COMPUTER AIDED TOOL MANAGEMENT SYSTEM; AN IMPLEMENTATION MODEL

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ABSTRACT

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In recent years considerable attention has been diverted towards devising new strategies to deal with the competitive nature of manufacturing environments. Such strategies are often influenced by the costs and quality of the manufactured products. An effective tool management and control system can significantly contribute to the efficiency of manufacturing facilities by maintaining the flow of production, reducing manufacturing costs, and be instrumental to the quality of finished goods.

Most companies however, have consistently overlooked the importance of tooling and its impact on the efficiency of their manufacturing facilities, consequently it has become a major production bottleneck. Hence, the need for uncovering the nature, extent, and underlying causes of tooling problems.

Having recognised the importance of a Computer Aided Tool Management And Control Systems (CATMACS) as a partial solution to the efficient management of tooling resources, the study then looks at the implementation of CATMACS in fourteen manufacturing companies in the UK, developing some 40 propositions.

Based on the developed propositions, a framework for the implementation methodology is constructed. The framework consists of five phases; Tool audit, Strategy, Design, Action, and Review. The framework has been evaluated and the inputs and outputs to the phases have been identified. The framework represents a significant step in understanding of CATMACS implementation, in particular:

- It addresses the need for such system.
- It provides the basis of an implementation toolkit.
- It provides guidance for the best way of implementing a CATMACS.
- It is constructed using hard data.

PREFACE

This thesis is submitted to the School of Engineering of Sheffield Hallam University for the degree of Doctor of Philosophy. This study was conducted in the division of Design and Manufacturing of School of Engineering.

I would like to express my deepest gratitude and appreciation to my supervisors **Dr. D.T.S. Perera** **(School of Engineering)**, and **Professor D. Tranfield** **(Sheffield Business School)** for their guidance and constructive criticism throughout the course of this study. I would like to thank my friends; especially Christine Osbourne and James Battersby for their help and support. Also my colleagues and administrative staff within the School of Engineering, and the Research Office for their help and support. Finally, I like to thank those individuals from companies who participated in this study.

The results obtained during the course of this research are to the best of my knowledge original, except where the reference is made to the work of others.

M.Shafaghi
May 1994

Process of PhD

The structure of the PhD thesis is illustrated in Figure 1. The chapters are represented by rectangular boxes, where, the chapter under review is highlighted by the thick arrow pointing to the right or top of the boxes. For example in figure 1, "General Overview" is the topic under discussion.

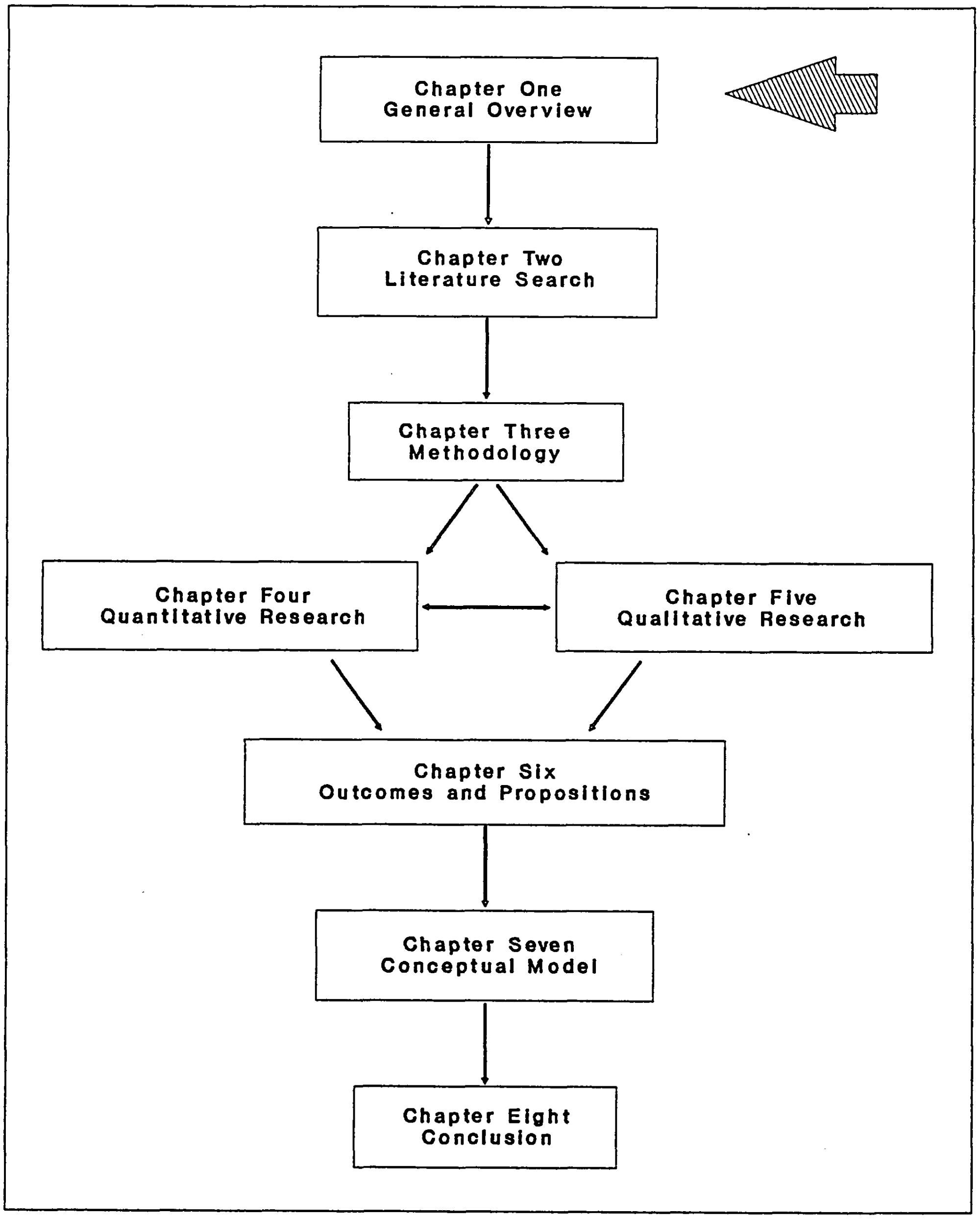


Fig 1: Process of PhD

CONTENT

CHAPTER ONE

TOOL MANAGEMENT SYSTEMS; General Overview,

1.1- Manufacturing and Tooling

A manufacturing company can be viewed as a system which transforms raw materials into finished products through the use of manufacturing resources. The manufacturing resources are crucial aspects in this process and can be considered to be anything that is required to produce the final product. As a manufacturing resource, tooling is a fundamental aspect of this transformation process, and it is an inescapable fact of manufacturing life that every manufactured product is built using a tool or by a machine that was made using tools.

Broom (1967) defined tooling as all equipment and special fixtures that the system can draw on and use during the setup and operation of a machine or assembly process. Allen et al (1980) expanded this definition to cover a wide range of equipment such as jigs, fixtures, pallets, cutting tools, rollers, brushes, tool holders, laps, chucks, mandrels, collets, centres, arbors, set-blocks, angle plates, templates, molds, cams, dies, tool magazines and patterns to name a few, and Melnyk (1988) categorised these various items to "**Transportation Tooling**", equipment used for transferring parts from one work station/area to another; "**Set-up Tooling**", equipment used primarily during the set-up, and "**Production Tooling**", equipment used at work centres in the production of given parts. Within the context of this study the term "tooling" is referred to as set-up, and production tooling.

1.2- Evolution of Tool Management Systems

Traditionally, dedicated machinery handled dedicated tooling. In such an environment generally, a limited number of tools were associated with each machine on the shopfloor and operators monitored, maintained, and replenished these in liaison with stores personnel who managed the tooling resources with the aid of card/index system. Advances in manufacturing technology such as Machining Cell and FMS also required the direct supply of tools from a local tool storage area. However, increasing versatility of NC and CNC machines, and a corresponding increase in work diversity, have resulted in increasing number of tools being associated with individual machines. As a result, the operators are no longer sufficiently in control to accept the responsibility for the management of tooling. Further, the availability of correct tooling in the right condition is vital to continuous flow of production in any manufacturing environment. Given these factors, it is imperative that management and control of tooling resources should receive far more attention. Computerised Tool Management systems are now considered the way forward for managing tooling resources.

1.3- Tooling Problems

Mason (1986), was the first to highlight the mismanagement of tooling. Based on company visits, he reported, although tooling may represent the third-most-costly function in the typical US metal working company, typically;

- 30-60% of tooling inventory is lost on the shop floor.
- 16% of scheduled production is not met due to tool unavailability.

- 40-80% of a foreman's and 20% of operator's time is spent expediting tools.

The costs associated with the above problems are often combined with hidden costs such as: machines down for tooling, missed delivery dates, dissatisfied customers, excess tool inventory, and tool duplications.

Atkey (1986) reported that the UK manufacturing industries were spending £170 million on tooling every year, Zuin (1990) reported that on average British manufacturers spend £15,000 on tooling every month, Mason (1991) reported that the US metalworking industry spends about $1.5 billion a year on cutting tools alone. Whilst these figures could be higher in 1994, they are directed towards the purchase costs of tooling and do not accommodate the costs associated with the poor management of tooling, therefore it may be fair to assume that the real cost of tooling could be much higher. Such costs have a significant impact on competitive nature of any manufacturing company. Devaney (1988) argued that recent innovations in manufacturing have prevented from yielding their maximum potential because managers consistently overlook the impact of tooling. This lack of vision for tooling has led companies to neglect the importance of this critical resource and have not changed the way they manage their tooling resources, consequently it has become a major production bottleneck. However, very little is known about the current state of tooling in the UK manufacturing companies. It may be fair to assume that the situation in the UK concerning the management of tooling resources is not much better than their American counterparts or other industrialised nations.

1.4- Computer Aided Tool Management and Control System (CATMACS)

In recent years considerable attention has been diverted towards devising new strategies to deal with the competitive nature of manufacturing environment. Such strategies are often influenced by the costs and quality of the manufactured products.

An effective tool management and control system can assist companies to maintain their competitive edge by reducing the manufacturing costs. Such a system can ensure the availability of right tools at the right place, at the right time, and right quantity, hence, manufacturing activities runs to the plant's schedule. However, a key issue concerning the effectiveness of such system is the availability of accurate and up to date tooling information.

Information processing is a key issue in any organisation. However, in manufacturing, due to the large number of different tools that must be monitored, managed, and controlled, it becomes increasingly important. Due to unavailability of such information, lack of cross references, poor control and poor communication between the departments, provided by card/index tool management systems, Computer Aided Tool Management And Control Systems (CATMACS) are now seen as a tool for improving the management of tooling resources. But, despite the availability of such systems since early 1980's, very little is known about the implementation of such systems.

1.5- Focus of the Research

Since early 1980's, a number of research programmes initiated in the UK have addressed various issues concerning the management of tooling resources. But, as far as the author is aware no formal attempt has been made to identify the company's situation with regard to the management of tooling resources in the discrete UK manufacturing industries.

It is crucial to develop a better understanding of this critical manufacturing resource by learning about tooling problems, their underlying causes, how they impact on the efficiency of manufacturing facilities, and how to best control it and benefit from the results of any improvements in the management of tooling. Such improvements which often points to the utilisation of a Computerised Tool Management Systems are now seen by many as the solution to tooling problems, and a means to improve the efficiency of manufacturing facilities. However, very little is known about the introductory process of such systems. As a result, the potential benefits of such systems has not been fully detected by companies who presumed a technology led strategy would enable them to improve the management of their tooling resources, and consequently, enhance the efficiency of their manufacturing facilities.

The rationale for this study is driven by the lack of knowledge concerning the management of tooling resources in the UK manufacturing industries, the scale and nature of tooling problems, and the urgency to benefit from a systematic approach to the implementation of a CATMACS.

CHAPTER TWO

LITERATURE REVIEW

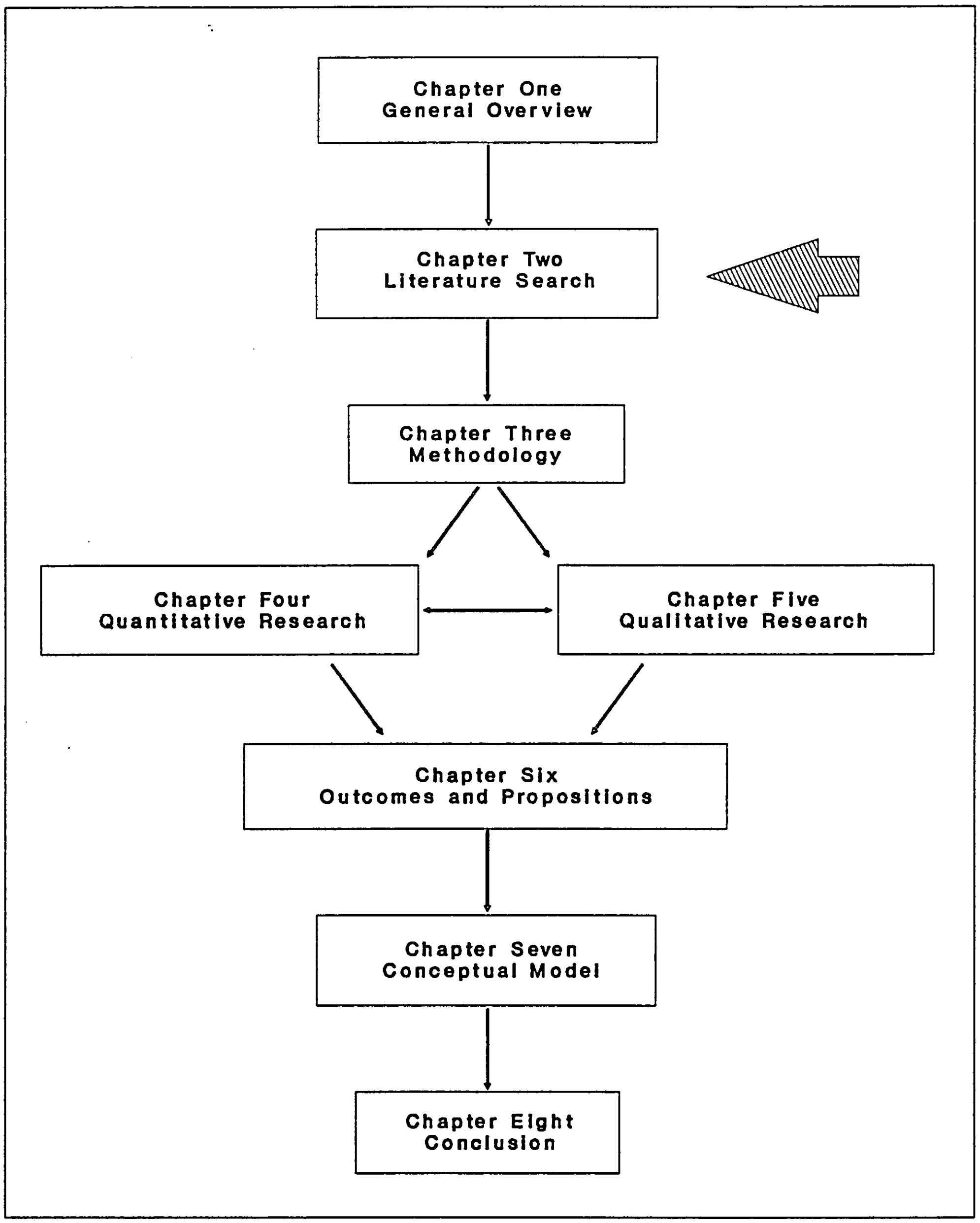


Fig 2: Process of PhD

CHAPTER TWO

LITERATURE REVIEW

2.1- Introduction

Chapter one provided the rationale for this study. This chapter reviews the literature, but concentrates mainly on issues which are relevant to the study. In general, the amount of literature on the management of tooling resources is very scarce and, the discussions on tooling are mainly limited to technical issues when dealing with existing literature. This lack of attention is important as it provides little visibility for tooling problems and further, there is no real vehicle for assisting managers to benefit from the introduction of Computerised Tool management Systems. The literature review consists of seven sections; **Tooling Problems, Tool Management System, Computer Aided Tool Management and Control System (CATMACS), Tool Management Software, Implementation of CATMACS, Research in Tool Management, and the Scope of the Research**. However, lack of literature in the area of implementation has forced the author to look in parallel and similar technologies, in particular in the field of Advanced Manufacturing Technologies (AMT), and CIM. This is also true when considering tool management software. (The term AMT refers to a wide range of innovations in manufacturing environments. It includes stand alone equipment such as CNC machinery, shopfloor data collection system, to complete automated system such as FMS).

2.2- Tooling problems

The desire to acquire and maintain competitive advantages in the market place have encouraged manufacturing companies to benefit from the introduction of advanced technologies such as Just-in-Time Manufacturing (JIT), Flexible Manufacturing System (FMS), and Computer Integrated Manufacture (CIM). Whilst these system offer the promise of enhanced competitiveness through improvements in quality, flexibility, costs and inventory reductions, their success is closely linked to tooling. This is mainly due to the fact that tooling is the fundamental aspect of manufacturing life. Irrespective of the type of operating systems, unavailability of right tooling can result in production stoppages. Therefore, effective utilisation of manufacturing facilities and continuous flow of production relies heavily on the availability of right tooling at the right place. Little et al (1988) suggests, Tool management is a critical issue when meeting the highly flexible requirements demanded, and Gray et al (1988) argues that, the way that tools are managed largely effects the productivity of manufacturing facilities, and there is evidence that lack of attention to structured tool management has resulted in poor performance of numerous production systems.

Most companies however, do not manage and control their tooling effectively; consequently it has become a major production bottleneck. Mason (1986), was the first to provide an insight into typical tooling problems in traditional manufacturing environments, he identified several key tooling problems and their magnitudes in some American companies. In a report where tool management and control was linked to manufacturing performance he noted that:

- Typically 30-60% of a shop's tooling inventory is somewhere on the shopfloor, lost and expensed.
- Typically 16% of production schedule cannot be meet due to tool unavailability.
- typically 40-80% of a foreman's time is spent expediting materials and tools.
- In some plants, operators spent up to 20% of their time searching for cutting tools.

Melnyk (1988) suggests that tooling is such a familiar item to most of us that we no longer understand it or appreciate its effect on the operation of manufacturing systems. Tooling is often treated as a manufacturing residual, something that is considered only after we have dealt with issues of capacity, design, manpower, and materials. As a result we are faced with a situation on the shop floor in which: tooling is poorly controlled, and schedules and delivery dates are compromised. Hence, the problems with the management of tooling becomes more severe. For example:

- There is not enough tooling,
- There is enough tooling but it is not where it should be,
- There is enough tooling but the tooling is either not set up or not adequate,
- Wrong tools are specified for a given jobs.

The above together with other problems such as:

- Value of excess and obsolete tool inventory,
- Additional cost of hot purchases,
- Cost of expediting tools,
- Late deliveries and dissatisfied customers,

and hence, consequent market losses may indicate the importance of tooling in today's manufacturing environment and the need for effective utilisation of this critical manufacturing resource. Mason (1991) characterised the management of tooling as bordering on criminal neglect in many companies and suggests, if raw materials or work-in-process were handled the way tools and tooling routinely are, the managers would be considered incompetent. Melnyk (1991) suggests, Tooling as a manufacturing task and problem, and as an area of research, lacks visibility and widespread acceptance.

In the UK, early studies have focused on the tool management problems of Flexible Manufacturing Systems (FMSs) including; [Kochan (1985) and (1987)], Kellock (1986), Perera & Carrie (1987), Bell & De Suza (1987), and Hollingum (1989)]. Stephens (1984) recognises the importance of tooling in FMS environment, and Rhodes (1986) considers tool management as a critical factor in FMSs. He suggested improperly developed tool management system can cripple such a system and greatly reduces system efficiency and capacity. Like Perera (1987) he proposed that each FMS has its own individual characteristics, therefore a single "standard" tool management system can not apply to all FMSs. Gray et al (1988) suggests that lack of attention to tool management has resulted in poor performance of many FMSs. He argued that; for an automated system to perform well, a high level of integration in necessary between tooling capacity and the other production functions such as process planning, scheduling, part design, and part programming. Whilst highlighting the importance of effective tool management within FMSs and CIM, Little et al (1988) discusses the requirements for a highly flexible integrated manufacturing environment, and identifies the main parameters which influence the tool management requirements specification for a particular FMS.

Although the above work has produced useful results in the management of tooling resources within FMS environment, it has not been beneficial to the majority of companies who utilise traditional manufacturing facilities. The absence of literature in traditional manufacturing facilities is quite evident and no attempt has been made to identify the full spectrum of tooling problems in the manufacturing industry and, it is important to note that; Mason and Melnyk's work are based on their experiences, not scientific research. The lack of concern for the management of tooling resources, their associated problems, and the impact of tooling on the efficiency of manufacturing facilities has encouraged the author to identify the nature and causes of tooling problems in the UK manufacturing industry, utilising qualitative techniques of data collection.

2.3- Tool Management Systems.

Mason [(1988),(1992)] defines the tool management system for a manufacturing company as a system which ensures that right tools are delivered to the right places throughout the plant at the correct times with the minimum investment in tools so that operations may run to the plant schedule. He suggested this definition should be more broad to include: tool design, tool purchasing, tool inventory, tool scheduling and status, tool storage facilities, and tool history. According to Melnyk (1988) tool management and control (TMC) describes all of the activities, direct and indirect which are necessary to manage the availability, use, maintenance and enhancement of all tooling resources needed by the shop floor to successfully direct the flow of work from release to completion. In contrast to others, Mason and Melnyk have encapsulated the essence of tool management. However, these definitions do not elaborate on their validity for any type of tool management system.

Kuchinic et al (1988) defines tool management as: "tool management is broad in concept, requiring a planning strategy to ensure that the appropriate tools are available in the right quantities, a control strategy to coordinate tool transfer between machines and cribs and to see that tools perform properly, and a monitoring strategy to identify and react to unexpected events". Tyner (1988) defines tool management as a process of getting the right tool to the right place on time. Kravitt (1988) suggested that, tool management systems, controls all types of manufacturing tooling including perishable tooling, consumed during use; durable tooling, such as jigs and fixture; and gauges and other measuring devices. Eversheim et al (1991) considers tool management as a process; resulting from the interaction of planning, execute and controlling function in the tool related information flow. Whilst such definitions can not be rejected, they do not really cover all that tool management is.

According to Chapman (1990) tool management is defined differently by different people. Tool management is not simply the control of tool inventory, it encompasses many diverse activities including; tool identification, tool presetting, tool ordering system, tool transportation, quick change tooling system, and post process gauging systems. But with wide variety of definitions, there is common agreement on the objectives of tool management systems first reported by Mason (1988). Long (1991) characterises these objectives to "five rights of tool management".

- The right tool,
- In the right place,
- At the right time,
- In the right condition,
- At the right cost.

Computerised Tool Management Systems can assist companies to fulfil the objectives concerning the management of their tooling resources.

2.4- Computer Aided Tool Management and Control System (CATMACS)

For many manufacturers tooling represent a significant investment. The urgency to manage and control this manufacturing resource effectively, has encourage some companies to benefit from the introduction of Computerised Tool Management. This is mainly driven by the lack of accurate and up to data provided by the card/index system. Information processing is a critical factor in the efficient management of tooling resources. Little et al (1988) suggests "Traditional approach to tool scheduling and kiting have made a significant contribution to improving the efficiency of tool management, but, as flexibility demands increase and FMS become more dynamic, information processing becomes the key issue". Although computers can not solve tooling problems, they can provide better access to stored information through a functioning tool database. Such a database can assist companies to improve the management of their tooling resources.

Kupferberg (1986) suggests that the changing competitive nature of manufacturing has made the traditional view of tooling obsolete. This is contrary to Mason's report (1991). In a update of his special report of May 1986 he argued that, although the management of tooling resources has been improving somewhat in specific sectors (Aerospace, Automotive), by enlarge, tool management is still in need of much greater attention from company management. This study supports his view.

Brown (1991) in support of his discussion on computerised tool management systems suggested, "while tool management system could be manual, they could seldom if ever work manually since we are capturing a huge amount of data which must be captured by an unwilling and unskilled workforce". Disregarding the comment concerning the attitudes and status of workforce, new manufacturing developments, Just-In-Time Manufacturing, Total Quality Management, and MRP (to name a few) are encouraging awareness of tooling and further, present economic and technological trends favour the growth of CATMACS.

Many authors have expressed the need for Computer Aided Tool Management And Control Systems, including Kiran et al(1988) and Hershkovick (1991). According to Mason (1991) experienced users of computerised tool management system cite the main benefits they have gained to be: Improved operating efficiency and control; and reduction of costs due to machine downtime, excess tool inventory, overtime, and the costs of hot purchases. This view is shared by many authors including Pond (1986) who suggested a Computer aided tool management and control system can make money for the companies by increasing their productivity through better utilisation of tooling, and Huber et al (1986) who argued that tools can make or break the major investment in a new system. Atkey (1986), Zuin (1990), and Mason (1991) have reported on annual purchase cost of tooling to British and American manufacturing companies (chapter one). However, Zuin who reported, on average British manufacturers will spend around £15,000 on cutting tools every month suggested this figure could be reduced by 20% if manufacturers adopted a Computer Aided Tool Management And Control System. This view was supported in a recent report in Manufacturing Engineer 1991. It suggested that, in pursuit of cost reductions and productivity improvement, the efficient selection and management of manufacturing consumables is now recognised as the area of significant opportunity.

Such benefits are only achieved through effective utilisation of Computerised Tool Management Systems. Parallel with AMT implementation cube (Tranfield 1988), the latter relies heavily on an implementation strategy which is based on Organisation, Business, and Technological dimensions (Page 25).

2.5- Tool Management Software

In recent years the growing concern about cost reduction, quality improvement, shorter product development lead-time, and market shares has increased interest in the adaptation of computer aided advanced manufacturing technology. Hence, the development and application of computer software in manufacturing has progressed at a very fast rate and companies are investing heavily to improve their manufacturing capabilities and with it, their competitive edge. Due to the importance of tooling in manufacturing, computer applications are now seen as the solution to the efficient management of tooling resources.

The software for tool management system can be developed in-house, purchased as an integrated manufacturing system such as production planing and control system, or purchased as a dedicated tool management software. Since the early 1980's, the number of manufacturing-oriented software packages available on micros, mini, and mainframes has greatly increased. However, the number of software packages dealing specifically with the management of tooling resources have been somewhat limited. Often these packages have been taken the form of stand alone systems designed for very specific functions (eg, tool tracking, management of tool crib, product costing/quotations), or sometimes, they are considered as a resource within some of the finite scheduling systems and often as a minor part of MRP/MRP II Packages.

Early tool management software generally provided information on tool inventory and were capable of handling tooling transactions. However, due to poor design and development they were not reliable, as a result the card/index system was operating as an auxiliary or back-up system. Software dedicated to tooling was first introduced in 1980 by ITC integrated concepts and was followed by companies such as [ABR Corporation, Applied Control Technologies Inc, Data Enterprises, GE Industrial Automation Systems Dep, OIR, Stanley Vidmar, Wickman Corporation, and WCI Control and Data Systems (American Machinist, May 1986)] who produced standalone tool management programmes within the price range of £1,500 to £28,000 plus. Since then there has been a growing interest from both software houses and manufacturing companies who consider computer application in the area of tool management to be essential to the efficient management and control of this critical manufacturing resource.

Perera (1991) who has followed the evolution of tool management software since 1985, describes the range of software by leading suppliers and, lists them as in table 2.1.

Debut	Software	Company	Operating Systems
1985	CTMS	AMTECH (UK) Ltd	XENIX, VAX/VMS
1986	TOOLWARE	ISIS INFORMATICS & ITC (USA)	PC-MSDOS, XENIX, UNIX, AIX, VAX/VMS
1986	TOMAS COROTAS(1990)	SANDVIK COROMANT	MSDOS, VAX/VMS
1989	STOREMAN (MATRIX)	AT&T ISTEL	VAX/VMS
1990	CIMTOOL	CIMTEL Ltd	MSDOS, UNIX, IBM/AIX

Table 2.1: Tool Management Software

According to him, tool management software is a rapidly growing market in the UK manufacturing Industry.

In 1985, POLSTORE (UK), a specialist in tool storage and retrieval systems, claimed that they introduced the world's first tool management system. the system included all the necessary modules such as tool transactions, tool assemblies, kit specifications, job control and monitoring, and tool purchasing. The tool search by description feature provided by this system was known to provide a user-friendly tool searching facility. In 1987 AMAZON COMPUTERS acquired CTMS which is now marketed by AMTECK UK Ltd.

In 1986 TOOLWARE was developed by ITC in USA. The system was then marketed by System Limited (now ISIS information Ltd). It offered the very basic functions required to manage a tool crib. However, other versions of this software "TOOLWARE EXPERT", and "TOOLWARE MASTER" are fully matured products. They support all tool management functions and multiple databases, together with variety of powerful facilities. SANDVICK, a leading supplier introduced its tool management software, TOMAS in 1986. In 1990 they launched a new product COROTAS, developed in Germany. The system is capable of supporting all tool management functions together with interfaces to automated tool handling system. In 1989 Istel (now At&T) released their product, STOREMAN. The system has been updated since, and is now a module within their factory management and operational control system called "MATRIX". Whilst CIMTOOL developed by CIMTEL Ltd can be utilised as a stand alone product, it can be integrated to other modules in their range of production management and control software. COSCOM and TDM (Tool Data Management), developed by German companies, are two other systems which have been reported in UK, Perera (1991)

Current software market for tool management is mainly dominated by a very limited number of software houses who have gained considerable experience in this field and offer a wide range of products such as standard tool inventory and control to interfaces to MRP systems, purchasing, automated tool storage and retrieval systems. Udoka et al (1990) suggests, there are more than half dozen providers of this type of software.

