generate Investment Ideas		
List Possible Investment Ideas		
Identify Operating Environment Changes		
Check Budget Availability		
Investigate Health and Safety Implications		
Identify Suitable Maintenance		
Cost Estimation for Investment Ideas		
Outline Investment Ideas		
Investigate Suitable Vendors		
Compile Vendor Document		
Distribute Vendor Document		
Prepare Tender		
Submit Tender		
Review Submissions		
Organise Returned Tenders		
Risk Assessment		
Quantitative Evaluation		
Qualitative Evaluation		
Check Maintenance Availability		
Document Evaluation Results		
Set Performance Targets		
Set Performance Measures		
Plan for Technology End of Life		
Check for Compliance with Health and Safety		
Construct Contingency Plans		
Finalise Delivery Arrangements		
Construct Expenditure Plan		
Outline Reasons for Selecting Specific Technology		
Outline Reasons for Selecting Vendor		

Construct Plan for Operating Environment		
Construct Maintenance Plan		
Construct Training Plan		
Outline Business Goals and Objectives		
Conduct Analysis of Current Business Situation		
Compile Relevant Information		
Create Business Case		
Submit Business Case to Appropriate Level		

Table 6.4: Checklist for Pre-Implementation Activities

Chapter. FrontPage allows the user to develop web pages which can be navigated with the use of hyperlinks. Each page contains information about a particular stage in the process. For example, there are a range of pages concerning the preparation and submission of a tender. The pages are linked by hyperlinks which are a feature of the software. Hyperlinks connect pages and are often used as shortcuts to allow the user to move directly to the web page they wish to view. Hyperlinks have been used in the process aid to allow rapid movement, should it be required, through the process aid.

Each activity within the process model is represented in the process aid. As with most web sites, the process aid has a home page which is an introductory page designed to welcome the user to the project. The Engineering Doctorate philosophy is discussed, and the author and the research project are also introduced. These initial pages serve to welcome the user to the process aid.

It is important that the user is aware of the aim of the process aid as an industrial tool and how the process aid can assist with the investment process. Pages have been designed to provide basic information about the purpose of the process aid and how the

Process Activity (Implementation)	Option A	Option B
Project Approved		
Initiate Training		
Finalise/Communicate Operating Environment Changes		
Finalise/Communicate Implementation Plan		
Arrange/Communicate Delivery Date		
Organise Maintenance		
Arrange IT Support (if required)		
Arrange Access for Delivery		
Arrange Progress Meetings With Vendor		
Document Arrangements		
Project Team Progress Meeting		
Management Progress Meeting		
Make Operating Environment Changes		
Prepare Location		
Final Check		
Project Team Progress Meeting		
Management Progress Meeting		
Delivery		
Installation		
Check Initial Pilot Run Against Performance Measures		
Locate Faults		
Consult Contingency Plan		
Agree Plan for Adjustment		
Contact Vendor for Assistance		
Contact Maintenance Provider for Assistance		
Contact IT Support for Assistance		
Conduct Adjustment		
Agree Further Adjustments/Contingency Plans		
Document All Adjustments Made		
Run Investment with Adjustments		
Locate Further Faults/Problems		
Project Team Progress Meeting		
Communicate Results		
Document Results of Pilot Run		
Distribute Results of Pilot Run		
Progress Meetings		
Develop Implementation Plan		
Run Investment To Standard		

Table 6.5: Checklist for Implementation Activities

aid was constructed with a view to assisting the manufacturing technology investment process.

Process Activity (Post-Implementation)	Option A	Option B
Assess Performance Against Measures Set		
Document Results		
Project Team Progress Meeting		
Management Progress Meeting		
Review Previous Business Case		
Compile Performance Report		
Initial Awareness of Investment Need		

Table 6.6: Checklist for Post-Implementation Activities

Figure 6.2 is an example of one of the first model pages. This page introduces the three-stage process model and uses hyperlinks to allow the user to move to the desired stage of the model. This model can also be seen in **Figure 5.4 (Process Model Overview).** **Figure 6.3** illustrates what the user sees when they click on the hyperlink that transports them to the pages concerning Pre-Implementation. On this page the user is introduced to the first activities within the Pre-Implementation stage of the process. They have the option to explore the process options and choose which stage they would like to investigate. The process aid has been constructed in this way to allow the user to revisit stages should they wish to. When the user clicks on the desired option, they are transported to the page, or pages, relating to that particular range of activities. For example, if the user clicks on Create Project Document 1, they will see the page illustrated in **Figure 6.4.** This page contains a main section which discusses the reasons for compiling a document at this early stage in the investment project. The page also contains a "notes" section containing a list of instructions that the user must follow to ensure the completion of the activity.

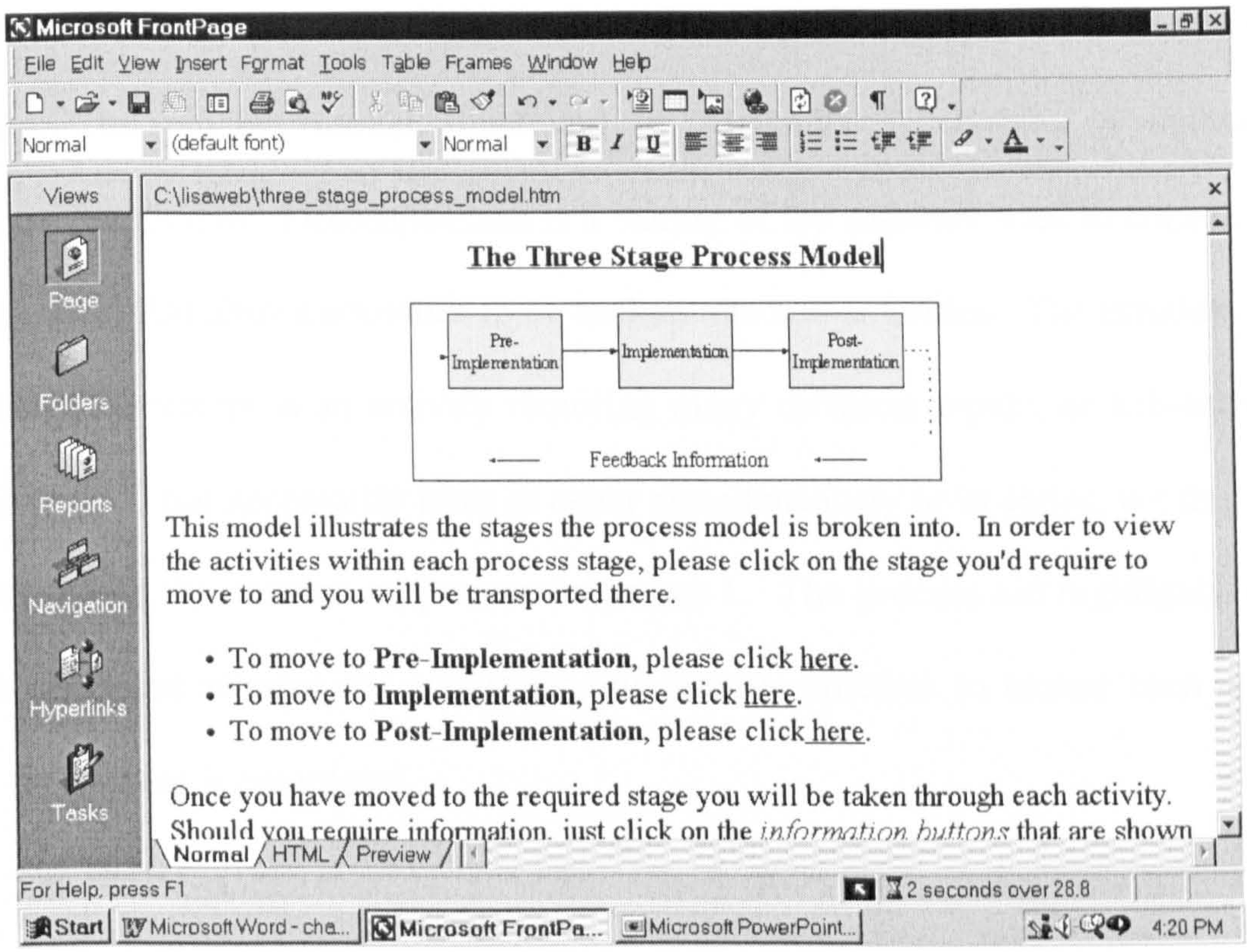


Figure 6.2: Introductory Page of Process Model

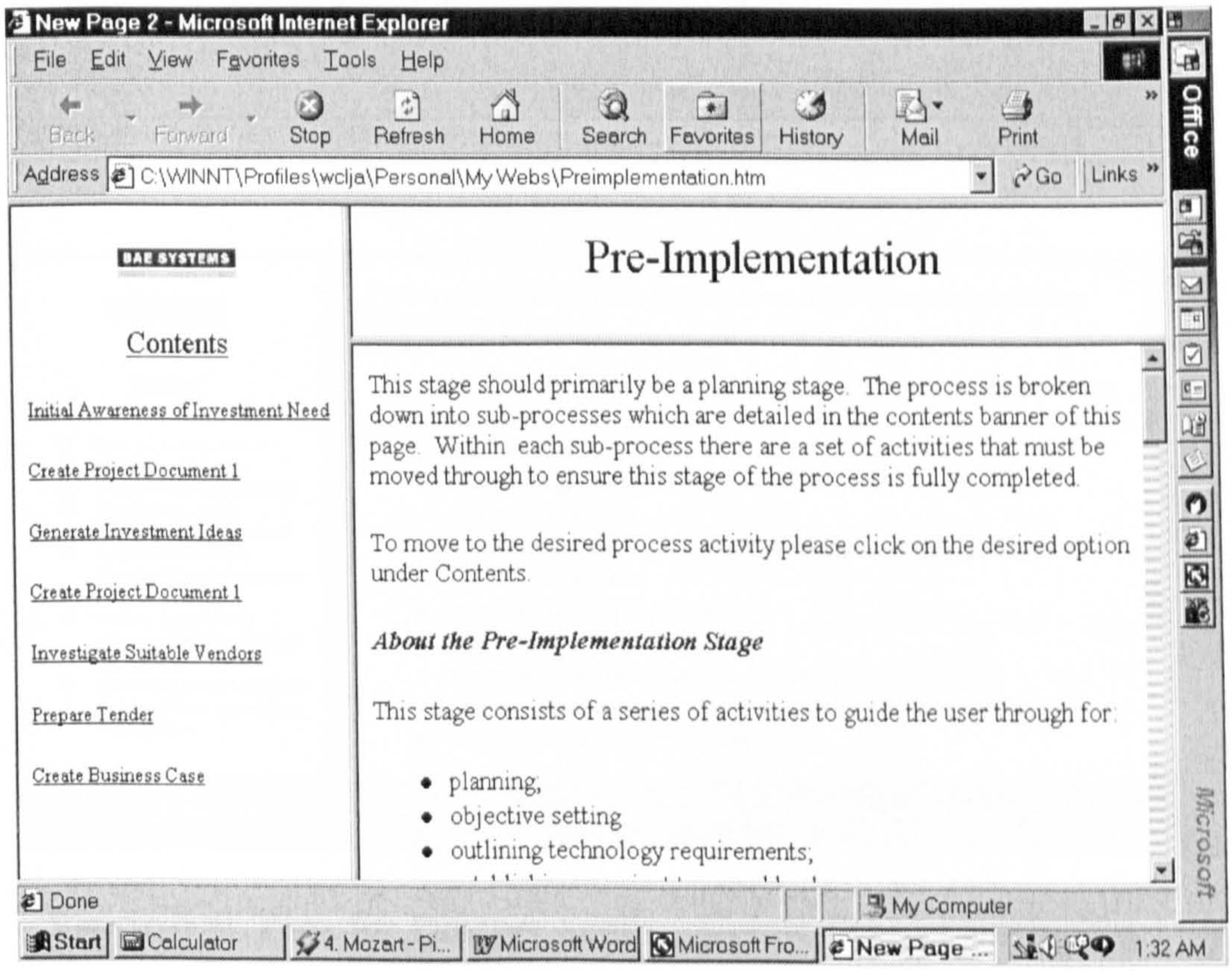


Figure 6.3: Introductory Pre-Implementation Page

The process activity ***Create Project Document 1*** is an example of a decomposed activity. The process model illustrated in Appendix L contains a number of decomposed activities. Decomposition is a feature of the software used to construct the process model that allows activities to be broken into sub-activities. The creation of the first project document is an activity requiring many different inputs, or sub-activities. These inputs do not necessarily have to occur simultaneously or in series, yet they must occur to enable the creation of project document 1. The process aid highlights all the sub-activities and stresses the importance of their completion to ensure each activity within the process is completed.

The activity ***Pilot Run*** is an example of a decomposed activity. The web page for this activity is illustrated in **Figure 6.5.** The web page for this activity has the same design

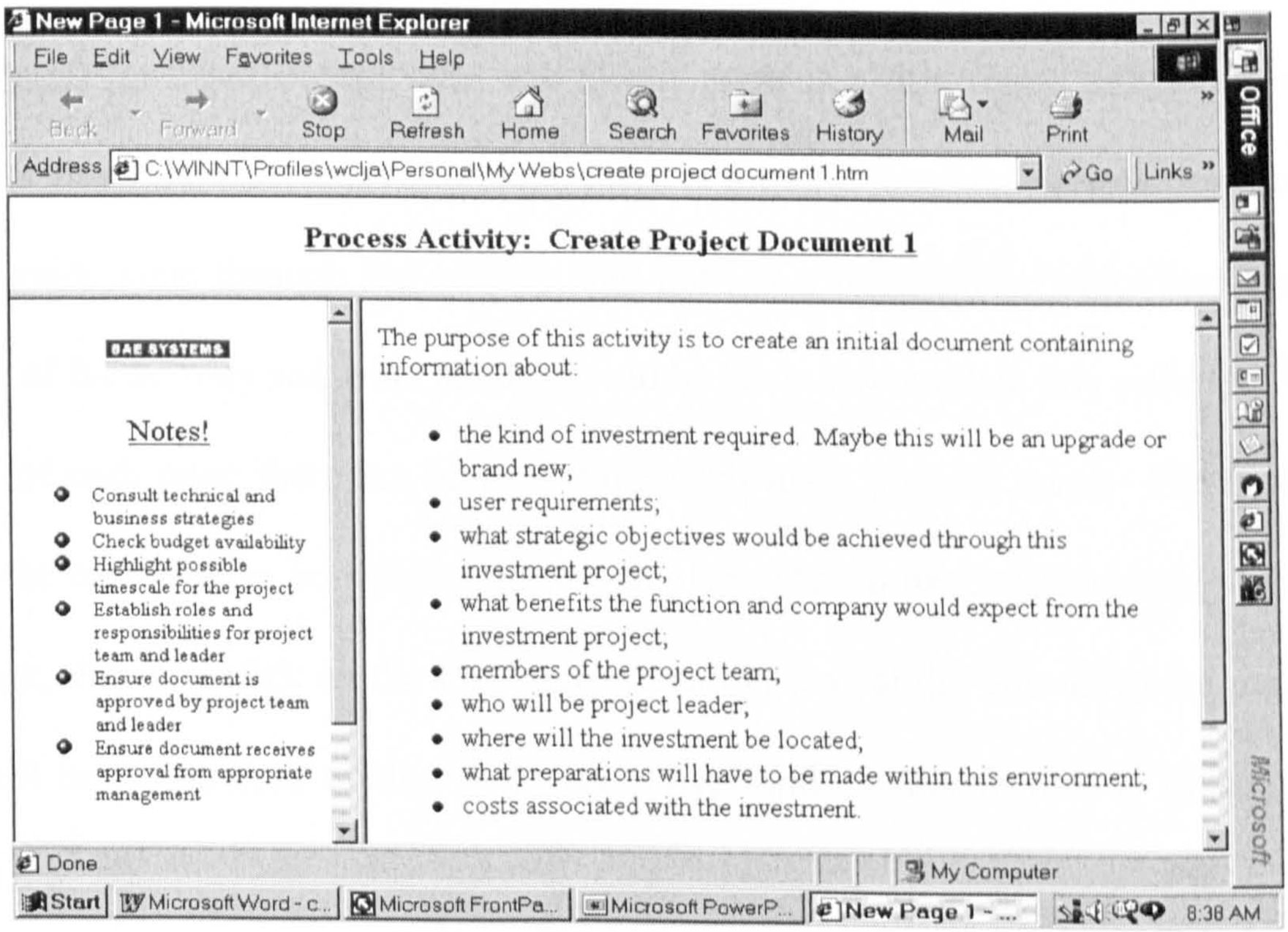


Figure 6.4: Page for Process Activity Create Project Document 1

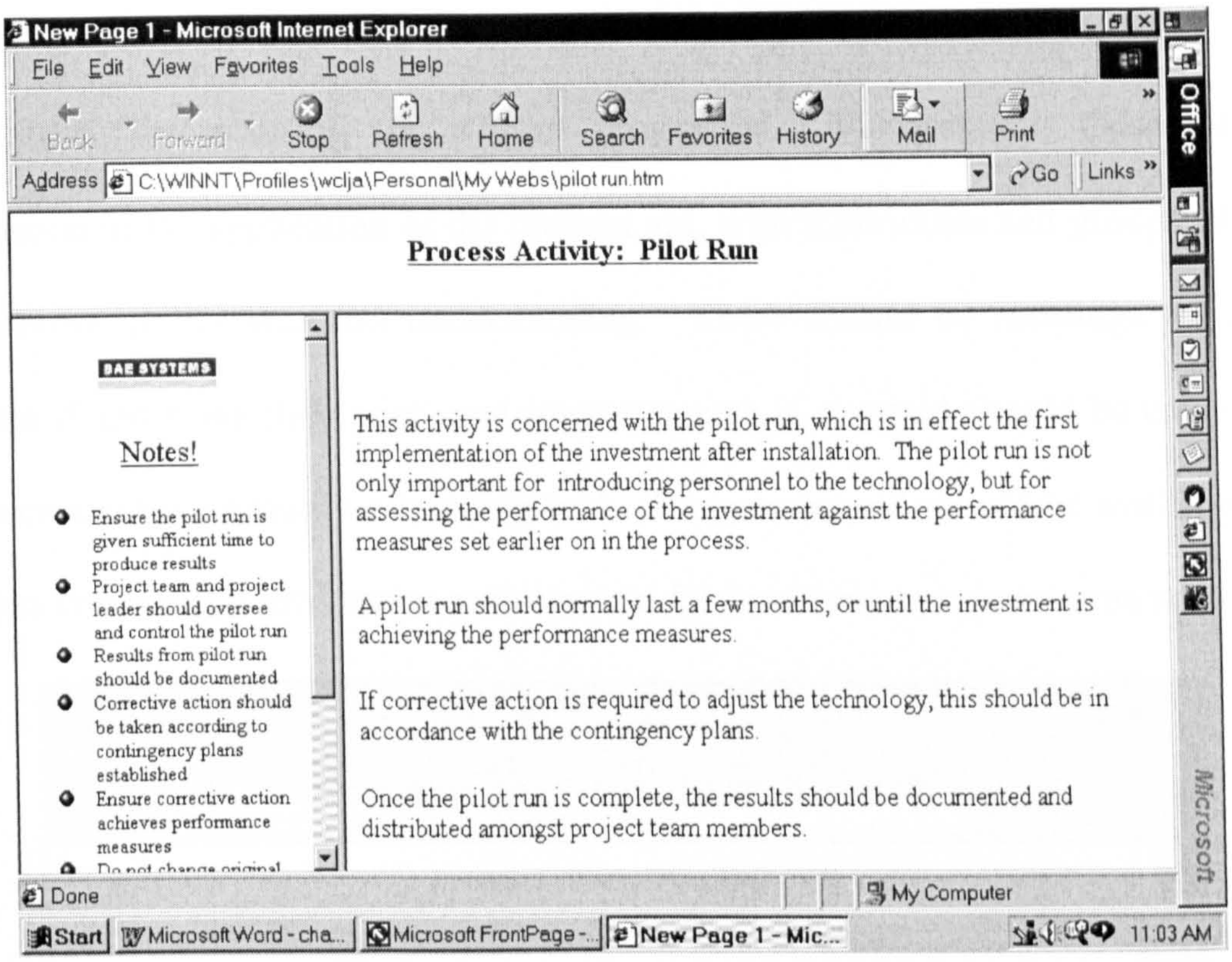


Figure 6.5: Page for Process Activity Pilot Run

as the pages for other decomposed activities: there is a title frame indicating which process activity the user is investigating, there is a frame providing instructions for the user to guide them through the activity, and there is a main frame which explains the purpose of the activity and what action should be taken to complete this activity. At the bottom of each page there are icons for the each main process stage. For example, should the user wish to investigate the Pre-Implementation page after viewing the Pilot Run page, they can click on the Pre-Implementation icon at the bottom of the page and they will be transported to that page via a hyperlink. This feature is illustrated in **Figure 6.6.**

It was also necessary to determine how the process aid would be applied within the collaborating company and for whom it is intended. The application of the process aid

requires project management, with the personnel of the organisation taking responsibility for ensuring the project progresses. Furthermore, there must be participation in the application of the process aid, with individuals and groups adopting it to achieve enthusiasm and understanding. There should be meetings to address problems if and when they arise, and improvements if required should be encouraged. The process aid is primarily a learning tool. The process aid should be available to all managers considering investment projects, and for investment project teams and leaders.