Software houses are usually involved in the production of variety of systems, and their wide range of powerful application modules offers each user a complete computer integrated manufacturing (CIM) solution. However, despite the availability of tool management software packages, some companies have considered the in-house development of such packages; [Mosley (1991), and Thomas et al (1991)]. Thomas suggested; "tool management is a complex organisational problem in many industries which much time and money being wasted due to both shortage and excess. Commercial software dealing with these problems is difficult to adapt to individual situations with the result that a more efficient and applicable methodology is being sought". But, despite the benefits of a custom-tailored system, it is fair to assume that, their development may not be suitable for most companies. This is mainly due to the organisational, financial, and technical capabilities together with the length of time required for the development of such software.

Tool management software selection is an important factor in the successful implementation of CATMACS. With the availability of software technology in tool management, companies are now faced with the task of selecting the right software package. However, lack of literature in this area has forced the author to look for parallels concerning the purchase of software packages. Schwab et al (1992) suggests; with increasing number of vendors, a multi vendor solution for purchasing software should be adapted. Many authors including [Jeye (1988), Johnson (1988), Pecora (1989), and Allen (1992), have discussed the criteria for vendor selection. But, with the increasing vast array of commercial packages, the task of selecting the right software becomes more important and requires a structured approach.

Thompson (1988) proposes a strategy for software selection, and many authors have recommended selection criteria for choosing the right software package: [Fitzgerald (1987), Heydt (1987), Blaum (1988), Nee (1988),Winsor (1988), Le Blanc et al (1989), Kilmar (1990), Theophano (1991), Castellanos (1992)]. But, some authors have argued that software evaluation improves the chances of selecting the right package, and have recommended criteria for software evaluation; [Clark (1987), Helsell et al (1987), Mullins (1987), Archer (1988), Effgen et al (1988), Krupp (1991)]]. However, the existence of available software has moved the emphasis to implementation [Geisler et al (1987), Schleich et al (1991), Bussert (1991), Launi (1991), and Chellis (1991)].

The views expressed by the above authors concerning the criteria for vendor, and software selection is directed at commercial packages. At this stage there is no evidence to whether or not such a procedures are adapted by the manufacturing companies concerning the purchase of tool management packages. Therefore it is important to develop a systematic approach to the selection of software for tool management system. This is an integral part of the implementation process which, its success relies heavily on the suitability of the software.

2.6- Implementation of Computerised Tool Management System.

The process of implementing manufacturing technology, in particular, CATMACS is often viewed as the process of installing technology by many manufacturing companies. This may be the case if the installed technology is compatible with the existing one. But, CATMACS implementation contains elements such as new procedures, and rules that changes the way in which tooling resources are managed. Hence, the implementation of CATMACS requires more than just adaptation of technology. It encompasses the actions from; development/purchase, and installation through to successful utilisation of the system. But, many important determinants of successful implementation are actions and conditions prior to purchase/development or installation. Bessant et al (1985) argued that; "we need to shift our attention towards issues of implementation and adaptation rather than simple adoption. Similarly, Barton (1988) suggested; "implementation requires adaptation of technology and its environment, and adaptation can infact be viewed as a part of the innovation process".

The pre-requisite for successful implementation of CATMACS are actions and conditions that have to be meet prior to the development/purchase of such systems, for example; existing system analysis, new system requirements, technical requirements, and organisation context. Long (1991) considers the combination of good physical organisation with a strong administrative foundation is a pre-requisite for successful introduction of tool management system. Whilst his view of optimising the internal customer/supplier relationship of the administrative process is directed at Total Quality Management (TQM), it undermines the importance of the organisation's commitment to the project. Melnyk (1988), has provided the following principle guidelines which should be considered when undertaking the actual process of implementing a tool management and control system;

- Identify and solve basic problems first.
- Do not look for one big answer to all problems, chances are there will be many little answers to many small problems.
- When bringing the system on-line, approach it from a phasing standpoint. That is, introduce one major category of tooling at a time. This allows the floor operators, as well as the crib attendants, time to adjust to the new method of operations.

Such guidelines are useful when embarking on the process of implementation, but they fail to provide any mechanism for the implementation of such system. This is also partially true about Duggan (1991) who proposed a fourteen step methodology for successful implementation of computerised tool management systems based on his own experience. Although his methodology is more comprehensive to that of Melnyk's, it fails to appreciate the importance of; management commitment, employee's participation, education and training, information base, the process of change, and system changeover. such factor are crucial to the successful implementation of CATMACS. The Liverpool University Method for Tool Management (LUM-TM) which is aimed at specifying the requirements of plant-wide tool management information systems in FMS environment consists of two phases of; Requirements Analysis, and Requirements Solution (Kehoe et al 1991). The LUM-TM provides a significant contribution to the efficient management of tooling resources. However, it is directed at FMS environment where, highly integrated computer controlled systems simultaneously process volumes of a variety of parts and it differs from a conventional manufacturing environment.

The success stories of CATMACS implementation has been reported in case studies; [Zeleny (1981), Gayman (1986), Bottazzi (1987), Albert (1987), Witkow (1988), Happersberger (1988), Anstiss (1988), and Hollingum (1989)]. The case studies are important in providing real life data regarding the incurred costs and benefits by the companies in improving the management of their tooling resources but, very little attention has been paid to the actual implementation process of such systems and technical details have always dominated. This is similar to implementation guide lines provided by some software houses where installation and operational details receives top priority with little in terms of training.

With significant amount of literature concerning various aspects of AMT implementation; [(Beatty 1990),(Hashmi et al 1990),(Steele et al 1990), (Baldwin 1990), and (Corbitt et al 1991), and CIM; [Lucas et al (1988), Jain (1989), O'Hara (1990), Seemann (1991), Howery et al (1991), Aletan (1991), and Von Ohsen (1992)] very little is known about the implementation of CATMACS, hence, limited literature. This is mainly due to newness of the concept and the time required for a large degree of implementation.

This study supports Voss's (1986) historical perspective of implementing manufacturing technology which examines the history of the major manufacturing innovation of 1970's. It suggests that there is little concern with implementation until about ten years after the diffusion of a new system. However, due to unavailability of literature on the implementation of CATMACS, it has therefore been necessary to look for parallels in similar technologies. In particular, the field of manufacturing and information technologies. Although, it is important to minimise the possibilities of translating experience from one technology field to another, some aspects of implementation are technology independent, for example the project champion, process of change, and employee's participation.

Several studies indicate that many applications of Manufacturing Technologies have not yielded their potential benefits. This view has been developed from the weight of evidence accumulated concerning similar and sometimes related applications of AMT and Information Technologies (IT) into manufacturing environments. Typically, applications of new, and particularly of integrated technology, are seen as patchy in terms of their success. The root cause of this has been attributed variously to insufficient account being taken of the relationships between these technologies and the business and organisational context in which they are located. These fundamental problems are often experienced and have been reported as problem manifest in the introduction and implementation of new technologies, [Voss (1985), Bessant and Haywood (1985), Watrelow and Monniot (1986), Ingersoll Engineers (1986), ,Tranfield and Smith (1988), Kirkwood et al (1989), and Maull et al (1990)].

Recent empirical work in the U.K. suggests an absence of "strategy" which is characterised by ad-hoc decision-making by management, and lack of understanding by senior managers about the "strategic possibilities" of AMT (Currie 1990). Ferravanti (1990) suggests that the process of choosing a system implementation strategy can be broken into three related areas; the scope of the first implementation, the method of cutover, and the data processing design methodology used, and Willis et al (1991) argues the need for pre-implementation strategy and recommends four steps in his approach.

Tranfield et al (1988) in a study of thirteen different applications of various aspects of AMT and Computer Aided Production Management (CAPM) in eight of the Britain's biggest manufacturers, concluded that the successful implementation of an integrated technology depends heavily on the development of an overall strategy based on the business, technology and organisational dimensions. Beatty (1990) recognises the importance of implementation strategy and considers a capable champion, system integration , and cross-functional implementation teams as the essential implementation factors.

Hrebiniak & Joyce (1984) have proposed a model for the implementation strategy, and Dean et al (1990) suggest that implementation of AMT consists of making and implementing a series of decisions based on Technical, Economic, and political factors (TEP). Kidd (1990) argues that the implementation strategy should be based on organisation, people, and technological factors. However, it has been purported that strategy is not an issue for consideration in small firms (Birley 1982), but, Dodgson et al (1991) argues that, in the case of innovation, strategy is important, if not essential, for the small and medium company's development and growth.

The basis of an implementation strategy is one of planned change centred on the framework of a policy and involving the tasks, individuals and structure of the organisation. Brooks (1986), and Gupta & Yakimchuk (1989) have identified the removal of organisational barriers as one of the main cause of successful implementation. Kotter & Schlesinger (1979) have identified the sources of resistance to change, and Blake et al (1964) and King et al (1989) express the need for strategic approach when introducing organisational changes. Rochester (1990) identifies the first step in change management is to gain an understanding of the nature of the change itself, and Lawrie (1990), and Hendricks (1989) have recommended a step by step plan for simple and effective change management programme.

Davids et al (1990) suggests that the implementation of AMT leads to conflict between management and labour primarily over potential job losses. However, the emerging problem is split between various sections of workforce, in particular, AMT users and nonusers. Bulworth et al (1990) recommends a seven step plan for successful implementation of employee involvement (EI). Schroeder et al (1989) argues that the adaptation of AMT is not a simple answer to the problems facing small manufacturers. However, adaptation of AMT is a necessary and regular part of doing business if a small manufacturer is to remain competitive. He then consider, planning and implementation to be the most critical elements in successful adaptation of AMT.

Implementation is a vital issue that must be carefully considered prior to the introduction of a CATMACS. Since industries and companies vary from one another in manufacturing processes, organisational behaviour, and working practices. There is no single strategy that can be exclusively adopted for the implementation of a CATMACS. Hence implementation strategy must be carefully planned and specific procedures must be tailored depending on the organisation characteristics and environment. Udoka et al (1990) proposes that, because of the complex nature of the factors affecting manufacturing systems implementation, companies implementing such projects have been unable to report on a consistent pattern of factors for successful implementation efforts.

Most of the above studies have identified the problems of implementing new technologies and suggested methodologies to utilise AMT more effectively. It is important to study how well these could be applied to implementation of CATMACS. Further, it is significant that the current literature on the implementation of CATMACS is purely based on individual experiences, and it is apparent that the implementation of such systems is in need of more attention. This has been the influencing factor in the development of a framework for the implementation of CATMACS by this study. The framework would provide guidelines for the best way of implementing such system.

2.7- Tool Management Research

There are only a limited number of publications that provide a detailed examination of tooling: Melnyk & Carter (1987), Melnyk (1988), Blackstone (1989) and, a literature survey provided little support to the research. However, some concepts of tool management have been addressed mainly in research programmes (table 1), conference proceedings [(CIM 1986), (TMC 1988) & (TMC 1991)], and case studies; [Zeleny (1981), Gayman (1986), Albert (1987), Bottazzi (1987), Witkow (1988), Happersberger (1988), Anstiss (1988), and Hollingum (1989)]. The current issues of tool management are usually found in journals and magazines in particular American Machinist (AM), and articles and books on Flexible Manufacturing Systems cover very basic tool management (Stephens 1984).

Perera (1990) who has followed the research programmes in UK since 1980 with interest, partially holds the academia responsible for not addressing tooling problems in conventional manufacturing systems. He categorises the past and current research programmes in UK to three areas of: Tool Flow Control in Flexible Manufacturing Systems, Tool Management & Control in Conventional Manufacturing Systems, and Automatic Tool Selection Systems (Table 2.2).

Period	Researcher	Institution	Topic
81-83	Kay	Cranfield	Tool flow simulation
83-87	Carrie & Perera	Strathclyde	Planing and control problems of FMS with high tool variety
85-	Bell & Newman	Loughborough	Tool management in highly automated batch manufacturing systems.
			The management of tool flow in multi cell batch manufacturing facilities.
			The design of Flexible machining facilities.
87-90	Kehoe & Little	Liverpool	Liverpool System specification for tool management system (FMS).
91-	James	Hull	Intelligent tool condition monitoring
86-89	Hannam	UMIST	Tool Database and Structure.
89-	Perera	Sheffield	Tool planing in discrete batch manufacturing.
			Tool management and control in conventional manufacturing systems
86-	Hinduja	UMIST	Tool selection.
89-	Maropoulos & Simmons	Durham	Tool selection and control
89-	Syan	Nottingham	Tool selection.

Table 2.2: Research programmes in UK. (Ref: Perera 1991)

Although the management of tooling resources has been receiving more attention since early 1980's, the lack of awareness of this potential cost saving area by manufacturing companies leaves considerable room for improvements. This may be due to lack of understanding of the concept of tooling as a manufacturing resource, and a systematic approach in eliminating the production bottlenecks by identifying the underlying causes of tooling problems.

2.8- The Scope of the Research

The literature survey provided some insight into management of tooling resources, but raised many more questions:

- Why tooling remains an ignored issue?
- What are the tooling problems?
- What is responsible for tooling problems?
- What is the current state of tooling in the UK manufacturing industries?
- Are UK manufacturing companies experiencing difficulties concerning the management of their tooling resources?
- What are tooling costs?

On the implementation side of the Computer Aided Tool Management And Control Systems (CATMACS), it is difficult to overlook the overwhelming volume of literature which suggests; in the implementation of advanced technologies, people, and organisational issues are as important as technological issues. Some of the questions which need to be answered are:

- What is a CATMACS?
- Why invest in such systems?
- Are companies benefiting from the implementation of CATMACS?
- What are the requirements for successful introduction of CATMACS?
- What are the critical factors in implementation of CATMACS?
- Are companies successful in implementation of such systems?

The answers to the above questions together with many other relevant issues based on hard data, are the topics of this thesis.

CHAPTER THREE

METHODOLOGY

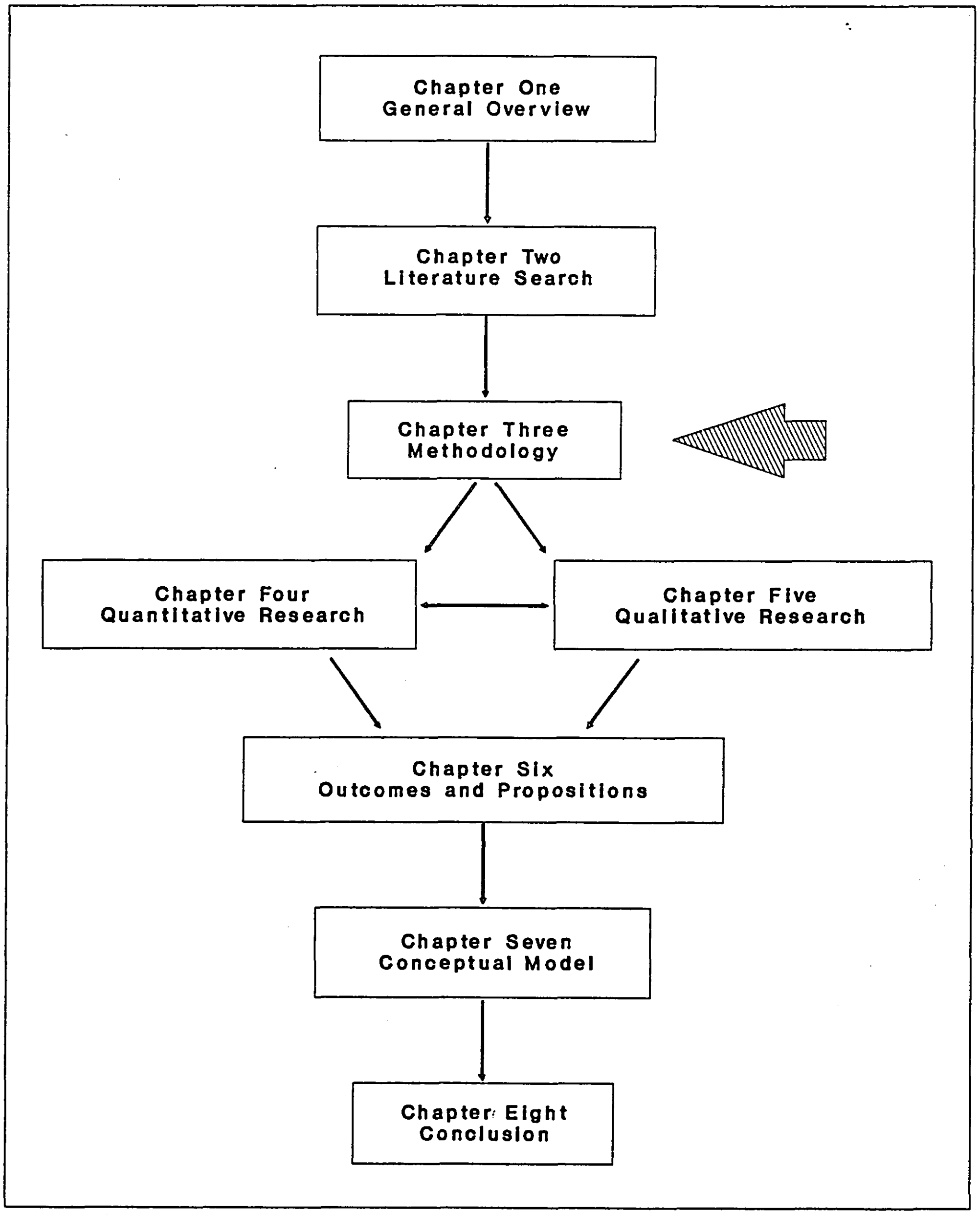


Fig 3: Process of PhD

CHAPTER THREE

METHODOLOGY

After reviewing the literature in chapter two, this chapter defines and defends the methodology used in this study, in particular the principle of moving from a relatively small base of case materials to theory. This chapter describes the research techniques used to conduct this study, and aims to place the work in the context of research methodologies developed by other writers.

Section 3.1- Introduction

Section 3.2- Research Methodology

This section describes the approach to the study and the motivation for the use of case studies and mail survey.

Section 3.3- Case Study

After defining the case study this section describes the author's approach to case study method.

Section 3.4- Questionnaire

Whilst highlighting the importance of the questionnaire, this section highlights the design approach adopted by the author.

Section 3.5- The Research Process

This section looks at the research process in the context of induction and deduction as seen by other authors.

Section 3.6- Qualitative vs Quantitative

defines the qualitative and quantitative techniques of data collection and their relation to the process of induction and deduction.

3- Methodology

3.1- Introduction

With widely differing methods of data collection, data analysis, and a variety of styles of reporting and presentation of the results available to researchers, the initial stage of this study was devoted to the development of an effective research design and strategy. This design forms the framework of the entire research programme and will detail the most suitable methodology. The rational for the methodology is heavily motivated by the lack of data concerning the management of tooling resources in the UK manufacturing industry, and the need to develop a framework for the implementation of CATMACS based on hard data.

3.2- Research Methodology

The methodology adopted three specific routes: a survey of the literature, a mail survey, and a series of industrial case studies utilising quantitative and qualitative techniques of data collection.

Whilst being aware of the distinction between the qualitative and quantitative techniques, the author is concerned with the objectivity of the research programme rather than the benefits or pitfalls of each technique. The advantages and disadvantages of each method are widely documented including [Schofield (1969), Miller (1970), Rose (1982), McNeil (1985), Chisnall (1986), and Baker (1988)]. However the multi-technique approach to this study underlies the desirability of using different methods of data collection for the purpose of theory building (Induction) and theory testing (Deduction), which together make up a sound research strategy. Payne (1964), and Chisnall (1986) favour the combination of survey techniques and Webb et al (1966) considers questionnaire and interviews are probably the most flexible and generally useful device we have for gathering information. Therefore it may be important to provide the reader with descriptive data regarding the two main components of this research methodology; case studies, and the questionnaire.

3.3- Case Study

The term "case study" usually refers to a detailed study of a single example. However, Baker (1988) argues that field research need not be confined to single cases, but may compare different social settings. With significant amounts of literature in field work, the case study approach has been recognised as a useful field research technique by many authors including; [Goode et al (1952), Bausell (1986), Eisenhardt (1989), and Gilbert (1993)]. But no one has encapsulated the meaning of the term case study as well as Eisenhardt (1989) in a series of statements below.

- The case study is a research strategy which focuses on understanding the dynamics present in a single setting.
- Case studies involve either single or multiple cases.
- Case studies typically combine data collection methods. the evidence may be qualitative, quantitative, or both.

- Case studies can be used to accomplish various aims; to provide description, test theory, or generate theory.

Baker (1988) considers the difficulties of establishing reliability in the field studies, Since case studies tend to be individualized and non routinised, therefore it is difficult for a second researcher to replicate the earlier work of another. In recent years, case studies have provided valuable insight into the field of manufacturing since they convey the success of new innovations and technologies. Such results have encouraged others to follow the reported examples.

This study has considered several Mini Case Studies to establish similarities and differences concerning the implementation of CATMACS. The development of case studies has been based on an extended interviews with the participant companies complemented with observation of the manufacturing operations and facilities (Chapter 5, section 5.3, page 75). A summary is then written up to draw attention to various issues relevant to the research, and finally the obtained data is adapted to analysis.

3.4- Questionnaire

A questionnaire is a method of obtaining specific information about a defined problem so that after data analysis and interpretation, the result will provide a better understanding of the perceived problem. A questionnaire is generally referred to as the backbone of most surveys and because of the impersonal nature of mail questionnaires, the drafting of effective questions is more important than ever. Further, the questionnaire should be self-contained, and instructions have to be printed on them to guide the respondents. With significant amount of literature relating to; definition, and different aspects of questionnaires, mail survey, and advantages and disadvantages of this technique of data collection over others [Parton (1950), Goode et al (1952), Schofield (1969), Rose (1982), McNeill (1985), Chisnall (1986), Baker (1988), and Gilbert (1993)], this study has only accommodated those aspects which were considered relevant to the research. The questionnaire was designed to:

- Get the precise information required,
- Be clearly understood by all the respondents,

and, the rules for questionnaire design were followed according to Baker (1988);

- Include only questions pertinent to the research,
- Make questions appealing,
- keep the questionnaire short,
- Have brief, but clear instructions,
- Preconsider all issues that respondents receiving questionnaire might have.

Baker's (1988) recommends two strategies for soliciting cooperation in a survey: stressing the importance of the research project as a contribution to science, and stressing the need of the researcher. These were partially adapted in a covering letter. However, it may be relevant to place the research methodology in the context of the research process.

3.5- The Research Process

The process of research has been categorised to Induction; a process of building theory from observation (Fig 3.1), and Deduction; a processes of testing the theory (Fig 3.2), by many authors including; [Evered et al (1981), Baker (1988), Eisenhardt (1989), and Gilbert (1993)].

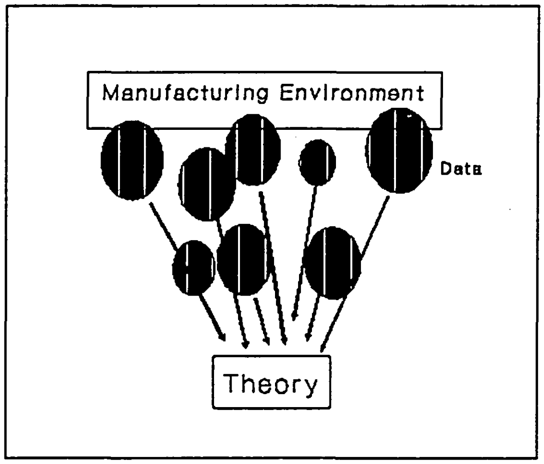


Fig 3.1: Theory building by Induction

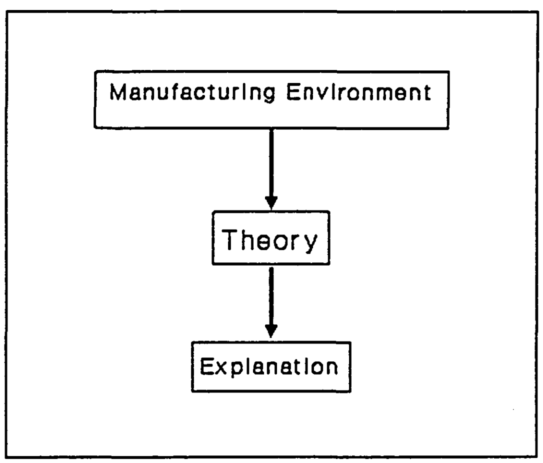


Fig 3.2: Theory testing by Deduction

Gilbert (1993) defines induction as a technique for generating theories, and deduction as a technique for applying theories. He suggests that in terms of definition these two methodologies are quite distinct, but in the course of research they often get intertwined. Kolb et al (1979) goes further by tying the two methodologies together in a model which they refer to as an Experiential learning Cycle (Fig 3.3). The two methodologies are represented by right hand side of the circle corresponding to inductive and left hand side corresponding to deductive research.

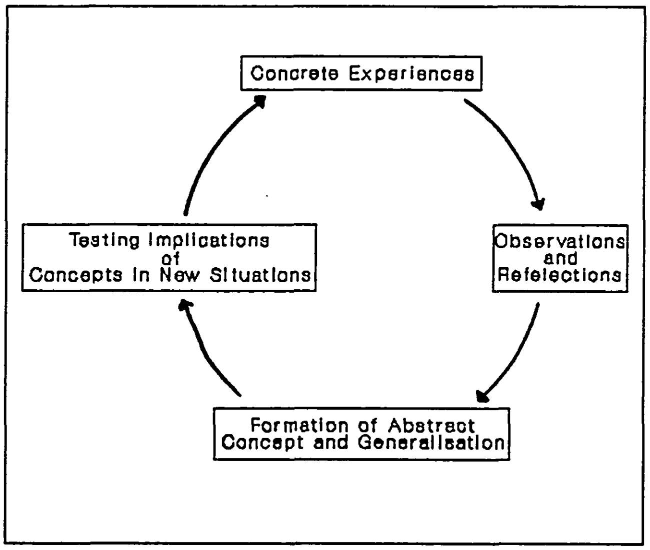


Fig 3.3: Experimental Learning Cycle

Baker (1988) argues that it is difficult to separate these two procedures in practice (Induction and Deduction), and a scientific model must include both theories and observations, conceptualising and data gathering, generalising and specifying. Such a model, however, usually undergoes changes as the evidence is brought to bear on the problem, resulting in reformulation of the hypotheses. Such a research process has often been viewed as a cycle in which various phases are interdependent. Describing the Wallace's (1971) model of scientific process which has been widely used and adapted to represent the research cycle (Fig 3.4), he attempts to provides a fuller conception of the scientific enterprise.

Wallace's model contains what wallace called "five principle information components whose transformation into one another are controlled by six principle sets of methods". The information components are the basic elements of science and are represented by white rectangular boxes. The methods are the ways of moving from one stage of the scientific process to the next and are represented by gray rectangular boxes. In Wallace's model the inductive half of the research process begins at the bottom of the circle with observations (principle information components) and moves toward hypotheses, and the deductive half of the research process starts with theories and moves through the process of deduction back to observation.

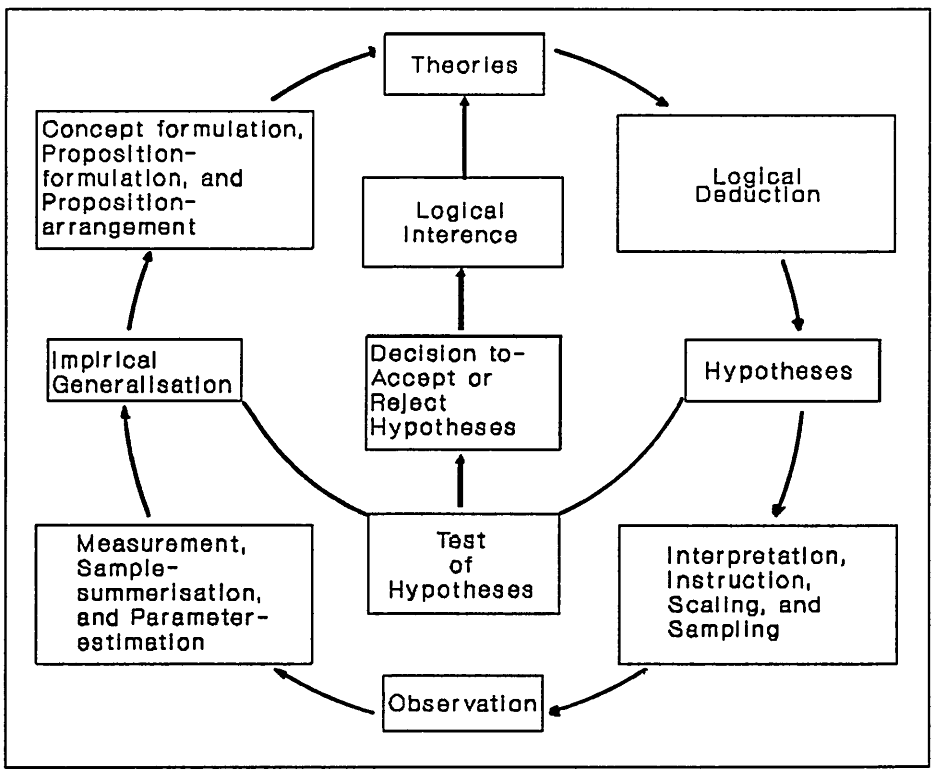


Fig 3.4: Wallace's Model of Science

Referring to Wallace's model, Baker (1988) suggests that the researchers do not have to go through every stage of this process in a single research programme. They may only choose to move from observation to an empirical generalisation (inductive), or start with hypothesis and work out a research plan to test it (deductive). Deductive studies usually rely on the more structured techniques of data collection such as a mail survey (quantitative), and Inductive studies more often utilise a variety of interviewing techniques of less structured kind (qualitative).

3.6- Qualitative vs Quantitative

The origins of qualitative methods of data collection are as old as recorded history and can be traced to historians, travellers, and writers ranging from the Greek Herodotus to Marco Polo. It was not until the nineteenth and early twentieth centuries, however, that what we now call qualitative methods were consciously employed in social research, Wax (1971).

Qualitative research, often called fieldwork or participant observation, involves first-hand, face-to-face participation by the researcher in a naturally occurring environment. Taylor et al (1984) refers to qualitative methodology in the broadest term to research that produces descriptive data, people's own written or spoken words and observations. From this definition therefore, the researchers develop concepts, insights, and understanding from the pattern in the data; hence, qualitative research is inductive. By contrast in quantitative research data is collected to assess preconceived hypotheses or theories (deductive). There is a considerable amount of literature on field research and other qualitative methods in education, social work, and applied field. However Sampson (1978) has warned that because qualitative research appears to be familiar to almost everybody, but is really understood by relatively few, there is a danger that it could be presumed to lack subtlety and to require little skill. To the expert, however, the facts are just the reverse, and it is a field of research that calls for sophisticated and sensitive skills.

Quantitative techniques however, rely on more structured techniques of data collection, such as mail survey with a standardised questionnaire, in contrast to inductive studies where participant observation and interviewing techniques of the less structured kind are utilised. However, it is important not to consider the two techniques as completely separate as both produce qualitative and quantitative data. Worsley (1977) suggests that the two methods/style of data collection should not fall into two completely separate compartments. It is better to think of them as being on a scale as shown in Fig 3.5.

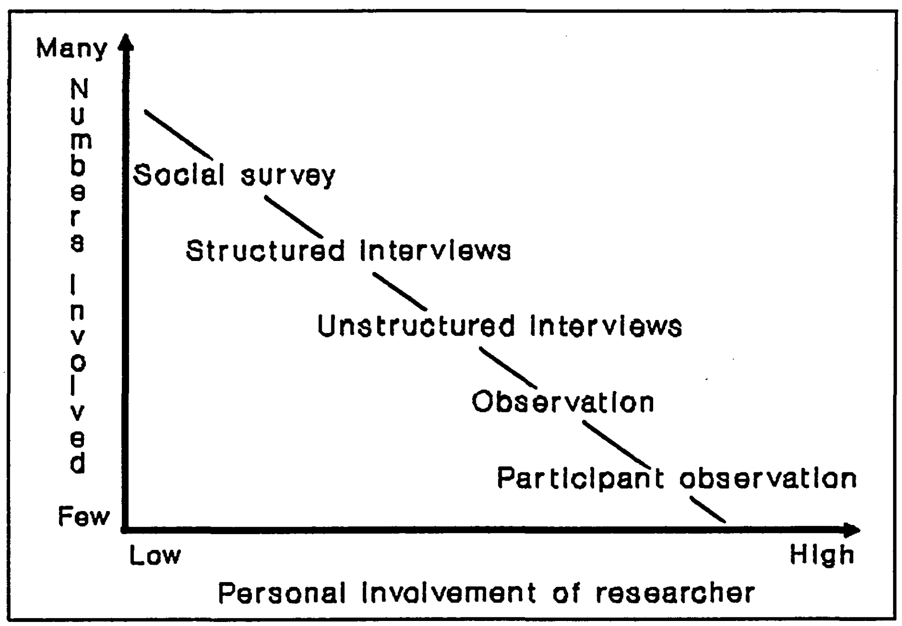


Fig 3.5: Methods of data collection

In Worsley's model, different methods of data collection are shown on the same scale. It is apparent that the more people who are studied, the less the researcher becomes personally involved with them (mail survey). However, the key issues regarding the methods of data collection concerns the reliability, validity and representativeness of the collected data rather than the method itself.

- **Reliability:** If the method of collecting data is reliable, anyone else using the same method should come up with the same results (taking the time factor into account).

- **Validity:** This refers to whether the collected data is the true picture of what is actually happening in a specific environment. Although there are always some elements of doubt about any survey-style research, since the questions are directed to organisations and the always in which they operate in a specific department-rather than individuals who have been subjected to personal questions, the data is really evidence of what it claims to be.

- **Representativeness:** This implies to the group of companies under study are typical of others. If they are, then we can safely conclude that what is true about this sample is also true of others.

CHAPTER FOUR

QUANTITATIVE RESEARCH

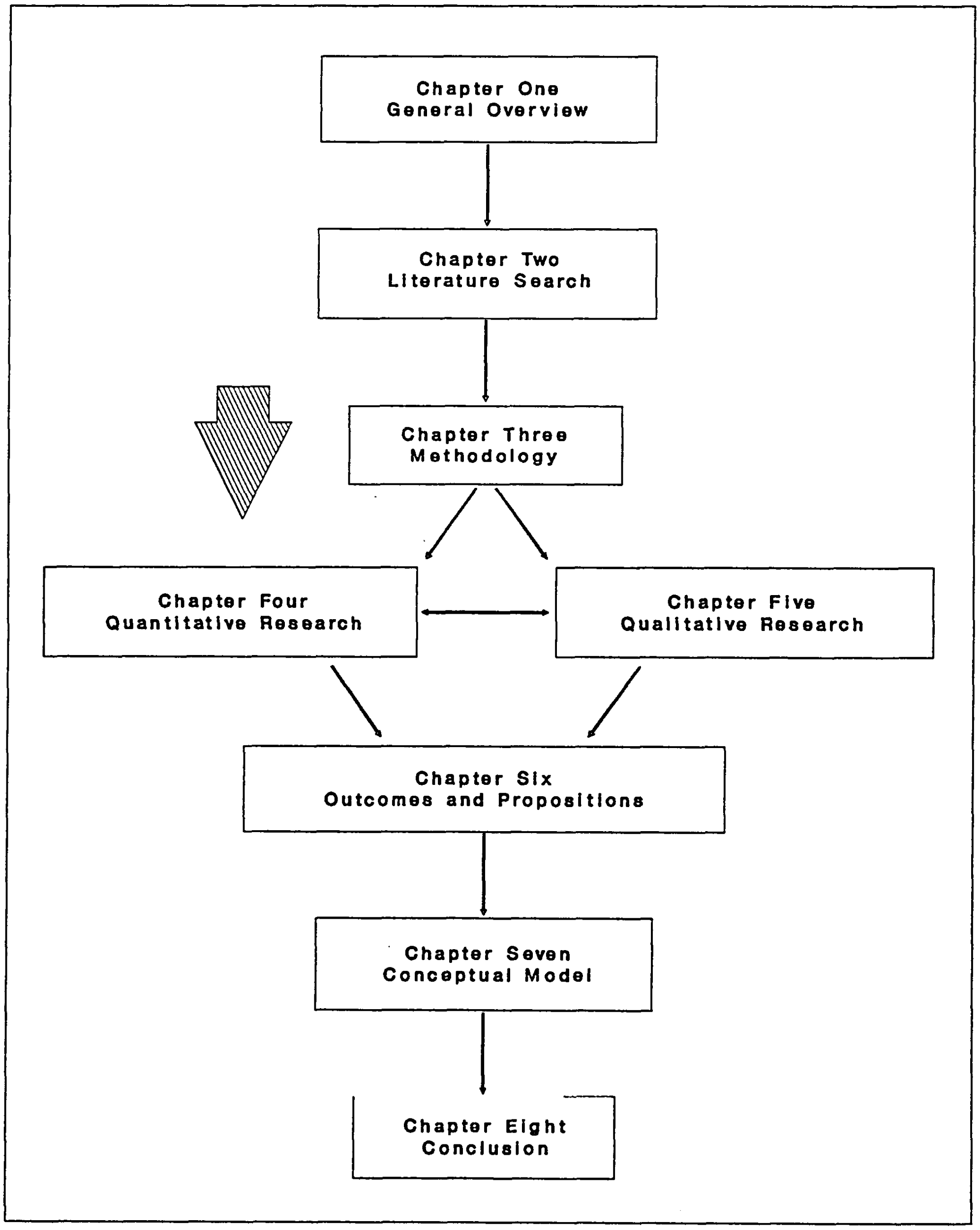


Fig 4: Process of PhD

CHAPTER FOUR

QUANTITATIVE RESEARCH

Based on the methodologies described in chapter three, chapter four is concerned with the results of the quantitative research. It provides general information on the participant companies sufficient for the reader to understand the developed outcomes. It was also considered necessary to include in this chapter those outcomes of chapter 5 which were found to be related to this chapter. This chapter is structured as follows:

Section 4.1- Introduction

Section 4.2- Research design

The research design employed in this part of study is discussed in this section together with the validity of small sample survey.

Section 4.3- Questionnaire Design

The structure of questionnaire is the topic of this section.

Section 4.4- Pretesting the questionnaire

The section deals with the validity of questionnaire in the context of similar approach by other authors.

Section 4.5- Sample classification and profile

This section classifies the responding companies and provides a profile in order provide an indicative perspective on the nature and extent of perceived tooling problems.

Section 4.6- Survey results

This section is allocated to the findings of the survey complemented with charts and tables.

Section 4.7- Tooling Problems

This section is concerned with the types of perceived tooling problems.

Section 4.8- In-company Interviews

This section provides further understanding of the nature and causes of tooling problems.

Section 4.9- Summary

This section summarises the results of quantitative research. In doing so, it confirms the reliability of the reports discussed at the beginning of this chapter.

4- Quantitative Research

4.1- Introduction

As described in chapter one, the poor management of tooling resources, and their impact on efficiently of manufacturing systems and facilities in US manufacturing industry, had encouraged the author to test the reliability of these reports within the UK manufacturing industries. The author's research into the literature has shown that no formal reported study has been conducted in the UK, and no attempt has been made to investigate company's situations concerning the management of tooling resources in the UK manufacturing industry. A hypothesis was then formulated that manufacturing companies do experience difficulties with the management of their tooling resources. It was then necessary to convert the hypothesis into the following questions:

- Are companies aware of their tooling problems?
- What are the types of perceived tooling problems?
- What are the underlying causes of tooling problems?
- Is there a link between the size of the company and the nature of tooling problems?

4.2- Research Design

To obtain relevant data from 300 UK manufacturing companies regarding the management of their tooling resources, a cross-sectional survey appeared to be the most suitable technique of data collection at this stage of the study. However, in-company interviews also complemented to the breadth of data from survey and provided further understanding of the nature and the extent of tooling problems.

Although the motivation behind the sample selection was based on the representativeness of the sample, one area of the concern at this stage was the size of the sample. The process of sampling or selection of part of a population from which the characteristics of the whole are concluded has long been accepted as a legitimate method of research procedure, hence, if the sampling is done correctly, then a relatively small number of participants will be representative if it provides useful data relevant to the study. Wall et al (1970) suggests a sample in a survey is often that which fulfils the requirements of efficiency, representativeness, reliability, and flexibility. He further argues in support of the validity of small samples by referring to the work conducted by other authors, where samples of 400, 515, and 233 achieved similar results to that of four figure numbers in all cases. Chisnall (1986), also supports the legitimacy of small sample if the population had characteristics that were homogeneous.

Three hundred questionnaires and covering letters were targeted to a mixed cross section of the UK manufacturing companies chosen from manufacturing directories during the period July 1991 to August 1992. The sample classification and profile provided in the chapter attempts to reveal the variety of responding participants. However, it is important to highlight the structure of the questionnaire and its validity first.

4.3- Questionnaire Design

A questionnaire was designed to collect data concerning the underlying causes of tooling problems. The structure of the questionnaire was divided into five interdependent areas:

- **Company background;** Covering such areas as products, number of employees, number of NC and non NC machines, and annual turnover.

- **Tooling information;** This section was directed at tooling data including tooling stock, value of existing stock, and annual tooling budget.

- **Tooling problems;** This section was aimed at tooling problems, and methods of solving these problems.

- **Tool management system;** This section was concerned about the existing tool management system within the company, and how it was developed.

- **Implementation;** This section covered the implementation issues of CATMACS.

4.4- Pretesting the questionnaire

The designed questionnaire was initially tested on a number of colleagues within the school of engineering. The questionnaire was then piloted on academics and managers, the later being responsible for the management and control of tooling resources in their respective companies. This validation is similar to that of Gilbert (1993), and Baker (1988). Each academic and manager reviewed the proposed questionnaire for concept and clarity, and a redesigned questionnaire was produced (Please see Appendix 1 for questionnaire and covering letter).

4.5- Sample Classification and Profile

Manufacturing industry	No of companies
Aerospace	2
Air conditioning	1
Coach,cabs body	2
Construction equipment	1
Defence systems	1
Electric motors	1
Engineering components	4
Gas turbine	1
Hoists	2
Industrial casting	1
Industrial and razor blade	1
Injection moulding components	1
Motor cycle	1
Motor vehicle	3
Parts for motor vehicle	8
Plumbing products	2
Process heater	1
Refrigerator	1
Satellite dishes	1
Screen printing equipment	1
Shoe machinery	1
Textile machinery	1
Tool (Cutting/Hand/Machine/Press)	6
Traction equipment	2
Total	46

Table 4.1: Classification by industry

The variety of responding companies (Table 4.1) is an attempt to provide an interesting and indicative perspective on the nature and extent of perceived tooling problems.

The sample for this study was not geographically structured, and the range of products varied. The responding organisations varied in size from less than 100 employees to more than 1000, and annual turnover ranged from under £10 million to over £50 million (Figures 4.1, Fig 4.2). The responding companies benefited from annual tooling budget of under £10K (lower limit), and over £50K (upper limit), the number of machines utilised by the companies had a range of under 50 to over 200, and the companies had a tooling stock of 50, and 200,000 (lower and higher range respectively) (Figures 4.3, 4.4, 4.5). Full information regarding the above have been provided in Appendix 2.

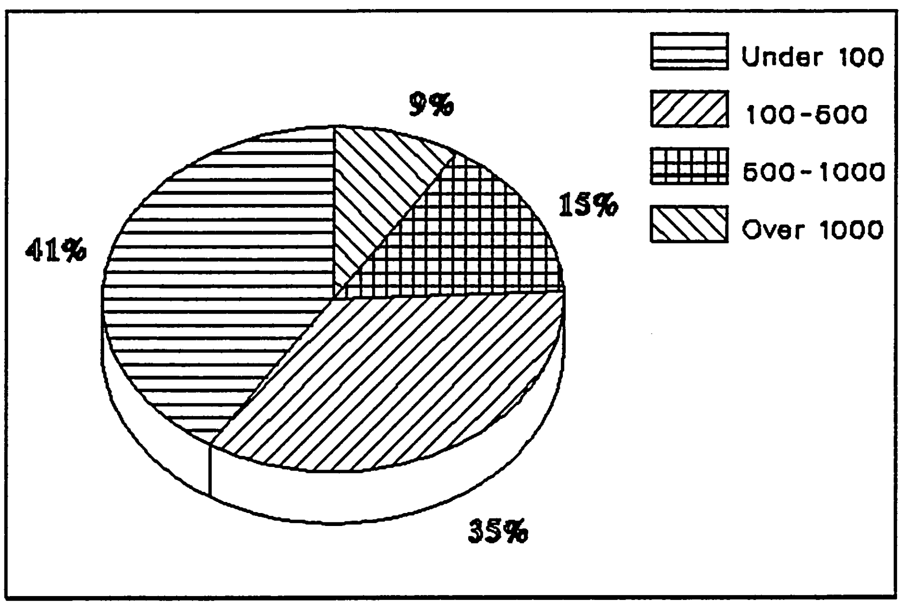


Fig 4.1: Number of employees

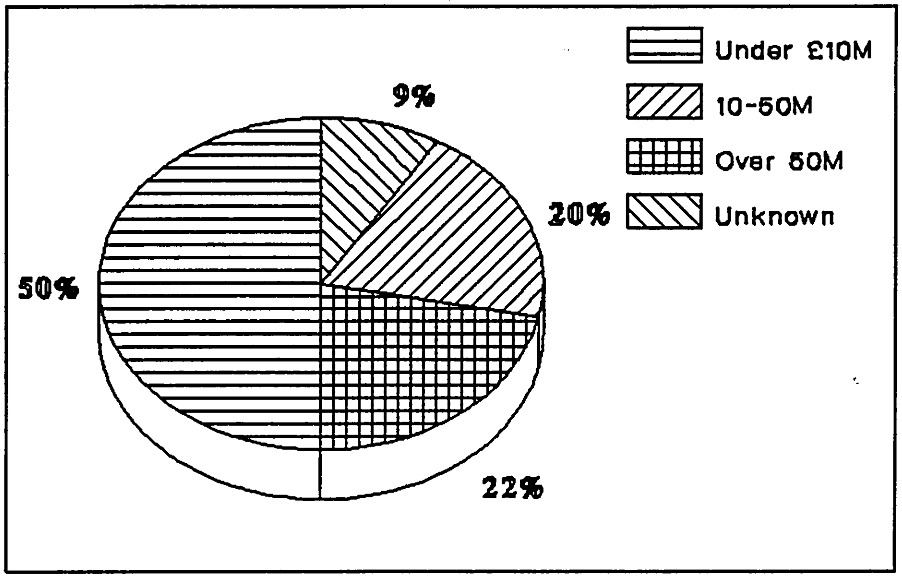


Fig 4.2: Annual turnover (£M)

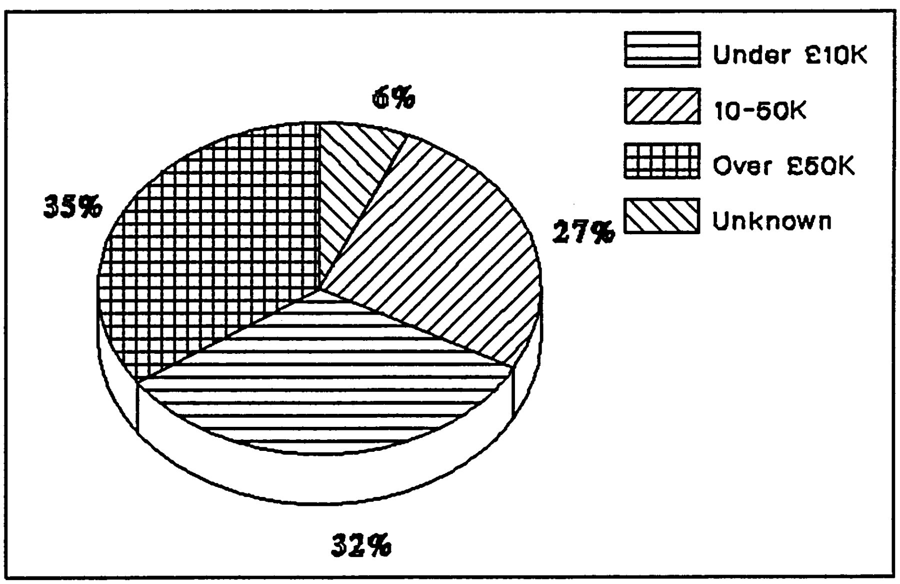


Fig 4.3: Annual tooling budget (£K)

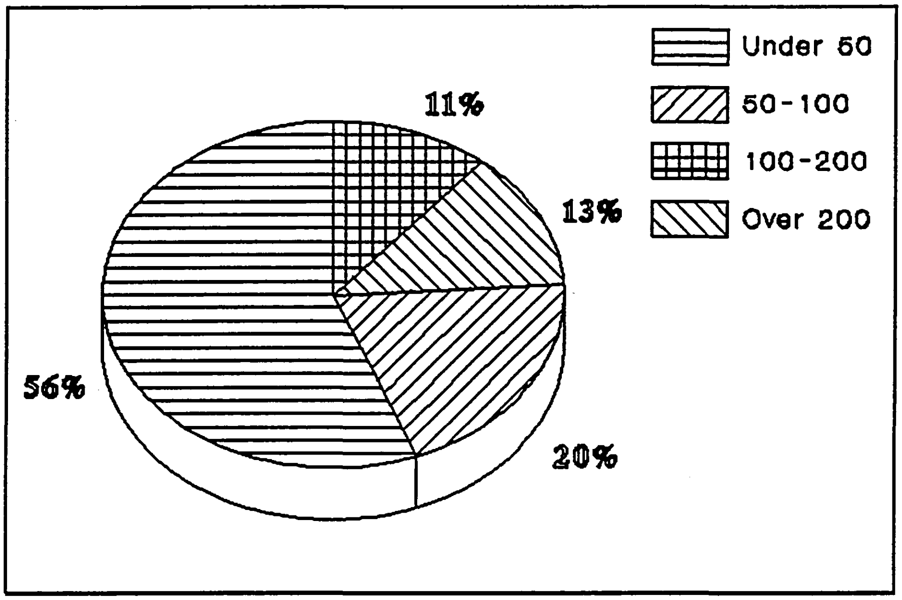


Fig 4.4: Number of machines

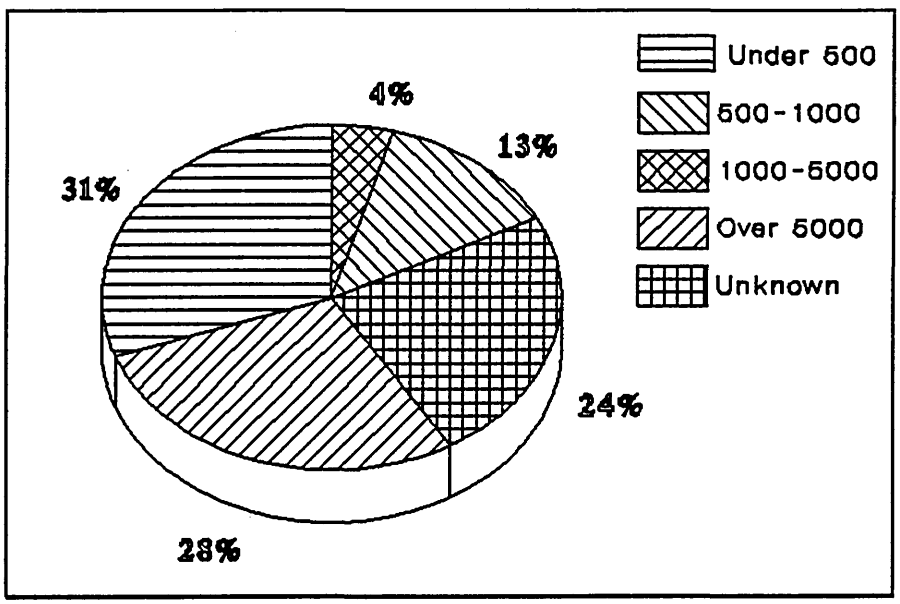


Fig 4.5: Tooling stock

4.6- Survey Results

From the survey twelve questionnaires were returned as undeliverable (this may have been due to the recession which forced a number of companies out of business at the time of this study), and six were unanswered for various reasons. A total of 46 valid questionnaires were obtained giving an overall response of 15.5%.

Approximately 1 in 3 of the responding companies considered tooling as an ongoing problem in their business unit, with approximately a further 1 in 4 seeing tooling as an occasional issue, and only one third of the responding companies did not see tooling as a problem in their organisation (Fig 4.6). Therefore, over 60% of the responding companies saw tool management as a problem.

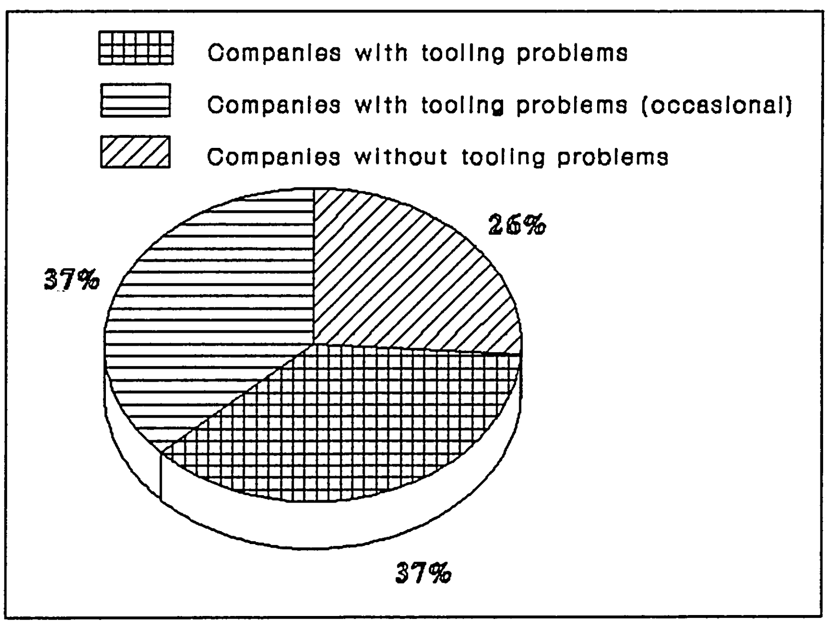


Fig 4.6: Classification of respondents by tooling problems

Figures 4.7, and 4.8 shows the average number of employees, and the average number of machines in relation to the annual turnover of the sample. The percentages of companies with tooling problems within the specified range of annual turnover can be seen in (Fig 4.9).