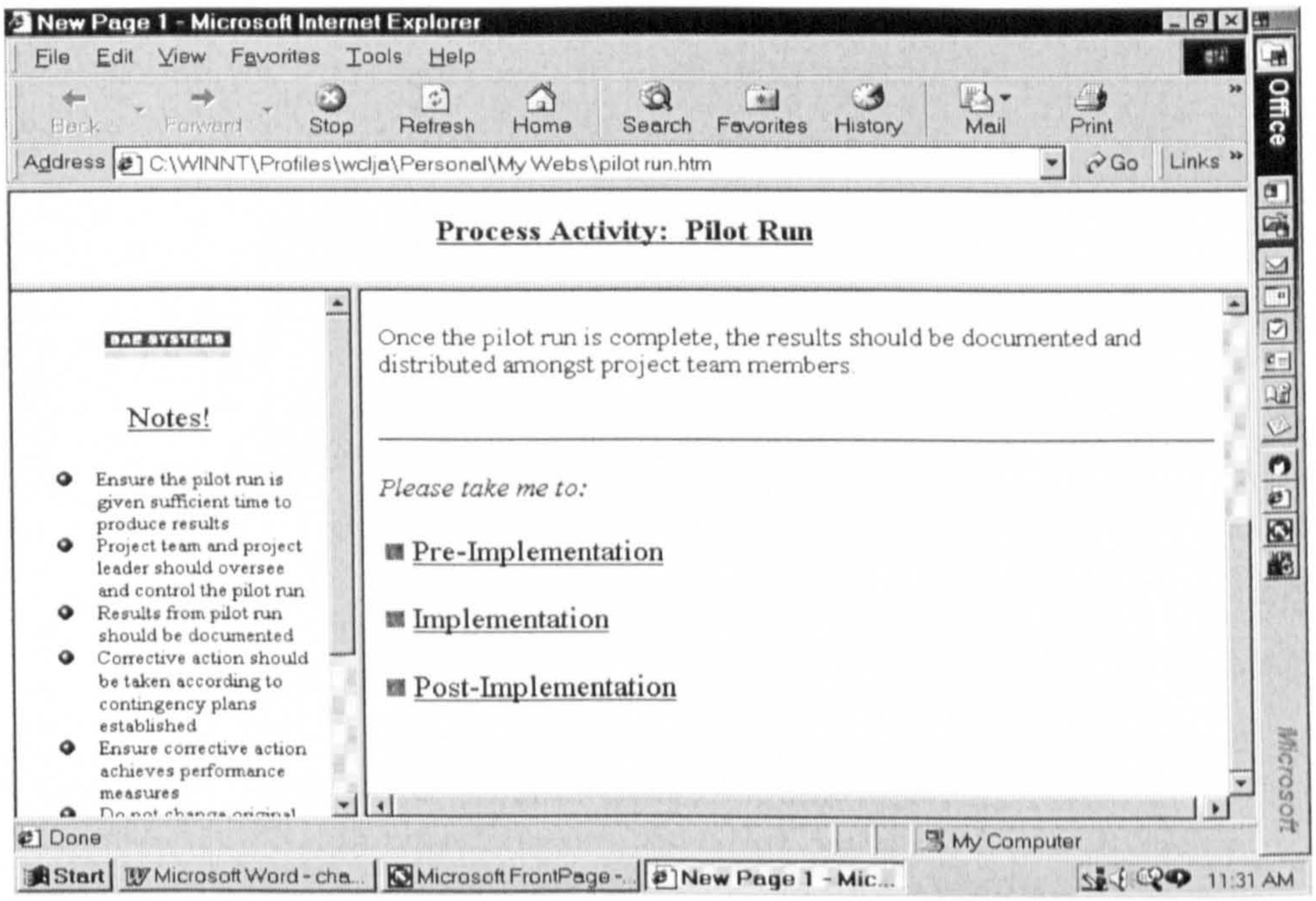


Figure 6.6: Navigation Buttons

6.4 Chapter Summary

This Chapter has focussed on the development of a checklist to aid the investment process. In order to translate the process model into a usable tool for industry, a technique for operationalising the checklist was chosen based on a set of requirements established for the process aid itself. The technique most appropriate for satisfying the requirements was electronic and eventually HyperText Markup Language (HTML) was selected as the means for operationalising the process model. Reasons for this selection

are discussed in the Chapter and several diagrams are provided to illustrate the design of the process aid.

Chapter 7 Industrial Case Studies

Abstract

The case studies signal the end of Phase 4 of the research methodology in which the process model and process aid were developed. The fifth stage of the research methodology is concerned with the validation of the process aid using a holistic case study within the collaborating company. The validity was achieved through the identification of two investment projects. The two projects were chosen as examples of "successful" and "unsuccessful" investments. One was chosen as it had succeeded in meeting business performance objectives, within an established time scale and budget, whilst the other failed to meet such criteria. The two case studies are presented and details of an analysis to assess the case studies against the process model checklist, assisted by the collaborator, are discussed.

7.0 The Purpose of the Case Studies

In order to validate the process model, it was decided to conduct two case studies of investments within the collaborating company. In reality, the time scale for planning and implementing manufacturing technology can often be several years long. Hence, it was not possible to validate the process model in real time. For this reason, the collaborator provided examples of investments that could be analysed retrospectively.

The collaborator agreed to discuss the performance of two past investment projects, the details of which are provided in this Chapter. The investments were selected for case study purposes as they illustrate the positive and negative degrees of success that can be

achieved with manufacturing technology investments. Voss (1988) claimed that for an investment to be considered truly successful it had to have achieved technical and business success. The criteria for technical and business success are shown in **Table 7.1.** For the purpose of this research, the checklist discussed in Chapter 6 has been employed for assessing the case study processes. The investments will be referred to as Option A and Option B.

Technical Success	Business Success
Top management support	Linking manufacturing technology to manufacturing policies
Links with suppliers	The way manufacturing is managed
Cross functional implementation teams	Managing to realise the benefits: A) Planning and budgeting; B) Measurement and control; C) Managing new technology as a learning process.
Planning	Taking an integrated approach
Workforce involvement and human factors	Changing the organisation
Skills and training	
Keeping management informed	

Source: derived from Voss (1988).

Table 7.1: Factors Influencing Technical and Business Success of Manufacturing Technology Investments

Option A

The first technology under investigation is a Sales Force Automation System, which is a system used by sales people and sales managers. Information regarding the revenue generated by sales people is inputted into the system and an aggregate picture of overall revenue is provided which may then be used by managers to report on divisional business performance. The company had invested in such a system a number of years previously and decided recently to upgrade this system in alignment with strategic developments. This system has been described as failing from the beginning and the

company were aware of the reasons why and were addressing them. To summarise, the company understand the main failings with this system to be user buy-in and neglecting to outline specific requirements for the implementation. With regards to planning, the company agree that there was insufficient planning prior to the installation and implementation of the investment. The literature review and interviews revealed that extensive planning is crucial for investment success and without it people often try to plan for the implementation during implementation itself. This was a problem with Option A.

The company were aware of the need to invest in more sophisticated technology, and upgraded their older system in alignment with strategic plans. However, when it came to planning for the new system they overlooked setting new user requirements and neglected to consult with the original users to ascertain their requirements. As a result of this, the original system users were not keen to commit themselves to a new investment as the older system was sufficient for their requirements. There were no new objectives outlined for the system, other than it was brought in to assist with the strategic moves the company had planned. A small team of people were assigned the role of overseeing the running of the system, yet no roles were defined and most were confused as to their tasks in relation to their new system. At this point there was no real project leader as people were reluctant to take on the responsibility of running the new system. To summarise, during this early stage when planning is of the utmost importance, there was little governance with regards to the proposed investment project and the system had been introduced with little preparation of people and the functional area.

The company were determined to remain firm with their choice of system, hence no further systems were investigated. The system was installed and it became apparent soon after the installation that the users were unwilling to use the software. Management were reluctant to back the system and as there was no organised project team to oversee the running of the system, people were unsure about what their tasks were in relation to the project. Despite further training and expenditure to ensure the system was fully integrated, it was apparent that this particular investment was not going to be a success. Eventually, a team was organised to oversee the running of the system and they began to address the problems that had arisen, problems that they believe would have been avoided at the beginning if they had carried out more extensive research and planning.

Option B

The next investment under investigation is a SAP system, which was a new system purchased for the finance function to replace older technology. This investment was regarded as a success in that all the original objectives were achieved, and the project was installed and implemented on time and within budget. The functional requirements were satisfied and the project was tightly controlled by a project leader who monitored all aspects of the planning and implementation.

From the outset, there was extensive planning and preparation for the SAP investment. A project leader was assigned to the project and people were given specific roles which they were to adhere to throughout the project. The scope of the project was kept tight and the team were pressured to keep within this scope throughout. Specific objectives

were outlined and all team members were instructed as to how these could best be achieved. The project leader was rigorous in controlling the project and all issues that were raised with regards to planning for the investment, and the implementation were clarified for the other team members and assessed in relation to the investment objectives.

Furthermore, the system was purchased from a vendor who understood exactly the requirements of the company. When the tender was issued to a range of vendors for review, this particular vendor, in their submission, displayed an impressive level of intuition with regards to the company's needs and objectives. Hence, the company selected this vendor confident that they would provide strong support throughout the project, especially during implementation. The vendor showed excellent support throughout the implementation, which the company believe aided the success of the project considerably.

The pilot run, which the company describes as the first implementation, was also regarded as a success. This was used to develop the system and the problems that arose were addressed during this. The results of the pilot run were documented and used to create a detailed implementation plan which was adhered to rigorously. Again, the project leader took measures to ensure that there was no deviation from the plan. The project team were always aware of the project objectives and these were considered at every decision. The project leader ensured that the objectives were always stated clearly and stressed the importance of making decisions with these in mind.

7.1 Applying the Checklists

In order to validate the process aid, the two investments were modelled retrospectively. One member of staff from the collaborating company used the checklists, this member of staff having had direct involvement in the management of both investments. It was considered that the results may be analysed to identify limitations in the investment process which would have been highlighted had the collaborator had prior access to the process aid. The collaborator was required to apply the checklists developed in Chapter 6 to the investments under investigation. In order to complete this task, the collaborator was required to state if they performed an activity and, depending on their response, place either a tick or a cross in the appropriate answer box. The tick indicates the collaborator did perform the activity with regards to the investment, whilst the cross indicates the activity was not performed. The collaborator was required to check each activity from the process model against their own investment processes. The purpose of this exercise was to establish a picture of the extent to which the process proposed in this thesis can influence manufacturing technology success.

In order to provide a complete analysis of the case studies, the collaborator was required to review the information they had provided and use this information to complete the checklists developed for the three stage manufacturing technology investment process. The following illustrates the collaborator's response to the checklists for Options A and B:

Process Activity (Pre-Implementation)	Option A	Option B
Initial Investigation of Investment Need	✓	✓
Outline User Requirements	✗	✓
Outline Project Objectives	✓	✓
Cost Estimate	✓	✓

Estimate and Outline Benefits	✗	✓
Establish Project Team	✓	✓
Assign Team Roles and Responsibilities	✗	✓
Assign Project Leader	✗	✓
Assess Possible Locations	✓	✓
Identify Possible Changes to Operating Environment	✗	✓
Establish Project Team Objectives	✗	✓
Compile Relevant Information	✗	✓
Distribute Relevant Information	✗	✓
Generate Investment Ideas	✗	✗
List Possible Investment Ideas	✗	✗
Identify Operating Environment Changes	✓	✓
Check Budget Availability	✓	✓
Investigate Health and Safety Implications	✓	✗
Identify Suitable Maintenance	✓	✓
Cost Estimation for Investment Ideas	✓	✓
Outline Investment Ideas	✗	✓
Investigate Suitable Vendors	✓	✓
Compile Vendor Document	✗	✓
Distribute Vendor Document	✗	✗
Prepare Tender	✓	✓
Submit Tender	✓	✓
Review Submissions	✓	✓
Organise Returned Tenders	✓	✓
Risk Assessment	✓	✓
Quantitative Evaluation	✓	✓
Qualitative Evaluation	✓	✓
Check Maintenance Availability	✓	✓
Document Evaluation Results	✗	✗
Set Performance Targets	✓	✓
Set Performance Measures	✓	✓
Plan for Technology End of Life	✗	✗
Check for Compliance with Health and Safety	✓	✗
Construct Contingency Plans	✗	✓
Finalise Delivery Arrangements	✓	✓
Construct Expenditure Plan	✓	✓
Outline Reasons for Selecting Specific Technology	✓	✓
Outline Reasons for Selecting Vendor	✗	✗
Construct Plan for Operating Environment	✗	✗
Construct Maintenance Plan	✗	✗
Construct Training Plan	✗	✓
Outline Business Goals and Objectives	✓	✓
Conduct Analysis of Current Business Situation	✓	✓

Compile Relevant Information	✗	✗
Create Business Case	✓	✓
Submit Business Case to Appropriate Level	✓	✓

Table 7.2: Checklist for Pre-Implementation Activities

The following are the collaborator's responses in the Implementation checklist:

Process Activity (Implementation)	Option A	Option B
Project Approved	✓	✓
Initiate Training	✓	✓
Finalise/Communicate Operating Environment Changes	✗	✓
Finalise/Communicate Implementation Plan	✗	✓
Arrange/Communicate Delivery Date	✓	✓
Organise Maintenance	✗	✓
Arrange IT Support (if required)	✓	✓
Arrange Access for Delivery	✓	✓
Arrange Progress Meetings With Vendor	✓	✓
Document Arrangements	✗	✓
Project Team Progress Meeting	✗	✓
Management Progress Meeting	✗	✓
Make Operating Environment Changes	✗	✓
Prepare Location	✓	✓
Final Check	✗	✓
Project Team Progress Meeting	✗	✓
Management Progress Meeting	✗	✓
Delivery	✓	✓
Installation	✓	✓
Check Initial Pilot Run Against Performance Measures	✓	✓
Locate Faults	✓	✓
Consult Contingency Plan	✗	✓
Agree Plan for Adjustment	✗	✓
Contact Vendor for Assistance	✓	✓
Contact Maintenance Provider for Assistance	✗	✗
Contact IT Support for Assistance	✓	✓
Conduct Adjustment	✓	✓
Agree Further Adjustments/Contingency Plans	✓	✓
Document All Adjustments Made	✓	✓
Run Investment with Adjustments	✓	✓

Locate Further Faults/Problems	✗	✓
Project Team Progress Meeting	✗	✓
Communicate Results	✗	✓
Document Results of Pilot Run	✗	✓
Distribute Results of Pilot Run	✗	✗
Progress Meetings	✓	✓
Develop Implementation Plan	✓	✓
Run Investment To Standard	✓	✓

Table 7.3: Checklist for Implementation Activities

The following are the collaborator's responses in the Post-Implementation checklist:

Process Activity (Post-Implementation)	Investment A	B
Assess Performance Against Measures Set	✓	✓
Document Results	✗	✓
Project Team Progress Meeting	✗	✓
Management Progress Meeting	✓	✗
Review Previous Business Case	✗	✓
Compile Performance Report	✗	✓
Initial Awareness of Investment Need	✗	✗

Table 7.4: Checklist for Post-Implementation Activities

7.2 Analysis of Checklist Results

Once the analysis was complete, the number of ticks and crosses were totalled and comparisons between the results were made. The total number of ticks for Option A was 51, whilst the total number of ticks for Option B was 77. In total, the number of process activities included in the checklists was 95. Therefore, Option A can be said to have been completed using 54% of the total process activities, whilst Option B was completed using 81% of the total process activities in the checklists. It is important to note that throughout the investment processes no additional activities were performed other than the activities in the process.

For Option A, the Pre-Implementation stage was completed using 58% of the activities in this stage. The Pre-Implementation stage for Option B was completed using 78% of the activities in the Pre-Implementation stage. For Option A, the Implementation stage was completed using 52% of the activities whilst for Option B, the same stage was completed using 66% of the activities. For Option A, the Post-Implementation stage was completed using 28% of the activities whilst the same stage for Option B was completed using 71% of the activities in this stage.

In the Pre-Implementation Stage, Investments A and B can be seen to have completed many of the same activities. These activities are listed in **Table 7.5.** The results here indicate that for both investments a degree of planning was conducted. However, the results reveal that for Option B, more planning activities, or Pre-Implementation activities were completed for Option B thus supporting findings in the literature review that extensive planning aids investment success. However, it is interesting to examine the activities in Pre-Implementation that were not conducted by the company for Option A that were conducted for Option B. The following are the activities that were not completed in the Pre-Implementation stage for Option A:

- Outline User Requirements;
- Estimate and Outline Benefits;
- Assign Team Roles and Responsibilities;
- Assign Project Leader;
- Identify Possible Changes to Operating Environment;
- Establish Project Team Objectives;
- Outline Investment Ideas;

- Construct Contingency Plans;
- Construct Training Plan.

From the above we can see that for Option A, the company neglected to outline requirements for this investment. The findings of the literature review and survey reveal that key to the success of an investment is the establishment of requirements. These must be set in the early planning stages of the process and communicated to all the project team. It is interesting also to see that, for Option A, a project team was established but not a formal team with defined roles and responsibilities. Whilst a project team may have existed for the duration of this investment project, there appears to have been little organisation or adoption of roles and responsibilities for guiding the planning and implementation. Again, the literature review and the surveys revealed that an investment will have a greater chance of success if assigned a leader and a formal project team with defined roles. The company argued that the team did not understand their roles and the findings here would support that.

Further investigation of these results shows that, for Option A, the company did not construct any contingency plans thus demonstrating a neglect to consider how the performance of the investment may be affected once in place, and how they would have to respond should problems arise. However, for Option B a contingency plan was constructed demonstrating an awareness of the need to anticipate and plan for all eventualities. The company neglected to construct a training plan, though the case study reveals that personnel were eventually sent on training programmes once the problems began. One may suggest had the company devised plans for risk prevention they may have identified possible problems earlier and devised suitable plans to cope.

Furthermore, had they devised appropriate training plans the personnel using the system may have been better equipped to cope with the problems as they arose.

Pre-Implementation Activities completed in Investments A and B
Initial Investigation of Investment Need
Outline Project Objectives
Cost Estimate
Establish Project Team
Assess Possible Locations
Identify Operating Environment
Identify Suitable Maintenance
Cost Estimation for Investment Ideas
Investigate Suitable Vendors
Prepare Tender
Submit Tender
Review Submissions
Organise Returned Tenders
Risk Assessment
Quantitative Evaluation
Qualitative Evaluation
Check Maintenance Availability
Set Performance Targets
Set Performance Measures
Finalise Delivery Arrangements
Construct Expenditure Plan
Outline Reasons for Selecting Specific Technology
Outline Business Goals and Objectives
Conduct Analysis of Current Business Situation
Create Business Case
Submit Business Case to Appropriate Level

Table 7.5: Pre-Implementation Activities Completed By Investments A and B

It is also interesting to examine the Pre-Implementation activities that the company did not perform for either Option A or B. These are as follows:

- Generate Investment Ideas;
- List Possible Investment Ideas;

- Distribute Vendor Document;
- Outline Reasons for Selecting Vendor;
- Construct Plan for Operating Environment;
- Construct Maintenance Plan.