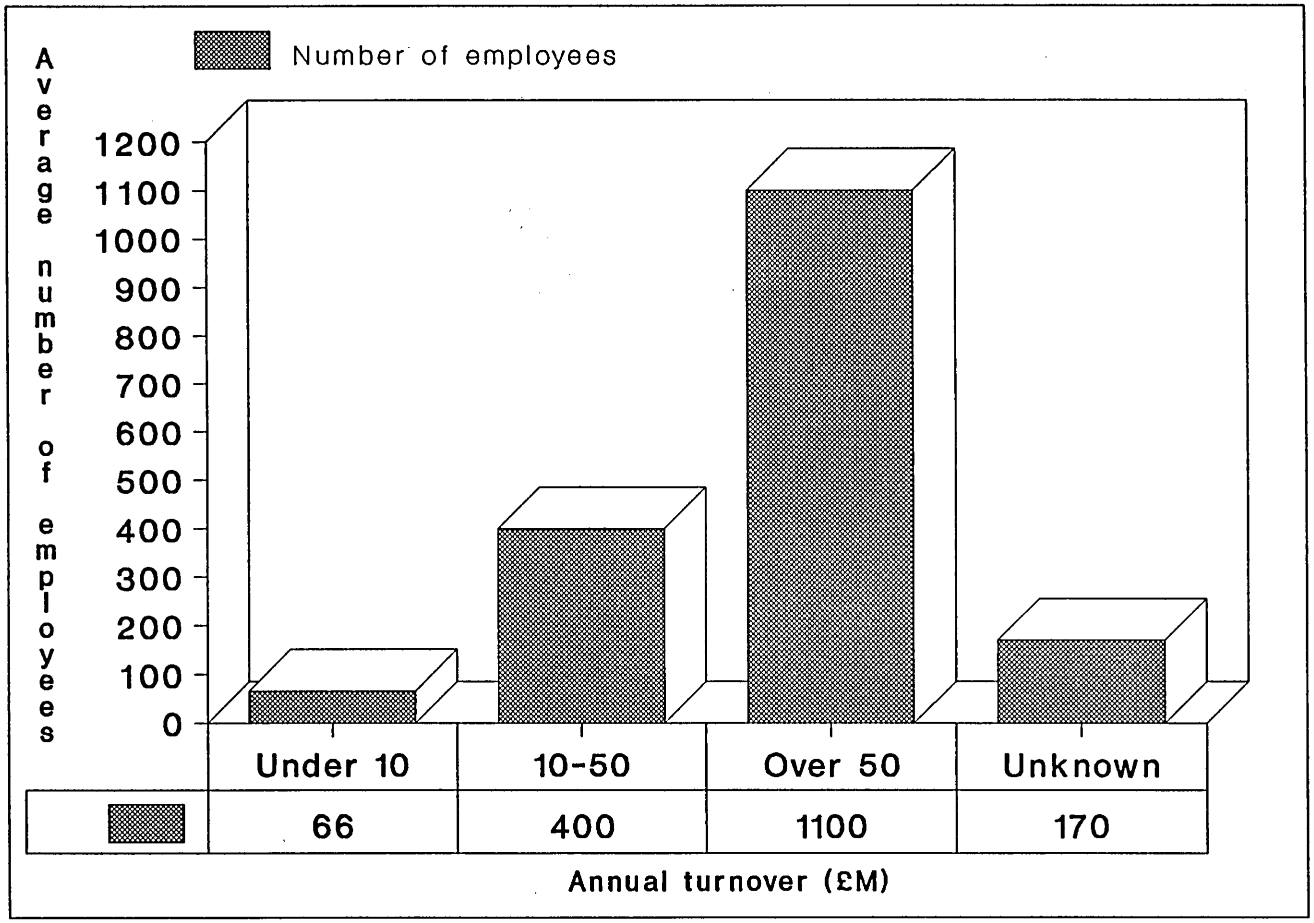


Fig 4.7: Number of employees verses annual turnover

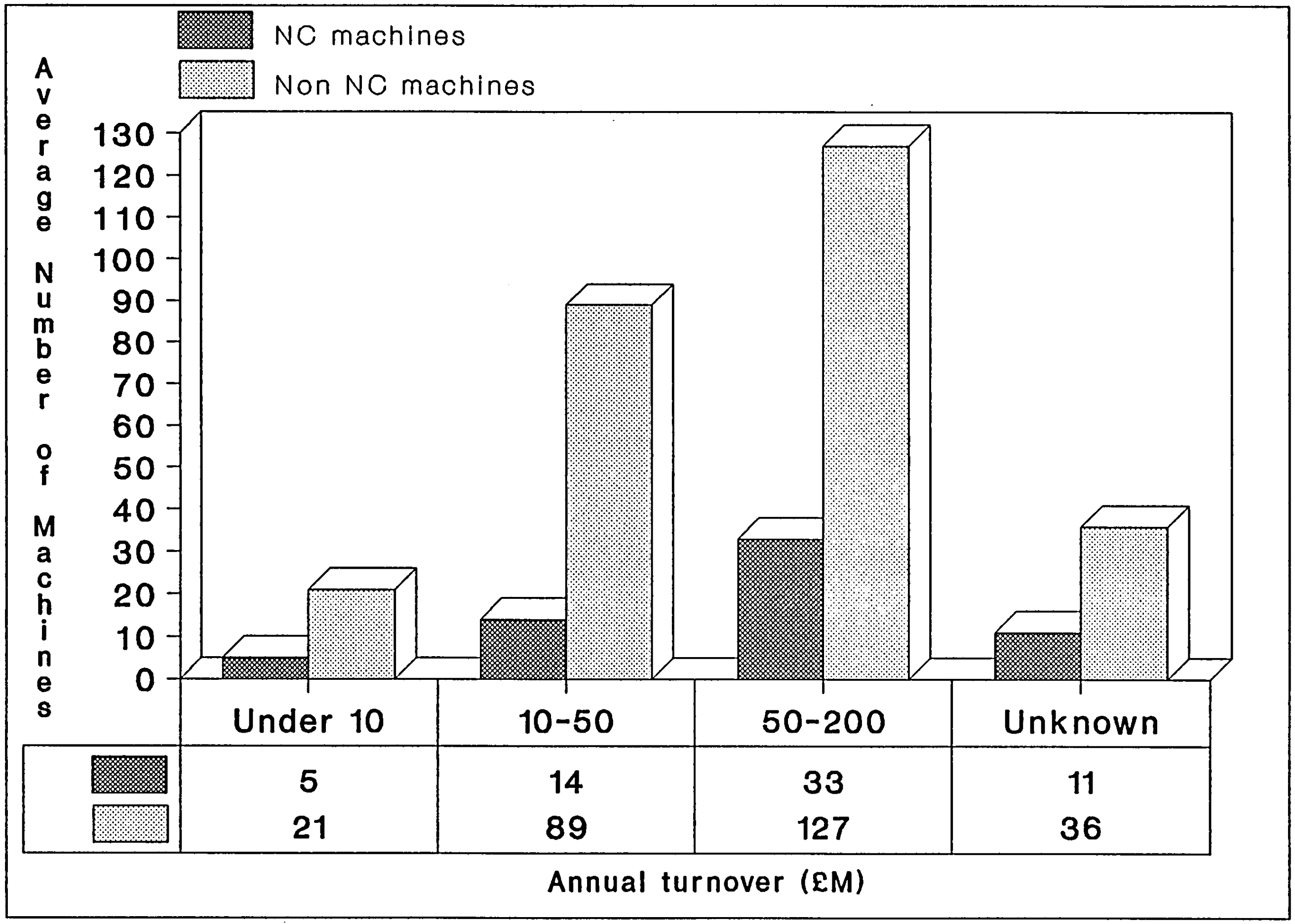


Fig 4.8: Number of machines verses annual turnover

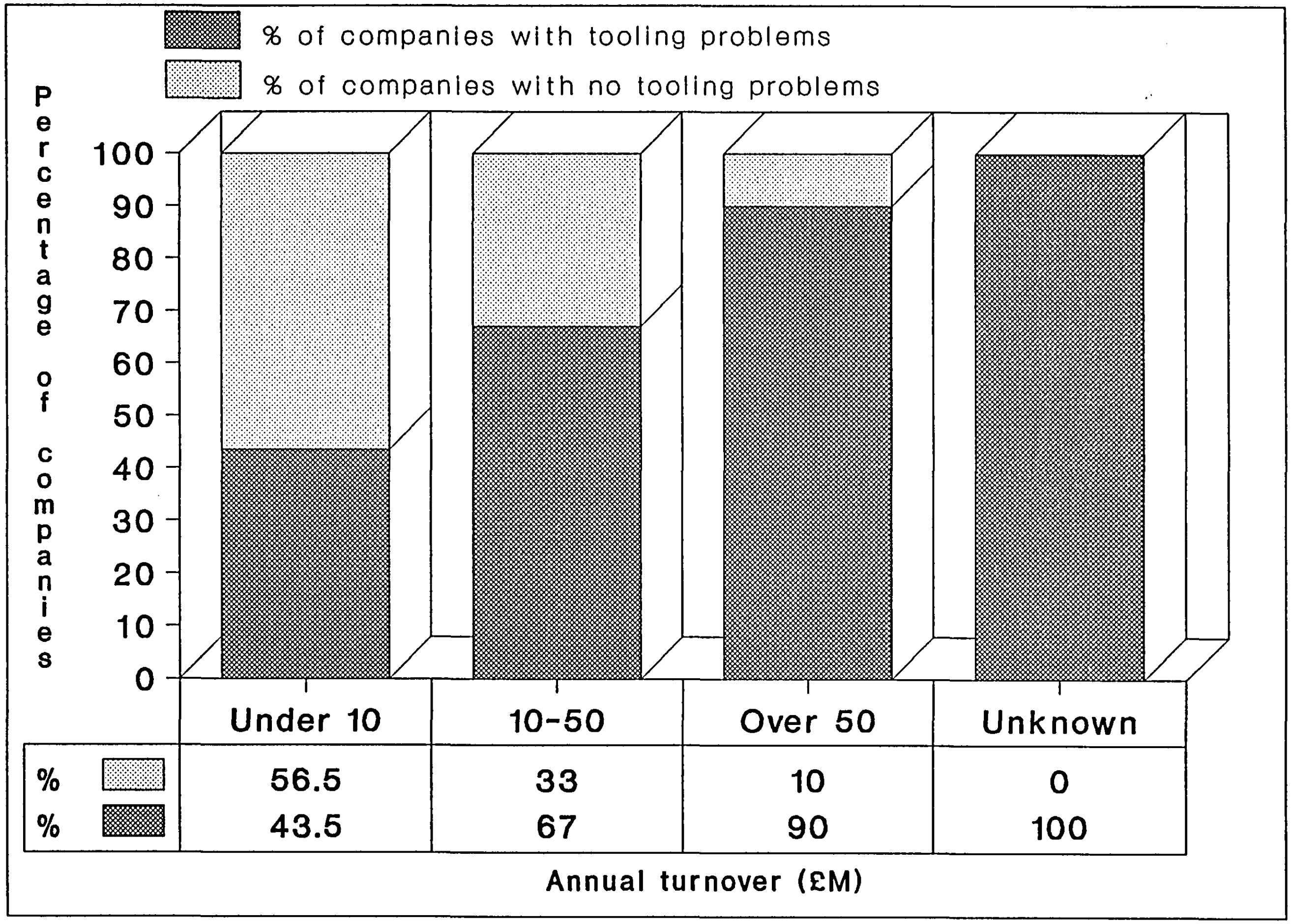


Fig 4.9: % of companies with tooling problems verses annual turnover

Not unpredictably, large manufacturing companies with high staff numbers, numerous machines and high annual turnover reported more difficulties associated with the management of tooling resources. This awareness could be due to the complexity of the manufacturing environment or the results of poor management of tooling resources.

Over 40% of the companies with annual turnover of under 10 million reported having problems with the management of their tooling resources, compared to 67% of companies with annual turnover of between 10 and 50 million, and 90% of companies with the annual turnover of over 50 million. It would seem that whilst tooling problems are not unknown in smaller companies, they escalate as companies grow in size. This is reinforced further by the findings illustrated in Figures 4.10, and 4.11. Fig 4.10 shows the number of NC, and non NC machines in relation to tooling budget. Although large manufacturing companies may benefit from a bigger tooling budget, their management of tooling resources requires far greater attention. Fig 4.11, highlights the extent of perceived tooling problems across the represented sample within the specified tooling budget.

Zuin (19) suggests on average British manufacturers spend around £15,000 on cutting tools every month. Our survey reveals that on average the responding organisations spent around £10,000 on cutting tools every month. However, we tend to believe that the true figure may be much higher for two reasons. Firstly, this figure does not take account of the costs incurred as a result of poor management of tooling which will be discussed later in this chapter, and secondly, in some companies, accounting practices makes it possible for the cost of tooling to be diverted to other accounts.

Overall, more than half of the responding companies (56%), provided figures relating to the cost of tooling as a percentage of production cost, and on average tooling accounted for over 3.5 percent of production costs (With 0.2% and 10% representing the range of response). However, it is important to note that the companies reporting no tooling problems (37%), held a limited number of tools and often were unable to provide any data regarding the size of their tool inventory, its value, or the cost of their tooling as a percentage of production cost.

It is fair to assume that companies with a large proportion of disposable tooling and those who utilise press tools, customer's tools, and consignment tool stores (where the firm is billed for the tools used from the supplier's tool consignment), may experience fewer difficulties in managing their tooling resources. But, this should not undermine the importance of tooling, its relevant costs, and its effect on efficiency of manufacturing facilities. Although 63% of the responding companies characterised their company situation with regard to tooling problems as significant, the specific nature of the tooling problems they faced varied in different companies.

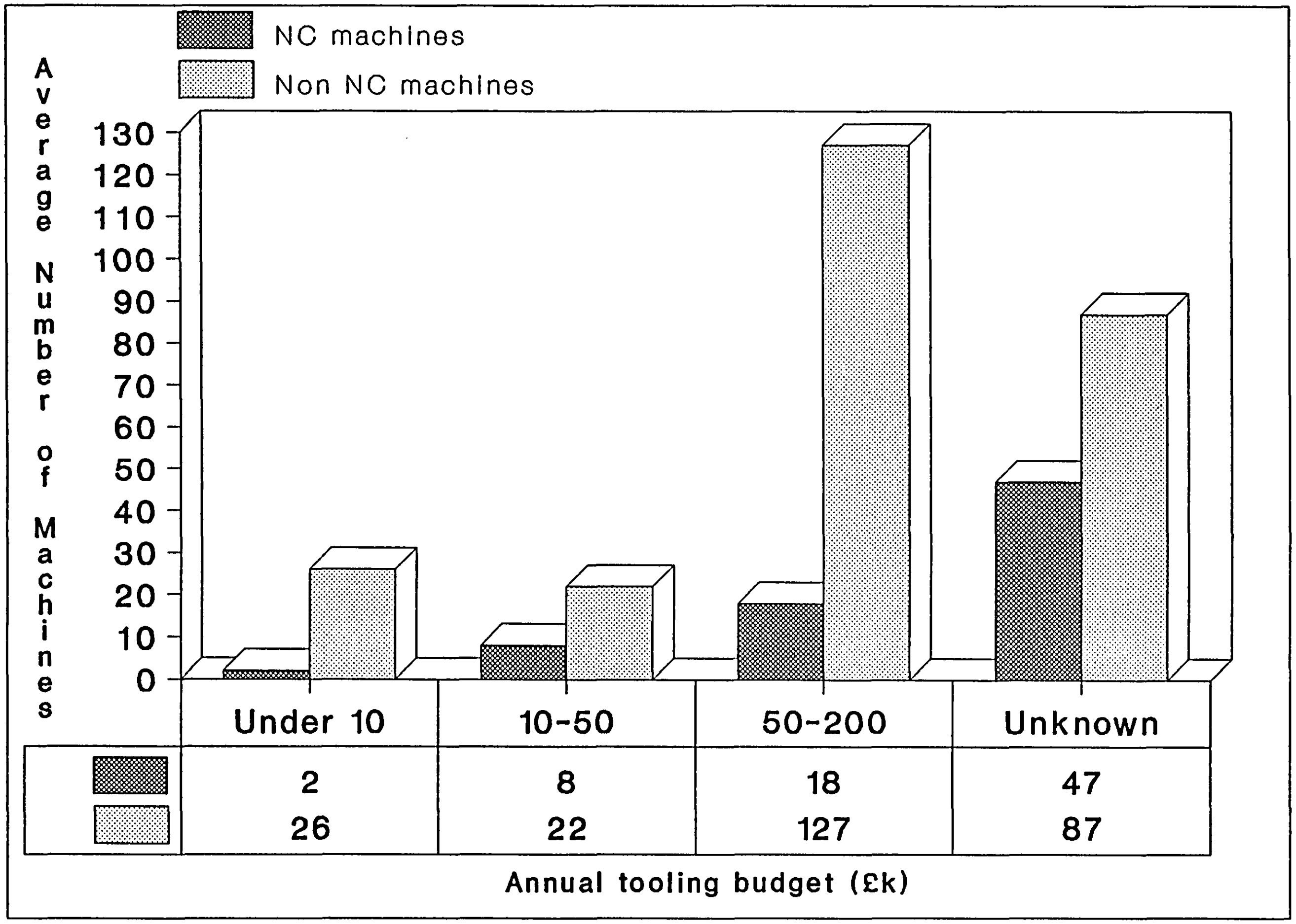


Fig 4.10: Number of NC, and non NC machines in Relation to annual tooling budget

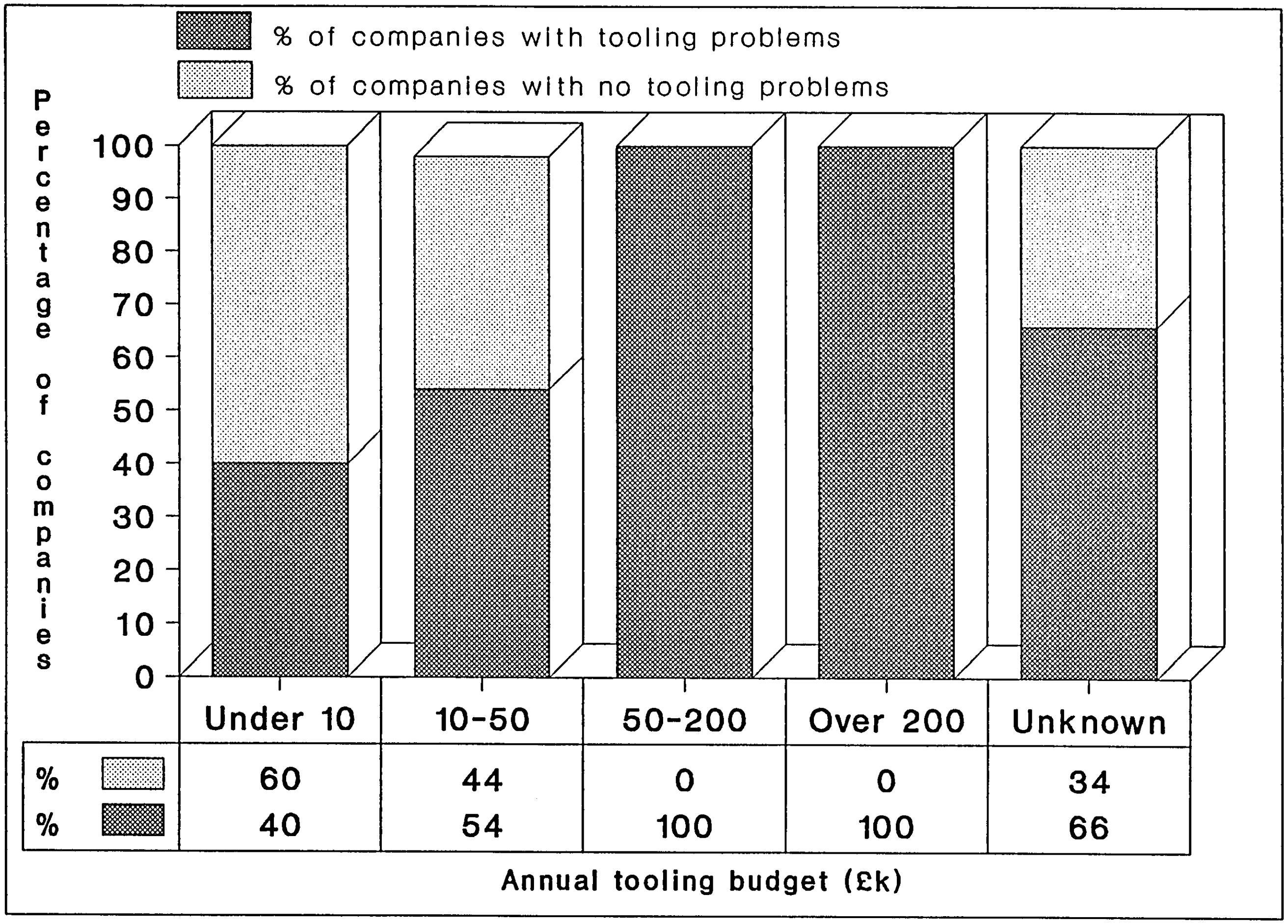


Fig 4.11: % of companies with tooling problems verses annual tooling budget

4.7- TYPES OF PERCEIVED TOOLING PROBLEMS:

The companies were asked to rank six major tooling problems in order of importance within their business units. The response suggested that perceived tooling problems varied. Table 4.2, shows the ranking of tooling problems by different companies. These problems were ranked from one to six, with (1) being the highest. For example, (31%) of the respondents ranked "high tool variety" to be their major tooling problem, where as (21%) of the responding companies ranked "tool unavailability" to be their biggest tooling difficulty.

Tooling problems	Rank							Total
	1	2	3	4	5	6	*	
Tool unavailability	21%	17%	7%	17%	3%	21%	14%	100%
High tool inventory	14%	17%	31%	10%	7%	7%	14%	100%
Tool tracking and control	14%	21%	17%	17%	21%	7%	3%	100%
High tool variety	31%	10%	7%	17%	7%	14%	14%	100%
Lack of tool services	14%	3%	7%	10%	21%	24%	21%	100%
Cost of tooling	14%	7%	21%	17%	14%	10%	7%	100%
* companies not responding to this problem								

Table 4.2: Ranking of tooling problems by responding companies

4.7.1- High Tool Variety

High tool variety refers to variants in tool sizes and differs from tool inventory. 31% of the respondents rated "high tool variety" to be their number one priority when considering tooling problems. This is mainly due to lack of consideration for tooling at design stages of products. However, an effective tool management and control system can help to negotiate a manageable quantity of tools to reduce tool variety.

4.7.2- Tool Unavailability

The importance of this tooling problem is highlighted by 21 percent of the companies who ranked "tool unavailability" as their main tooling problem. Tool unavailability is referred to as the unavailability of tools at the right time, at the right place, in the right quantity, and in the right condition. This definition practically encompasses the outcome of all tooling problems. However, further understanding of the nature of this important tooling hurdle is needed in order to eliminate the unnecessary cost and expense.

4.7.3- Cost of Tooling

14% of the responding companies considered the costs of tooling to be their major tooling problem, 17% ranked this problem second and fourth, and 21% ranked this problem third in their list of priorities when dealing with tooling. This relatively low ranking may be due to the fact that the cost of a single tool is relatively small in manufacturing terms, and further, accounting practices can sometimes distort the true costs of tooling in some manufacturing companies. The cost of tooling may be categorised into Apparent and Hidden costs. Apparent costs are associated with the purchase and utilisation of tooling resources. They are easily identifiable, can be measured, and their effect on manufacturing cost is quite apparent. They may be classified as:

- **Purchase cost;** This refers to the actual cost of tool purchase, cost of hot-purchases, and the cost of making the tool (where the tools are made in-house). These costs could be reduced utilising a tool purchasing policy.

- **Utilisation costs;** Unsystematic issues, returns, and stocking, lack of proper tool refurbishment services, lack of faith in the tool management system by the operators where more tools are taken out than needed, and self service tool cribs are some of the utilisation cost and are contributory factors in reducing the productive time.

- **Control costs;** Inventory losses due to poor control, over stocking, tool shortages, hidden stock, and tool status monitoring are some of the factors influencing the cost of tooling.

The Hidden costs, however, are the result of poor management and control of tooling resources. According to responding organisations they include: time spent expediting tools, long set-up-times, lost time due to tool unavailability, wastage due to wrong tool usage, poor quality products, and delays in delivery times.

4.7.4- Tool Tracking and Control

There is clear evidence that all the responding organisations were familiar with this aspect of tool management and its effect on tooling costs. The prerequisite for an efficient tool tracking and control system is either a computerised or manual tool database. This database should contain the records of all tools, their number, location, status, and their transactions. Although this is fine in theory, in practice, productive time is affected because the tool is not where it should be, is not in the right quantity, is not in good condition, is not the right tool for the machine, or it has not been ordered. In some cases, a tool control and tracking system exists when the tool room is manned by only a tool crib person, but the system cannot be operational when the tool room is unmanned. The solution may be a set of systematic and recorded procedures complemented by a training programme for all the shop floor operators affected by tooling.

4.7.5- High Tool Inventory

14, 17, and 31 percent of the responding organisations ranked this common tooling problem either their first, second, or third major tooling problem respectively. It may be fair to assume that, since the majority of responding companies were not aware of their actual tool inventory (allowing a margin for error of 10%), the true figures may be much higher. Excessive numbers of tools, storage, obsolete tooling, and waste, can contribute towards the cost of product and may relax the degree of control needed for efficient management and control of tooling resources. Companies with a rationalisation programme can reduce the size of their tool inventories by identifying their obsolete tools which have been accumulated over the years.

4.7.6- Lack of Tool Refurbishment Services

With only 10% of the responding companies considering the lack of tool refurbishment services as a most important problem in their business unit, this potential tooling problem received a low priority. However, although this service can be accommodation for internally or acquired externally, without a clear policy and control procedures, the lack of tool refurbishment services can interrupt the flow of production.

4.8- In-company Interviews

Whilst concern with the implementation issues of Computerised Tool Management and Control System, the in-company interviews complemented to the breadth of data and provided further understanding of the underlying causes and nature of tooling problems. The findings from the interviews regarding the management of tooling resources are discussed under four headings;

4.8.1- Lack of Understanding of Concept of Tool Management

Tool management and control describes all activities required for the effective management of tooling resources on the shop floor. However, in many companies, it is often viewed from an engineering, production, and inventory perspective instead of a total system perspective. This lack of system perspective may be due to the traditional perception of the low-tech nature of tooling, and lack of integration of tooling within the context of the entire system within the company. However, tooling is a manufacturing resource, and successful completion of any production order depends on the availability of men, machines, materials , and the right tools throughout the whole of the manufacturing process. Several functions are involved in solving the tooling problems, and it is this which makes tooling a genuinely integrated, ie, multi-functional , issue.

4.8.2- Lack of Tooling Strategy

The absence of a clear, well defined strategy regarding the management of tooling resources is often evident across the responding firms. In many companies decisions such as tool replacement/renewal points, tool status, and tool life are made by the machine operators. Such decisions can contribute towards the cost of waste, rejects, reworks, and can affect the quality of the products. Some companies have realised the need for the strategic management of tooling resources. Further, the development of such vision is often rewarded in financial terms. A production manager reported that "tooling strategy has been a major factor in reducing the cost of tooling by determining, the tooling levels and relevant costs, tool replacement, and tooling assignment."

4.8.3- Lack of Prioritisation

Tooling is often regarded as a manufacturing residual by many companies, and little consideration is given to its effect on the efficiency of production systems. A manufacturing engineer said, "the only time we give priority to tooling is when we have a problem involving tooling". He reported that lack of prioritisation to tooling at design stages of products could be a contributory factor in the size of their tool inventory of 142,000 tools.

4.8.4- The Degree of Awareness

The degree of awareness of tooling problems appears to be influenced by the size of the company and the management of its tooling resources. The impact of tooling on efficiency of production systems and manufacturing costs is underlined by the majority of respondents. Delays in the production schedule, delivery dates, set-up times, and the costs of expediting tools, store services, rework and scrap, waste, tool tracking and control, time lost, and tool inventory were frequently reported. However, very little is known about the true nature of the perceived problems and their specific effect on manufacturing costs. For example, calculating the tangible and hidden costs of poor management of tooling resources is by no means a simple task but, improvements and savings are only noticeable when an efficient tool management and control system is installed.

4.9: Summary

The key issues regarding the management of tooling concerns the lack of tooling strategy, lack of prioritisation, the degree of awareness, and the lack of understanding of the concept of tooling and its importance as a source of productivity. This is perhaps hinted at in the case of the 37% of the responding companies who reported not considering tooling a problem in their business unit, yet, could not provide any data regarding the size of their tool inventory, its value, or their annual tooling budget. However, 67% of respondents considered tooling as a production bottleneck and are of the view that, an effective tool management and control system can improve productivity and assist in improving the competitive edge of their organisation.

The cost of a single tool is relatively small in manufacturing terms, but when added for example, to the value of tool inventory, cost of expediting tools, cost of tool losses, cost of delays in production schedule, value of obsolete tooling, and cost of hot purchases, poor tooling can account for a significant part of production cost. At a time of increasingly global competition, where the effects of poor tooling can impact directly on the competitive dimensions of cost, quality, delivery and lead times, companies without a tooling strategy, structure, and system will find themselves missing a significant opportunity to improve their competitive position.

Enhancing competitiveness and market opportunities have encouraged U.K manufacturers to recognise the importance of advanced manufacturing technologies, but widespread reports of patchy success rates is pointing up the importance of strategically managing the introductory process. However, the management and control of tooling resources still tends to receive less attention than other aspects of the production system.

CHAPTER FIVE

QUALITATIVE RESEARCH

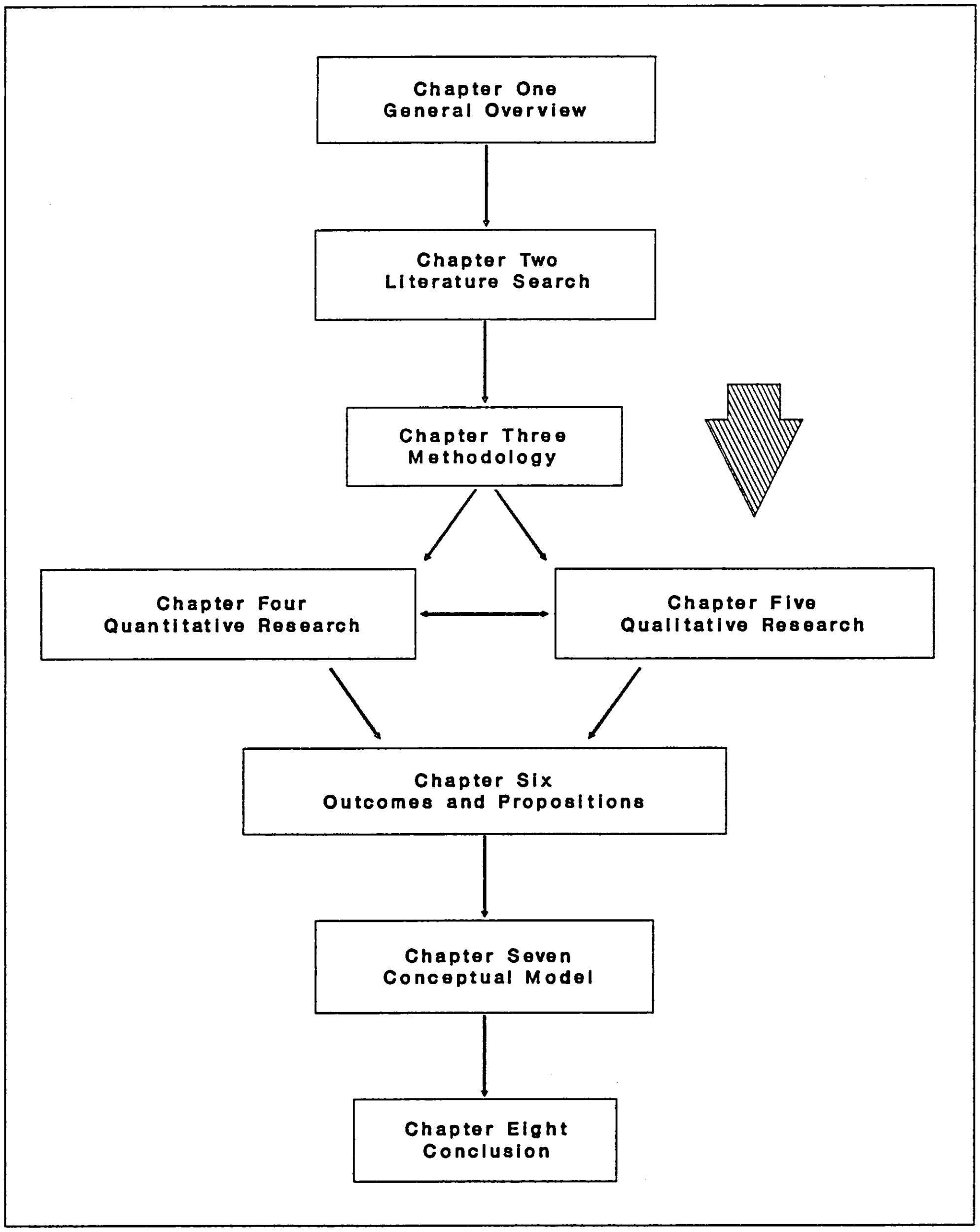


Fig 5: Process of PhD

CHAPTER FIVE

QUALITATIVE RESEARCH

Chapter four provided a broad spectrum of problems associated with the management of tooling resources and highlighted the need for the efficient management of this manufacturing resource. Chapter five has been developed to provide a background to each of the case studies involved. It attempts to provide sufficient information on the management and control of tooling resources in the participant companies for the reader, to become familiar with each case study and facilitate his understanding of the context of outcomes provided in chapter six. It aims to offer the base research from which to draw the propositions for an effective implementation methodology.

Section 5.1- Introduction

This section highlights the reasons behind the introduction of computerised tool management system by some companies.

Section 5.2- Case Selection

This section describes the selection procedures for case studies.

Section 5.3- Research Design

The research design employed in this part of the study is the subject of this section.

Section 5.4- Case Analysis

The systematic approach for analysing the large volume of data generated as a result of case studies is the topic of this section.

Section 5.5- Case Studies

This section involves a detailed case study write-ups regarding the management of tooling resources within the selected companies.

Section 5.6- Summary

Section 5.6.1- Sample Classification

5- QUALITATIVE RESEARCH

5.1- Introduction

It was established in chapter four that the majority of responding companies are experiencing difficulties in the management and control of their tooling resources. The impact of such problems on the efficiency of manufacturing facilities has encouraged many companies to consider the introduction of computerised tool management systems in an attempt to improve their management of tooling resources, and to eliminate the production bottlenecks developed as a result of poor management of tooling resource.

The need for computerised tool management and control systems has been expressed by many authors including [Brown (1991), Mason (1991), Hershkovick (1991), Zuin (1990), and Pond (1986)], However, very little is known about the implementation of such systems. Using qualitative techniques of data collection, this chapter aims to benefit from the experience of the participants in the implementation of such systems.

5.2- Case Selection

To complement the breadth of data from the survey, follow-up-data was obtained form eighteen companies. Based on the information generated from the mail survey, these companies are known to use a computerised tool management system. The Mini Case Studies aimed at investigating the issues associated with the management and control of tooling resources, in particular, the implementation of computerised tool management systems. However, due to the lack of availability and reliability of the data provided by some companies, fourteen companies were selected for this study.

5.3- Research Design

The most obvious source of information are people directly involved with the implementation of computerised tool management systems. The most popular approach adapted by most researchers is that of interviewing company personnel and assessing their experiences with the implementation process, its implications, and generalising this information to all companies.

The research design employed at this section is a series of mini case studies based on semi-structured, or focused on-site interviews complemented with observation of the manufacturing operations and facilities. The interviews were carried out on-site, each interview averaging approximately two hours. The interviews were held with one company director, one company buyer, and twelve other personnel from manufacturing departments. The questions focused directly upon the management of tooling resources and other relevant issues. However, in many cases, the interviewees requested participation in the interview from others who dealt with different aspects of tooling within the company. This provided the opportunity of recording additional perspectives on tool management within the company. Table 5.1, shows the overall functional area of interviewees.

Functional Area	% of Respondents
Management	22
Purchasing	7
Production	64
Design	7
Management Level	
Top	7
Senior	7
Middle	14
Junior	22
Supervisory	50

Table 5.1: Functional area of interviewees

5.4- Case analysis

Analysing data is in the heart of building theory from case studies and requires a systematic approach so that forms or patterns can be developed. The method used for this part of the study is similar to that of Eisenhardt (1989), where she describes a multi stage process from case to hypothesis construct. The first stage of this process is referred to as within-case analysis, it involves case study write-ups for each company. The purpose of this stage is to become familiar with each case as a stand alone entity, and to give the researcher/reader a familiarity with each case which, in turn, facilitates the cross-case comparison.

The second stage is a cross-case search for patterns. The tactics for this stage are numerous and are reported to be driven by the reality that people are notoriously poor processors of information, and they often reach conclusions based on limited data. The tactics adapted by the researcher are to select categories or dimensions from the questionnaire and interviews, and then look for similarities or differences. The purpose of this stage is to force the author to go beyond the initial impressions and to improve the probability of capturing the novel findings that may exist in the data. This is followed by the final stage of comparing the emergent frame with the evidence from each case study. This chapter is concerned with within-case analysis, where a case study attempts to highlight the management of tooling resources within each company.

5.5- Case Studies

5.5.1- Case A, Shoe Machinery Manufacturer

Company "A" is a manufacturer of shoe machinery, it has a leading role in the UK and international market. It has a long established reputation for quality world wide, and together with its factories in Germany, Italy, and America occupies the highest ground in the international market. The company employs 240 employees, and its machine shops contain 20 CNC and 35 non CNC machines, with 20% of tools considered disposable. On average the company carries 10,000 tools in stock at a estimated value of under £50K, and has an annual tooling budget of under £20K.

The tool management system operating within their traditional manufacturing facilities was based on paper/index card system, and the company's tooling costs was estimated at 4% of production cost with an annual increase of 10%. The company's priority in terms of tooling problems were tool unavailability together with high tool variety, and high tool inventory. With 5% of time responsible for expediting tools every week, the company's solution to their tooling problems was to purchase more. However, the company's situation regarding the management of tooling was reported to be significant and in need of urgent attention.

Commitment to quality, and maintaining market shares, necessitate improvement in the efficiency of manufacturing facilities. Through their contacts with DTI, they were advised to benefit from the introduction of Advanced Manufacturing Technology. MRP (Material Requirements Planning) which was designed to handle all aspects of production including FMS system at a cost of £200K was installed on a main frame computer at 1984. The tool management and control system was part of this MRP, However, some modifications to the system was needed to comply with desired requirements regarding the management of tooling resources by the company's engineers (this was mainly due to the employees participation).

A formal team headed by the shop floor supervisor and made up of representatives from all departments concerned were delegated to guide the implementation of computerised tool management system under the guide lines recommended by a consultant from DTI. It is important to note that, tooling was the last module in the perceived MRP system, and was implemented separately.

Having developed a formal plan for the implementation, the team then presented the objectives of the perceived tool management system to the operators concerned, specifying the time table for implementation. Operators suggestions were then investigated and they were then subjected to one week of training. However, it is important that apart from allocating all the necessary resources to the project, the management also participated in the education and training programme.

A major difficulty confronting the company at this stage was the transfer of data into the computer data bases. The task of locating tooling related information recorded on index card from four work shops was by no means an easy task. There were many tools in the system without any proof of their existence and the recorded information on the card system were insufficient and had to be modified to comply with the data base requirements of the computerised system. The operators who were delegated to carry out this task were also responsible for carrying out their normal job activities, as a result this transaction process took much longer than anticipated, allowing for both systems to be operational at the same time. This was due to the fact that because the tools were not all available in the computer tool data base, some of the transactions still had to be recorded using the old paper system.

The transaction process however, provided the company in locating the majority of their obsolete tooling which accounted for 10% of their tooling stock, hence reducing the size of the tool inventory. The company also reported reductions of 50% in time spent for expediting tools, 80% in the costs of hot purchases, 20% in tooling budget, 40% in costs of rework and scrap, 40% in wastes and 10% in set-up times; and improvements of 50% in meeting production schedule, 20% in tool tracking and control, and 10% in quality. They also reported improvements in store services, and delivery dates, but did not quantify the percentage.

Although the company reported the success of their tool management and control system implementation, a production engineer pointed out the complexity of the system and the problems associated with it. The slightest imbalance within the overall system would effect the management of tooling resources, resulting in loss of control over this crucial manufacturing resource. However, the company is considering managing their system on a network, or to separate the tool management system from MRP, in an attempt to secure the availability of tools at all times, and in the right condition and quantities.

The considerable improvement in output and business efficiency, was reported to be the measure of success of implementation process, together with financial and organisational gains. This is also reinforced by the payback period of 24 months. However, the company considers management commitment, outside support (consultants), shop floor acceptance, and positive attitudes to be the important factors in the success of their computerised tool management and control system implementation.

5.5.2- Case B, Precision Parts Manufacturer

Company "B" Is part of a group of four privately owned companies which is managed by management teams delegated by the owner. It manufactures precision parts for Rolls-Royce, and Aerospace industries. To maintain the standards and specifications required by its customers, the company's commitment to quality has seen a continued level of investment in the business. The company has an annual turnover of under £5 million, employs 60 employees, its workshops contains 11 CNC machines, and 55 non CNC machines, it has a annual tooling budget of over £70K, and the company's tooling stock of over 25000 tools are valued at under £100K.

The company's old tool management system was based on index card/paper system and was managed by a tool room manager who has a long employment history with the company. Although his contribution to the company was considered vital regarding the management of tooling resources, tool unavailability often affected the flow of production. However, lack of control over tooling resources, high tool variety, lack of tool refurbishment services, high tool inventory and cost of tooling were reported to be the company's major tooling problems respectively.

Although the company reported their situation with the management of tooling as "significant" but under control, on average employees spent 5% of time per shift expediting tools. The company's usual method of solving tooling problems was first to expedite, upon failure, the company would then authorise the purchase; this often resulted in delayed delivery dates.

In late 1980's, a visit to National Exhibition Centre (NEC) in Birmingham persuaded one of the company's project engineers to seek more information about tool management software offered by a leading supplier of such a system. The software company were then invited to present a demonstration at the company. After reviewing the package, shop floor management prepared a proposal together with a theoretical justification based on the time wasted for expediting tools and cost of delays in production schedules. This was then presented to the company owner who gave a positive response to purchase and installation of the proposed computerised system.

Running on the net work of two PC's and at the cost of over £30,000, the system was installed by the software company who provided a short training programme for the tool room manager. The tool room manager was then delegated to locate, collect, and enter all tooling information into the tool databases, and at the same time continue with his day to day responsibilities.

Building the tool database took less than one year and required a great deal of effort and energy. However the company benefited from lower tool inventory, reductions in obsolete tooling, cost of hot purchases, set up times, time losses, and improvements in tool tracking and control, tool room services, and production schedule.

The degree of control over tooling resources however, remains a problem. This problem is mainly due to the fact that, the company operates a two shift system. Since the tool room manager can not be available at all times, access to tool room is available to all operators and tools are booked out by any one using index/paper system, such transactions are then transferred to computer by the tool room manager.

Despite the presence of a proper implementation plan, employee participation, and formal education and training programme, the production planning engineer reported that the system has paid for itself quite easily (payback period of 24 months) and the implementation of their computerised tool management and control has been a success and they have never looked back since. This success is measured in business efficiency, output efficiency, organisationally, and financially by the company. However, the company considers the presence of a capable champion and the commitment from everyone to make a system work may be the critical factors in the successful implementation of such system.

5.5.3- Case C, Crankshafts Manufacturer

Company "C" manufactures crankshafts for automotive industry. It employs 400 people, and has an annual turnover of under £30 million. On average, the company carries over 5000 tools in stock at a value of under £200K, and its work shops contain 20 CNC machines and approximately 350 non CNC machines. The company benefits from an annual tooling budget of over £150K, from which, 40% is spent on non disposable tools.

In early 1980's, the company had realised that its manufacturing facilities can no longer support the quality and standards required by its major customers. In a report by prepared by consultants, the company was advised to change some of their manufacturing practices and up date their machinery in order to maintain their profit levels and market status. This resulted in a substantial investment. However, the company realised that the benefits of their investment was being affected by poor management of tooling resources.

The existing tool management system was based on paper/index card system, and company's situation with regard to tooling was reported to be significant and in need of more attention. Lack of control over tooling resources made unauthorised tooling, a normal practice. This resulted in difficulties in tracking tools on the shop floor, together with the associated problems of tool loses and added costs of hot purchases.

A number of attempts to modify the existing procedures and practices regarding the management of tooling provided some short term improvements but failed to produce any results. The company was then advised by the consultant to benefit from the utilisation of computerised tool management and control systems. The company decided to introduce the proposed system in the workshop equipped with the modern and up to date manufacturing facilities which they refer to as "new production areas".

A senior production engineer was delegated to lead the project with the assistance of a number of personnel from the departments affected as a result of the introduction of the new system. The team started their work by visiting number of companies who had implement such a system, this was then followed by viewing, and assessing a number of available software packages at the time for technical, and operational details. As a result, they chose a package provided by a company who were specialised in the manufacture of such software at a cost of approximately £30,000.

Although the consultants did not participate in the process of implementation, they provided some guidelines regarding the process. A formal plan for implementation was drawn up, and the objectives of the company's computerised tool management and control system were specified and presented to the employees.

After the installation of the system, the software company provided some training for the key personnel, but insufficient time allowed for this process encouraged company "C" to embark on an education and training programme of their own. During the two weeks of training, the operators were encouraged to express their views regarding the system. This resulted in some modification to operational aspects of the new system, and, everyone felt good about the new system.

This was then followed by transferring the tool data into the system databases. Unavailability of tooling information in some cases made this task which was underestimated in terms of time and effort more difficult. This activity was carried out for different classes of tools at a time, parallel to the alteration to the tool room.

The company considers their computerised tool management system has contributed significantly to the efficiency of their manufacturing facilities, they reported reductions in obsolete tooling, tool inventory, cost of hot purchases, tooling budget, cost of rework and scrap, waste, set-up times, and time losses for expediting tools, and improvement in production schedule, store services, tool tracking and control, and delivery dates.

The senior production engineer reported that the implementation of their computerised tool management and control system had been a success, the company measures this success in out put efficiency, business efficiency, financially and organisationally. He also considered, management commitment, education and training, and operators confidence in obtaining the right tools at the correct time to be the critical factors in success of such system.

However, despite the success of the new system, its impact, and the company's production engineer who said "Tooling is the cinderella of production and is not considered until the last minute. It should be the first decision in how will we make the product", the system is only being utilised in new production areas.

5.5.4- Case D, Precision parts Manufacturer

Company "D" is a division of a long establish company in the aerospace industry. It manufactures fuel pumping (injection) equipment, and employs 355 people. The company has an annual turnover of under £30 million, and its work shops contain 15 CNC machines, and 120 non CNC machines. On average the company carries over 6000 tools in stock at the estimated value of under £50K, with 60% of tools classed as non disposable, the company benefits from an annual tooling budget of £175K.

The company's existing tool management system was based on a card/index, but the efficiency of machining centres, and the flow of production were effected as a result of poor management of tooling resources. Tool unavailability which was a major influence on production delay, often resulted in hot purchases; this was reflected on the company's tooling costs. This was reported to be the company's number one problem considering the management of tooling; however, high tool inventory, difficulties in tracking tools on the shop floor, high tool variety, and lack of proper tool refurbishment services were also effecting the efficiency of manufacturing facilities.

The unavailability of right tools at the right time, place, quantity, and condition made it possible for the operators to spent up to 20% of their time expediting tools each week. Overall the company's situation with regard to tooling was reported to be significant and in need of more attention. However, the usual method of solving tooling problems were fist, to expedite, second, to purchase more tools, and finally, investigate the causes and the nature of occurred problems.

The company was reported to be aware of the benefits that could be achieved through introduction of a computerised tool management and control system through their sister companies, however, the decision to utilise such a system was delayed till 1990, when the company moved to its new and purpose built premises.

A tool room supervisor who was delegated to lead a team were given the task of selecting the tool management software, and guiding the process of implementation. Having drawn up a list of requirements for the perceived system based on the nature and causes of tooling problems in their own company, the team visited a number of companies who utilised such a system, and viewed three of the available tool management software packages. The insufficient budget allocated by the company limited the choice of software; however, the team selected a package at a cost of under £30K, and the system was installed in early 1990.

The team then develop a formal plan for implementation, benefiting from the experience of outside consultants. The objectives of the proposed tool management system were then presented to the employees who had to participate in the education and training programme provided by the company.

A five day course (part time) proved sufficient for the operators who had some degree of computer literacy, but was insufficient for the operators who had little knowledge of computers and key usage. However, as a result of employee's participation, some operational aspects of the software package had to be altered, which was welcomed by shop floor management. During the training period, tooling data were transferred to computer data bases. This task was allocated to secretarial personnel in order to speed up the operation, but, some of the imputed data had to be checked for accuracy when it had come to the attention of one of the shop floor operators.

The system was fully operational in mid 1991, as a result, reductions of 20% in time spent for expediting tools, 20% in obsolete tooling, 15% in tool inventory, 45% in costs of hot purchases, 30% in tooling budget, 5% in costs of scrap and rework, 25% in costs of waste, 25% in set-up times, 20% in lost time, and improvements of 10% in production schedule, 25% in store services, 25% in tool tracking and control, and 40% in delivery dates were reported by the company.

The implementation of their computerised tool management and control system was reported by the company's buyer to be a success, this is measured in financial terms, business efficiency, out-put efficiency, and organisational terms. He considers the management of change, education and training, and sufficient time for implementation together with allocation of resources to be the critical factors in the success of their project.

When he was asked to elaborate on the critical factors, he commented, despite the achieved result, together with the estimated payback period of 24 months, more time, resources, and consideration should have been diverted towards the selection of software and its vendor. It appears with annual maintenance of over £1000, the company is experiencing operational and technical difficulties regarding their tool management software, the latter concerns the problems associated with system integration.

5.5.5- Case E, Engine-Assembly parts Manufacturer

Company "E" is a division of large car manufacturing company. It produces engine, assembly and interior parts. It has an annual turnover of under £100 million , employs 2000 people, and its workshops contain 40 CNC machines and 200 non CNC machines. An annual tooling budget of over £100K assists the company in maintaining the flow of production. On average, the company carries 15,000 tools in stock, at a estimated value of £1.5 million from which, 75% of tooling is considered as non disposable.

Although, the company considered tooling as a problem in their business unit only sometimes, and their situation regarding the management and control of tooling resources was reported to be not significant, the company's tooling related problems were as such that, 25% of foremen's time was spent expediting tools every week.

The existing tool management system was based on index card system and the size of tool inventory which was reported to be influenced by the product range of over 300 products was considered to be the company's major tooling problem. But, lack of tool availability at the required time, difficulties in tracking and control of tooling on the shop floor, and cost of tooling were reported to be the other difficulties concerning the management of tooling. Tool unavailability however, was considered responsible for production bottlenecks. This was dealt with by means of purchasing more tools, where it was reflected on the overall tooling budget, and costs of finished products.

The increasing costs of tooling together with its effect on the efficiency of manufacturing facilities was a major factor in reviewing the existing procedures and practices concerning the management of tooling within the company. Such a reviews often resulted in new procedures and tighter control over this manufacturing resource, but failed to provide a solution to efficient management of tooling. However, being aware of the available technologies in the market, the company decided that a computerised tool management system may be the solution to their tooling problems. Further, it would assist the company to maintain its status within the industry in terms of adaptation of new manufacturing technologies.

A team headed by a manufacturing engineer was delegated to assess the suitability of the available packages in the market to company's manufacturing facilities. Although the team did not have any specification regarding the purchase of perceived tool management system, or imposed any evaluation criteria over the offered software packages, on majority agreement, they purchased a package from a leading software house who are specialist in this field at a cost of under £40K.

The system was installed and based on a formal plan for its implementation, the team then embarked on a pilot project where the system became operational on a very small scale. The objectives of the pilot project were first, to test the system for technical, operational details, and performance, second, to use this set-up to train the operators. Upon success of the pilot, the objectives of the company's tool management and control programme were presented to the employees and at a board meeting, and system went live.

Tooling data were then transferred from index cards to system data bases; however, although tool data was input to the tool databases class by class, this operation took much longer than anticipated. Parallel to above, a one week (part time) education and training programme was provided for the operators by the company, and tool room layout was altered in an attempt to provide a new setting for the new system, and to ensure authorised access only.

As a result of computerised tool management system implementation, reductions of; 15% in obsolete tooling, 10% in tooling budget, 25% in set-up times, 25% in time losses, and improvements of 25% in store services, and 50% in tool tracking and control were achieved. The improvements in quality, delivery dates, production schedule were also reported, however, the company did not quantify the extent of this improvements.

The company reported that, not considering the estimated payback period of less than 12 month, the implementation of their computerised tool management and control system has been a success. Their success is measured in output efficiency which has resulted in financial gains. But, the manufacturing engineer reported that, in their experience, education and training, consultation, and implementation plan are the key factors in the success of their tool management system.

5.5.6- Case F, Textile machinery Manufacturer

Company "F" manufactures textile machinery, and holds a substantial shares of its market. It employs 650 people, and has an annual turnover of under £30 million. On average, the company holds over 15,000 tools in stock at the estimated value of under £50K, has an annual tooling budget of £300K, and its machine shops contain 30 CNC, and 90 non CNC machines.

The existing manual tool management system was based on an card/index system and lack of control over its resources have always resulted in delays in production schedule. Although the company characterised their situation regarding the management of tooling resources as significant and in need of more attention, very little attention was diverted towards this critical manufacturing resource. The company's major tooling problems were reported to be high tool variety, costs of tooling, lack of tool availability at the required time, high tool inventory, difficulties in tracking and control of tooling on the shop floor, and lack of tool refurbishment services.

The extent of tooling problems were as such that, on average 5% of the operator's time was spent expediting the right tools every week. But the lack of tool availability often resulted in rescheduling work, which in turn resulted in delays and loss of revenues, and unsatisfied customers. Maintaining and improving the existing levels of revenues together with the need for producing prompt deliveries became the top management's priority. This resulted in a number of meeting between top management and production managers, where their attention was drawn to inefficient management of tooling resources. However, the responsibility of solving tooling problems were passed to the production personnel.

A shop floor supervisor was delegated to find a solution to company's tooling problems. He started their work by analysing their existing tool management system. In a meeting presented to the management, he highlighted the company tooling problems and concluded that their existing manual system was no longer capable of managing their tooling resources, specially with a large amount of tooling data that had to be up dated all the time, to ensure the availability of right tools, at the right time, place, quantity, and condition. He recommended that a computerised tool management system could contribute significantly to the efficient management of their tooling resources. This proposal was accepted by the top management, However, the company decided to develop their own tailor made package benefiting from the experience of outside consultant.

A list of specifications based on the findings of the project champion was drawn up and a company employee (CIM Engineer) who had some knowledge of developing such a package began to work in early 1989. However, the progress proved to be very slow. The lack of precise specification, and personnel participation often resulted in some modification to the package. Although, this can be beneficial, on this occasion this modification went on for a long time, during which the consultant decided to leave the company to it. The package was completed in late 1990, and the company embarked on a planned implementation process.

Lack of commitment to, and participation in, the project by the top management in partial allocation of resources often discouraged the project champion who had limited knowledge in the field of implementation of Advanced Manufacturing Technologies, and had to make compromises in order to keep the project alive. This is a good example were the top management has passed the book to the shop floor, assuming a technology led strategy would automatically enhance the efficiency of manufacturing facilities.

It took the tool room personnel six months to transfer tooling data to the computer data base during which the tool room layout was altered in an attempt to accommodate the tools in suitable draws, and to impose a better degree of control over tooling transaction. A pilot project was used to test the system for technical and operational details, the set also provided a base for a five day part time course for operators who had limited knowledge of computer and use of keyboard. The company reported substantial reduction in tool inventory, obsolete tooling, cost of hot purchases, cost of rework and scrap, time spent for expediting tools, set-up times, time lost, tooling budget, and improvement in production schedule, store services, tool tracking and control, quality, and delivery dates.

The company considers their implementation has been a success, they measure this in financial gains, business efficiency, and organisationally. But despite their success, the company is still experiencing difficulties regarding the management of their tooling resources. The root causes of this problem are diverted towards the system capabilities and organisational issues. Being aware of this problem the company delegated the production engineering department to be responsible for correcting the mistakes in late 1993. Not surprisingly, the company considers the presence of a capable champion, management commitment, and education and training to be the critical factors in the success of the implementation process.

5.5.7- Case G, Gas turbine manufacturer

Company "G" Manufactures Gas turbines. It employs 2500 people, has a an annual turnover of under £100 million, and its work shops contain 30 CNC machines and 60 non CNC machines. On average, the company carries over 100,000 tools in stock at a estimated value of £900K, and company benefits from an annual tooling budget of over £100K.

Prior to the introduction of computerised tool management system, a manual system based on index card was responsible for the management and control of tooling resources within the company. However, due to high product/part variety, the plant has developed a high requirement for tools for the machining centres. This has resulted in a tool inventory of over 100,000 tools from which half are considered as disposable tools. As a result, tool tracking and control on the shop floor has become a major problem together with its relevant costs. High tool inventory, cost of tooling, lack of proper tool refurbishment services, difficulties in tracking and control of tooling on the shop floor, high tool variety, and tool unavailability were reported to be the company's major tooling problems. Further, on average, the operators spent 5% of their time expediting tools every week. This was said to be the usual method of solving tooling problems within the company. Overall the company's situation with regard to management of tooling was reported to be "significant and in need of more attention".

The costs of tooling, its poor management, and its effect on the efficiency of manufacturing facilities have long been a major concern for the company. However, in mid 1980's the company decided something had to be done very soon. A team headed by a production engineer and tool room manager were delegated to find a solution to the company's tooling problems. In a report presented to the top management, the team highlighted the company's tooling problems and concluded that, the existing tool management system could no longer support its machining centres, however, they proposed that, a computerised tool management and control system may be the solution to their problems.

As a result of the report and company's determination to solve their tooling problems, the funds were made available for the purchase of the proposed system. The team then continued by examining and evaluating the available tool management software packages in the market at the time. Hence the company purchased their tool management software from a leading manufacturer who are specialised in the field at a cost of under £40K.

The formal plan for the implementation of the system allowed one week for a pilot project. This provided the opportunity for evaluating the performance of the system and also training of the operators who would be using the system. During this period, the operators were encouraged to express their views regarding the proposed system. Slight modification to the software was an indication of the company's intentions concerning the success of the implementation process. After the installation of the system, the tooling data were transferred to computer databases, using operators to input the data. However, during the transaction period, the tool room layout was altered, but, the manual system was still in operation.

The implementation of a computerised tool management system has resulted in meeting delivery dates and complying with production schedule. The tool room is more efficient, and they can track and control their tooling on the shop floor. A production engineer said "we can now locate any tools within seconds, we know where they are, and how many are there, and in what condition they are in". Further, he reported reductions; in time spent for expediting tools, obsolete tooling, tool inventory, cost of hot purchases, tooling budget, costs of waste and scrap, time loss, and set-up times. However, he could not quantify the achieved result.

According to the group leader (consumable tool stores), the system is being partially utilised, and the manual (card/index system) still remains operational in some departments. It seems, although the system is new, the attitudes and practices are not. She considers that commitment and determination to make the system work, proper planning with time tables, and consultation together with education and training are the critical factors in the success of such a system.

Despite its pitfalls, the company reported that they have been partially successful in implementation of their tool management and control system. They measure this success in out put and business efficiencies, and financial gains.

5.5.8- Case H, Transmissions-Axles and Gearbox Manufacturer

Company "H" manufactures transmissions-axles and gearbox for the automotive industry. It employs over 250 employees and has an annual turnover of under £40 million, with 42 CNC machines and 8 non CNC machine, the average number of tools in stock is said to be over 5000 (70% Disposable) at a value of under £20K. The company benefits from an annual tooling budget of over £250K, with the annual increase of over 4.5%.

The company's old tool management system was based on index/paper system, and lack of proper control over tooling resources made it difficult for the availability of right tools in the right place, at the right time, and at the right quantities. But, lack of tool refurbishment services, difficulties in tracking tools, high tool inventory, and cost of tooling was reported to be the other problem areas regarding the management of tooling. However, the company's solution to tool unavailability was first, to expedite, and second, to buy more tools. The extent of tooling problems was as such that, on average 3% of time was spent expediting tools every week, and company's situation concerning the management of tooling resources was said to be significant and in need of more attention.

The commitment to adaptation of Advanced Manufacturing Technologies had already provided the company with an edge over their competitors, however, poor management of their tooling resources was effecting the efficiency of their manufacturing facilities. This was the major factor in considering a computerised tool management and control system in an attempt to improve the management of their tooling resources. This was by no means the company's first option. The company spent eighteen months analysing the existing system and identifying the nature and underlying causes of tooling problems in order to improve the efficiency of their existing system. Although there was some improvement, the production bottlenecks developed as a results of tooling related problems encouraged the company to benefit from the utilisation of a computerised tool management system. However, the company's top management required justification for this investment. A formal team headed by the tooling engineer who was responsible for the management of tooling resources had identified the immediate and expected benefits of such system together with the long term financial gains. This information was presented to the company's top management where, they agreed with the proposed investment.

The team then spent three month drafting a list of requirements for the new system (system requirements and specifications), this was then modified to be used as a tool for evaluating the available software in the market. According to the tooling engineer, they conducted a survey of all tool management packages in the market, and they short listed two of the proposed packages for close examination and pilots.