One may assume because the company had firm ideas about what investments they wished to purchase, they did not investigate other possibilities. However, when considering Option B the company did prepare a detailed outline of their proposed investment choice, an activity not performed by the company when deciding to opt for Option A. Perhaps the company were already aware of the Option and did not need to investigate further. However, the presence of an organised and tightly controlled project team for Option B would suggest that they have conducted this activity. The results have revealed that the team for Option A were less organised than the team for Option B, hence less rigid planning has been executed. The same exercise was performed to examine the process activities completed in the Implementation Stage and the Post-Implementation stage. **Tables 7.6** illustrates the activities completed in the implementation stage during Investments A and B.

Implementation Activities completed in Investments A and B
Initiate Training
Arrange/Communicate Delivery Date
Arrange IT Support (if required)
Arrange Access for Delivery
Arrange Progress Meetings with Vendor
Prepare Location
Delivery
Installation
Check Initial Pilot Run Against Performance Measures
Locate Faults

Contact Vendor for Assistance
Contact IT Support For Assistance
Conduct Adjustment
Agree Further Adjustments/Contingency Plans
Document All Adjustments Made
Run Investment with Adjustments
Progress Meetings
Develop Implementation Plan
Run Investment to Standard

Table 7.6: Implementation Activities Completed in A and B

The above table highlights that the company initiated training programmes for their personnel. However, a previous analysis revealed that the company only established a training plan for Option B. It is not possible to draw conclusions about the outcome of this activity on the performances of the individual investments. However, the author assumes that a calculated training programme is likely to be more effective than one without any prior consideration. The table also highlights that for both investments the company established links with the technology supplier. However, for Option B, the company was keen to stress the importance of a strong relationship with the vendor and the positive effect this can have on the overall investment performance.

The remaining activities in the table are concerned with the pilot run and how the outcome of this effects the implementation of the investment. The results show that both investments were subject to a pilot run which produced results enabling the company to conduct comparisons between the desired performance targets and the actual performance achieved. Implementation plans appear to have been developed for both the investments. However, it is not possible to draw conclusions about the

outcome of this activity, nor is it possible to suggest the extent to which the planning at this stage contributed to the overall investment performance.

The following activities are those that were completed during the Implementation stage by Option B only:

- Finalise/Communicate Operating Environment Changes;
- Finalise/Communicate Implementation Plan;
- Document Arrangements;
- Project Team Progress Meeting;
- Make Operating Environment Changes;
- Consult Contingency Plan;
- Agree Plan for Adjustment;
- Locate Further Faults;
- Communicate Results;
- Document Results of Pilot Run;
- Distribute Results of Pilot Run.

Many of the activities listed could be said to have been performed by a project team. It is interesting to note that the company developed implementation plans for both of the investments, but only one implementation plan appears to have been finalised and communicated. One may suggest that the communication of the implementation plan for Option B has positively affected the performance of the investment. The literature review and the studies revealed the importance of communication between those

involved in an investment project, not least the communication of a plan such as that relating to an implementation which could be ongoing for years. The lack of a formal, well defined project team may have negatively impacted upon the structure of communication links thus discouraging the proliferation of the implementation plan.

It is also interesting to note that whilst the company did not create a contingency plan for Option A, they appear to have constructed and consulted such a plan for Option B. The approach to taking action to correct implementation problems is also shown to be far more structured for Option B than it is for Option A. Furthermore, there is evidence of greater communication throughout Option B than for Option A. This may be attributed to the presence of the project team and a strong project leader. The case studies have revealed that the company did not assign a project leader to Option A.

With regards to the Post-Implementation Stage, the company does not appear to have compiled a performance report for Option A. However, this is not the case for Option B for which a performance report was compiled and distributed. It is important that, in this final stage of the investment process, the company compile the results they have derived from previous activities and use these to aid future technology selections. The surveys revealed the cyclical nature of the technology investment process, and it is because of this that companies will continue to upgrade, or replace their technologies constantly. However, in order to prevent the same problems occurring with new investments as occurred with old ones, the information gained as a result of tracking the performance through documents should be coupled with the business case to assist the company with their future investment decisions. One may suggest as a result of not

compiling a performance report and neglecting to review the business case, the company may go on to repeat the same mistakes that they made with Option A.

Leonard-Barton *et al* (1985) also outlined the challenges that managers must face when considering how to best introduce a manufacturing technology investment:

- Early involvement of the technology supplier in the process to inform users;
- Organising the infrastructure to receive the investment;
- Choosing the most suitable site for housing the investment;
- The need for one person to champion the investment;
- Providing training for those users who need it and providing information and/or about the investment to overcome resistance to change;
- Setting longer term goals, as the investment may take time to reach projected targets.

Further analysis reveals that, with regards to Option B, the company has managed to satisfy the challenges outlined by Leonard-Barton *et al* in the 1980's. Furthermore, the surveys revealed a list of factors that can positively affect the performance of an investment when incorporated into the investment process. These are listed as follows:

- Establish a review procedure and adhere to this;
- Try to keep to one project leader;
- Conduct a thorough justification of all possible investment projects;
- Organise maintenance and technological support from the outset;

- Involve all stakeholders, or necessary personnel, as early as possible in the investment process;
- Encourage stakeholders to communicate their desires and preferences for investment choice;
- Encourage all personnel involved to have commitment to, and a sense of sharing in the project;
- Frequently communicate the progress of the investment;
- All problems associated with the investment should be communicated as soon as they arise;
- Outline as many risks as possible to the project;
- Plan for risk and make preparations to accommodate problems, should they occur;
- Senior management backing;
- A clear understanding of the effects an investment will have, and communication of this;
- An organised and thorough business case.

A further analysis of the results reveals that the factors above are reflected in the investment process for Option B. One may assume that the incorporation of these factors into the investment process for Option B has positively influenced the performance of this particular investment.

7.3 Validation

The purpose of the case study was to illustrate the validity of the process model and its practicality and usefulness in an engineering environment. There are three types of

validity: face, criterion and construct (Anastasi, 1988). Face validity is used to represent the validity of the assessment technique from the perspective of the evaluator. Criterion validity is the term used to define the effectiveness of a given instrument when used in a specific application. Construct validity exists when the measurement instrument demonstrates the measurement of the construct it is supposed to substantiate (Anastasi, 1988; Reynolds, 1997). The case study was concerned with construct validity. By achieving construct validity, the research must exhibit reliability, or internal consistency. The process model attempts to prove face validity by presenting a reasonable solution to the research problem. Criterion validity and construct validity are substantiated through the development and use of the checklists, and the case studies.

Had the process aid been available during the process for Option A then one may say that either the new process would have been followed, since an examination of the more successful investment would indicate a good possibility of success, or the company would have followed their own process and failed to make a success of their investment. However, had the process been followed, the company would have had some indication that neglecting to complete the activities would increase the likelihood of a poor result. Furthermore, the process for Option B was followed without the inclusion of extra steps, thus indicating success for the process model.

Thus, whilst complete confidence in the process model cannot be proven without a "real" investment – which is prohibited by the confines of this research project – the case studies give confidence in the reliability of the process model.

7.4 Chapter Summary

This Chapter has detailed the validation of the process model, an exercise completed within the collaborating company. As it was not possible to conduct a validation of the model using investments currently under implementation, two investments were examined retrospectively. The results of these studies are detailed as are the results of the checklist analysis. The checklist analysis was conducted to validate the process model and ensure the process model is robust. The checklist was used to highlight those activities performed during the investment processes. The study revealed that there were more activities completed during the process for Option B, the more successful investment, than for Option A. The results of this study are discussed and presented in comparison with the findings of the literature review and the surveys.

Chapter 8 Conclusions

Abstract

This Chapter summarises the whole thesis and attempts to conclude the work conveyed throughout. Unlike the other Chapters, this Chapter relates to the work as a whole, initally describing an overview of the research before discussing limitations within the research. Subsequently, general recommendations for future work are presented, before concluding the work in its entirety.

8.0 Overview of the Research

This research was prompted in response to the requirements of the collaborating company, Matra Bae Dynamics. The company has experienced a period of great change, one that is unlikely to cease in the near future. This constant flux, coupled with moves to consolidate the European defence industry, has seen the collaborator turn their attention inwards to their own business processes. This introspection has revealed a concern to secure strategic and financial success for the future, and virtual vertical integration (VVI) has been identified as a proactive approach to conducting 21st century business. Virtual vertical integration is based on the principles of the virtual organisation, forming partnerships with organisations for the purpose of acquiring skills and technologies in order to exploit market opportunities. This investigation of VVI highlighted the need to focus upon the core elements of the business and identify those key to remaining competitive. The collaborator believed that the benefits of VVI would be more easily realised through a greater awareness of how to identify and implement

core technologies. Hence, the need for a process to structure the acquisition and implementation of manufacturing technologies was highlighted.

However, there are many factors that impact upon the acquisition of manufacturing technologies, and companies are not always able to control these. There are factors external to the company, such as competitor behaviour and customer demands to contend with, not to mention the factors existing within the company such as budget availability, the business strategies, managerial styles, and the culture of the organisation. Furthermore, there is the issue of the process of acquisition itself and how this should be executed. If managers expect returns in the short run, they may neglect to consider the benefits that may arise in the longer term. However, it has been argued that for a full evaluation to be conducted, managers must consider the strategic implications of purchasing technologies as well as the financial.

In response to these, this work developed a research methodology comprised of six phases. The first stage was the literature review phase focussing on the process of manufacturing technology, the problems associated with this process, how research has attempted to overcome these problems, and managing investments in manufacturing technology. The second phase, Phase 2, was a survey of aerospace and defence suppliers with the objective of gaining basic information about the acquisition of manufacturing technologies to enable the construction of a conceptual process model. Phase 3 focussed on the development of this process model, whilst Phase 4 used the process model to develop a process aid for use within industry to assist in the process of investing in manufacturing technology. Phase 5 of the research methodology was

concerned with the validation of the process model through a case study, whilst Phase 6, concerning the limitations of the research, is detailed in this Chapter.

8.1 Limitations of the Research

Whilst the research objectives have been fulfilled there remained some limitations with the research. For example, the process model was a culmination of the research conducted and hence it was not possible to commence validation of the holistic process until the latter stages of the research project. Furthermore, once an investment is purchased and installed in the company, the implementation that follows can require many years. Hence, it was not possible to validate the process model using a current investment for the study. The case studies were conducted retrospectively to allow each stage of the process model to be examined. A limitation with this approach is that the author was unable to actually experience an investment project and validate the process model in real-time. Also, by conducting a retrospective case study the author was relying on the collaborator's ability to recall facts about the investments. Furthermore, the author assumes that the collaborator's responses to the checklist were subjective, thus raising the possibility of inaccuracies in the case study and checklist data. There is no reason to suggest that the collaborator would wish to influence the data in any way, but a research project to monitor the performance of an investment in real time may reduce the possibility of inaccurate responses.

The author would have preferred to adopt a method for analysing the case studies that would have allowed profiles to be created to represent the performance differences between the case studies. However, the research results support the theory of

manufacturing technology investment performance, so one concludes that whilst a different method may have provided a wider, perhaps more accurate range of results, the checklist method was a success.

8.2 Recommendations for Future Research

The case study illustrated the application of the checklist within the collaborating organisation. However, whilst the checklist has been useful for this study and the results supported the findings in the literature review and the surveys, further research is required to monitor the effects of following this process in real time.

Further recommendations for research include an investigation into how the manufacturing technology investment process presented in this thesis supports the achievement of virtual vertical integration.

Whilst the process presented in this thesis has a solid theoretical grounding, it has also been developed using real data collated from two surveys of aerospace and defence companies. The process is intended to be a generic one, but a suggestion for further research is to compare this process to that taken from another industry.

Also, a recurring response in the interview surveys was lack of time and resources for structuring a process such as that for manufacturing technology investment. The author suggests the initiation of a research project to investigate how a process such as the one presented in this thesis impacts upon a real investment project.

The process developed has been validated within the collaborating company and thus proven to be robust. However, the author recommends that a more detailed process be constructed and then validated where possible. The purpose of this research project would be to develop the investment process further to include activities which may be vital to an investment performance success, but have not been discovered in this research project.

8.3 Summary of the Research

As described in Chapter 1 of this thesis, the Engineering Doctorate is a multi-disciplined research qualification, with an emphasis on relevance to industry. Thus to qualify as an EngD thesis the research must have:

- Made a contribution to knowledge of the core research subject;
- Have a general relevance to industry and offered benefits to the collaborating company.

8.3.1 Contribution to Knowledge

The research presented in this thesis differs from other research in this area in that a holistic process has been developed, based on findings from the literature review and from industrial surveys, for the purpose of assisting managers in their investment planning and implementation. The research has drawn from other academic sources for the basis of the process model, but this model has been developed to consist of almost one hundred activities that have been revealed to positively affect investment performance, and is far more comprehensive than other methodologies found in the

literature. A process aid has been developed specifically to address the need for structure and consistency in the investment process. The process aid consists of a set of pages that the user can navigate in order to track their process progress, but also contains advice about what is required in order to produce a positive outcome from each activity.

8.3.2 Relevance to the Collaborating Organisation

The research project was highly relevant to industry and to the collaborating company in particular. In Chapter 1 the research objectives were outlined and the development of a process aid suggested as a means to assist the collaborator in their quest to improve their technology acquisition process. The research project introduced the concept of virtual vertical integration, the foundations of which are laid in the process of acquiring the necessary technologies. An underlying objective of the research project was to develop a process for investing in manufacturing technology, thus providing the collaborator with the knowledge, and a tool (the process aid), for selecting and implementing manufacturing technologies with a view to creating a virtually vertically integrated organisation. With regards to the research project, the main objectives have been fulfilled. Within the collaborating company, the process aid has been well received, thus satisfying the objective to provide the collaborator with a process to assist their acquisition of the necessary technologies to help them achieve their long term strategic aims.

8.4 Conclusions

The work described in this thesis had four initial objectives. The first was to address the need for a greater understanding of the technology investment process by investigating the whole process within the collaborating company. The thesis clearly demonstrates an investigation of the whole process through the literature review and the use of a survey involving the collaborator.

The second objective was to breakdown the process of investing in manufacturing technology into key stages and to analyse these in detail. Again, this has been clearly demonstrated through the development of the conceptual three stage model using data from the literature review and the surveys. By highlighting the main stages, the author could begin to identify constituent activities, thus satisfying the third objective.

The third research objective was to detail the process of acquiring and implementing manufacturing technology and to build a model of this. The process model discussed in Chapter 5 demonstrates the achievement of this activity. Once the process model was constructed, a process aid for application within the collaborating company was developed, thus satisfying the fourth research objective.

In totality, this work provides a management-led, formal process to aid consistency and control in the manufacturing technology investment process for the aerospace industry. This work has been substantiated through a case study with the collaborating company, whilst the merit of this doctoral research can be measured by the acceptance of several publications and the approval of the process aid by the collaborator.

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Appendix A

Introduction

The EngD scheme is available at UMIST and the UNIVERSITY OF MANCHESTER.

UMIST and the University of Manchester stand at the centre of the largest educational precinct in Europe, and possess excellent library and computing facilities. Fundamental and applied research takes place in all areas of engineering, a significant proportion of this is in collaboration with industry.

The University of Manchester has an outstanding record of teaching, research and innovation in science and engineering. The Faculty of Science contains all engineering and related areas of study, and industrial sponsorship is a major feature of courses within these areas.

UMIST also has departments in all major engineering disciplines, and its School of Management is ranked amongst the best in the UK. UMIST is committed to close collaboration with industry, and ten professorial appointments have been funded by major companies in the last five years. The strength of UMIST is also reflected in its industrial units and a wide range of teaching company schemes and sponsored industrial research programmes.

Background of the EngD

During recent years the traditional approach to doctoral research in universities has been subject to criticism regarding its suitability for producing engineers who are well suited to the management needs of manufacturing companies. It has been implied that a PhD conducted within the confines of a university laboratory and restricted to a narrow field of study, is too specialised to meet all the demands of modern manufacturing companies.

As a result of these criticisms, the Science and Engineering Research Council (now Engineering and Physical Scienced Research Council - EPSRC) set up a working party to study postgraduate research training in Britain, and to establish its effectiveness in satisfying the needs of industry compared to schemes operated in other major industrial nations. The result of the report is the instigation of the new EngD degree, which is intended to take highly qualified and well motivated young engineers and put them through FOUR YEAR training, involving industry based research and taught management courses, (Engineers already possessing an MSc can complete the course in THREE YEARS). This is a significant deviation from all previous doctoral programmes in Britain, as both the research and taught elements must be passed in order to gain the EngD degree.

It is considered that the EngD approach to research combines the best aspects of a conventional PhD with the practical implications of linking the research to the specific needs of a collaborating company.

All this is supported by formal lecture courses and a personal development programme. Therefore, at the end of the programme, successful Research Engineers have not only gained the EngD degree but, in addition, they have also received valuable industrial experience and in-company training. Holders of the EngD would therefore be expected to be on a "fast track" to promotion into senior management positions at an early stage in their career.

For engineers not wishing to take this approach the traditional PhD will still provide the main source of research training.

The EngD Degree at Manchester

The Manchester EngD programme has been designed specifically to cater for students who wish to pursue a career in industrial management. Each Research Engineer will undertake an intellectually challenging research investigation with industry, including appropriate time on company premises working with professional engineers and managers. This will be supplemented by examined management and technical lecture courses, together with presentations to improve communication skills.

The programme is suitable for recent graduates or people already in industry, and each individual's background will be taken into account during project selection and the specification of technical courses.

Each project will have an academic supervisor and an industrial collaborator. Principle objectives are that Research Engineers become competent to analyse industrial problems, take decisions within the limits of the information available and communicate these decisions effectively. The framework for an EngD study will include:

- a challenging industrial problem of high technical merit
- assessing the relationship of the work to corporate strategy
- studying influences of the market place and the environment project management within the defined timescale and budget
- economic and financial considerations leadership and teamwork defining design and production requirements

Each Research Engineer will be counselled regarding effective collaboration, a viable research methodology and the overall needs of the doctoral thesis. It is important that the industrial objectives of the research programme should be met, and that the doctoral thesis should treat the company as a case study within which a general approach can be developed/tested. It will be necessary for the Research Engineer to become fully integrated within the company's research team, and this will be the responsibility of the industrial advisor. In many cases Research Engineers will have some budget responsibility, and will be responsible for at least part of the project management activity.

At the end of the first year, a major report must be produced detailing the research undertaken and lecture courses attended. An oral examination will take place which may address all aspects of the year's study.

Appendix B

Matra BAe Dynamics

British Aerospace and Largardere signed an agreement to form Matra BAe Dynamics in October 1996 and it began trading on 1st November 1996. The Company incorporates almost half of the French and the greater part of the British Missile industries and is now Europe's premier guided weapons company with a turnover of £1 billion.

It has been formed through a partnership of the former guided weapons businesses of British Aerospace Dynamics and Matra Defense and has 6,100 employees based in the UK and France.

The Company has over 40 customers in five continents, a comprehensive range of high technology products and skills, and unmatched capability to meet customer requirements across land, sea and air.

http://www.bae.co.uk/static/mbaed.htm
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Appendix C

About BAE Systems

Bringing together British Aerospace (BAe) with Marconi Electronic Systems (MES) has created a new group, BAE Systems, that is not only greater in size, but also greater in terms of the enhanced capability required to support aerospace and defence customers all over the world.

BAE Systems has a world class prime contracting capability, combining key in-depth skills in naval platforms, military aircraft, electronics and other technologies. This enables us to offer outstanding complimentary capability to customers across the main defence sectors, as well as in the civil aircraft market. We are also working towards a major boost in operating performance through the synergies and opportunities available to the new group, not least through the cross-transfer of best practice across all our operations.

The commercial practices we employ in the civil aviation marketplace naturally feed through to our dealings in the ever-changing defence sector; and conversely, many of the technology breakthroughs we achieve in military programmes enable us to develop the right solutions for our wide customer base.