Each of the proposed software packages were installed for a trial period of two weeks where they were tested against the system specification drawn up by the team some months before. Although both software packages did comply with the company's requirements, they favoured the package introduced by a major software company who specialised in tool management software. The selection criteria was heavily influenced by the user friendliness of the package, and after sales assistance.

With a strategic approach based on technological and organisational dimensions to implementation, the company drew up a formal plan for the implementation of the new system benefiting from the expertise of outside assistance.

The company's objectives regarding the implementation of the proposed system were then specified and presented to the employees, fostering their participation. Although the company did not reward those who were instrumental in the implementation of the system, they were subjected to an extensive training programme together with those who would be affected as a result of the introduction of new system.

At the time of interview the company were unable to provide any quantifiable measures regarding the benefits of the new system; however, they reported reduction in time spent expediting tools, tool inventory, cost of hot purchases, tooling budget, cost of rework and scrap, set-up times, and improvements in store services, tool tracking and control, and quality. The situation was the same in a further contact in 1993.

The company reported that the implementation of their computerised tool management and control system has been a success and they have achieved their objectives in reducing set-up times, cost of tooling, and improving tool tracking and control on the shop floor. They measure this success in out put efficiency and financial terms, which is reflected on payback period of 6 months. However, the company considers initial specification for the proposed tool management package, method of implementation, and implementation time table to be the critical factors in the implementation of such system.

5.5.9- Case J, Traction Equipment Manufacturer

Company "J" is a part of large group of companies and manufactures traction equipment. It employs 1100 people and has an annual turnover of under £100 million. On average the company carries over 20,000 tools in stock at the cost of £80K from which 70% are non disposable, and with 15 CNC machines and over 90 Non CNC machines, the plant utilises a tooling budget of over £175K.

The company has benefited from the implementation of advanced manufacturing technology in the past, and although the existing tool management system is based on manual (card/index) system, some functions of tooling is managed through a computerised system developed by the parent company. Such a function may include tool data base, and ordering procedures, where the orders are generated manually and then entered in to the computerised system.

Enhancing competitiveness, maintaining continuous flow of productions, and meeting delivery dates necessitated the reviewing of the current practices concerning the management and control of tooling resources. The company's major problem regarding the management of tooling was unavailability of right tooling at the right times, which often affected the production schedules. High tool variety, high tool inventory, tool tracking and control on the shop floor, lack of proper tool refurbishment services, and cost of tooling were reported to be the other major tooling problems respectively. With 30% of tooling stock considered obsolete, the company's usual method of solving tooling problems was to purchase more. On average operators spent 30 minutes per shift expediting tools, and overall the company's situation with regard to tooling was reported to be significant and in need of urgent attention.

The investment of £50K in a computerised tool management and control system was heavily motivated by its expected benefits, and its interface with the existing manufacturing facilities. Further, the perceived system has already been tested successfully in a sister company. The latter did not provide any opportunity in evaluating other available packages, and prohibited the company in drafting any system specification.

The company's strategy regarding the implementation of CATMACS was based on organisational and business dimensions, and their approach to implementation of computerised system was reported to be one of planned change. After the installation of the system the tooling data (tool inventory) was electronically transferred to the new system. However, the utilisation of the system was subjected to a modular introduction of different classes of tools. For example, jigs and fixtures were the first categories of tooling transferred to the new system followed by drills.

A formal team headed by a manufacturing engineer who was delegated to lead the project were assigned for a pilot project. The objectives of the company's tool management and control system was presented to heads of departments, supervisors, and foremen. Although there was no opportunity to investigate the operator's suggestions, they were subjected to a brief training programme. However, due to the familiarity of operators with key usage and computers, the training was limited to the operation aspect of new software.

The major issue confronting the company concerned the utilisation of the system by the operators. It seems there was very little faith in the performance of the new system and the card/index system was still operational. Obtaining excessive numbers of similar tools to insure their availability and safekeeping was a good example of the existing environment surrounding the new system. It appears the situation might have developed through a number of factors: first, the poor performance of the previous computerised system, second, lack of identification of the nature of tooling problems prior to the introduction of new system, hence, existing problems have been transferred into the new system, third, the situation might have been developed as a result of poor control over tooling resources, and lastly, insufficient time allowed for education and training and the lack of opportunity for operator to participate in the implementation of the system.

Despite the existing situation, the company considers the implementation of CATMACS to be a success and reported reductions in; obsolete tooling, tool inventory, time lost and improvement in; tool tracking and control, and store services. This success is measured organisationally and in out put efficiency.

The plant identified trust and confidence in the system, education and training, and control and security to be the critical factors in successful implementation of any computerised tool management and control system, and estimated a payback period of two years.

5.5.10- Case K, Electronic Motors/Traction Equipment Manufacturer

Company "K" manufactures electronic motors and traction equipment for locomotive industry. It has an annual turnover of over £50 million, and employs 800 people. Maintaining traditional manufacturing practices, and the lack of investment in advanced manufacturing technologies, has been a major factor in the reduction of its market shares in the past. However, the company has realised the importance of such investment and is determined to make up the ground. The company has a tooling budget of £75K, its machine shops contain 18 CNC machines and 50 non CNC machines, and on average the company carries over 160000 tools in stock at the estimated value of over £150K.

Prior to the introduction of CATMAC, the lack of consideration for tooling throughout the plant was quite evident, and the company's manual (card/index) system was incapable of supporting its production facilities. This was further aggravated through the organisation side of the management of tooling resources. However, the company reported tool unavailability to be their major tooling problems. This refers to unavailability of right tools at the right place, in the right condition and quantity and at the right time, and encompasses a wide range of tooling associated problems within the company. Tool tracking and control, lack of proper tool refurbishment services, cost of tooling, high tool inventory, and high tool variety were reported to be the company's other tooling problems respectively.

The extent of tooling problems were as such that, on average the operators spent twenty minutes per shift expediting tools, and the solution to tooling problems was to purchase more. As a result, the company considered their situation with regard to tooling as significant and in need of urgent attention. The increasing costs associated with the poor management and control of tooling resources and its influence on the manufacturing cost alert the management to seek solution in reducing the perceived costs.

Without any attempt in identifying the extend and nature of tooling problems within the existing system the company decided that a computerised tool management and control system would be the answer to their tooling problems. With no consideration to requirements and specifications regarding the new system, the company purchased a computerised tool management system at the cost of over 50K. This is a typical example where the management assumes that the technology will enhance the company's performance automatically and dictates a technology led strategy with no concern for organisational dimension of Advanced Manufacturing technology.

The system became operational when it was installed in 1989. The software company provided a short training course on the use of software for limited number of staff. However, the majority of operators who had a very limited knowledge of computers and key usage-were to receive their training from the key personnel on the plant. Although the plant reported the presence of a strategic plan for implementation, a formal team to facilitate the implementation project, and a champion (project engineer) who had worked as a consultant in the past, the implementation process proved to be a total failure.

The lack of eduction and training at all levels, insufficient and incomprehensive training for the operators, and the lack of participation of operators in identifying the requirements for the new system led to the objectives of the company never being materialised. Further, the sense of dissatisfaction and lack of faith regarding the system and its associate problems made it necessary to utilise the manual paper system as much as possible and return to old practices. A machine operator said,"they have more problems with tooling than they ever had with the paper system".

The implementation project gradually became abandoned, However, in 1991 the project engineer reported "they have decided to implement the computerised system properly starting from the beginning with clear plans and targets and sufficient time for education and training. He is optimistic about their intentions; however, when asked, a number of operators said his views are not shared by every one on the shop floor.

In a further contact in 1993, the company reported further progress. So far 50% reductions in time spent for expediting tools, 10% reduction in the size of tool inventory, 70% reductions in the costs of hot purchases, 20% reduction in waste, and 50% reduction in time lost have been achieved. The estimate return on investment is not significant, but, the company reported the expected return of 100% in 36 months.

The company considers the implementation of CATMACS to be partially successful, and it is measured in financial and organisational terms. Management commitment in allocating the necessary resources and their participation in education and training, operator's education and training, site security, investigating operator's suggestions, and rewards for people who are instrumental in the implementation process was reported to be the critical factors in successful implementation of such a system.

5.5.11- Case L, Engine Valves and Plumbing Products Manufacturer

Company "L" produces engine valves for the automotive industry, a range of plumbing products, and the majority of its own special tooling. In total, the company employs over 1000 people and has a product range of over 300, and benefits from an annual turnover of under £100 million.

Due to high product variety, the plant has produced a relatively heavy requirement for tools for the machining centres. The plant needs to machine small batches of different parts to meet a flexible assembly schedule, adding to the pressure that the right tools be available at the right time. With 6 CNC machines, and 200 non CNC machines, the company carries approximately 20,000 tools in stock, at a cost of £900K.

Prior to the introduction of computerised tool management system, the picture regarding the company's tooling resources was one of chaos. Most of the company's tools were out on the shop floor or in boxes which could be considered as "unauthorised toolrooms". Tooling problems ranged from: high tool inventory, lack of control over tools once they have been issued to shop floor, and tool unavailability, to tool abuse. The above generally resulted in delays in delivery dates, machine breakdowns, poor quality products, and long set up times of 8-12 hours.

Lack of control over tooling resources encouraged operators to make the required tools on the shop floor without checking on their availability or without any authorisation. This resulted in a very high tool inventory with added disadvantages of storage, tool losses, delays in production schedules and delivery dates. This high tool inventory was later found to be a big part of obsolete tooling.

The company's manual system (card/index system) was not working and the company's decision to invest in a computer aided tool management and control system was heavily motivated by the nature and extent of its tooling problems. The problems were significant and required urgent attention. The company's production Manager who has worked as a tool maker for nearly a decade, has gained considerable experience in the management of tooling resources and also in the field of implementation of AMT through his professional career.

He had recognised the importance of tooling in today's manufacturing industry, and its effect on the efficiency of manufacturing facilities. Having recognised the causes of tooling problems in the company it took him great effort, time and energy to persuade the company managers to first, invest in a computerised system and second, to give tooling some priorities in terms of manufacturing resources.

A team, headed by the Production Manager was delegated to examine and analyse the existing tool management and control system in the company. After four weeks a report was prepared and presented to the company. The report highlighted the tooling problems in the company and its effect on the efficiency of manufacturing facilities. It concluded that the existing tool management system was no longer capable of supporting their manufacturing processes, and for the company to remain competitive and maintain its market shares, it was vital that more attention was given to the management and control of tooling resources. The report recommended that a computerised tool management and control system could assist in solving their tooling problems, and further, it would help to reduce the cost of tooling within the company. However, the report could only provide theoretical data in support of the justification for the perceived system.

Having considered different options, a decision was taken to purchase and utilise a CATMACS. A number of available packages at the time were examined, however, the company favoured a package introduced to them by a software company at a cost £40K in 1989. The company's strategy regarding the utilisation of a CATMACS was first to establish a tool data base. This data base should contain all the descriptive information about every tool on the shop floor. Secondly to reduce the set up times; thirdly, to improve quality and reduce waste; and fourthly, to reduce the costs of tooling. In order to exploit the full potential of CATMACS, the company decided on an extensive education and training programme. This was mainly due to lack of computer literacy within the company, since the training provided by the software company was not effective due to its time span. Overall the implementation of CATMACS was based on the company's concern for business, organisational, and technological dimensions.

Building the tool database took two months. Using clerical staff to input the data proved to be very beneficial to tool-crib people as they did not have to enter the tool data themselves. This was by no means an easy task since, the manual system could not provide the necessary tooling data. Using clerical staff to input data therefore had the disadvantage of inaccurate entries, which resulted in double checking.

To give the tool crib personnel a sense of ownership over the new system, they were targeted for special attention. A prototype system was installed in the tool crib to facilitate the education and training of tool crib people, and they were encouraged to participate and evaluate the efficiency of the new system. This was then further extended to all departments which were effected by the new system. After investigating the operator's suggestions as a result of a number of meetings, the CATMACS package had to be modified. But despite the occurred cost, the system was nearly accepted by every one concerned.

The discipline of doing a proper tool inventory has paid unexpected dividends for the company. The plant reported locating some 50% in obsolete tools in previous tool management system, and over £100K worth of usable tools were returned to the tool crib. In addition over £0.5 million worth of obsolete tools were collected in and around shop.

When the company's production manager did the justification for the tool management system, he calculated the return on investment (ROI) of £14K for first three months, after the system has been operational. He then estimated that the money generated from the sale of obsolete tooling, together with the savings from reductions in machine down-time, tool duplication, overtime, repairs and rework would easily compensate for the cost of CATMACS in the first year. According to the production manager "the implementation of CATMACS has taken longer than anticipated". This was mainly due to complexity and extent of tooling problems in the company and further, the company was merged with a sister company in 1990.

The company has improved the productivity of its machines and reduced lost time and set-up times significantly. Reduction in the size of tool inventory, and identification of obsolete tooling have been some of the few tangible benefits of the new systems. Further more, the production manager reported that "they now have system that can monitor and control their tooling resources more effectively". The company has achieved its objectives regarding the implementation of CATMACS and consider it a success. This is measured in financial, operational, and organisational terms.

5.5.12- Case M, Hydraulic Power Equipment Manufacturer

Company "M" manufactures hydraulic power equipment. It employs 600 people and has an annual turnover of under £50 million. Its workshops contain 40 CNC machines and 100 non CNC machines, and on average the company carries about 4000 tools in stock at a value of between £100-200k. The company has an annual tooling budget of £250k from which, half accounts for disposable tools.

The major problem confronting the company regarding the management of tooling resources was the control of tooling on the shop floor. the extend of problem was such that, a full time expediter was employed to ease the situation. High tool inventory and cost of tooling was reported to be the other problem areas. With expediting considered to be the usual method of solving tooling problems, the company's situation with regard to tooling was said to be "significant, but under control".

The company has considerable experience in the implementation of Advanced Manufacturing Technologies. Collaborative research with UMIST has resulted in MRP which controls materials flow, and a Shop Floor Data Collection/Machine Monitoring (SFDC/MM) system. In order to create a FMS of extreme size, Automatic Guided Vehicles (AGV's) are used to connect the automated islands. However, the company had realised that the potential benefits of such investments could be negatively influenced as a result of poor management and control of their tooling resources.

To comply with the company's high-tech environment, the company decided that a computerised tool management and control system would insure the continuous flow of production and improve the efficiency of their manufacturing facilities. This was further encouraged through collaborative research, conferences, and relevant literature where, the benefits of such a system were highlighted.

Having been approached by a number of software companies in late 1980's, they conducted a careful examination of existing tool management software available in the market at the time. The company decided that a computer aided tool management and control system would be highly beneficial to company. But, the company favoured the development of a tailor made tool management software in-house in collaboration with a university.

The strategy regarding the implementation of CATMACS was heavily motivated by technical and organisational dimension. However, the level of technology and expertise employed in the development of the proposed software did not assist the company in achieving their objectives. Further, it added to the existing problems.

The nature of the technical problems concerning the developed software necessitated the utilisation of a manual system when the breakdowns occurred (software crash). This in turn had the disadvantages of total chaos in management and control of tooling resources. After careful consideration the developed software had to be made redundant.

However, despite this set back, the company has already benefited from a 25% reduction in the size of their tool inventory, 100% reduction in obsolete tooling, and 50% reduction in time spent expediting tools. But, by far, and the most important benefit from this experience was that, since the system was developed in-house, the operators and those who were associated with the management of tooling within the company had the opportunity to participate in the development of the software. This gave the operators an opportunity to express their preferences and dislikes regarding the developed software. The participation of employees often resulted in some modification to the software. However, the system was accepted by every one concerned and further, this provided an opportunity for the operators to improve their computer literacy and become familiar with the mechanism of tool management software.

The company's decision to purchase a off-the-shelf/ready made tool management software was heavily influenced by the realisation of the potential benefits of such a system. After consideration to the requirements for the proposed software a number of available packages were reviewed and tested on key areas such as operational details, system capabilities, and system integration. The company favoured a package from a company who were specialised in tool management software at a cost of £40K.

based on the lessons learned from the past experience, the system was installed. After initial training of the key personnel, provided by the software company, operators were trained by the key personnel and the system went on live. The company cites the main benefits gained from the CATMACS to be improved operating efficiency and control, reduction of costs due to machine down-time. They reported 100% reduction in obsolete tooling, 50% reduction in time spent for expediting tools, 80% reduction in the cost of hot purchases, 80% improvement in tool tracking and control, 50% reduction in set-up times, and 25% reduction in tool inventory.

The company has been successful in implementation of CATMACS and their success is measured in financial and organisational gains. Commitment of the senior manager to the project, and their participation, education and training, control, and implementation plan was reported by the production engineer to be the most critical factors in successful implementation of a computerised tool management and control system.

5.5.13- Case N, Manufacturer of Defence System

Company 'N', is a manufacturer of defence systems. It has a dominant role in the U.K, and a substantial share of the international market. In mid 1980's, the company realised that, while it seemed to occupy the high ground in the market, revenues are being effected through fears international competition caused by changes in external political environment. Maintaining and enhancing competitiveness necessitate that the company should make more use of new developments in manufacturing technologies and concepts.

The company has an annual turnover of under £100 million, in total employs 1100 people, and its two factories contain 75 CNC machines and 150 non CNC machine. Due to the nature of the business the company carries 142,000 tools in stock at a value of over £400k, has an annual tooling budget of approximately £500K, and tooling costs accounts for approximately 5% of the production cost.

The existing tool management system was based on a card system, and their situation with regard to tooling was said to be significant and in need of attention. The company's tooling problems in order of importance were unavailability of right tooling at the required time, high tooling inventory, cost of tooling, high tool verity, difficulties in tracking tools on the shop floor, and lack of proper tool refurbishment services. With 50% of obsolete tooling in stock, the usual method of solving tooling problems was to expedite them.

The company was experiencing difficulties in managing and controlling their tooling resources, and although at the time tooling was an ignored issue in manufacturing industry, the business strategy of the company required a close examination of the situation in an attempt to reduce the manufacturing costs.

The company was familiar with the implementation of Advanced Manufacturing Technologies, and had some experience with a computerised tool management system which was part of a existing inventory control system. But, the system was not capable of satisfying the company's requirements regarding the management and control of tooling resources. Further, due to the unpopularity of the existing system it was hardly utilised, hence, the card/index system remained the only system which could have some influence in the management of tooling resources.

The pressure for changes from a number of sources; political, economical and technological, necessitated the enhancement of the existing tool management system. A series of meeting with the top management, the funds were made available for the purchase of a tool management and control software. The company then considered a number of available tool management software in the market, however, the company favoured a package from a special supplier at a cost of £60K.

The system was installed in 1988 when, the company developed a plan for the implementation of their new tool management system. Tooling data were then transferred from the old system into new databases, and system became operational. But, the lack of strategic approach concerning the process of implementation is quite evident later in the study, this was further explicitly reported by a manufacturing engineer.

The partial commitment of the management in allocating the necessary resources, and their participation made it possible to implement the system without a project champion, a formal tool management team, and a pilot project. Overall the strategy concerning the implementation of the system was based on technological and business dimension, with little or no concern for organisational dimension.

A formal presentation of the objectives of the company's CATMACS was made to employees, followed by a short training course in key usage and other operational aspects of computerised tool management and control system. Operator's suggestions were then investigated. This proved to be very beneficial, as it necessitated some modification to the software.

As a result of CATMACS implementation reductions of 50% in obsolete tooling, 40% in tool inventory, 50% in tooling budget, 10% in waste, 20% in lost time, 5% in costs of hot purchases, 5% in cost of rework & scrap, 20% in expediting tools, and increases of 20% in tool stores services efficiency and 40% in tool tracking and control was reported.

At the time of this interview the company were experiencing difficulties with the new system. This problems were associated with the operational issues such as tooling transactions, system integration, and interfaces with other manufacturing facilities.

With company experiencing a long learning curve due to lack of concern for explicit corporate change strategies, and unsystematic vision of tooling, the company considers the implementation of their computerised tool management and control system to be partially successful, and this is measured in out put efficiency. However, the company considers education and training, and commitment to the project to the critical factors in the success of implementation process.

5.5.14- Case P, Piston Manufacturer

Company "P" produces pistons for automotive industry. It has a large share in its U.K market, and it also sells to a number of European countries. The company has an annual turnover of £100 million, employs over 1000 people, and its machine shops contain 80 CNC machines and over 200 non CNC machines. With 80% of tooling classified as disposable, the company's tooling stock accounts for 30,000 individual tools with the estimated value of £200K. The variety of different parts manufactured by the company has been an influencing factor in the size of the tool inventory.

The company's existing system was based on index/card system, and company's situation with regard to tooling was said to be "not significant". However, high tooling inventory, high tool variety, difficulties in tracking tools on the shop floor, tool unavailability, lack of proper tool refurbishment services, and cost of tooling were reported to be the company's major tooling problems respectively.

Market expansion, automation of existing processes, the need for efficient management of tooling resources, and keeping pace with increasing quality and cost requirements demanded by one of the major customers (a car manufacturer), were exerting pressure on the company to change their approach regarding the management and control of tooling. The company were advised by the car manufacturing company to utilise a computerised tool management system developed by a specific software company. This tool management software has been used by the car company and have proven to be very effective.

The constraint on the choice of software limited the company in benefiting from reviewing other available packages in the market at the time. Hence, complying with the requirements necessary to accommodate the new system.

In May 1991 the company installed its Computer aided tool management and control system at a cost of £35K. This figure does not account for the cost of hardware (twelve pc's on a network). Although the strategy regarding the implementation of CATMACS was initially based on business and technology dimensions, the company had to develop a clear set out seven month plan for implementation of CATMACS.

In February 1992, A project team headed by production Engineer (CATMACS champion) and made up of heads of all department concern with the management of tooling were responsible for identifying the objectives and scope of the new system, and its implementation. The team started their work by defining the existing system and the problems associated with it. The work then continued with the collection and refining the data required for the system. This appeared to be a critical issue regarding the implementation of computer based tool management system, since the effort and time required for this stage was underestimated.

User procedures were drafted and were further refined in the weeks to follow. This was conducted in parallel with a ten day training for the users. The training was then followed by refining the procedures and their documentation through users participation. This was further enhanced by a one day pilot study. The users were then tested on the key entry procedures. Final checks were made on the accuracy of the data and the system is went live in Aug 1992.

At the time of this interview in June 1992, the system was partly operational. However, there was clear evidence that insufficient time has been allocated to the implementation of the system, further more it seems the importance of employee education and training had been underestimated by the company's management. The company was contacted on June 1993, they reported that the system was not fully operational and more time was required to complete the implementation process.

According to the company's production engineer "As with many areas of automation the problem is not the availability of technology, but more of putting it together in a system and applying it to a particular situation. The problems that we were faced with our computer aided tool management and control system, are not so much the technological ones, but rather analytical and organisational ones such as how to best input tool data and how to organise the tools and the relevant information; how to introduce the new system, how to foster participation from all departments concern, and how to make the system work".

The company considers people and organisational changes to be the critical factors in successful implementation of the Computer aided tool management and control system. Although the system is not fully operational, the benefits of lower tool inventory levels and waste, reduction in obsolete tooling and improvement in tool room services are quit apparent. We cannot conclude at this stage whether or not the company has been successful in its implementation of CATMACS, but despite the time and effort directed at this project, the company has little to show for it. Partial allocation of resources, lack of consideration to the importance of education and training indicates the lack of commitment from the company's management.

5.6- Summary

It appears that the management of tooling resources has been receiving more attention from some sectors of industries such as Aerospace, Automotive, Defence, and heavy machinery. Although this may be due to the competitive, and technologically advanced environment in which they operate, It is significant that such industries have realised the impact of tooling on the manufacturing costs, and the efficiency of their manufacturing facilities. Table 5.3, illustrates the annual tooling budget and tooling stock value as indicated by the participant companies. However, it is important to note that, this is a familiar pattern which can be seen across all sectors of manufacturing industries but with varying degree. Hence adaptation of CATMACS in not an issue for large companies only. From this point of view, the study does not fully support Mason (1991) who argues "Although the management of tooling has been improving somewhat in specific sectors (Aerospace, and Automotive), but by and large, tool management is still in need of much greater attention from company management.

The sample classification and profile provided in the following pages attempts to provide the reader with sufficient information concerning the participant companies without referring to case studies.

5.6.1- Sample Classification and Profile

Company/Case	Product
A	Shoe Machinery
B	Precision Parts (Aerospace/Automotive)
C	Crankshafts
D	Precision Parts (Aerospace/Automotive)
E	Engine-Assembly Parts
F	Textile Machinery
G	Gas Turbine
H	Transmissions-Axles & Gearbox
J	Traction Equipment
K	Electronic Motors/Traction Equipment
L	Engine Valves & Plumbing Products
M	Hydraulic Power Equipment
N	Defence System
P	Pistons

Table 5.2: Company Classification by Product

Case/ Company	No Employed	Annual Turnover £M	Annual Tooling Budget £K	Tooling Stock Value £K
A	240	?	10-20	20-50
B	60	Under 5	70	50-100
C	400	10-30	150	100-200
D	355	10-30	175	20-50
E	2000	50-100	100+	1500
F	650	10-30	300	20-50
G	2500	50-100	100	900
H	250	5-10	250	Under 20
J	1100	50-100	175	50-100
K	800	50-100	75	100-200
L	1000	50-100	150?	900
M	600	30-50	250	100-200
N	1100	50-100	500	400
P	1000	100+	Unknown	200+

Table 5.3: Classification by Number of Employees, and Financial Data

Case/ Company	Number of Tools	% Disposable	% Non Disposable	No of Machines NC	Non NC
A	1000	20	80	20	35
B	2500	40	60	11	55?
C	5000	60	40	20	350
D	6000	40	60	15	120
E	15000	25	75	40	200
F	15000	30	70	30	90
G	100000	50	50	30	60
H	5000+	70	30	42	8
J	2000+	70	30	15	90
K	200000	25	75	18	50
L	20000	50	50	6	200+
M	4000	50	50	40	100
N	142000	46	54	75	150
P	Unknown	85	15	80	300

Table 5.4: Classification by Tooling Data

CHAPTER SIX

OUTCOMES AND PROPOSITIONS

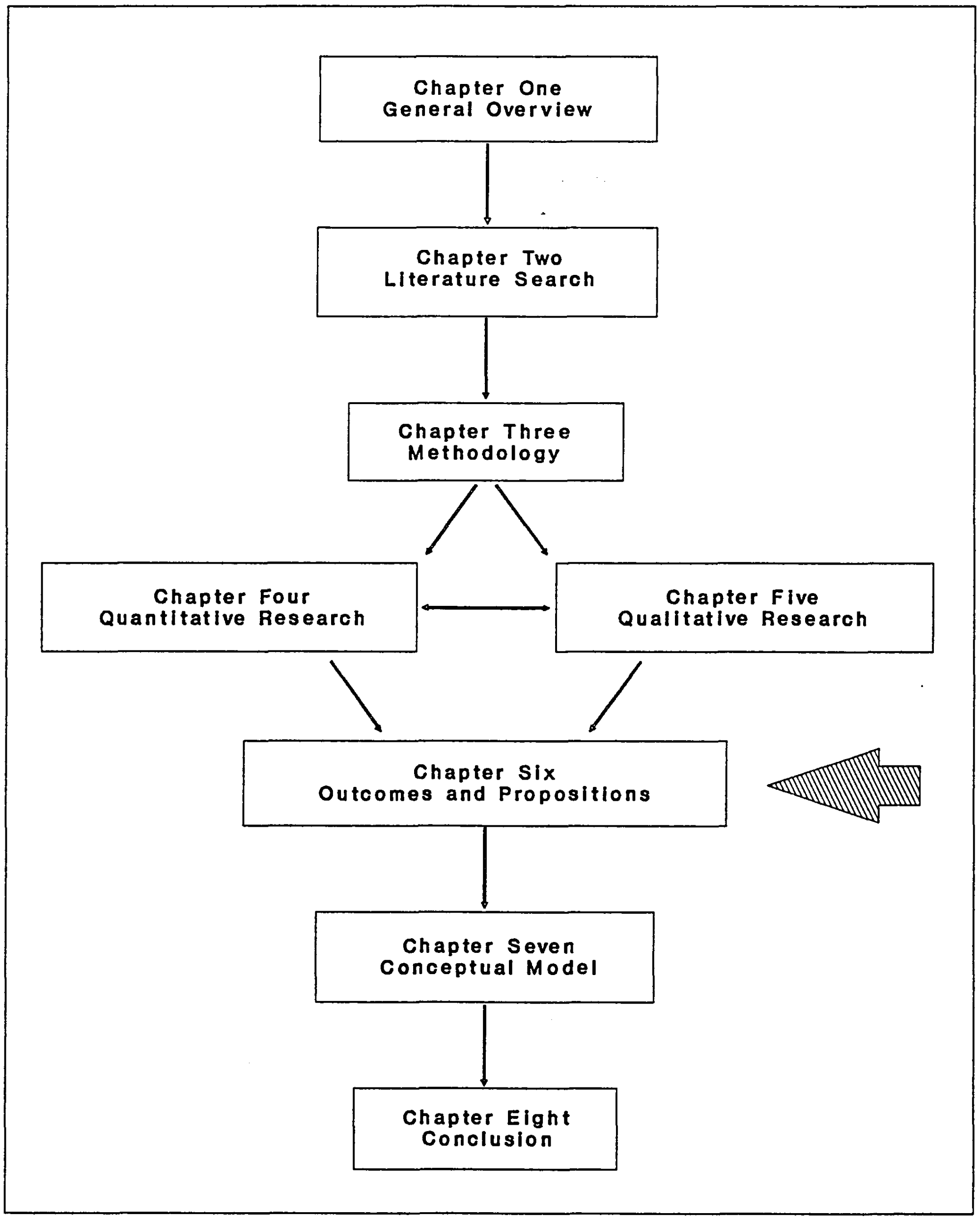


Fig 6: Process of PhD

CHAPTER SIX

OUTCOMES AND PROPOSITIONS

The within-case analysis in chapter five aimed at providing descriptive data regarding the implementation of CATMACS in participant companies. The case study write-ups have assisted the author to cope early in the analysis process with the often enormous volume of data. Whilst providing the author/reader with familiarities concerning each case, it facilitates the cross-case comparison presented in this chapter, hence, chapter six is concern with the case study outcomes and the development of the propositions. This chapter is structured as follows;

Section 6.1- Introduction

Section 6.2- Case Study Outcomes

The outcomes of case studies are presented in this section under thirteen sub-headings.