Our Vision

Our aim is simple, but ambitious: to be the Benchmark Aerospace and Defence Systems company worldwide.

We will achieve this by maximising the value of our existing businesses and capabilities; by growing the business, and by being a lead player in the global consolidation of the aerospace and defence systems industry.

http://www.bae.so.uk/dynamic/articles/d38218.htm
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Appendix D

Matra BAe Dynamics Agrees Acquisition of Interest in LFK

British Aerospace and Largardere have today agreed an extension to their equally owned Matra BAe Dynamics guided weapons joint venture by the acquisition of a 30% interest in the German guided weapons business LFK, a subsidiary of Daimler Benz Aerospace. The agreement is subject to regulatory approval.

In 1996, LFK had sales of DM884 million and made a loss before tax of DM42 million which included costs associated with the restructuring programme to which the performance of the business is now responding. The business had net assets of DM65.7 million as at 31st December 1996.

The acquisition of LFK by Matra BAe Dynamics represents a further step towards consolidation of the industry in Europe. It builds on the ongoing successful integration of the UK and French guided weapons businesses bringing a German participation to further strengthen Matra BAe Dynamics as Europe's leading guided weapons company. The move will enhance the European guided weapons industry through shared marketing of an integrated product range and will enable national and export customers to derive greater value from their missile procurement.

http://bae.co.uk/html/p101097.html
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Appendix E

Company Evolution

- May 1997 – Reflectone Inc, which designs, manufactures and sells flight simulators and systems, becomes a wholly owned subsidiary of British Aerospace plc. British Aerospace Training Systems invests in the newly formed Oasis International Leasing Company. British Aerospace announces it is to end production of Jetstream 41 turboprop aircraft.
- June 1997 – British Aerospace joins Lockheed Martin's Joint Strike Fighter (JSF) team.
- July 1997 – British Aerospace acquires 49% of STN Atlas Electronik GmbH, the German based systems integration business for approximately £90 million.
- October 1997 – Matra BAE Dynamics agrees acquisition of a 30% interest in German guided weapons business LFK, a subsidiary of Daimler Benz Aerospace. British Aerospace signs agreement to acquire Siemens Plessey Systems UK and Siemens Plessey Electronics Systems (Austrailia) for approximately £319 million subsequent to regulatory approval.
- November 1997 – British Aerospace forms new business unit British Aerospace Defence Systems from 50% shareholding in BAeSEMA, 49% shareholding in STN Atlas and other company defence systems activities, including Siemens Plessey Systems subject to completion.
- December 1997 – British Aerospace sign a co-operation agreement with Kazanah Nasional Berhad of Malaysia to develop Malaysia's capability in design and manufacture of aerospace products.
- March 1998 – British Aerospace disposes of its 26.1% interest in Orion Network Systems Inc for $143 million in cash. British Aerospace reduces its shareholding in Orange plc with the disposal of shares representing 16.11% in Orange plc for £763.8 million. British Aerospace retains a 5% interest in Orange.
- April 1998 – British Aerospace completes the acquisition of Siemens Plessey Systems (SPS) from Siemens AG following regulatory approval. SPS renamed British Aerospace Defence Systems ltd. Aero International (Regional) partners British Aerospace, Aerospatiale and Alenia agree on company dissolution. British Aerospace agrees the acquisition of a 35% interest in SAAB AB, the Swedish aerospace and defence company, for £269 million subject to regulatory approvals. British Aerospace founds its Virtual University. The Virtual University will link education, training and development for the British Aerospace workforce with the acquisition of new technologies and strategic research. Foreign shareholding limit raised to 49.5% with a new limit of 15% on the number of Ordinary shares which any single foreign owner may hold.
- June 1998 – British Aerospace plc finalises a £750 million revolving dance floor to refinance its existing facility and fund corporate projects.
- July 1998 – UKAMS becomes a wholly owned subsidiary of Matra BAE Dynamics.

http://www.baesystems.com/dynamic/articles/d841546.htm
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Appendix F

UKAMS Becomes a Wholly Owned Subsidiary of Matra BAe Dynamics UK

UKAMS, the company responsible for the development and initial production of the UK variant of the PAAMS (Principal Anti Air Missile System) project for the Common New Generation Frigate, has become a wholly owned subsidiary of Matra BAe Dyanamics UK following an agreement signed today between Matra BAe Dynamics, British Aerospace plc and GEC-Marconi, formerly UKAMS shareholders.

This agreement gives Matra BAe Dyanmics the prime contractor role for the UK variant of the project and UKAMS will in future operate from the Company's Stevenage and Bristol sites. Matra BAe Dynamics will retain the Vertical Launcher element of the project and elements of the missile development and British Aerospace Defence Systems (which incorporates the former Siemens Plessey Electronic Systems Limited) will retain the Multi-Function Radar. GEC-Marconi will retain the Long Range Radar. The PAAMS Command and Control System will be shared between Matra BAe Dyanmics and GEC-Marconi.

"UKAMS has been successful in getting us to where we are today in this complex tri-national programme. The UKAMS partners have agreed that this step is now the right one and essential to completing contract negotiations. It is also essential to ensuring its subsequent efficient implementation. In the next phases of the programme it will allow for faster decision making and provide simpler access to specialist technology and resources."

Dave Hewitson, Matra BAe Dynamics Programme Director

Many of the key UKAMS people will be continuing with the project, providing what is intended to be a seamless transfer from the customer perspective. All efforts will be targeted at achieving contract signature for the Full Scale Engineering Development and Initial Production Phase before the end of the year.

The recent UK Strategic Defence Review has re-emphasised the need for improved area defence for the Royal Navy and PAAMS forms an integral element in meeting this requirement. Matra BAe Dynamics and British Aerospace, together with GEC-Marconi, are committed to moving this programme forward in the UK and Europe.

http://www.baesystems.co.uk/dynamic/d864507.htm

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Appendix G

Aerospatiale Matra, British Aerospace and Finmeccanica Achieve a Major European Ambition

Aerospatiale Matra (AM), British Aerospace (BAe) and Finmeccanica (FNM) have today signed a Heads of Agreement to establish a joint venture in missiles and missile systems bringing together their current activities in this field.

These are – Matra BAe Dynamics (MBD), a 50/50 joint venture of BAe and AM; the missiles systems divisions of AMS, a 50/50 joint venture of Finmeccanica and Marconi Electronic Systems, which is now finalising its merger with BAe, and the fully owned missile subsidiary of Aerospatiale Matra.

With a turnover of about Euro 2.5 billion (£1.5 billion), the new European missile group will employ over 10,000 people in Italy, the UK and France will alos hold the 30% shareholding in LFK, the main German guided weapons business, currently owned by MBD.

The Group will be owned 50% by AMS and 50% by a holding company owned by BAe, as to 25%, and AM, as to 75%, giving effective parent company interests as follows: AM 37.5%, BAe 37.5% and FNM 25%.

The group, will have a complete range of land and sea based surface to air systems as well as air launched and anti-ship weapons for worldwide customers, and will be the prime contractor or main partner in all European missile programmes. It has an order book totalling more than four hundred years of predicted furture sales.

The Group will combine most of the key participants in the future European Beyond Visual Range Anti-Aircraft missile (BVRAAM), currently under competition by the British Ministry of Defence, and will bring to that customer an efficient, seamless organisation to manage this important programme.

Fabrice Bregier, the current Chief Executive Officer of MBD, will head the Group.

"This move is a natural development in the consolidation of the European aerospace and defence industry. It is in accordance with the wishes of the European Governments with regard to industry consolidation and produces synergies and brings further scale and enhanced technological capability together with additional value for customers and shareholders."

http://www.baesystems.co.uk/dynamic/d751158.htm
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Appendix H

Cranfield UNIVERSITY

Strategic Decision Support for New Manufacturing Technology Investments

Company Name.....

Company Address.....

Postcode..... **Telephone/Fax. Number**.....

1. What products are manufactured/assembled by your company?

---

2. How many years has your company been in business?

---

3. What competitive strengths are pursued by your company? Please tick.

- ❑ To make profits in price competitive markets
- ❑ To make rapid design changes
- ❑ To make rapid volume changes
- ❑ To make rapid product mix changes
- ❑ To offer a broad product line
- ❑ To offer consistent quality
- ❑ To provide fast deliveries to customers
- ❑ To make dependable delivery promises
- ❑ To customize products to customer needs
- ❑ To provide effective customer service

Other: _____

_____

4. What factors influenced your manufacturing technology investment decisions?

	Not important				*Very important*
New trends in market/customer demand	1	2	3	4	5
Increasing product complexity	1	2	3	4	5
Strategy of product differentiation	1	2	3	4	5
Product(s) not designed for manufacture	1	2	3	4	5
Time-based competition	1	2	3	4	5
Increasing competitive pressure on costs	1	2	3	4	5
Pressure for increasing internal productivity	1	2	3	4	5
Competitors made similar investments	1	2	3	4	5
New manufacturing technology became available	1	2	3	4	5
Need to replace obsolete production equipment	1	2	3	4	5
To learn about new manufacturing technology	1	2	3	4	5
To pursue a technological development strategy	1	2	3	4	5

Other

5. Why have you/do you invest in manufacturing technology?

6. Would you describe the decisions to invest in manufacturing technology as:

- ❑ Opportunity (initiated voluntarily to improve a stable manufacturing environment)
- ❑ Problem (stimulated by manufacturing inefficiencies that do not require immediate attention)
- ❑ Crisis (initiated to respond to intense manufacturing problems requiring immediate attention)
- ❑ Other (please discuss)

7. Do you undertake post-implementation reviews of new manufacturing technology investments?

- ❑ Yes, for all projects
- ❑ Yes, for some (please discuss)

- ☐ No post-implementation review is carried out
- ☐ Other (please discuss)

8. What kind of performance measurement system is used to evaluate company management

- ☐ Short term financial performance
- ☐ Strategic performance
- ☐ Other (please discuss)

9. Which financial criteria are used to evaluate the performance of company management?

- ☐ Return on investment (ROI)
- ☐ Profit of the year after charging interest on total capital employed by the plant
- ☐ Profit of the year before interest and taxes
- ☐ Cash-flow
- ☐ Variance between actual and standard costs
- ☐ Other (please discuss)

10. Tick any of the following as appropriate:

	NOT IMPLEMENTED		HAVE IMPLEMENTED		
	Evaluated	*May try in Future*	*Very Successful*	*Worthwhile*	*Reject*
Automatic warehousing	( )	( )	( )	( )	( )
Business process re-engineering	( )	( )	( )	( )	( )
CAD/CAM	( )	( )	( )	( )	( )

CAPP	( )	( )	( )	( )	( )
Cellular manufacture	( )	( )	( )	( )	( )
Central databases	( )	( )	( )	( )	( )
Computer integrated manufacturing	( )	( )	( )	( )	( )
Concurrent engineering	( )	( )	( )	( )	( )
Continuous improvement/Kaizen	( )	( )	( )	( )	( )
Design for Manufacture/Asssembly	( )	( )	( )	( )	( )
Electronic Data Interchange	( )	( )	( )	( )	( )
E-mail	( )	( )	( )	( )	( )
Expert systems	( )	( )	( )	( )	( )
Flexible manufacturing systems	( )	( )	( )	( )	( )
Just in time	( )	( )	( )	( )	( )
Kanban	( )	( )	( )	( )	( )
Manufacturing Resource Planning (MRPII)	( )	( )	( )	( )	( )
Materials Requirements Planning (MRP)	( )	( )	( )	( )	( )
Master production scheduling	( )	( )	( )	( )	( )
Numerical/Computer numerical control	( )	( )	( )	( )	( )
Operator inspection	( )	( )	( )	( )	( )
Product data management	( )	( )	( )	( )	( )
Robotics	( )	( )	( )	( )	( )
Statistical process control	( )	( )	( )	( )	( )
Teamworking	( )	( )	( )	( )	( )
Total preventative maintenance	( )	( )	( )	( )	( )
Total quality management	( )	( )	( )	( )	( )
Other.....	( )	( )	( )	( )	( )
.....	( )	( )	( )	( )	( )
.....	( )	( )	( )	( )	( )

11. What are the driving forces influencing new manufacturing technology investments?

12. Which best describes the conception, initiation and final authorisation of an investment project?

- ❑ Conception at a lower level in the company
  Proposal gathers support as it is passed up through the company
  Final authorisation is by top management and is more a formality

- ❑ Conception and initiation at a lower level in the company
  Formal approval or rejection by top management

- ❑ Investment was a top-down corporate policy

13. Who is involved in the investment decision process?

14. Who is generally involved in the implementation of a new manufacturing technology investment?

- ❑ Implementation is carried out entirely by the suppliers
- ❑ Implementation is carried out by suppliers and in-house staff
- ❑ Implementation is carried out entirely by in-house staff
- ❑ Other (please discuss)

Thank you for taking the time to complete this questionnaire. Please return this questionnaire in the pre-paid envelope enclosed, or by fax (01234 750852) for the attention of Lisa Argument.

Lisa Argument
Enterprise Integration (Building 53)
Cranfield University
Bedfordshire
MK43 0AL
Telephone: 01234 754194
Fax: 01234 750852

Appendix I

Section 1 - Current use of new manufacturing technology

- What performance measures have you planned for a manufacturing technology investment?
- When were the performance measures impacted in the implementation process?
- Did the benefits accrued satisfy the original performance measurements?

Section 2 – Budgeting Process

- Discuss the main decisions made in your budgeting process.
- What influences this process of justifying manufacturing technology investments?
- Discuss issues encountered when justifying manufacturing technology investments.
- How are problems overcome?

Section 3 – Manufacturing technology implementation process

- Discuss the main decisions made in your manufacturing technology implementation process.
- Using a previous investment as an example, can you describe problems encountered during the implementation process?
- What would you cite as the causes of such problems?
- How do you address problems associated with this process?

Section 4 – Post-implementation process

- How long after the implementation of an investment would you perform an audit of its progress?
- Discuss the main decisions made during this post-implementation process.
- What action (decisions) do you take if the post-implementation performance of a manufacturing technology investment is better than the original performance measures?
- What action (decisions) do you take if the post-implementation performance is worse than the original performance measures?
- How would you address implementation problems through the budgeting process?
- How would you address implementation problems through the post-implementation process?
- Is the traditional budgeting process suitable for justifying new and future manufacturing technologies?
- How do you capture the learning points from a manufacturing technology investment implementation

Section 5 – Process Aid

- Where do you see you main decision points in the whole process of justifying, implementing, and auditing your technical investments?
- What are the main decisions?
- Would a process aid be useful for supporting these decisions?
- If so, how should it be? (form)
- What assistance should it provide for each decision?

Appendix J

Interview Results

Some of the following are not transcriptions of the interviews that were conducted with personnel from the sponsoring company. Where possible, the interview is repeated verbatim but due to requests from some of the interviewees it has not been possible to reproduce all of the interviews verbatim. In these cases, the author has presented the interview results as if they were interview transcripts. Furthermore, some interviewees were unable to answer all the questions on the questionnaire and in an attempt to provide sufficient information gave answers where able. Also as requested, the author has not indicated the source of information or where each individual interview was conducted.

Interview A

What performance measures have you planned for a manufacturing technology investment?

The performance measures that are planned for are generally for process improvement such as reduction in time to design, development, etc. These are the ones associated with meeting customer requirements and product type technologies. It is important to decide if it is an essential technology or not, because if it is not classed as essential it may be difficult trying to develop a business case for it. Other measures tend to concern the cost of the product, in that by reducing the time to make the product you can reduce the costs associated with it. By producing something in a fixed period of time with a fixed number of resources you can reduce your production costs. Unit production cost is a key measure and if a particular type of technology will reduce this it is likely to be purchased. It is important that they invest in technologies that improve upon present processes.

When were the performance measures impacted in the implementation process?

You are aware of the unit production costs from the start. However, due to the nature of defence products in that they take several years to develop you don't see any improvement for a few years. It may be important to have performance measures but due to the time it takes to produce what we do it is difficult to see how the investment is meeting its original performance measures. We often don't know until it is too late and because so many things have occurred during the time from initial development to final product we can't really say what had an effect, how and where. This has become a key issue. It is important to know and understand what impacts upon your production processes because when you know this you can begin controlling and manipulating them. Without performance measures you don't have a baseline from which to work and make improvements. We know how long it takes for certain things to be completed because we do this every day and often is it difficult deciding how to improve something. Payback is a key measure in terms of investment. We are interested in cutting costs hence it is important to know when our investments will start paying for themselves.

Discuss the main decisions made in your budgeting process.

In terms of budgets, there tends to be a set amount of money for investments, although if something is essential then there is often some slack. Usually there has to be a very

good case for an investment before money is spent. People like to see how much something is going to cost so preparing a good business case is important in the budgeting process. There are significant numbers of people all going for the same money and how this money is split affects the investment process. It has often been the case that people have been given the bulk of the cash for pursuit of a particular investment while other business cases (which may save the business millions of pounds over time) have been left crying out for cash. With regards to key technology areas, this concept is managed by one person who makes the decisions based on input from managers within the key technology areas. All these managers tend to have their own reasons for needing cash to invest and someone has to decide who is eligible for financial assistance. It is often because of this that small advancements are made in a few areas and little in one area. So, for investment in and the management of technology, it is important to construct a business case in relation to what the business needs in terms of technology and what the drivers are in terms of performance. Decisions are then concerned with how to allocate the money available in alignment with the strategic direction of the company. It may be different for other companies, though.

What influences this process of justifying manufacturing technology investments?
What the customer wants is a major influence. Within the company people are influenced by their own perception of what they should be doing and sometimes strategic intents are often not explicitly mentioned. The prime drive at present is how to reduce costs within the company so any investment that will contribute to this will be favoured.

Discuss issues encountered when justifying manufacturing technology investments.
A main issue is not having an understanding of the strategic direction of the company. Also, it is important that we have a contract before making any investments otherwise we'd go ahead and invest and risk being left without a contract. This is a problem within defence; investing in a type of technology and then not getting the contract, or getting the contract and then having to go through the whole process of investing which can be time consuming. It is possible to create a business case for any project that is imminent, and outline the areas that need attention through an investment. It is important to outline the risks associated with an investment because once you know these you can act accordingly early to minimise these.

How are the problems overcome?
Risk management is very important. One of the issues involved with the budgeting process is actually knowing what the process is. There are various levels and there are many people involved, for example, key technology area managers. You must understand who put in the request for money, who has agreed it, how necessary the investment is and how will it contribute to a project. Furthermore, there has to money available otherwise nothing will happen. Communication between people is another problem.

Discuss the main decisions made in your manufacturing technology implementation process.
The budgeting process is annual. You can make a request for a budget for a five year program but you must justify each year. Every year you have to do a business case in order to continue and if there is no money available then you may have to struggle to accrue benefits. Problems occur because once you have the money to invest, you use this and then for a while no-one asks any questions until they want to know the extent to which it is delivering a return on the initial outlay.

Every problem manifests itself in different ways. User buy-in is a problem, communication, budgets. As far as user buy-in is concerned, trying to convince people that they should become involved in something can be difficult. User buy-in can make all the difference between a successful project and a failing project. Meeting peoples' expectations of something is difficult as people can be difficult to convince something's worth. Trying to balance the budget and satisfying people's expectations is difficult. Also, understanding what people want is difficult as they often have their own perception of how they should be behaving. You also have to make sure that the right technology is available.

How do you address problems associated with this process.
Having top management buy-in is important as managers control the money which can be used when problems occur. The budget is always controlled by someone else which is a problem when you need to implement something. Ownership of budgets is a problem but it is not such a big problem if you have a good process in place for having access to the money and spending it. There has to be communication with regards to the budget and how to spend this to satisfy objectives and strategies. People must be involved from the beginning – the necessary people – and have an idea of the risks involved. People need to have the idea that they are sharing risks and this prevents further problems should things go wrong if people won't accept blame. Often technology investments can suffer because the necessary people haven't been involved from the beginning.

How long after an implementation would you perform an audit?
Nine out of ten times nothing happens once an investment reaches the end of its life. It would be useful to have more post-mortems incorporated into the whole process and we are trying to do it with some investments and products. Learning reviews are being introduced to enable us to learn from what we've been doing and how. It can be difficult understanding how to use the information that comes from a review of this sort. A true learning organisation would spend added amounts of time at this stage of an investment's life. It is also important to be able to judge when an investment has reached the end of its usable life and when all learning points have been gathered. How do we know we've learned from something? This is subjective and very much dependent on individuals.

Discuss the main decisions made during this post-implementation process.
A good point to note here that there is no set time as to when "implementation" begins or ends. Maybe the end of an implementation is when a project ends and you replace or update your original investment, and the beginning of an implementation could be when

training and support are in action. Or, does an implementation begin when the investment is being installed or when the decision is taken to purchase equipment?

Also, how do you know when something is obsolete? You need good judgement here to be able to know when something is finished. Perhaps the end of a project is when you finally dispose of the equipment. The main decisions really concern how cost effective an investment is to maintain, how much training is required, and what is the upgrade and maintenance plan for that particular investment. How to dispose of an investment is also a decision that we all eventually reach.

A good investment process is one where you know how much you want to spend, you have an investment in mind, you can justify it and you know to whom to present the justification. You also need to know how to request funding, how to best put the business case together, how to prepare a long term plan, and encourage user buy-in and commitment. You need to always show commitment to a project but reviews are necessary to monitor the progress and air any worries. From a company viewpoint you need to understand the strategic direction of the company and make decisions based on this. You also need to understand how budgets are split. There will always be a mismatch between what technologists want and what accountants will allow. Ownership of budgets is a problem. One person needs to have ownership of their own budget and then they can spend it how they want and not how someone else expects it.

A very important thing to learn is the problem of over-investment, however this may occur. Learning from an investment can prevent this in the future or certainly go some way towards this. A key point is to know what you have gained from the last investment and how much further forward you need to be to be able to achieve your targets. In order to prevent over-investment you need to have calculated performance measures in place from the start for your investment and ensure that you know what to measure to be able to get the most out of the investment. Once you have done this for one investment it should give you a better idea of how to behave with a new investment and to what extent the planned investment meets targets in comparison to others.

What action is taken if the performance of an investment is better than the original performance measures?

A review is very important here to be able to record actions taken. A good idea is to assess all costs associated with an investment from birth to disposal. There is no formal learning process in place so when something is very successful you only hear of it by word of mouth.

What action do you take if the performance of an investment is worse than the original performance measures?

If the performance is worse than you expected then you go back into the budgeting process for that investment and get more money. Everything comes back to money.

Points to remember for the decision aid

What are people trying to implement and why? Who is going to use it? How will they be using it? Where are they going to use it? What are they using it for? Do we really need an investment? There may be a need for decision points and risk gates, and how

these points should be managed. There should also be an assessment of possible outcomes.

Interview B

What performance measures have you planned for a manufacturing technology investment?

We want to invest in a new machine but our suppliers can't afford to invest in anything. This holds up our processes as our suppliers don't have the same capacity. As far as current investments the interviewee it is not possible to discuss these at present as we are in the process of deciding if we should go ahead with the investment we have in mind.

When were the performance measures impacted in the implementation process?

I can't say where implementation begins and ends. It may begin when the initial investment idea is proposed. In this case, you need to have a firm reason why you want to invest. If you have the capability in your supply chain then this can also minimise problems. An investigation of your supply chain the extent to which they can support any changes is important. Vendor choice is important once you know the cash is available. I believe implementation begins once you make the decision to invest and begin making the necessary preparations to introduce the new investment into the company. The investment would have to be running for a while before you could start assessing performance measures and how the investment is meeting original targets specified in the business case. Measuring production cost savings is important for us.

Did the benefits accrue satisfy the original performance measurements?

Only a few investments are picked and reviewed to assess the extent to which they satisfied any objectives outlined for them. I would like to think that all of the investments we have made meet the original performance targets. This depends on so much and relies heavily on people doing the necessary homework prior to an investment to ensure the necessary people are involved, and a thorough investigation of possible investment choices is conducted to ensure the right investment is selected.

Discuss the main decisions made in your budgeting process.

We look at our investments technically and financially in terms of performance measures. All investments above a certain amount of money must be reviewed by the most senior management. It is important that this review is conducted because above a certain level the lower level managers might not have the level of understanding about the strategic direction of the company as a whole that senior managers may have. It is easy to lose sight of such things when one is working within the same environment for a long period of time. As far as decisions go, we look at the technical benefits of pursuing an investment, how the investment fits the strategic direction of the company, or business unit, the financial returns, and if the investment is a necessity. This raises the question of developing our own technical solutions. Can the company provide the technology without having to source it externally?

What influences the process of investing in manufacturing technology?

Core competencies are a big influence and making efforts to excel in these. An understanding of what competitors are doing is also important as it may be dangerous to

become involved in something that is ongoing within a bigger competitor. Understanding what percentage of suppliers business is the business offered by BAE Systems is also an influence on the budgeting process. If suppliers are being given good business by BAE then it is likely they'll provide a better service to them. New technologies and developments in these influence the budgeting process.

Discuss issues encountered when justifying manufacturing technology investments.
At the top level there has to be consideration of what the individual business units require. The money that BAE Systems has is generated through the stock exchange and the share price. This is one issue. Core competencies are another. There is often conflict between what different people want. For example, accountants may have a different idea about what the company needs compared to more technologically minded personnel. Also, what one business unit wants may be in conflict with what senior managers are investigating. Team working is another issue and the way people work together. Benchmarking is also an issue.

How are problems overcome?
Across BAE it can be difficult monitoring investments to ensure that they not only serve to improve operations at a business unit level but are aligned with the strategic direction of the whole company. By using the above issues BAE hope to overcome this problem. Generally, the best examples of investments involve a great deal of communication between the necessary personnel beforehand.

Discuss the main decisions made in your manufacturing implementation process.
Deciding if an investment is affordable. Also, flexibility within an investment is important. Reviews are necessary to make sure the risks identified at the beginning haven't occurred. A project manager is necessary to monitor the whole project and it's progress so someone needs to make a decision about this.

What problems are encountered during the implementation process?
Often the investment doesn't live up to what is promised in the brochures provided by the vendor. If problems occur with an investment they are often dealt with by putting more money into the investment and arguments with the vendor. A post-implementation review would highlight such problems and hopefully this information could be used to prevent similar problems occurring in the future.

What would you cite as the causes of such problems?
Over-zealousness is often the cause of problems as is lack of continuity in control over the project. If one person is familiar with an investment project yet they have to move somewhere else then problems can occur when the new person takes control. Lack of continuity in planning and proposing the investment is also a problem. If someone proposes an investment then they should take responsibility for seeing the whole project through, especially when problems occur. As far as learning goes there is no measure by which you can assess the extent to which people are learning. It is not easy to say when people have learned sufficient to be able to make positive changes. Each investment has its own problems related to it but by communicating these to others in the company it may be that such problems are minimised.

How do you address such problems?
Planning for technology to be available on a certain date can overcome problems related to the delivery and implementation preparations. Benchmarking can also help overcome problems. Trust is important but not easy to encourage.

How long after the implementation of an investment would you perform an audit of its progress?
There is no set period and if a review is conducted it often depends on the size and nature of the investment. In about 1-2 years of an investment being live there is a review. There are a number of issues that need to be addressed through a review. These include what was learnt from the investment, both positive and negative. It is very good to capture these learning points and understand why, if any occurred, we didn't anticipate problems. It is good to understand what surprises occurred and why. This can help in moving one step further in preventing the same thing occurring in the future. It is very important to have a good understanding of what is happening in your supply chain and with your equipment vendors. For example, some investments require maintenance from an external company and if the company is poor at its job and unreliable then this can cause severe problems during implementation.

What action do you take if the post-implementation performance of a manufacturing technology investment is better than the original performance measures?
It is important to understand what happened and how this can be repeated with other investments. It is also good to know how the company benefits from good investment performance.

What action do you take if the post-implementation performance of a manufacturing technology investment is worse than the original performance measures?
Risk management must be improved from the beginning and a more robust contingency plan is required. Understanding where the costs lie is important as is knowledge capture although this isn't always done. People don't often have the time to devote to understanding why something wasn't as successful as originally expected. There may be many different reasons why a technology investment performed poorly, for example, the people using the technology may not have been involved in the planning. It is useful for the people using the technology to be involved in the planning as this can create a communication loop throughout the implementation process.

How would you address the implementation problems through the budgeting process?
There is an element of gut feel attached to an investment and if something feels right then it may be given the go ahead. A hurdle rate is used to assess the risk associated with an investment and this is often adjusted. Investments often have far reaching implications and this is just one of the reasons why companies make investments. The benefits are often felt in the longer term so it may be a good idea to adjust the hurdle rate used to account for the fact that investments yield benefits in the long term. Also, different departments have different views about what should be done with investments and taking these into account in the planning stages is important.

Is the traditional budgeting process suitable for justifying new and future manufacturing technologies?

It isn't suitable for reasons outlined above. There will always be a conflict of interests and by judging everything based on the financial returns people tend not to take risks.

How do you capture the learning points from a manufacturing technology investment implementation?
It is useful to know what went well in an investment and what went badly. However, the process of knowledge capture doesn't always run smoothly, if it runs at all, and it can be hampered by many different things. It would be useful to have access to all information about past investments to be able to use the information when selecting future investments. A post-implementation review should build on the information you have and further questions should be asked. There should be a structured process in place for collecting information and recording it. Again, time is crucial here and people don't always have the time to spare for such tasks. Often plans for investing are unspoken. People always behave in a certain way and often there isn't sufficient time placed on the planning and assessing stages of the investment process.

Where do you see the main decision points in the whole process of justifying, implementing and auditing technology investments?
One of the key factors is planning and strategic planning is very important. It is good to be reactive but taking a proactive stance to something is an approach that must be learned. Value planning, value creation and value management are all important areas. The timing of submission of a business case and its structure is also important. There has to be enough time to review a business case and understand it properly. People also need to be sufficiently briefed about a business case.

Would a decision aid be useful for supporting these decisions?
A decision aid would be useful yet it would need to capture enough information. Not everyone has the same experiences which is why a decision aid would be useful but it would have to contain all that information to account for the gaps in learning between people. A decision aid should be something that promotes learning, but something that also helps capture the learning points from an investment and the lessons learnt. It is important to know who will be using the decision aid and develop it with the user in mind. Once it has been decided who should use the decision aid it will then be possible to input the necessary information to enable that user to make informed decisions. There should be a list of who is involved with the decision process and their functions. Their needs should be outlined and how they plan to use the investment. It should contain information about financial justification and the strategic issues relating to investing in manufacturing technology. Any plans for the investment should be aligned with the strategic plan for the company. It should have an easily updated framework and an easy to follow process.

Interview C
Section 1
Investments are measured by key performance indicators and there are critical success factors that the company wish to excel in. Investments are made with these critical success factors in mind. Value based management is key here. It is important to look at investments that have a positive effect on the company operations. For example, if an investment will reduce labour hours to perform a task or will reduce the time it takes for

a task to be performed then it is likely the company will look to selecting it. Effectiveness is one of the main measures. If any of the key performance indicators can be changed positively through an investment then this is key to the company. It is important to know what effect an investment will have.

Section 2

It is useful to understand where value exists in the business and maximise this through investments. It is important to know where the value drivers are and base an investment selection on these. If the investment will positively effect these then this will influence the investment choice. If a person takes ownership for an investment it is always good that they see it through until the end. This is not always the case as people have a habit of enjoying when an investment is performing successfully and neglecting their responsibilities when the investment is under-performing. Problems arise because the investment is brought into the business with most people being unsure of the effect it will have. It can be difficult trying to ascribe a value to the level of improvement required from an investment. All people want different things and it can be difficult trying to be objective about what to excel in. Being accurate in measurements is very important. Choosing what to invest in can raise a variety of problems. Different investment choices will have different effects and it is not always easy deciding which one will be best for the company. A benchmark is useful here. Gut feel is often what people rely on when selecting investments.

Sections 3 and 4

Not all investments satisfy original expectations and this causes many problems for the company. Post-implementation reviews are not carried out and if anything is documented about the performance of an investment once the implementation is over then it is very little. Reviews would be useful to identify what causes problems and how these may be addressed in the future. This area of the investment process is weak. If post-implementation reviews are applied then they are weak in structure and not evenly applied throughout the company. If there are no documented results about the performance of an investment then there is nothing to refer to when selecting new investments. Hence, learning points aren't captured and the same mistakes are repeated, forfeiting progress. Changing personnel can also cause problems. When one person leaves a job, any problems that were associated with that job tend to be left as they are and aren't dealt with.

Section 5

Time should be spent conducting a full justification of an investment choice and planning for its eventuality. How successful the justification process is depends on the quality of information available and how this information is used. The quality of the justification process depends on the information available, the time spent conducting an analysis, and the people conducting the analysis. It is only necessary to involve the required people as too many people can cause further problems.

Important questions to ask when selecting an investment are:

- What problem needs to be addressed?
- What will be achieved through the investment?

- Will the investment be addressing a symptom of a problem or the root cause of a problem?
- What will change as a result of the investment?
- What will be solved through the investment?
- How will investment success be defined?

Time is also important when making investment decisions. People don't always have sufficient time to make informed decisions but if time is available then it should not be squandered. When implementing an investment it is important to have clear goals and objectives for the technology. Those involved with the investment should have a clear understanding of the justification process and what will be achieved through this. Choosing a vendor is important and the extent to which they provide after sales service and maintenance. When choosing a vendor it is important to have clearly defined goals and objectives for the investment. Also, ranking critical success factors could be a part of the justification process.

Communication is vital at all stages of the investment process and a project manager should be assigned to oversee the progress of the investment. It is important to monitor the extent to which success is achieved in the critical success factors. If an audit is conducted then good points to adhere to are:

- how well the project team worked together;
- how well resources were employed;
- project timescales.

There also needs to be some understanding of other issues affecting the process, for example, personnel changes and the effect this has on the whole investment process.

An auditing process shouldn't be afraid to ask the difficult questions and should start with the assumption that it was a bad investment and then attempt to suggest improvements. An investment audit should be positive in its approach to seeking answers about the investment. A positive approach will help promote learning and will hopefully be a step towards changing the mindset of people when selecting investments. A fundamental question to ask when selecting investments is why invest in the first place. There needs to be a solid reason to go ahead with an investment other than something being the latest fad. When it comes to designing a decision aid one must decide if it is going to be general or detailed. It must be designed for a specific user so an understanding of what the user requires is important. Companies make many investments in different types of technology and this may complicate matters when trying to design an aid to help investment decisions. The aid should be designed in such a way as to allow for investments in differing technologies. A common process would make investment decisions so much easier.

It is important to clarify what you want to achieve from an investment and what you want to affect. A decision aid may be very useful for giving all those involved in the investment process an idea of what is expected of them and the investment itself. It may offer an understanding of the whole process and outline goals and objectives for their chosen investment. It may be useful to understand what individuals want from the

investment and input this into the decision aid to provide others with an understanding of the expectations of the team. People don't always share the same opinion but it is always useful to understand how others think. A decision aid may be the necessary medium through which people can communicate their investment expectations. A decision aid may also help prioritise things and organise the investment process. It should also contain data about why one investment was selected over another, or at least provide a structure in which data relating to this decision can be included.

Interview D

Section 1

It is important to organise the whole process of justifying, assessing, introducing and supporting new technology investments. Not everyone has the same understanding about the investment process and budgeting for investments, hence it is important to begin work on structuring this process. In terms of the lessons learnt from investments we believe we are weak and tend not to look at the bigger picture. Some types of technology are less risky than others and also the measures differ, depending on the investment. Measures are the basis for any investment and it is important to outline areas in which to excel. Investments should be purchased with these in mind. It is important to have a clear definition of what is expected from an investment and have plans to achieve these expectations. Value plans are important as they outline the measures for an investment and it is important to know if a particular technology will meet technical and strategic requirements. Research must be conducted to ensure the right type of technology is selected.

Section 2

In the budgeting process there are two main stages. There is a long term plan and this must be managed as well as the short term, yearly plans. There has to be a clear understanding of strategic needs and emerging needs. People have to be aware and be accomplished at aligning the present needs of the company with any emerging needs. These are outlined in the value plan. It is important not to forget shareholder value and that any benefits realised from an investment will directly or indiretly affect shareholder satisfaction. The whole investment process is influenced by a variety of issues, for example, the need for an investment, the level of risk associated with an investment, and the capability of the company to satisfy shareholders. Discounted cash flow techniques are used for justifying investments, but sometimes when there is an absolute need for an investment there will be less deliberation.

As far as data concerning investments, there are an abundance of data but no information. Data have to be organised into something usable to assist the learning process. Creative accounting can mask any problems that may underpin an investment so it would be very useful for functions other than accounts to understand the mathematical justification of investments. It is important to invest with a need in mind and not to purchase technology because it is sophisticated and glamorous. Often making small adjustments through investments can be more effective than investing in huge systems, though this very much depends on the reason for the investment and the need it is satisfying. It is important to have an understanding of the key competencies of the company and invest with these in mind. A good idea when selecting an investment is to ensure that it will enhance key competencies.

Reviews are very important to understand the progress of the investment and these are conducted quarterly to improve the process and reduce risk. The key thing is to improve planning overall. The review process needs to be more robust as often this can prevent investing in something that another site has purchased or has experienced problems with.

Section 3
Monitoring developments in technology is always important and matching emerging needs to the developments. Risk is always a problem and this increases with lack of understanding. There is a process in place for organising budgeting and implementation. It is important to have all the necessary people involved from the beginning and they should all be aware of the need for the chosen investment. This is done through a process launch. A supplier is selected and the tendering process begins. Suppliers are rated and the one who most satisfies the specification is selected. Once a supplier is selected the equipment can be installed. All stakeholders must be involved and communication is vital at this stage to ensure the investment is satisfying all stakeholder expectations. Most problems occur when you involve people later on in the process.

Poor planning also causes problems, as does lack of knowledge of those involved. Problems must be flagged early on in the process and these should be communicated to all the stakeholders. The culture of an organisation heavily influences the degree to which issues are communicated and this needs to be developed to ensure that people are open about mistakes and problems. Teamwork is another key factor in ensuring the success of an investment.