Section 6.3- Propositions

This section deals with the development of the propositions from the case study outcomes.

6-OUTCOMES AND PROPOSITIONS

6.1- Introduction

A multi stage process for building theory from case study was described in previous chapter. This chapter is concern with the last two stages of this process where, cross-case search for patterns is followed by the comparison of emergent frame with the evidence from each case study.

6.2- Case Study Outcomes

6.2.1- Company position

The mail survey revealed that 63% of respondents are experiencing difficulties regarding the management of their tooling resources. For the purpose of this section however, it is important to establish the position of the companies under investigation with regard to management of tooling prior to the introduction of computerised tool management systems. Table 6.1, shows whether or not the companies under investigation considered tooling as a problem in their business unit, and if so, what was the companies situation with regard to tooling.

The nature and causes of tooling problems were dealt with in previous chapters, however, this section provides a clear picture regarding the motives behind the introduction of computerised tool management systems. There is clear evidence that, dissatisfaction with the existing manual system, and its associated problems has encouraged the responding companies to embark on such investment. This is irrespective of the degree of significance of the precieved tooling problems.

Company number/ Case	Position with regard to tooling problems (Yes-No-Sometimes)	Situation with regard to tooling (Scale: 1-4)
A	Yes	4
B	Sometimes	2
C	Yes	3
D	Sometimes	3
E	Sometimes	1
F	Yes	3
G	Yes	3
H	Sometimes	3
J	Yes	3
K	Yes	3
L	Yes	2
M	Sometimes	2
N	Yes	3
P	Sometimes	1
Key: 1 = Not significant, 2 = Significant, but under control, 3 = Significant, and needs more attention, 4 = Significant, and requires urgent attention		

Table 6.1: Company position with regard to tooling problems

But, it is important to establish whether or not the companies made any attempt to analysis or investigate the causes of their tooling problems prior to the introduction of a new system.

6.2.2- Tool Audit

Most companies specially those under investigation were aware of the difficulties concerning the management of their tooling resource. However, the majority of the companies viewed "tool audit" as a means of establishing quantitative measures, but some attempted to identify the underlying causes of tooling problems by analysing the flow of tools throughout the manufacturing system objectively. This is illustrated in table 6.2, where the commitment made by the companies to this stage is represented by a scale of "1 to 10", representing minimum and maximum effort respectively. This stage may be crucial to the success of implementation process and will be dealt with in more detail in chapter seven. However, to comply with the tactics developed by the author, the categories or dimensions are selected in order of succession.

Company/Case	A	B	C	D	E	F	G	H	J	K	L	M	N	P
Level of Commitment to Tool Audit	5	5	8	8	5	6	7	10	5	2	10	9	8	1

Table 6.2: Level of commitment to tool audit (Scale: 1-10)

6.2.3- Investment Justification

Financial justification is usually a pre-requisite to introduction of and any new technologies in most companies. It was not surprising to discover this was also true about the introduction of computerised tool management systems. Generally, this justification was catered for in terms of projected cost savings, and expected benefits by the majority of participant companies. But in companies "B", and "P" where the decision to utilise such a system was taken at board level, the interviewee was not aware of any formal justification. However, there is little evidence which suggests decisions on the introduction of such systems are made without prior justification. Even in the case of company "P" where the utilisation of their CATMACS was purely based on a major customer's requirements, the decision to comply with such demand was heavily motivated by the need for continuous and future businesses.

6.2.4- Tool Management Software

The way by which this process was approached by many companies suggests that,the majority of the participants had established well defined and clear objectives by drawing a list of requirements for the perceived software which exceeded the proposed costs, and choice of vendor. However, the choice of vendor requires considerable attention, but, due to the limited number of specialised software manufacturers, the later did not appear to have much cause for concern.

Two of the responding companies however, preferred the development of a tailor made tool management software package in-house. One of the companies has already scrapped their project and opted for a ready made package; another company, after three years, are considering the abandonment of the project. There is an argument for and against the development of such software in house. These arguments are supported by both academia and professionals, although it seems the technical expertise employed for these developments may be the cause of such arguments. This section will be dealt with in more details in chapter seven together with the specific requirements drawn up for vendor, software and hardware selection. Table 6.3, illustrate the choice of software, its cost, and whether or not any consideration was given to software requirements. If so, did it result in any modification to the proposed software?.

Co-No	Software Package Ready made/In-house	Cost £K	Developed Specification	Modification
A	Ready made	*	Yes	Yes
B	Ready made	30	No	No
C	Ready made	30	Yes	Yes
D	Ready made	30	Yes	Yes
E	Ready made	40	No	No
F	In-house	**	Yes	Yes
G	Ready made	40	Yes	Yes
H	Ready made	30	Yes	Yes
J	Ready made	50	No	No
K	Ready made	50	No	No
L	Ready made	50	Yes	Yes
M	In-house/Ready made	50	Yes	Yes
N	Specialist Supplier	50	Yes	Yes
P	Ready made	40	No	No

Key:
* = Tool management is part of a MRP system.
** = Estimated costs of over £30K

Table 6.3: Choice of software

there is clear evidence that the companies who conducted a tool audit, also provided a criteria for system requirements based on the elimination of their existing tooling problems. This has been a major factor in providing the need for modification to the proposed software both prior and after the purchase. Acquisition and installation of software is followed by the implementation, from which, change is a crucial process.

6.2.5- The Change Process

With a significant amount of literature on the subject, very little attention has been diverted towards the management of change concerning the implementation of computerised tool management systems. Although elements of employee's participation, and education and training has been frequently reported in the case studies. The results are not encouraging. A major factor in the successful introduction of such systems is the attitude of the operators regarding the system capabilities. The extent of the problem has been as such that for some month after the implementation of the system, operators in some companies (cases; A, F, G, J, K, M, and P) have resulted in unauthorised practices, and preferred the use of a manual system over the computerised one.

The roots of this problem often lies in the perception of companies regarding the management of tooling. Tooling has not been recognised as a manufacturing resource, and is often viewed as an overhead in some manufacturing environment. As a result its impact on the efficiency of manufacturing facilities is often ignored, hence, the implementation of such systems is perceived by many companies as just "installation of the system". This is also true when considering different levels of integration within the system, and usually tooling is the last item on the list. However, it is important to emphasize that most problems associated with the implementation of such a system concerns people rather than technology, therefore, more consideration for management of change can improve the chances of success.

6.2.6- Implementation Plan

An overriding aspect of computerised tool management system implementation within the participant organisation is that, some form of project management has been in operation. This is regardless of size of the system, its complexity or simplicity, and its different applications. However, very little is known about the extent of this. In general, tasks, resource allocation, setting deadlines, and work organisation have been the main ingredients of an implementation plan. It was demonstrated in cross-case analysis in chapter five that, companies with clear plans, objectives, targets, and time table, have been more successful in the implementation of such systems. Nonetheless, it is important to see the impact of different strategies adopted by the companies regarding the implementation of such systems. This section is illustrated in table 6.4. It may be useful to point out that the responses concerning the implementation strategy are based on chronological order as provided by the respondents.

This section is similar to the study carried out by Tranfield et al (1988), However, the results are not as comprehensive. But, it is clear that strategies which are lead by business and technology dimensions with no concern for organisation dimension, have not achieved their potential benefits (company A, J, K, N, and P). This is also true about companies B, and D. Although they have been successful in the implementation of their system, lack of concern for the organisational dimension was considered to be responsible for some of the difficulties encountered after the implementation of systems. Companies (C, E, H, L, and M) who based their implementation strategy on business or technology dimension together with concern for organisational dimension reported better results.

Company /Case	Implementation Plan (Yes/No/Partially)	Implementation Strategy (O/T/B/D)
A	Yes	B/T/O
B	Yes	B/T
C	Yes	T/O
D	Yes	B
E	Yes	T/O
F	Yes	T/B
G	Yes	B/T/O
H	Yes	O/T
J	Yes	B/T
K	Yes	T
L	Yes	O/B
M	Yes	O
N	Yes	B/T
P	Yes	B

Key;
O = Organisational Dimensions
T = Technological Dimensions
B = Business Dimensions
D = Other Dimensions

Table 6.4: Implementation plan, and Strategy

Although a strategy based on three dimensions of technology, organisation, and business may be the ideal situation, this was not the case for company "A" who experienced technical problems, and company "G" who reported partial success due to organisational problems. It appears companies "A, and "G" have not fully explored the relevant dimensions.

6.2.7- Project Leader

The majority of responding organisations considered the presence of a committed, and capable champion with some degree of authority an essential criteria for the success of the implementation process. However, very few benefited from the presence of a formal implementation team, outside consultant, and a pilot project. Table 6.5, explores the companies situation with regard these elements.

Company /Case	Project Champion	Outside consultant	Formal team	Pilot project
A	Yes	Yes	Yes	No
B	No	No	No	No
C	Yes	Yes	Yes	Yes
D	Yes	Yes	Yes	No
E	Yes	No	Yes	Yes
F	Yes	Yes	No	Yes
G	Yes	No	No	Yes
H	Yes	No	Yes	Yes
J	Yes	No	Yes	No
K	Yes	Yes	No	No
L	Yes	No	No	Yes
M	Yes	No	Yes	Yes
N	No	No	No	No
P	Yes	Yes	Yes	Yes

Table 6.5: Project leader

Companies "B, and "N" did not benefit from the presence of a project champion, outside consultant, a formal implementation team, or a pilot project, yet, they reported success, and partial success of their implementation project respectively. When comparing these cases, Both companies utilised a ready made software package, with company "B" making no alteration since they did not have any specification or requirements regarding the utilised software. Both companies utilised an implementation plan together with an implementation strategy based on business and technology dimensions. The companies do differ in size, company "B" is much smaller than company "N", and appears to have a better trained and committed work force, and benefited from the full support of the top management. but, company "N" blamed their partial success on the lack of commitment by the top management, project champion, and the lack of time allocated to education and training of the operators.

The majority of the companies benefited from a project champion. knowledge, commitment, authority, leadership qualities, and dedication of the champions in companies (C, E, H, L, and M), together with the support from the top management were reported to be a crucial factor in the success of the project. In the case of the remainder of companies, the champions were somewhat limited in their achievements. This was said to be mainly due to the lack of commitment by the top management, and unavailability of necessary resources. A typical example of this situation was company "K" where, a consultant was employed by the company as a "CIM project engineer", he was delegated to lead the implementation process. Despite his effort, after two years, the company reported partial success. The project engineer put the blame on lack of management commitment, partial allocation of resources, and site security.

The presence of a consultant was reported by companies (A, C, D, F, K, and P), yet, there was little evidence regarding their full involvement with the project, and hence their contribution. The formal team allocated for the implementation process has often paid dividend for the companies, and the majority of the companies who embarked on a pilot project used this set up for training the operators. However, despite its success, the selection of more capable personnel for this task was often viewed as biased.

6.2.8- Management commitment

It appears allocation of resources, driven by the commitment of the top management to the project, has a significant impact on the success of the project. Whilst it is interesting to see the level of commitment in different companies, it is important to distinguish between full and partial commitment. It was decided at the design stage of the questionnaire that the companies who allocated all the necessary and required resources to include education and training would be categorised as companies with full commitment, and companies who allocated the necessary funds but did not give sufficient consideration to implementation issues would be categorised as companies with partial commitment.

The level of commitment to the project by the management varied in responding organisation (table 6.6), and had a direct relationship with allocation of resources. Levels of commitment may be perceived as allocating all the necessary resources to the project. However, company policy may dictate otherwise. The clear pattern developed from case studies indicates the low levels of commitment often result in partial allocation of resources , hence contributing to partial success or failure, (companies F, G, J, K, and P).

Company /Case	Level of commitment (High-Low-Medium)	Allocation of Resources (Y-N-P)	Objectives presentation (Y-N-P)
A	Medium	Y	Y
B	High	Y	N
C	Medium	Y	Y
D	Medium	P	Y
E	High	P	N
F	Low	P	N
G	Low	P	N
H	High	P	Y
J	Low	P	Y
K	Low	Y	Y
L	High	Y	Y
M	High	Y	Y
N	Medium	P	Y
P	Low	P	N
Key: Y = Yes, N = No, P = Partial			

Table 6.6: Level of management commitment

The lack of commitment has also prohibited some companies to present the objectives of the project to their employees. Some companies with low levels of commitment, informed the various head of departments within the company, but, it is important to note that the operators would be using this system, and it is advantages to give them some form of recognition by keeping them informed.

Companies with high levels of commitment, irrespective of the full allocation of resources, and presentation of objectives to the employees, often achieved their objectives (companies B, E, H, L, M). Although the companies with medium level of commitment reported success and partial success of their implementation project, there is evidence that they are not benefiting fully from the potential benefits of their system. This is due to technological and organisational problems. The evidence from case studies suggests high levels of management commitment often results in success, regardless of allocation of resources and objective presentation. Medium levels of commitment often influences the allocation of resource, and objectives presentation, hence, patchy success, and low level commitment is often associated with failure and partial success.

6.2.9- Education and Training

Education and training is widely considered to be a critical factor in the success of any implementing new technologies, and a computerised tool management system is no exception. However, the degree in which the employees were subjected to this process varied in responding companies. It is also appropriate to find out the effect of employee's computer literacy, their participation, and operation of any incentive schemes on this process. Table 6.7 illustrated the time allocated for the employee's training, their degree of computer literacy, their participation, and if their inputs were acknowledge by the company.

From the pattern in case studies, it seems the implementation of the system does not require a significant investment in the process of training. But, the companies who allocated a two weeks training programme improved their chances of successful implementation. These companies however, benefited either form the high degree of computer literacy existing within the company or high degree of employees participation.

Company /Case	Training (Days)	Computer literacy (Scale 1-10)	Employee participation (Scale 1-10)	Incentives (Yes-No)
A	5	4	5	No
B	5	2	1	No
C	10	5	5	No
D	5	5	5	No
E	5	5	4	No
F	5	2	8	No
G	2	2	5	No
H	10	5	8	No
J	1	8	1	No
K	1	2	1	No
L	10	2	10	Yes
M	1	8	8	No
N	1	6	2	No
P	10	2	2	No
Scale: 1-10 = Representing low and higher limits respectively				

Table 6.7: Education and training

Company "P" may be a good example where commitment to the training programme has been over shadowed by the lack of computer literacy and employee's participation. This company reported partial success in the implementation process, and blamed the lack of participation, and commitment to education and training. Companies (G, J, and K) provided very little in terms of training and employee participation, as a result, these companies had very little to show considering their investment. For the remainder of companies, it is difficult to embark on any conclusion. Companies with some degree of computer literacy may require less investment in terms of training, and employees participation may be regarded as a hidden motivater in the implementation process, hence, it could influence the efficiency of the training programme.

A clear indication was given by all companies regarding the operation of any incentive schemes, only company "L" considered the utilisation of some form of incentives for the operators who were instrumental in the implementation process. The company provided a 10 days training programme for its operators, the majority of whom had no knowledge of key usage, with maximum level of employee participation , together with an incentive scheme, the company reported significant achievements.

6.2.10- System Changeover

The computerised tool management system does not become operational until tooling data is input into the system. The majority of the companies under investigation underestimated the extent and the effort required for this aspect of the project. Although all companies chose to input the relevant data for different classes of tools at a time to facilitate this process, the techniques varied. It is considered important to identify the adopted methods, the transferrer, and the time required for this transaction. Another activity which often is carried out parallel to above, is possible alteration to the tool room. Table 6.8, illustrates this area.

Company /Case	Method of transfer (M/E)	Transferrer (S/T)	Time (weeks)	Tool room alteration
A	M	T	20	Yes
B	M	T	52	No
C	M	T	24	Yes
D	M	S	4	No
E	M	T	52	Yes
F	M	T	24	Yes
G	M	T	52	Yes
H	M	T	24	No
J	E	N/A	N/A	No
K	E	N/A	N/A	No
L	M	S	8	Yes
M	E	N/A	N/A	No
N	E	N/A	N/A	No
P	M	T	32	Yes

Key:
M = Manual, E = Electronically (Transferring tooling data from existing computerised databases).
S = Secretarial Staff, T = Tool room personnel

Table 6.8: System changeover

Manual transfer of data involves collection of all tooling related information. Using a keyboard, this information is then transferred to computer database. Companies "D", and "L" who benefited from the assistance of clerical staff for this operation, encountered minor discrepancies, as a result, data had to be checked for accuracy. However, the speed in which data is was transferred, accelerated the process of implementation, and reduced the possibilities of utilising manual and computerised system at the same time, as this was the case in the companies who used tool room personnel for this operation. This was mainly due to the length of time required for this activity.

The companies who benefited from some form of existing computerised tool databases dealt with this activity in a matter of hours.The decision on changing the tool room layout was reported by over half of the companies to be based on: the need for systematic transaction, security, and a better degree of control over tooling resources. In addition to above, company "L" reported "changing the tool room layout automatically gives the message that new procedures and practices are in operation, this is an important factor in changing the attitude of operators".

6.2.11- System benefits

The utilisation of computerised tool management systems has provided the participant companies with significant improvements regarding the management of tooling resources and hence, the efficiency of their manufacturing facilities. The extent of these benefits varied in different companies and this is illustrated in table 6.9.
Although some of the responding organisations have not provided a measure regarding the extent of the improvement, there is a clear pattern which indicates, as a result of a computerised tool management and control system, that the responding organisations have reduced the size of their tool inventory, obsolete tooling, time spent for expediting tools, cost of hot purchases, costs of rework and scrap, tooling budget, set-up times and delivery dates, and improved tool room services, tool tracking and control, and production schedule. However, the quantifiable values reported by some of the respondents provided an indicative perspective regarding the extent of these benefits.

	Company (% Improvement)														Average %
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	
Tool inventory	-*	-*	-*	-15	-*	-*	-*	-*	-*	-10	-*	-25	-40	-*	22.5
Obsolete tooling	-*	-*	-*	-20	-15	-*	-*	-*	-*	NC	-*	-99	-50	-*	46
Time spent expediting tools	-50	-10	-*	-20	-25	-*	-*	-*	-*	-50	-*	-50	-20	-*	32
Store services	+*	+10	+*	+25	+25	+*	+*	+*	+*	+30	+*	+*	+20	+*	22
Tool tracking and control	+20	+10	+*	+25	+50	+*	+*	+*	+*	+70	+*	+80	+40	+*	42
Cost of hot purchases	-80	-*	-*	-45	-*	-*	-*	-*	-*	-70	-*	-80	-5	-*	56
Cost of rework and scrap	-40	-*	-*	-5	-*	-*	-*	-*	-*	NC	-*	-*	-5	-*	16.6
Tooling budget	-20	-15	-*	-30	-10	-*	-*	-*	-*	NC	-*	-*	-50	-*	25
Set-up times	-10	-10	-*	-25	-25	-*	-*	-*	NC	NC	-*	-50	NG	-*	24
Production schedule	+50	+15	+*	+7	+*	+*	+*	+*	+*	NC	+*	+*	+5	+*	19
Delivery dates	+*	+*	+*	+40	+*	+*	+*	+*	+*	NC	+*	+*	+2	+*	21

Key:
* = +/- unquantifiable value,   NC = No change,   NG = Not given

Table 6.9: System benefits

On average the responding organisations benefited from a 22.5% reduction in the size of their tool inventory, 46% reduction in obsolete tooling, 32% reduction in time spent expediting tools, 56% reduction in the cost of hot purchases, over 16% reduction in the cost of rework and scrap, 25% reduction in tooling budget, 24% reduction in set-up times, 22% improvement in store services, 42% improvement in tool tracking and control, 19% improvement in the production schedule, and 21% improvement in meeting delivery dates. Due to unavailability of references it is difficult to confirm the validity of such measures in all of the above categories. However, Mason (1986,1991) provided some quantifiable measures concerning the benefits of CATMACS implementation. He reported; 60% reduction in the size of tool inventory, 40% reduction in the costs of rework and scrap, and 20% reductions in tooling budget. It appears that the extent of such benefits varies from one company to another.

Although some companies could not provide quantifiable values due to unavailability of such information, based on our experience, we are of the view that they would not reject such findings. further, because the measures are based on hard data, we can conclude that the results are representative.

6.2.12- Evaluation

Based on the results of the previous section, one may assume that the implementation of computerised tool management systems has been a success in all the companies under investigation, But, five companies reported only partial success. Further, there were differences of opinion regarding the measure of success. These two areas are illustrated in table 6.10, together with the estimated payback period.

Company /Case	Evaluation (S-F-PS)	measure of success (F-O-B-P)	(Payback Period) (month)
A	S	P-B-F-O	24
B	S	O-P-F-B	24
C	S	B-P-F-O	NG
D	S	F-B-P-O	24
E	S	P-F	12
F	S	F-B-O	36
G	PS	P-B-F	60
H	S	P-F	6
J	PS	P-O	24
K	PS	F-O	36
L	S	O-F-P	12
M	S	F-O	36
N	PS	P	NG
P	PS	P	NG

Key:
S = Success, F = Failure, PS = Partial success
F = Financially, B = Business efficiency,
O = Organisationally, P = Out put efficiency,
NG = Not given

Table 6.10: Evaluation

From table 6.10 the majority of the responding companies considered the implementation of their tool management system a success. But, companies who experienced technical, and organisational difficulties (G, J, K, N, P) reported only partial success. Although, the companies measured their success in terms of a combination of the factors described in table 6.10, it is clear that computerised tool management system has positive effects on the efficiency of manufacturing facilities. The latter is complemented by the fact that the companies have received a better return on their investment than some financial institutions. Only company "G" who partially benefited from the implementation of CATMACS reported a payback period of five years, compared to the majority of the companies who achieved 100% payback within the maximum of three years. This study partially supports the documented proof suggested by Brown (1991) who reported a computerised tool management and control system could have a payback period of 6 to 9 months.

The payback periods reported by the respondents provides an incentive for companies who wish to benefits from the introduction of such systems. However, It is important to identify the factors which influence and have an impact on the payback period.

Whilst it is difficult to relate the payback period directly to a series of activities concerning the implementation of CATMACS, is also difficult to ignore the impact of such activities on the success of these systems, and their payback periods. This is mainly due to the fact that companies vary from one another in size, culture, manufacturing processes, organisation structure and behaviour, and working practices. For example, the development of software specification, or, modular implementation of CATMACS could contribute to two different payback periods in two different companies. However, some CATMACS implementations have provided shorter payback periods than others. This is mainly due to the following apparent reasons.

- System analysis.
- System requirements.
- Implementation plan.
- Project Champion.
- Employee's participation.

- Employee's education and training.
- System changeover.

Generally, companies who identify tooling problems through the analysis of their existing tool management system often develop a software specification to deal with such inefficiencies. Such analysis and system requirements ensures the suitability of the proposed software and reduces the chances of future pitfalls, hence, reducing the chances of any delays. It may be argued that such analysis and requirements are actions prior to the actual implementation process. However, we are of the view that the implementation of CATMACS requires more than just adaptation of technology, and many important determinants of successful implementation are actions and conditions prior to development/purchase, installation, and utilisation of the system (section 2.6 page 21). Case "H" may be a good example where the company reported a payback period of 6 months. But, this company spent over 12 months analysing their existing tool management system in an attempt to identify the nature and causes of tooling problems. Whilst recognising their achievement, the absence of an implementation plan at the beginning of the project is quite evident.

An implementation plan accompanied with clear and well defined targets and realistic time scale often contributes to shorter payback period. Modular implementation and pilot projects are often instrumental in this process as they reduce the impact of change and highlight any inefficiencies within the proposed system. However, commitment, dedication, and knowledge of the project champion often has a significant impact on the success of the system and the proposed targets and time scales.

An important factor concerning the successful implementation of CATMACS and its payback period is the degree of acceptability of the system by the end users. Their positive attitudes and commitment to the project can only be fostered through participation, and education and training. Although the degree of operator's computer literacy can effect the payback period, a well structured/organised education and training programme can compensate for this inefficiency.

System changeover is referred to as the transfer of tooling data into computer databases, and has a significant impact on the success of the implementation process and its payback period. This is due to the fact that the CATMACS cannot operate without accurate and up to date tooling information. However, the time, and resources required for this process often exceeds companies expectation. This is mainly due to the unavailability of tooling data, and the lack of tooling information provided by the index/card systems. The electronic transfer of tooling data provides the most reliable and accurate technique within hours (depending on the size of data). However, this technique is not an option for the majority of companies who utilise manual techniques of data transfer, benefiting from the assistance of tool room or clerical personnel. The reported time scale for this activity varies from 4-52 weeks, hence, the speed in which data is transferred accelerate the process of implementation.

6.2.13- Critical Factors

Critical factors in the implementation of Advanced Manufacturing Technology are being widely reported, however it is important to see whether they apply to the implementation of computerised tool management systems. The responding companies were in a good situation to experience such factors first hand. These are illustrated in table 6.11, as reported by the responding companies.

company number	Critical Factors
A	Management commitment, Operator's acceptance, and Positive attitudes.
B	Management commitment.
C	Operator's confidence.
D	Allocation of resources, education and training, Time, and The process of change.
E	Education and training, Implementation plan, and Consultation.
F	Champion, Management commitment, and Education-and training.
G	Management commitment, Education and training, and Consultation.
H	System specification, Method of implementation, and Time.
J	Confidence in the system, Education and training , and Control.
K	Management commitment, Site security, Education, and training at all levels.
L	The change process, Information base, Team work.
M	Education and training, Control, and proper plan for Implementation.
N	Management commitment, Champion, Education and-training.
P	People, and Organisational change.

Table 6.11: Critical Factors

Although the responding companies have expressed their experiences regarding the critical factors, they seem to have a lot in common, but, differently expressed. For example, operator's suggestions, positive attitudes, consultation, confidence in the system, site security, information base, and team work, are the sort of problems which one could associate with education and training, and the management of change.

Based on the above information, and face to face experience of the author with the participant companies, it appears that, management commitment, project champion, employee's participation, education and training, and management of change, may be the critical factors in the implementation of such system.

6.3- Propositions

The propositions have been developed from the outcomes of case studies, and personal interviews. These are intended to form a focus for the findings of the study in an attempt to find a rationale for the out come of fourteen case studies. The developed propositions are based on majority rule, but, where a potential proposition could not be verified by majority of cases, it has not been developed.

6.3.1- Company Position

Tooling if often viewed as a manufacturing residual, with little concern for its effect on manufacturing facilities.

> **1a** Companies who give no priority to tooling, often reduce the efficiency of their manufacturing facilities.

There is significant evidence which points out to inefficient management of tooling resources in the manufacturing environment. This has encouraged some manufacturers to look for a solution in new innovations and technologies.

> **1b** Companies who experience difficulties in the management of their tooling resources are the frontiers for the introduction of computerised tool management systems.

This proposition provides the basis for a second proposition:

1c The bigger the company, and its manufacturing activities, the higher the extent of its tooling problems.

6.3.2- Tool Audit

Proposition "1b and 1c" is based on the theory that the size and level of manufacturing activities has a direct relationship with the number of tools that have to be monitored, serviced and controlled. These two propositions however, lead to the following comprehensive proposition.

2a Companies who identify the underlying causes of tooling problems prior to purchase, or development of a Computerised Tool Management System (in-house), significantly improve the chances of successful implementation.

A system audit can provide the companies with sufficient data regarding the management of their tooling resources. This data often bears the underlying causes of tooling problems within the company, consequently, it often leads to system definition, which can be used for the benefit of the computerised system. For example company "H" spent over twelve months analysing and identifying the nature and causes of their tooling problems, a further three months was then spent drawing a set of requirements for the proposed software. Disregarding the period of time allocated to this task, all the participant companies except "K, and P" attempted to identify the problems and improve the management of their tooling resources to various extent. This resulted in proposition "2b"

2b Companies who develop a set of requirements and specifications for the computerised tool management system, often achieve their objectives regarding the implementation of CATMACS.

This proposition is important because it is based on the company's existing tooling problems, and utilisation of a computerised system is intended to assist in overcoming such problems. Hence the knowledge of CATMACS concept can place the company's requirements within the context of suitable and available packages.

2c Knowledge of CATMACS concept often facilitates the development of the system requirements.