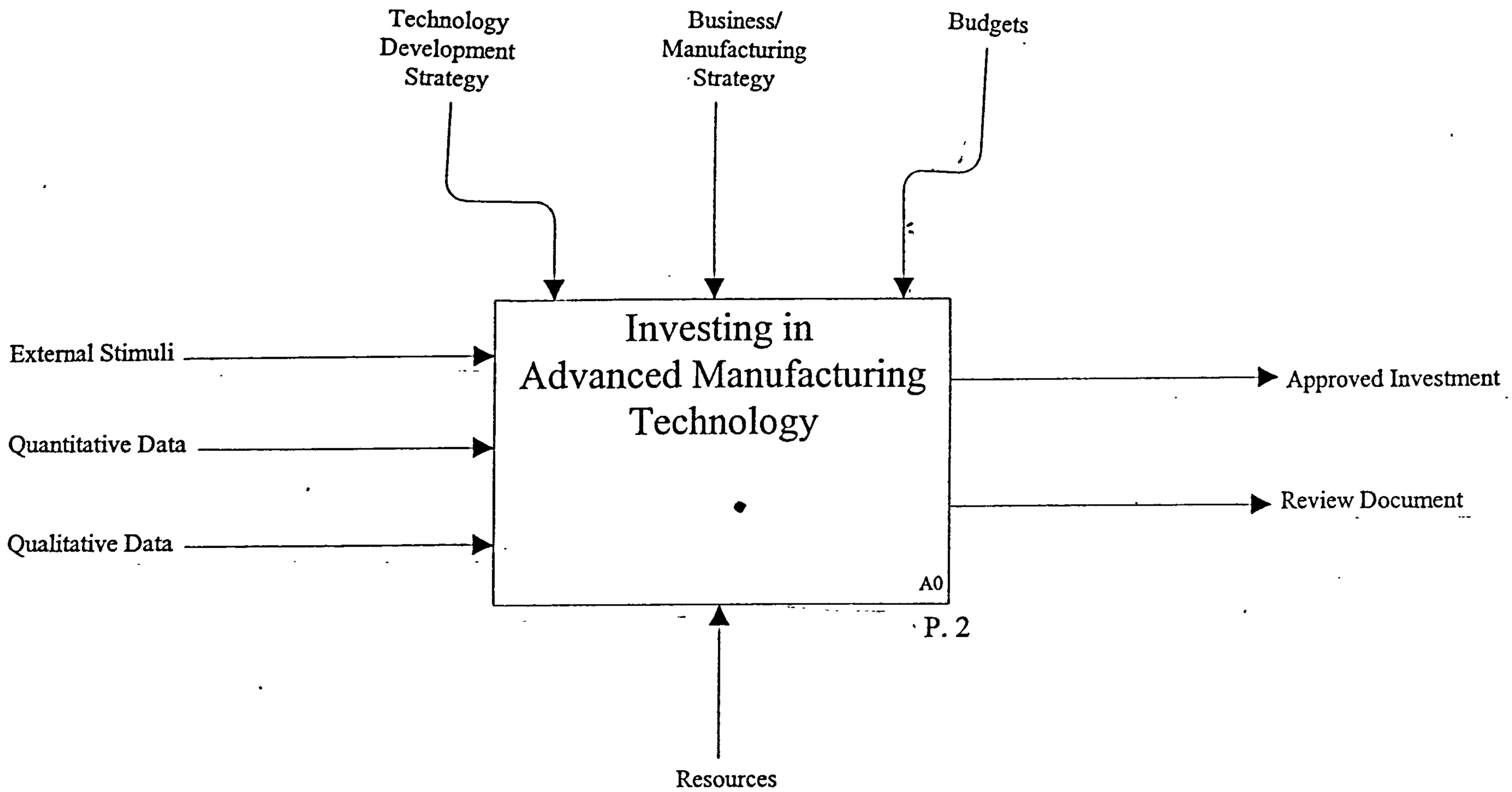
Section 4
Reviews of an investment are conducted regularly but final audits are conducted 6 to 12 months after an investment. Audits usually seek to determine if objectives were achieved and if plans were adhered to. The review process is weak and the weakness lies in not learning from the mistakes that have been made and understanding what went wrong. Financial control is good as is meeting technical targets but there are areas that need improving. Maybe more lateral thought is required about investing and how to improve the process. It is important to be intelligent about the risk associated with an investment and manage this. Risk management should identify problems early as problems can often be related to poor initial planning. Traditional budgeting techniques are employed to assess potential investments but there is increasing focus on understanding where value exists in the company and how this can be managed. A post-implementation review should be like a continuous improvement process and assist learning.

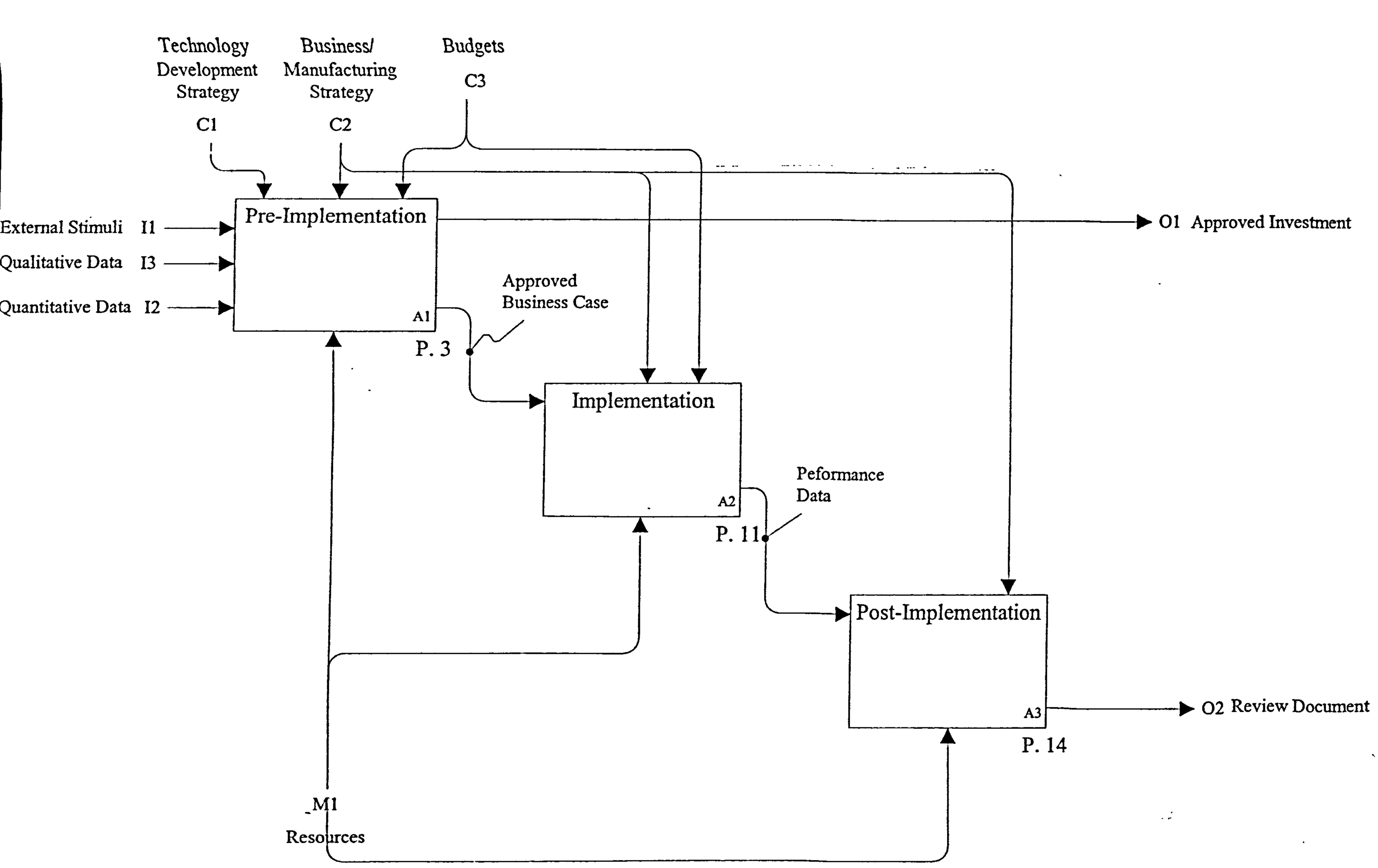
Section 5
Risk analysis is one area that requires research and assistance. The review mechanism requires improvement and a formal feedback loop is required to assist learning. Subjective opinions need to be eliminated as these are detrimental to productivity. There has to be more objectivity about the investment process. If people continue doing things in the way they have always been done then nothing will change and the same mistakes will occur. Areas for improvement include risk management. This needs to be

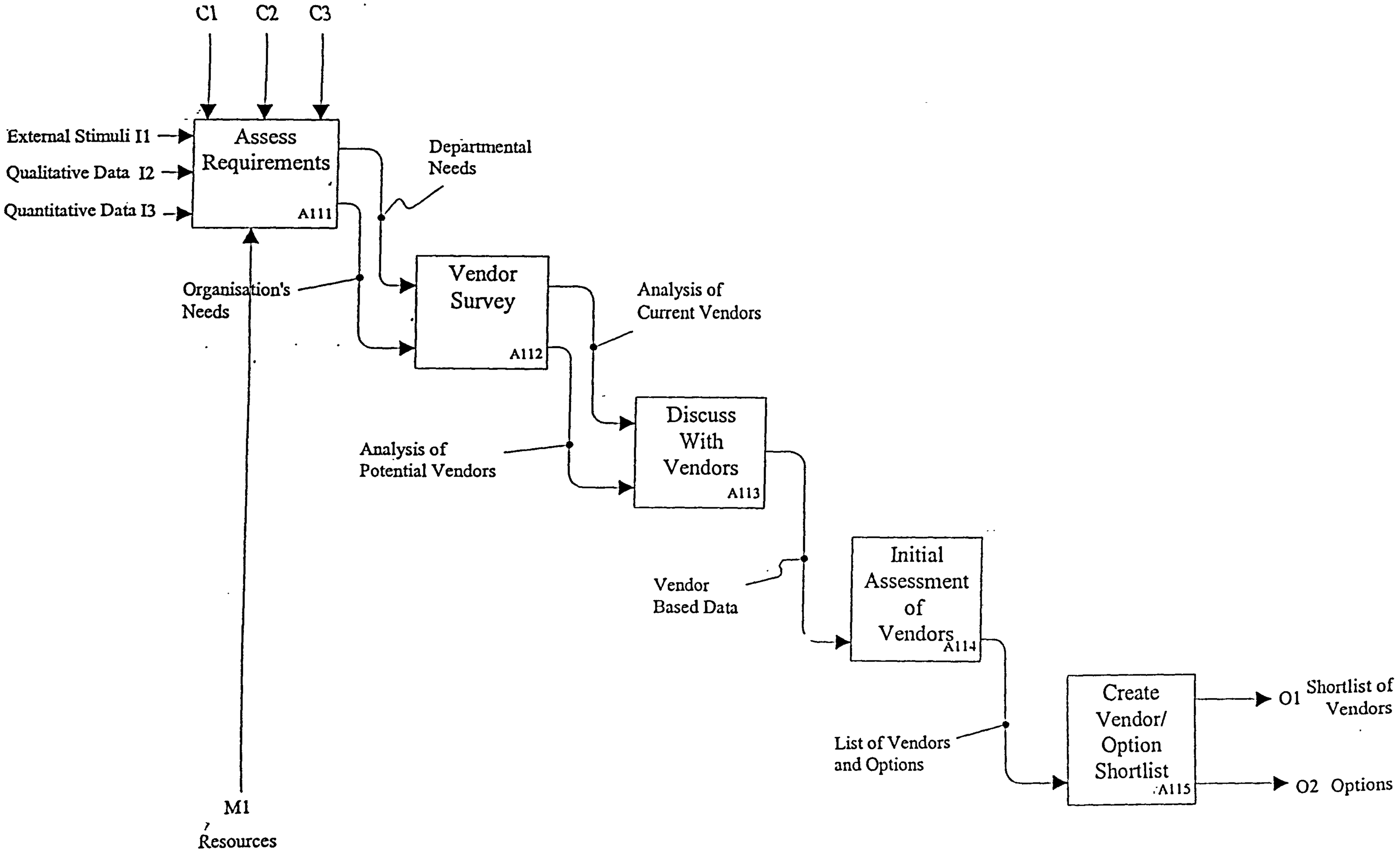
more robust as does the review process. The review process should be viewed as a learning process and for this to be achieved there has to be serious changes in the way people think and behave.

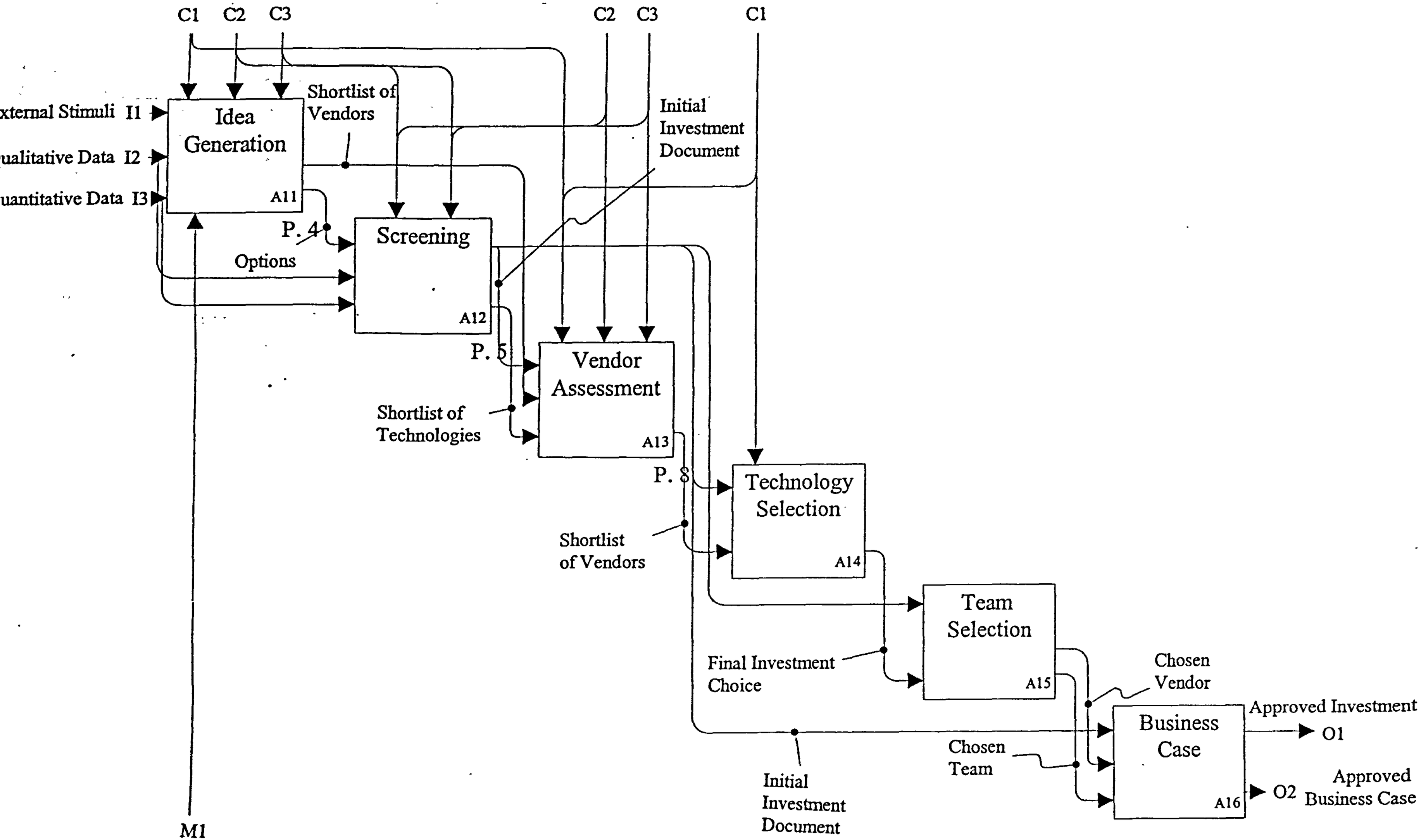
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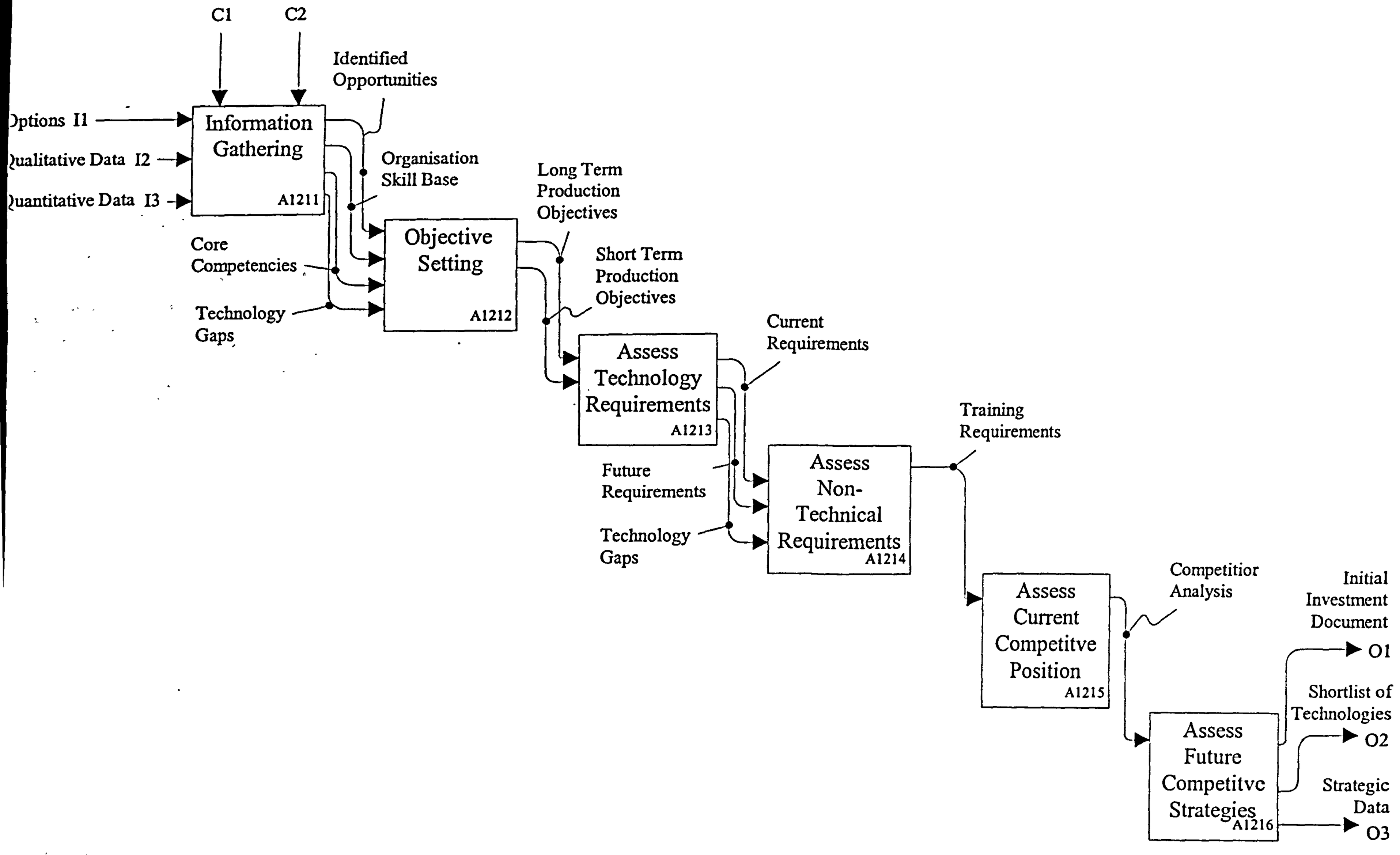
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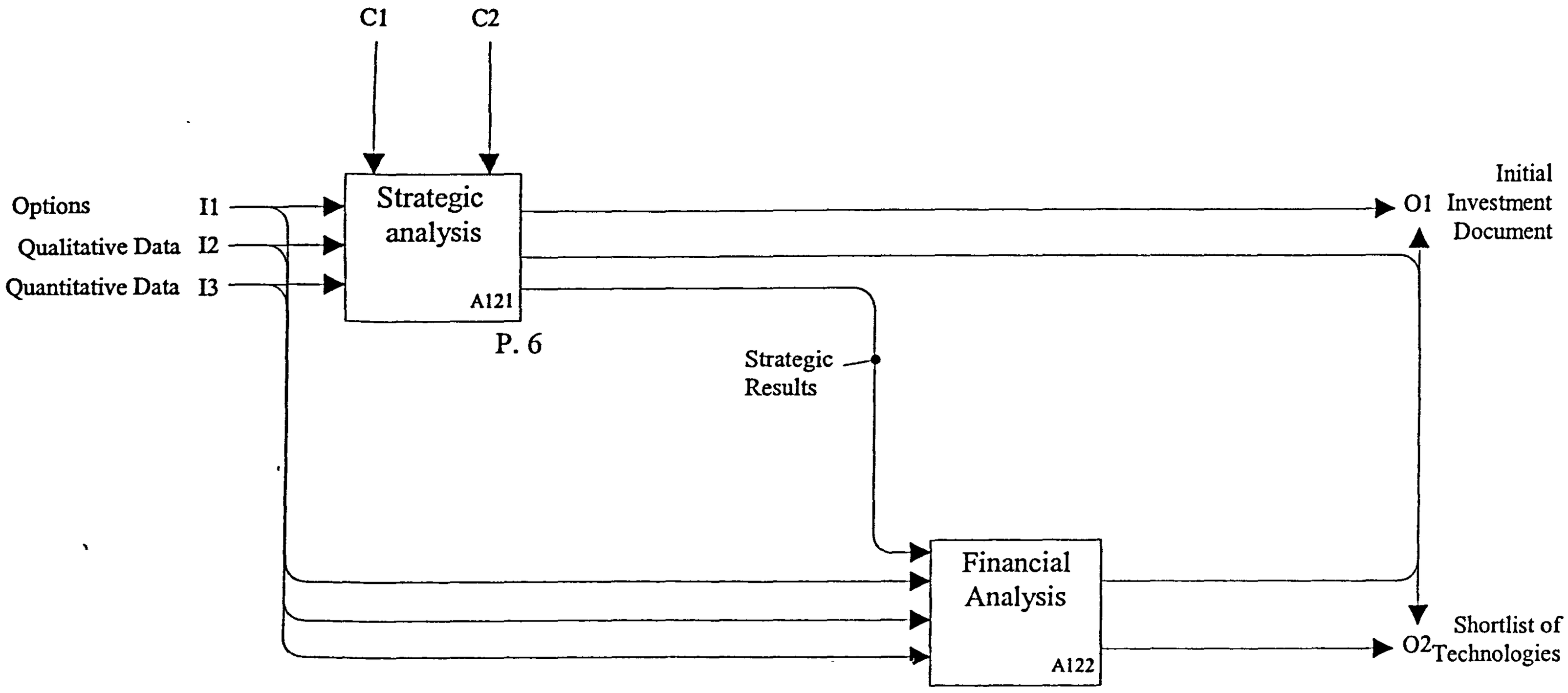

Technology Development Strategy
Business/ Manufacturing Strategy
Budgets
External Stimuli
Investing in Advanced Manufacturing Technology
Approved Investment
Quantitative Data
Review Document
Qualitative Data
A0
Resources

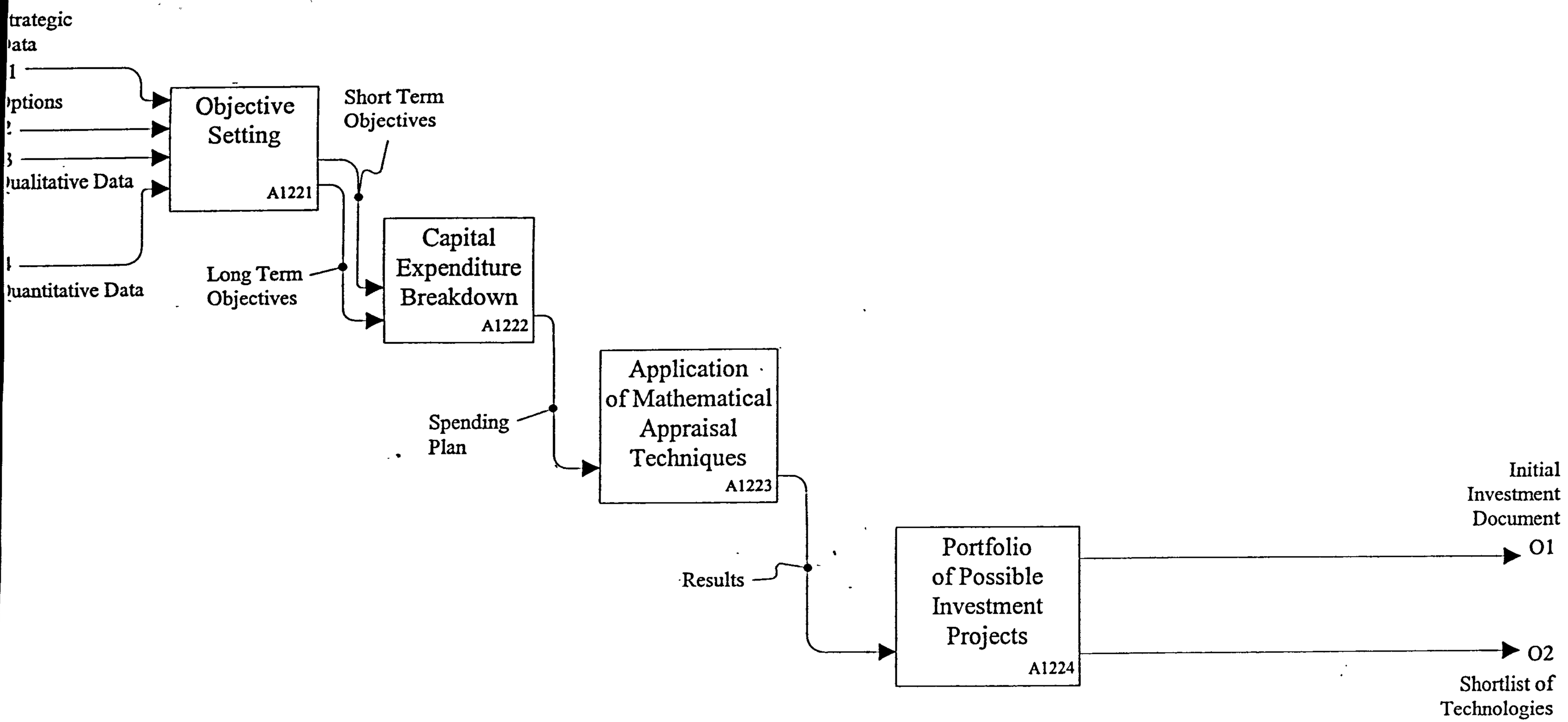

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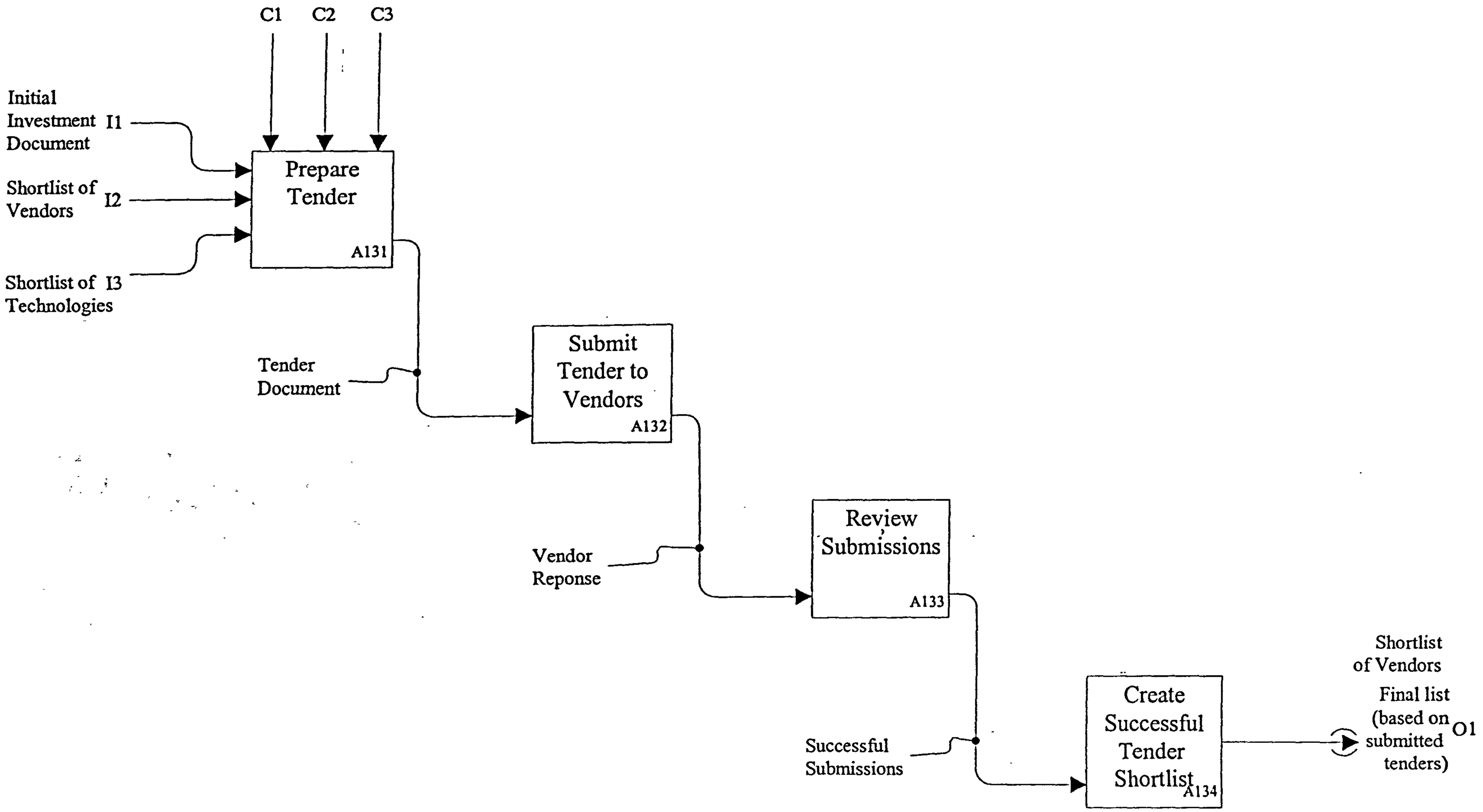

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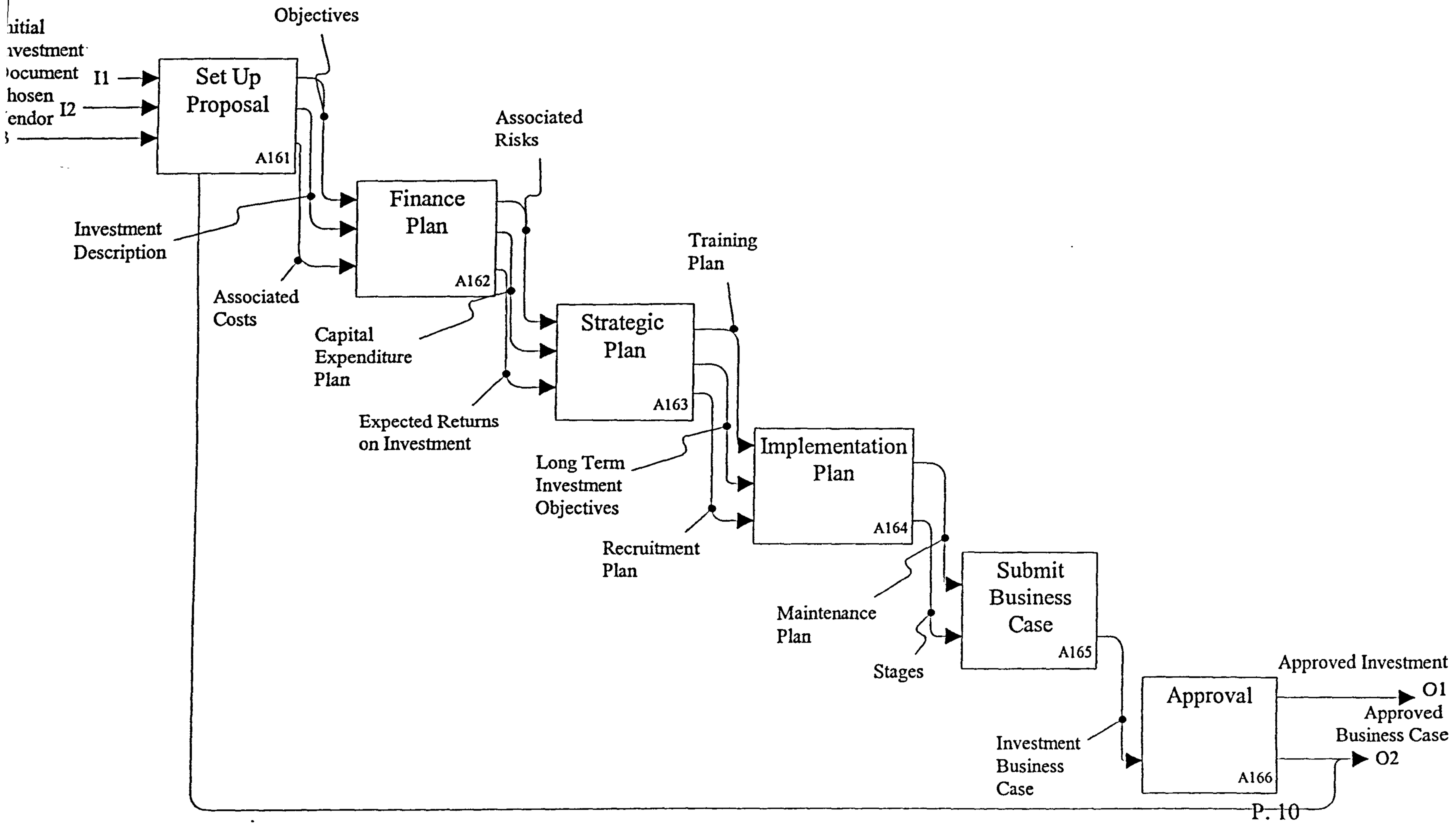

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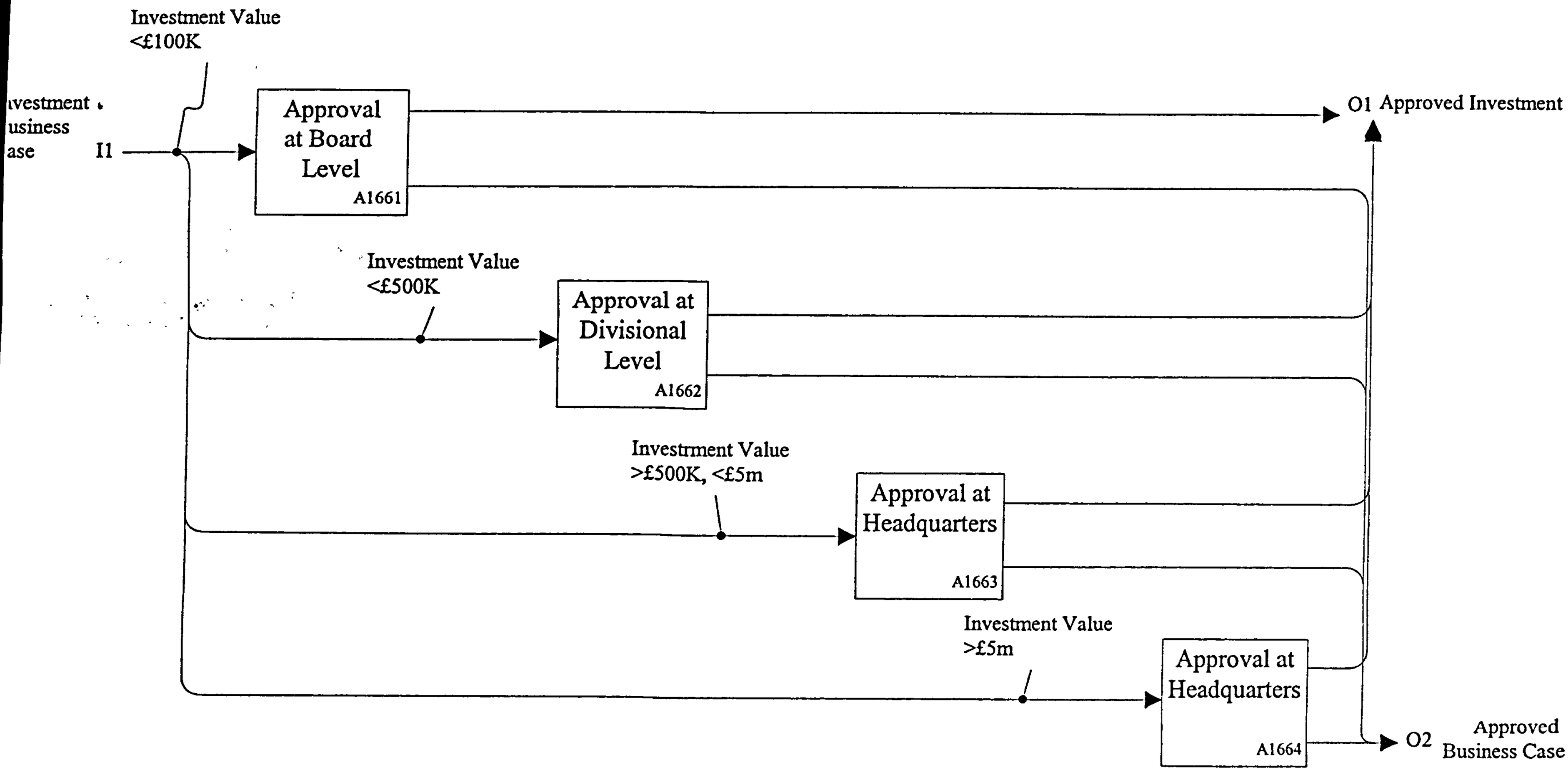

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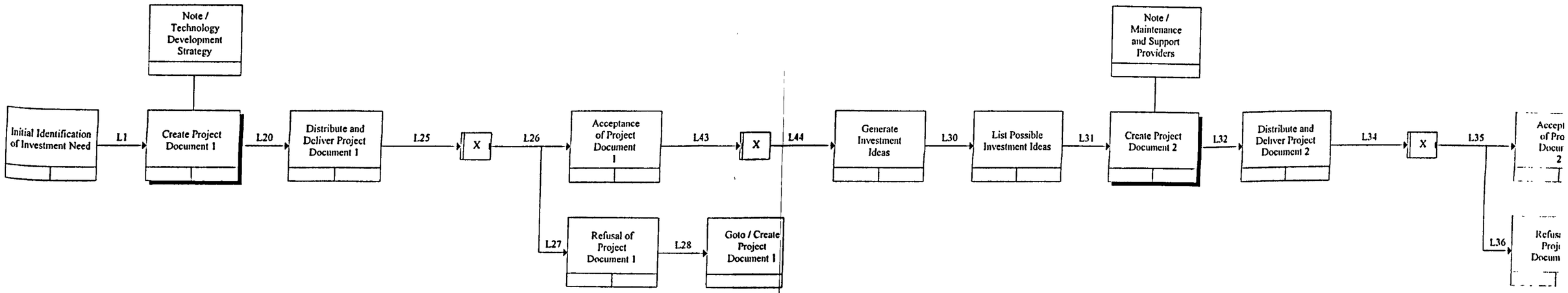

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>£5m
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O2
Approved Business Case

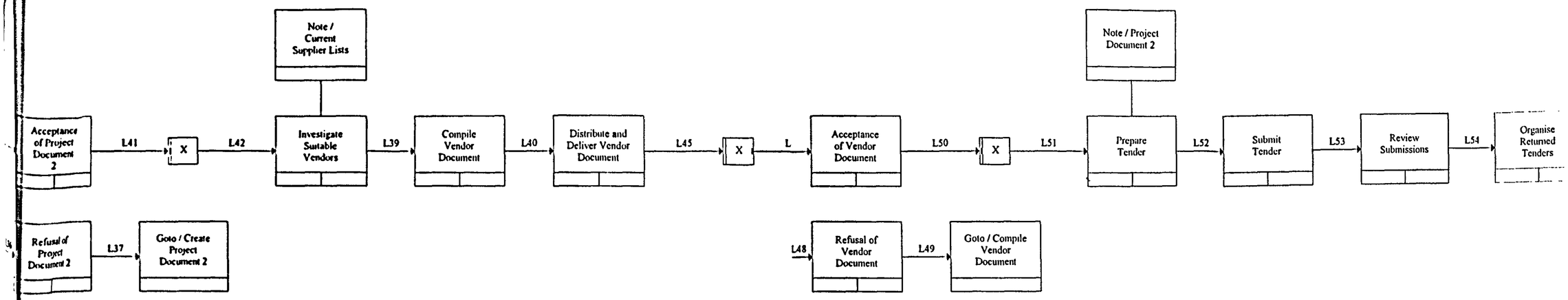
Appendix L IDEF3 Model of the Process of Investing In Manufacturing Technology

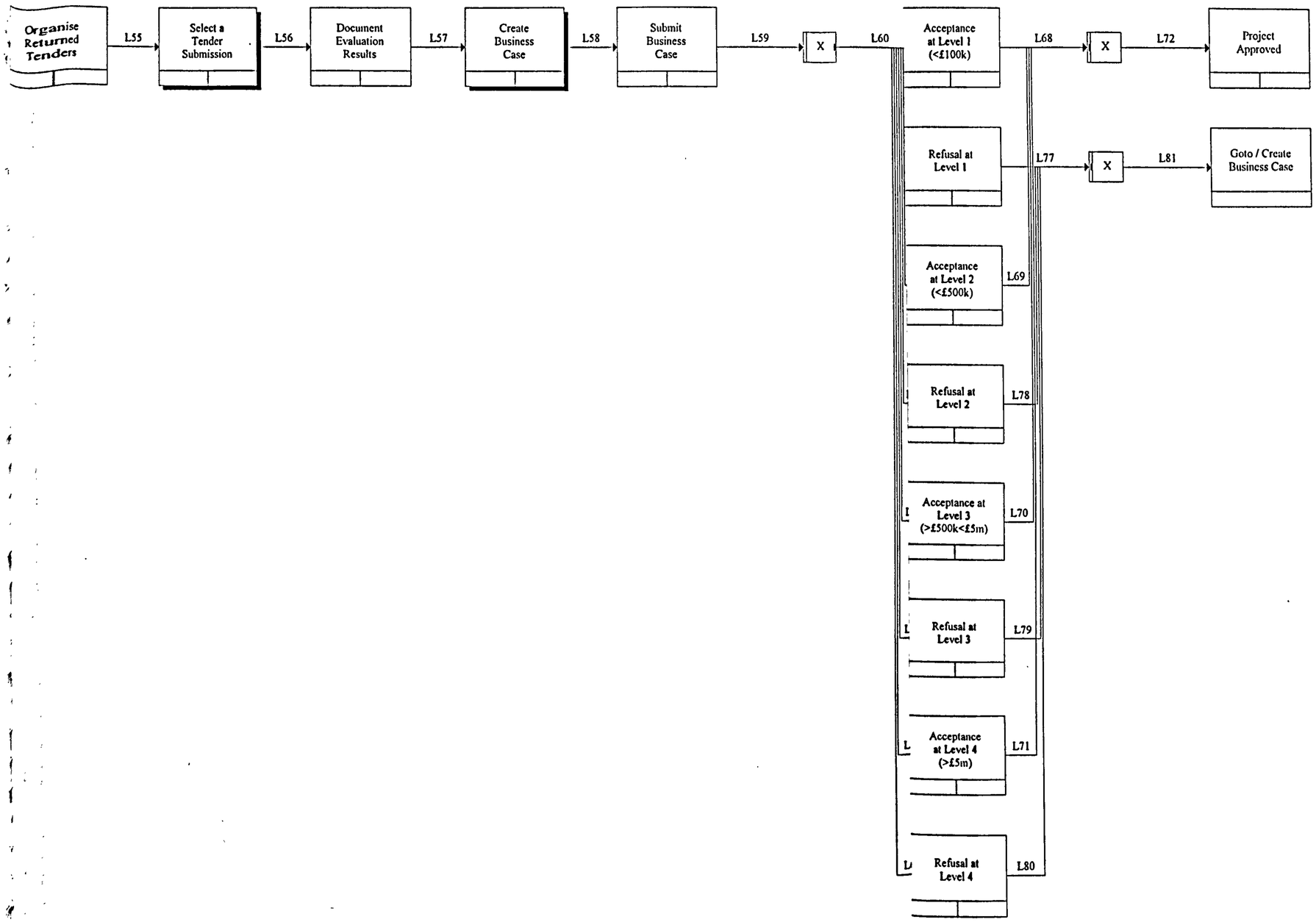
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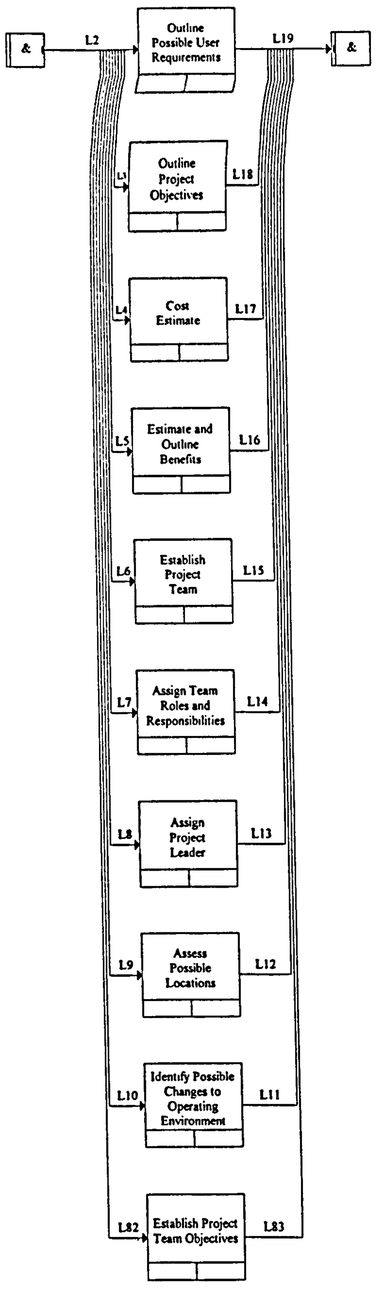


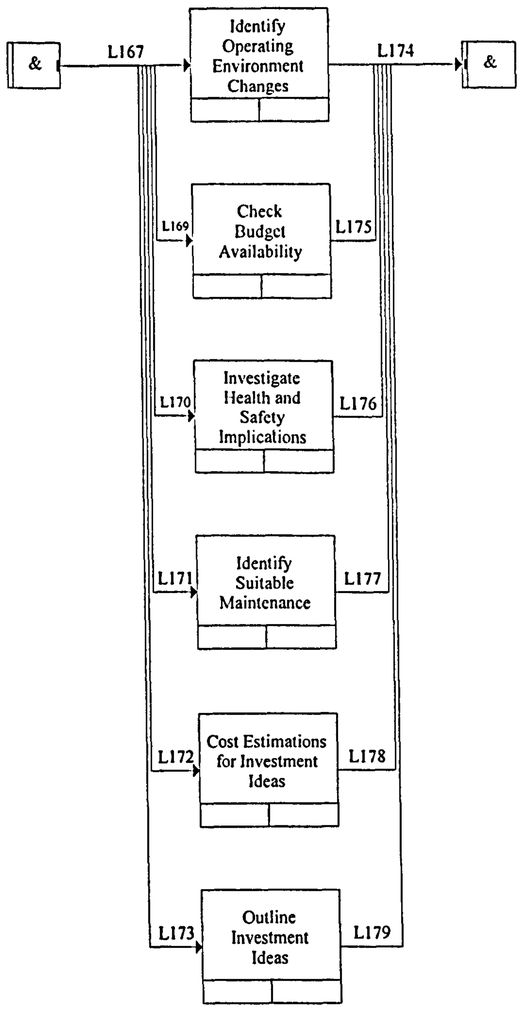
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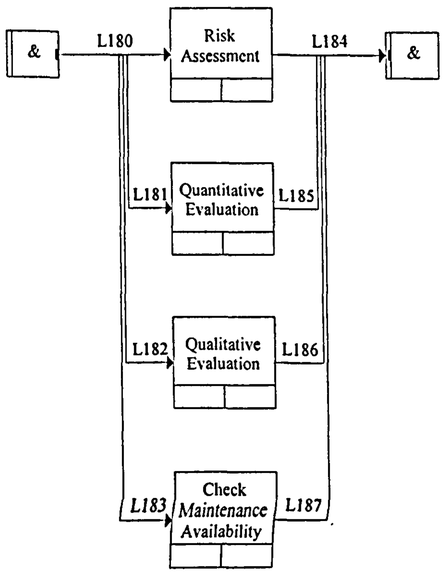

Organise Returned Tenders
L55
Select a Tender Submission
L56
Document Evaluation Results
L57
Create Business Case
L58
Submit Business Case
L59
X
L60
Acceptance at Level 1 (<£100k)
L68
X
L72
Project Approved
Refusal at Level 1
L77
X
L81
Goto / Create Business Case
Acceptance at Level 2 (<£500k)
L69
Refusal at Level 2
L78
Acceptance at Level 3 (>£500k<£5m)
L70
Refusal at Level 3
L79
Acceptance at Level 4 (>£5m)
L71
Refusal at Level 4
L80

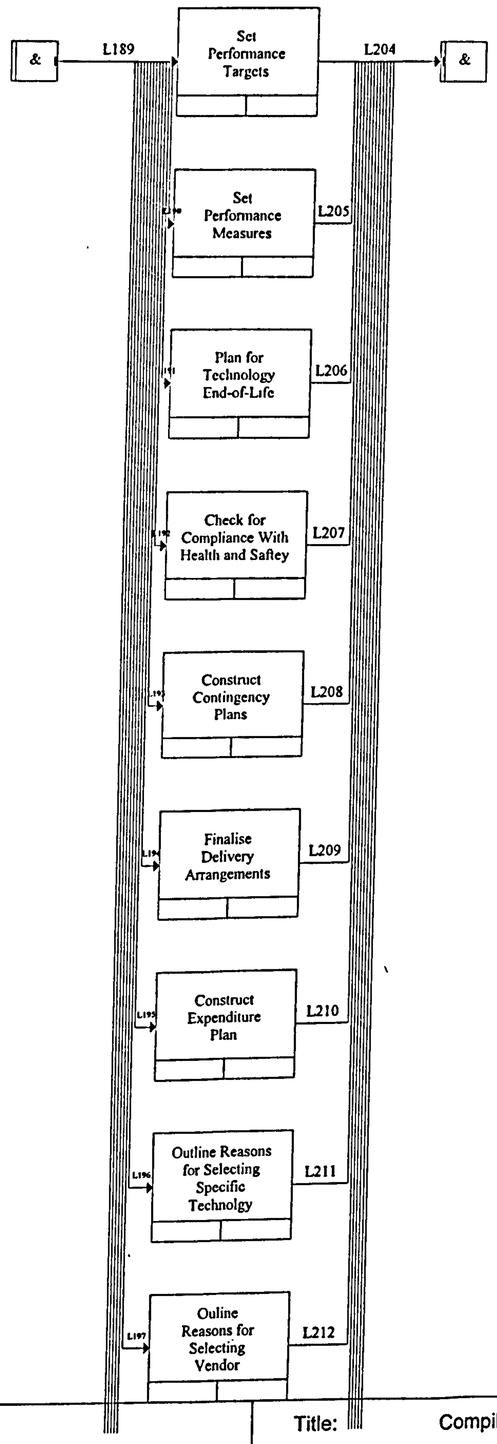
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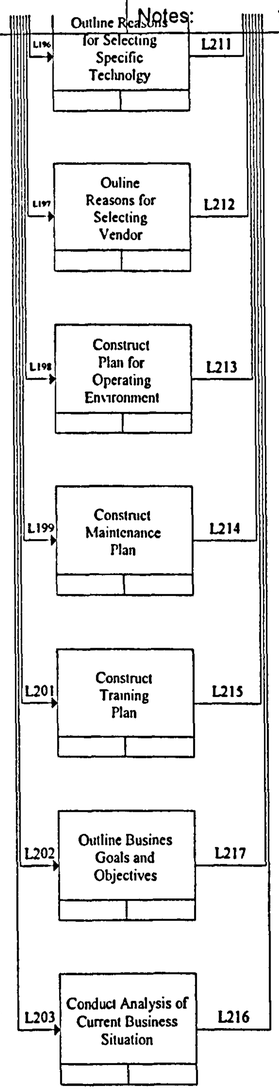



&
L167
Identify Operating Environment Changes
L174
&
L169
Check Budget Availability
L175
L170
Investigate Health and Safety Implications
L176
L171
Identify Suitable Maintenance
L177
L172
Cost Estimations for Investment Ideas
L178
L173
Outline Investment Ideas
L179

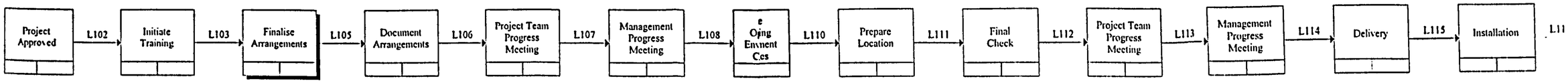
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&
L189
Set Performance Targets
L204
&
Set Performance Measures
L205
Plan for Technology End-of-Life
L206
Check for Compliance With Health and Safety
L207
Construct Contingency Plans
L208
Finalise Delivery Arrangements
L209
Construct Expenditure Plan
L210
Outline Reasons for Selecting Specific Technolgy
L211
Ouline Reasons for Selecting Vendor
L212

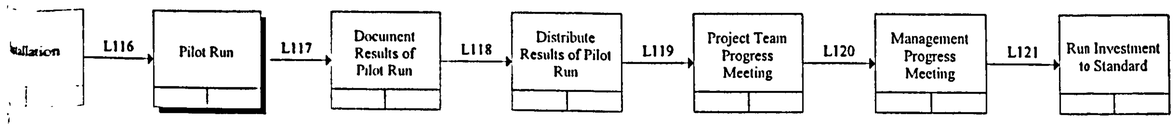

L196
Outline Reasons for Selecting Specific Technolgy
L211
L197
Ouline Reasons for Selecting Vendor
L212
L198
Construct Plan for Operating Environment
L213
L199
Construct Maintenance Plan
L214
L201
Construct Training Plan
L215
L202
Outline Busines Goals and Objectives
L217
L203
Conduct Analysis of Current Business Situation
L216

sed At:	Author:	Lisa Argument	Date:	1/31/2001	x	/orking	READER	DATE	Context
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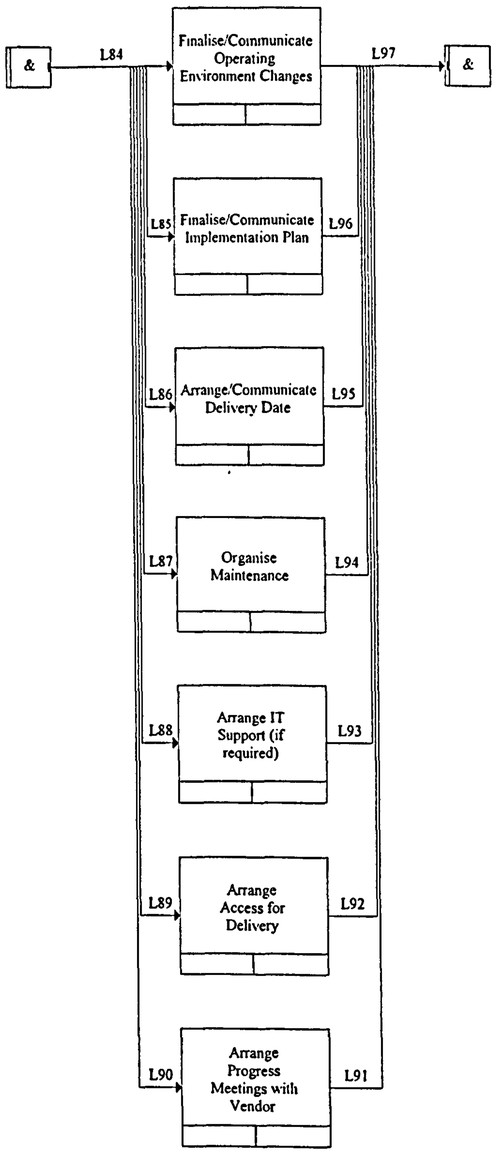


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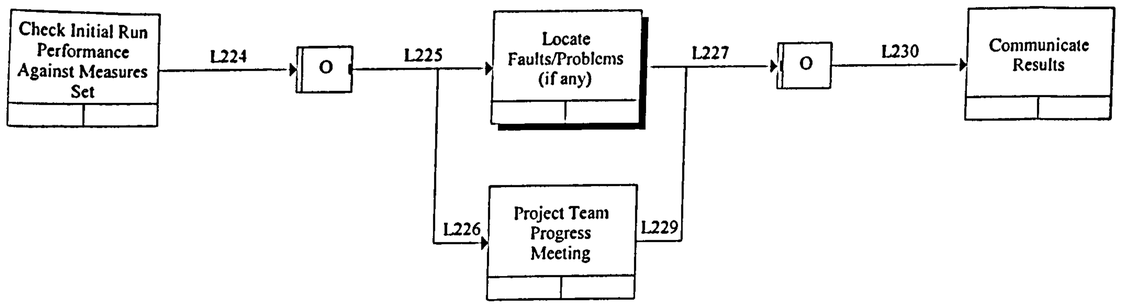


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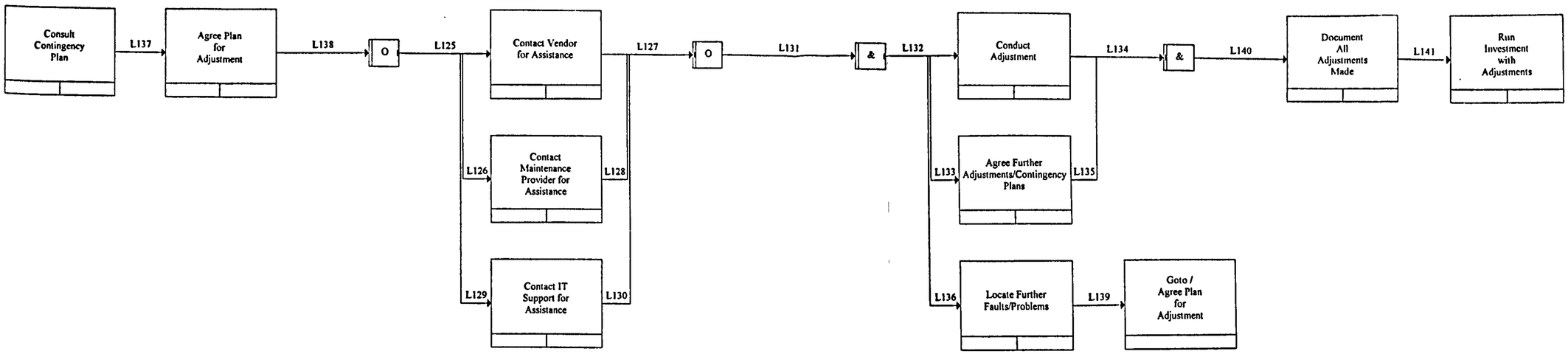


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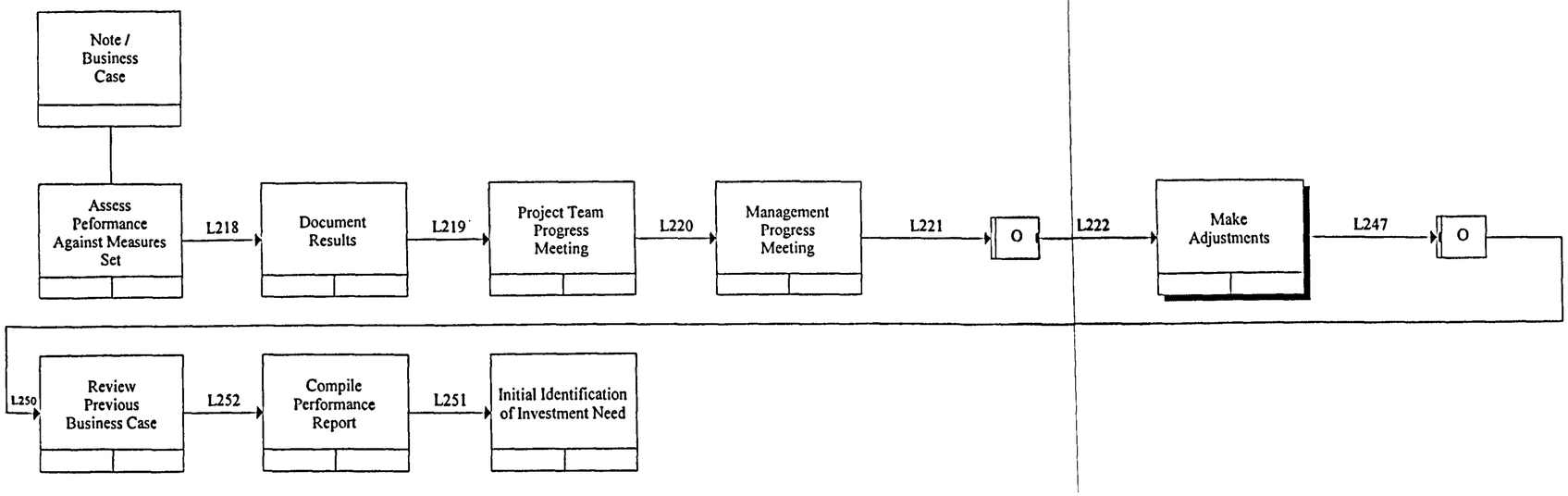
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