6.3.3- System justification

An area of concern regarding the implementation of CATMACS is its justification, which takes two forms: system and financial, which although connected to one another, are separate issues. However, proposition "3a" is developed to accommodates both forms.

3a Justification for system/investment is an indication of the level of interest, and often leads to reasonable expectation.

Although justification was generally based on the expected benefits and cost savings, it was expressed differently by the participant companies. For example in company "B" costs of expediting tools and delays in production schedule, in company "F" tool unavailability, and in company "L" cost of tooling provided the justification for the investment. But, it is important to note that, companies who had formulated their expectations regarding the implementation of the system were more successful in achieving them.

3b Expectations are more likely to be met than used as factors for justification.

6.3.4- Tool management software

There are a limited number of software houses who are specialised in this area. Their reputation is based on their expertise, quality of products, and after sale service. This lead to propositions "4a", "4b".

4a Companies who utilise a ready made package from reputable software houses, experience little or no difficulties concerning its technical, and operational details.

Proposition "4a" is based on the fact that the majority of responding companies utilised a ready made package. But, in the case of company "M", although the development of their tool management software (in-house) provided them with the benefits of; reductions in the size of their tool inventory, obsolete tooling, and time spent expediting tools, it did not assist the company in achieving their objectives concerning the management of their tooling resources. Despite its failure, it enabled the company to develop a clear set of specifications for a ready made package. The author is aware of two more cases (Not reported) where the development of such software (in-house) has not yielded its full potential. This may be due to the technical expertise required for the development of these packages.

Most responding companies usually developed some form of specification regarding their computerised tool management system. Hence, they demanded special attention from the software manufacturer. These demands often required some technical, or operational modifications.

> **4b** Companies who develop software specification, often demand modification, consequently, improving their chances of a successful implementation.

This proposition provides the basis for proposition 4c.

> **4c** Companies who evaluate the proposed software against their required specification are more successful in the implementation of CATMACS.

6.3.5- The Change Process

The lack of attention to tooling and its impact on the efficiency of manufacturing facilities, together with the low levels of investment (in manufacturing terms) required for the introduction of CATMACS in most companies has often overshadowed the importance of the management of change within the participant companies. As a result this did not lead to any proposition. However, companies "D,L, and P" reported that this process is a critical factor in the successful implementation of CATMACS.

6.3.6- Implementation Plan

The presence of some form of planning for implementation was quite evident throughout the case studies, and lead to a number of propositions.

6a Companies who develop an implementation plan are more likely to meet their objectives.

6b A well structured implementation plan, provides a means of measuring progress, hence, increasing the likelihood of success.

6c A module/phased implementation plan, provides short term targets which are visible, easier to monitor, and enhances the chances of success.

6d The more input from the departments involved, the higher the level of their commitment to the project.

An exceptional situation was reported by company "B" which is relatively smaller than other companies who took part in this study. In this company the implementation of CATMACS was not based on a formal plan. Although, the observation of operations and manufacturing facilities together with conversation with shopfloor operators suggested that the system is not being fully utilised, the production planning engineer reported that the implementation of their system has been a success. Whilst recognising their achievements concerning the management of tooling, there were clear evidence concerning the absence of an implementation plan.

An interesting finding which led to proposition "6e" was that the majority of the companies who introduced single tool categories at a time, allowed the shopfloor operators time to adjust to the new system, hence increasing the chances of success.

> **6e** Modular implementation increases the chances of successful implementation.

The objectives of computerised tool management system implementation varied from one company to another, but they all led to the desire for the need to improve the management of tooling resources, and reduction in manufacturing costs.

The strategy regarding the successful implementation of Advanced Manufacturing Technologies has been described by Tranfield (1988), as a strategy which based on organisational, technical, and business dimensions. It is interesting to see the impact of such dimensions on the development of propositions.

> **6f** Strategies which do not cater for an organisational dimension reduce the full potential benefits of CATMACS implementation.

Despite the reported success by many companies, lack of concern for this dimension was blamed for the majority of the organisational problems concerning the implementation of CATMACS.

6.3.7- Champion

The need for a project leader/champion is widely reported throughout the case studies except companies "B", and "N" where, they reported partial success in the implementation of their CATMACS. However, the criterias of authority, knowledge, drive, enthusiasm, commitment, dedication and ability described by the companies, points to the contribution of a champion as a diving force in such projects. This has lead to following propositions:

7a To succeed, the champion needs the drive, responsibility, and authority to carry out the task of implementation effectively.

The position of champion in the organisation was over-shadowed by his knowledge, ability, and commitment. This lead to two propositions:

7b Regardless of position, the champion should have the knowledge, and ability to manage the transformation effectively.

7c Implementation is more likely to be successful where the champion exhibits a constant level of commitment and enthusiasm.

This proposition is important for two reasons; first, it leads to the next propositions, emphasising the importance of the champion's commitment to the project; second, his commitment level can be easily over-shadowed by the commitment from the top management.

7d High commitment of the champion can influence the degree of commitment provided by the user group.

7e Champion's contribution to the project is significant if he has the management's support.

Some companies (A, C, D, F, and K) benefited from the services of an outside consultant but, this did not lead to any propositions. However, The implementation of a pilot project was welcomed by many companies, and resulted in proposition "7f".

7f A pilot project provides real time data for serious implementation, consequently,its success contributes towards system implementation.

6.3.8- Management commitment

Management often plays an important part in the implementation process. Their commitment by allocating resources and participation in the project, is indicative of their level of interest in the project. This has a significant impact on the successful implementation and has lead to following propositions;

8a Medium and high levels of commitment displayed by the company's management improves the chances of success.

8b Companies who allocate all the necessary resources to the project, reduce the chances of failure.

It is important to note that companies "G", "J", "K", "N", and "P" who benefited from low, and medium level of management commitment (Please refer to section 6.2.8), reported partial success concerning the implementation of CATMACS. This was further supported by the above companies who considered "management commitment" as a critical factor in successful implementation of CATMACS.

An interesting proposition emerged through the case studies, which some what represents the commitment of the company to the project and its importance. This has taken the form of proposition "8c".

8c Companies who present the objectives of their computerised tool management system to their employees, increase the chances of successful implementation.

6.3.9- Education and training

A well designed training programme is vitally important to the successful outcome of the implementation process and covers training provided by the vendor, and the company's own training programme. Software houses generally provide some training for the proposed system, however, the extent of this training has some impact on the out come of the project. This lead to following propositions.

9a Companies who take advantage of full training offered by the vendor, make better progress than those which take the minimal training.

9b The higher the magnitude of education and training, the higher the chances of success.

9c The higher the degree of computer literacy, the lower the magnitude of training. Consequently, lower degree of resistance to change.

9d The greater the complexity of technology (hardware/software), the higher the level of learning required in the organisation.

Proposition "9a, and 9b" are often influenced by the level of the company's computer literacy, and complexity of technology irrespective of the training source. Company "P" is a good example where, a ten days training programme contributed little to the partial success of the implementation process. This is also true about companies "G", "J", "K", and "N" who benefited from a one day training course. Not surprisingly the above companies reported "Education and Training" to be a critical factor in the success of the implementation of CATMACS.

There was a majority agreement on the impact of management's participation in the education and training programme. This led to proposition "9e".

9e Participation of management in the education and training process, can only assist the implementation.

Another area of concern which is related to this section is, employee's participation throughout the project. This has been an influencing factor in the success of such projects in many companies (Except companies "G", "J", "N", and "P" who reported partial success) and has lead to a three propositions;

9f The higher the level of employee's participation, the higher the likelihood of acceptability, and hence success.

9g Investigating operator's suggestions, increases the level of acceptability of the system, and reduces the chances of failure.

However, there is little evidence regarding the impact of incentives on the success of such a project.

9h The highest reward for those who are instrumental in the implementation process is its success.

6.3.10- System changeover

Transferring tooling data into computer data bases is usually the longest activity in the implementation of computerised tool management system for many companies. However, the time span depends heavily on the utilised method. Companies "D", and "L" who allocated the task of building the tool databases to secretarial staff, managed to complete this process in 4, and 8 weeks respectively. But, some inaccurate entries resulted in double checking. This resulted to proposition 10a.

10a Companies who use tool room personnel to input data, usually reduce the chances of incorrect entry.

System changeover is usually accompanied by some alterations to tool stores.

10b Changing tool room layout is an indication of new practices and procedures.

6.3.11- System benefits

All the companies under investigation reported their success and partial success in improving the management of their tooling resources. This led to proposition "11a".

11a Companies who embark on the implementation of CATMACS are often successful in achieving their objectives.

This is due to number of factors including; extent of change, low level system complexity, and organisational factors. However, companies measured this success differently.

6.3.12- Evaluation

The code used to analysis this part of the study in "section 6.2.12, table 6.10" relied on four responses "F-O-B-P" representing; financially, organisationally, business, and output efficiency respectively. Assuming output efficiency often leads to business efficiency which in turn, leads to financial gains, the companies have measured their success in financial gains. If this line of logic is reasonable, then, it leads to proposition "12a".

12a Unavailability of financial data complicates the financial justification of CATMACS implementation. But, the benefits of such implementation are measurable in financial gains.

This proposition is influenced by the lack of knowledge and awareness concerning the cost of tooling within the surveyed sample. However, estimated project cost savings and expected benefits have often provided the justification for such investment.
Proposition 12a may be complemented by the next proposition and it is based on the payback period reported by the sample under study (6, and 60 months representing the range).

12b Average payback period of CATMACS is three years.

6.3.13- Critical Factors

The critical factors regarding the implementation was expressed in different form and context, however, when analysed, it leads to the proposition:

13a The critical factors in implementation of CATMACS are; management commitment, project champion, employee's participation, education and training, and management of change.

CHAPTER SEVEN

THE MODEL

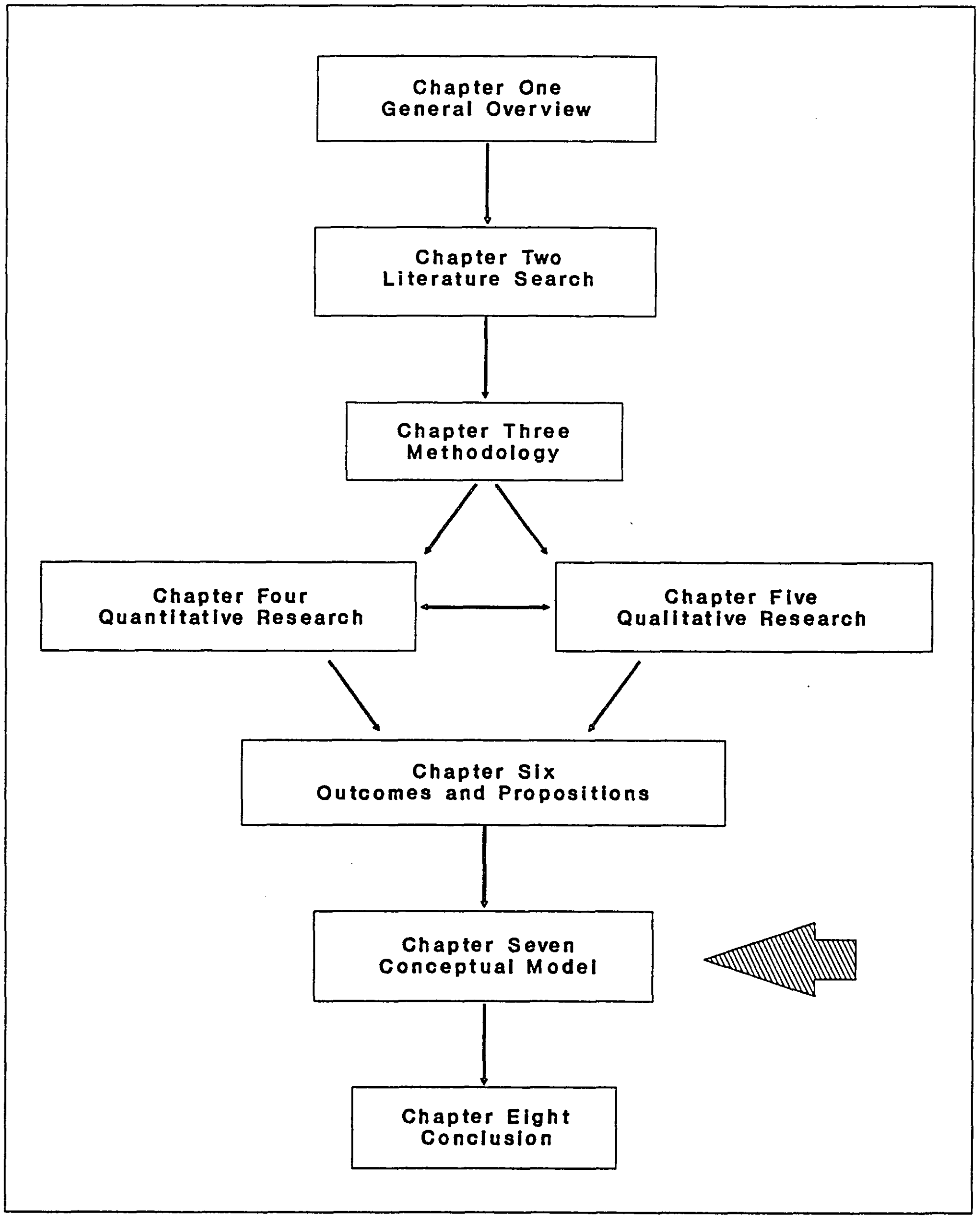


Fig 7: Process of PhD

CHAPTER SEVEN

THE MODEL

7.1- Introduction

Based on the outcomes and propositions developed in chapter six, this chapter develops a framework for a methodological tool which could, upon further development, be used by companies and consultants in the implementation of CATMACS. Whilst the framework has been developed inductively from case studies, it was impossible to divorce the relevant theories from the literature. However, to provide the reader and anyone embarking upon such task with more information, each phase of the framework is expanded, and is followed by the relevant propositions.

7.2- Initial Framework

The model was initially developed based on the propositions of chapter six. Whilst the 40 propositions were developed under thirteen dimensions described in chapter five, they fell into five categories of;

- Propositions relating to existing feature of the company and their position regarding the management of tooling.
- Proposition concerning the future management of tooling resources.
- Propositions relating to preparation for the implementation of CATMACS.
- Propositions relating to Implementation of CATMACS.

- Propositions relating to achievements.

A review of the propositions however, revealed a parallel between their sequence and what may be regarded as a morphogenic change (General change model) which addresses the following questions;

- **Where are we now?**
- **Where do we want to go?**
- **How do we get there?**
- **What action must we take?**
- **How do we know we are there?**

To find a series of derived propositions related so closely to a general change model was encouraging and the link was undeniable. Therefore, if the propositions indicate a structure, by developing such structure to accommodate the propositions, we should conclude with a methodology for implementation. Such methodology, if followed through, avoiding pitfalls and benefits described in the propositions should lead to a successful implementation. With this in mind, a framework for the methodology has been developed (Fig 7.1) based on five sequential phases;

- **Strategy** Improving the management of tooling resources.

- **Tool Audit** Analysing the company's situation with regard to tooling (system analysis, and system requirement)

- **System Design** Development of requirements for software, hardware, organisation context, and action plan.

- **Action** Making CATMACS operational in the company environment.

- **Review** To evaluate the performance of the project as a whole.

Each phase is important and successful implementation of CATMACS is the function of all these phases. The relevant propositions are shown in table 7.1. However, the definition of the terms used for each phase is as follows:

Phase 1- Strategy

Terms:

Terms	Definitions
Technology Dimension	Installation strategy.
Business Dimension	Competitive position of the company.
Organisation Dimension	Organisation Design.
Prioritisation	Level of priority within manufacturing environment.
Environmental Factors	Management Commitment.

Phase 2- Tool Audit

Terms:

Terms	Definitions
Current System	Existing tool management system.
CATMACS Concept	Concept of computerised tool management and control system.
System Bottlenecks	Tooling problems.
System Definition	Requirements for the proposed system.

Phase 3- Design

Terms:

Term	Definition
Organisation Context	Departments and people who would be affected as a result of change, together with those who are instrumental in the change process

Phase 4- Action

Terms:

Terms	Definitions
Environmental Change	Internal changes.
System Conversion	Replacing the manual system by computerised tool management system

Phase 5- Review

Aim- To evaluate the outcome of the project as a whole.

CATMACS Implementation Model

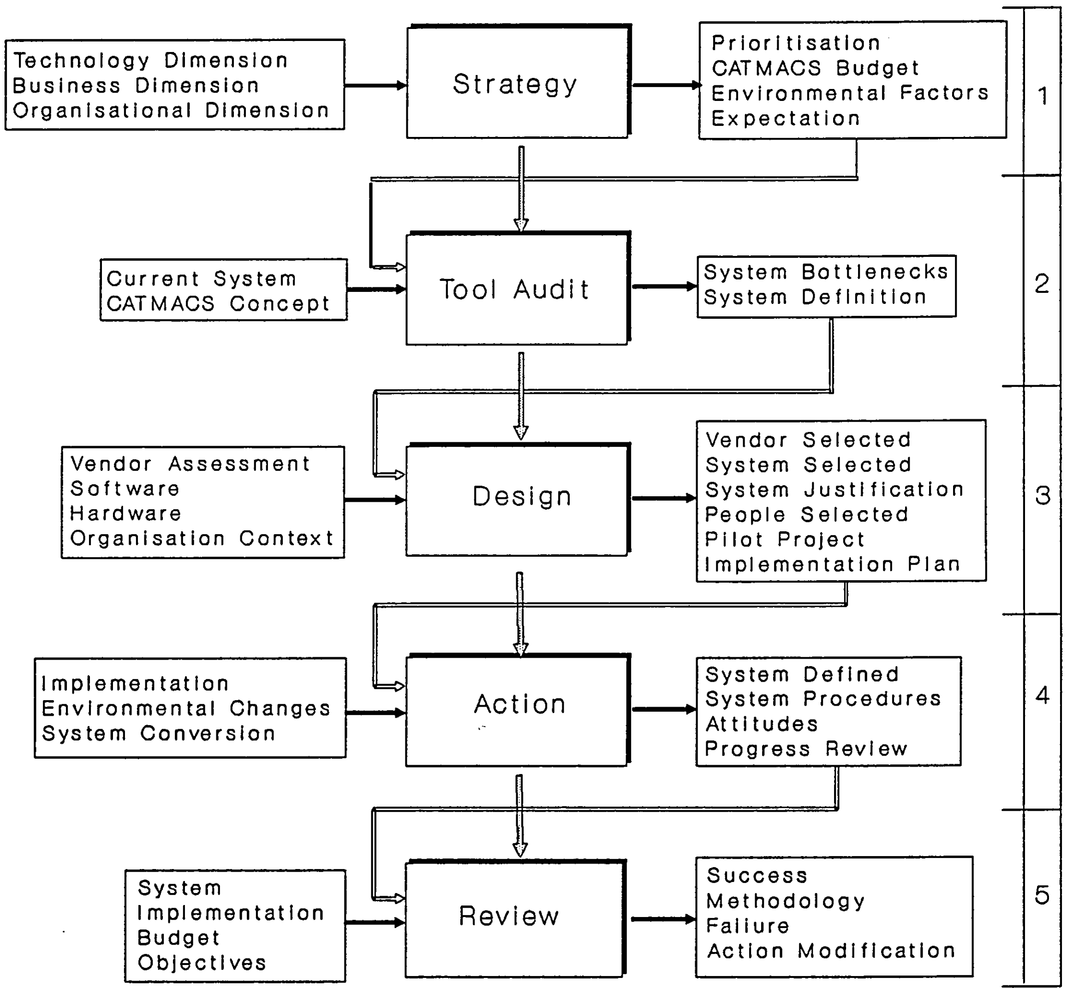
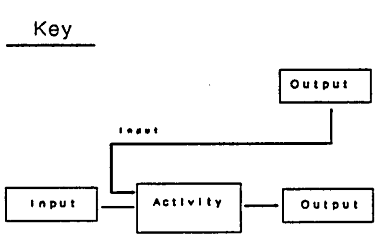


Fig 7.1: Initial Framework



Phase	Inputs	Outputs	Propositions
Strategy	Organisational Dimension Business Dimension Technology Dimension	Prioritisation Environmental Factors CATMACS Budget Expectation System Justification	1a 8b 3a 3b 6f 8a
Tool Audit	Current System CATMACS Concept	System Bottlenecks System Definition	1b 2a 2c 1c 2b
Design	Vendor Assessment Software Hardware Organisation Context Prioritisation Environmental Factors CATMACS Budget, Expectation	Vendor Selection System Selection People Selection Pilot Project Implementation Plan	4a 7e 4b 8c 4c 9e 6a 9f 6d 9g 7a 7b
Action	Vendor, System, People (selected) Implementation Plan, Pilot project. Installation Environmental Change System Conversion	System Defined System procedures Attitudes	6b 7f 10a 6c 9a 10b 6e 9b 7c 9c 7d 9d
Review	System Implementation Budget Objectives Attitudes	Success Benefits Methodology Action Modification	9h 11a 12a 12b 13a

Table 7.1: Propositions, Inputs and Outputs relating to each phase of the Framework

7.3- Phase 1- STRATEGY

The successful implementation of AMT relies on a strategy which is based on organisational, technical and business dimensions Tranfield (1988). However, a strategic approach to the management and control of tooling resources may be viewed as an essential ingredients for successful utilisation of this manufacturing resource.

On the business side, the objective of CATMACS strategy is to improve the efficiency of manufacturing facilities, and hence, the competitive edge of the company by setting policies and defining procedures regarding the management of tooling resources from implementation to utilisation. From this point of view, the intervention of CATMACS satisfies both short and long term needs of the business/company. On the organisational dimension, CATMACS is operator's system and its successful utilisation relies heavily on their acceptance and attitudes of the end users. Therefore considerable attention should be diverted towards organisational issues (Section 7.3.3). It is however difficult to separate this dimension from the technical issues which are equally important.

On the operation side, decisions such as; tool replacement/renewal point, tool status, tool life, minimum and maximum stock levels, and order levels can contribute towards the costs of waste, rejects, reworks, and can affect the quality of the products. However, with strategic management of tooling resources such costs can be avoided. Further there is evidence that strategic management of tooling resources can result in financial awards. A number of issues that have to be addressed at this stage are as follows:

7.3.1- Prioritisation

Tooling is often regarded as a manufacturing residual by many companies, and little consideration is given to its effect on the efficiency of production systems. Melnyk (1988) suggests "The only time tooling receives any attention is when there is a problem involving tooling". This view was expressed in different terms by the majority of the respondents. A manufacturing Engineer reported that lack of prioritisation of tooling at the design stages of products has been a contributory factor in the size of their tool inventory, over 100,000 tools.

7.3.2- Environmental factors

This refers to the commitment of the company's management to the proposed system project. It also encompass the promotion of concept of tooling as a manufacturing resource and a source of productivity by the management.

7.3.3- Expectation

Setting expectation may be an integral part of the implementation process. It is important that minimum levels of expectation together with expected changes, and any negative expectation are communicated with the individual and departments involve. Such expectation often improve the chances of the successful implementation. further, negative expectation often reduces the impact of anticipated problems.

7.3.4- CATMACS Budget

An estimation of the costs involved should be prepared in the form of a realistic budget, and should include;

1- Cost of hardware.

2- Cost of software.

3- Annual cost of maintenance, and up grading.

4- Cost of personnel.

5- Cost of education and training.

6- Cost of documentation.

7- Cost of implementation.

7.3.5- Propositions:

1a Companies who give no priority to tooling, often reduce the efficiency of their manufacturing facilities.

3b Expectations are more likely to be met and used as factors for justification.

6f Strategies which do not cater for organisational dimension reduce the full potential benefits of CATMACS implementation.

8a Medium and high levels of commitment displayed by the company's management improves the chances of successful implementation.

8b Companies who allocate all the necessary resources to the project, reduce the chances of failure.

7.4- Phase 2- Tool Audit

The objective of a tool audit is commonly viewed as means of establishing quantitative measures by many companies. However, tool audit may be seen as a process which provides the bases for the introduction of an effective computerised tool management and control system, alternatively it can enhance the performance of the existing system. It further assists in identifying the nature of tooling problems within companies. Computerisation does not solve poor management practices, if anything, it creates more problems. However, the solution to existing problems would enhance the efficiency of the manual system, which in turn, facilitates, and improves the success of CATMACS implementation. The objectives of a tool audit may be summarised as follows;

1: To establish quantitative measures (tooling stock and their values).

2: To provide the basis for building a tool database based on accurate data.

3: To assist in identifying the underlying causes of tooling problems by analysing the flow of tools throughout the manufacturing system objectively, and to study the current operational practices Fig 7.2.

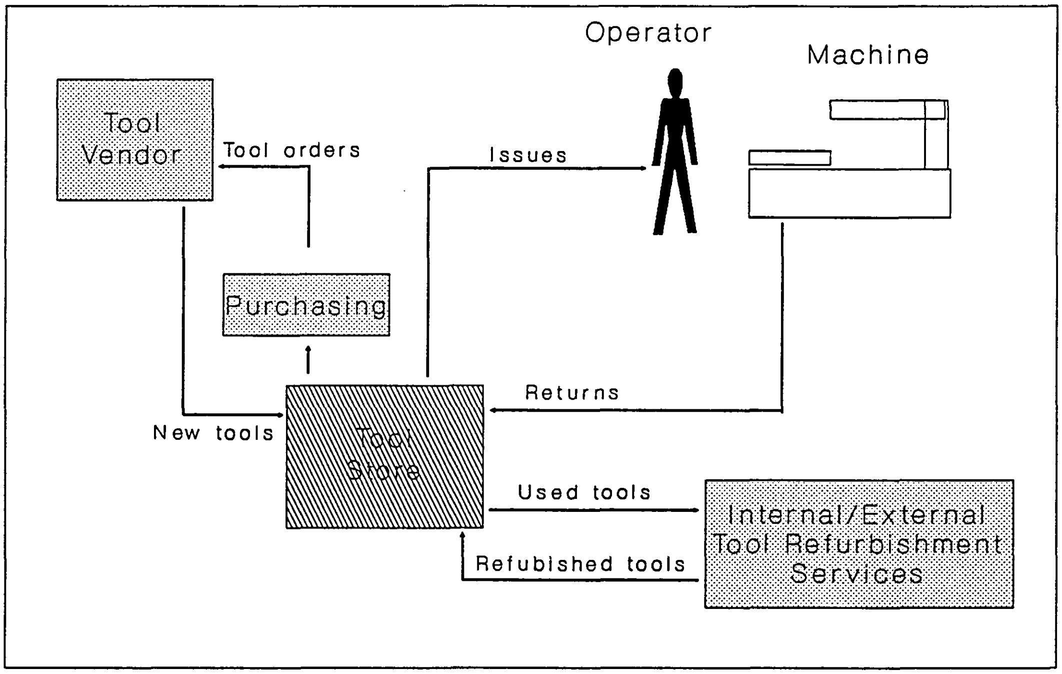


Fig 7.2: The flow of tools through manufacturing systems

The approach in which the objectives of tool audit are achieved is through;

- Identifying the size and value of existing tool inventory.
- Assessing the policies and procedures concerning the management and control of tooling resources.
- Addressing the organisational structure.
- Addressing the control procedures.

7.4.1- Identifying the size and value of existing tool inventory;

The key issue concerning objectives 1, and 2 is the presence of an organised and effectively administered tool crib where tools can be readily and systematically stored and identified. The first step in conducting a tool audit is to identify the size of the existing tool inventory, and its value. Tool coding and classification provides a convenient method of identifying tools, as it conveys the maximum amount of information in a shorthand version. But, it is vital that a suitable tool marking procedure is employed and operational. When building the tooling inventory, it is important to identify and distinguish between different classes of tools. This is due to the fact that tooling differs in terms of physical size, cost, storage requirements, disposable/non disposable, and the required degree of control. Some companies favour the "ABC" analysis which provides various degrees of control over tooling, with A class being the most important in terms of cost.

When conducting a tool audit, the identification of the obsolete tooling provides a number of major benefits; first, they can be removed from the system. Second, the space provided, can be used for storage of other tooling. Third, the disposal of obsolete tooling often results in financial gains. This can contribute towards the cost of new system, and further, it facilitates the financial justification of the investment. The above benefits were appreciated by the companies who removed their obsolete tooling from the system.

Tool crib layout is often subject of some modification when conducting a tool audit. tool cabinets, special racks, draws, and all storage facilities should be clearly market. The transaction bay is another area which should be considered prior to any changes concerning the tool crib layout. At the basic level, The tool crib should be geared; to impose better control over tooling resources, maximum utilisation of available space, proper storage to avoid tool damages, faster location of tools, faster transactions, and elimination of queues by the tool crib bays.

There is no rule regarding the physical collection of tools throughout the shop floor and their storage in the tool crib and could vary from one organisation to another. This is also true about designing security, developing procedures, and establishing accountability. However, a strategy should be adopted to foster the return of all tools by the operators. This is essential to the success of the operating system and should be approached with care. A gradual approach (considering one class of tool at any one time) accompanied with the operator's participation, education, and training could greatly influence a successful transaction. Fig 7.3, illustrates this stage of a tool audit where; downward arrows represents the constrains on the activity, upward arrows, represents the means by which the activity has been conducted, and arrows pointing away from the right hand side of the activity representing the outcome, and input to the next activity. However, there is no sequential requirement for the activities which are surrounded by circles.

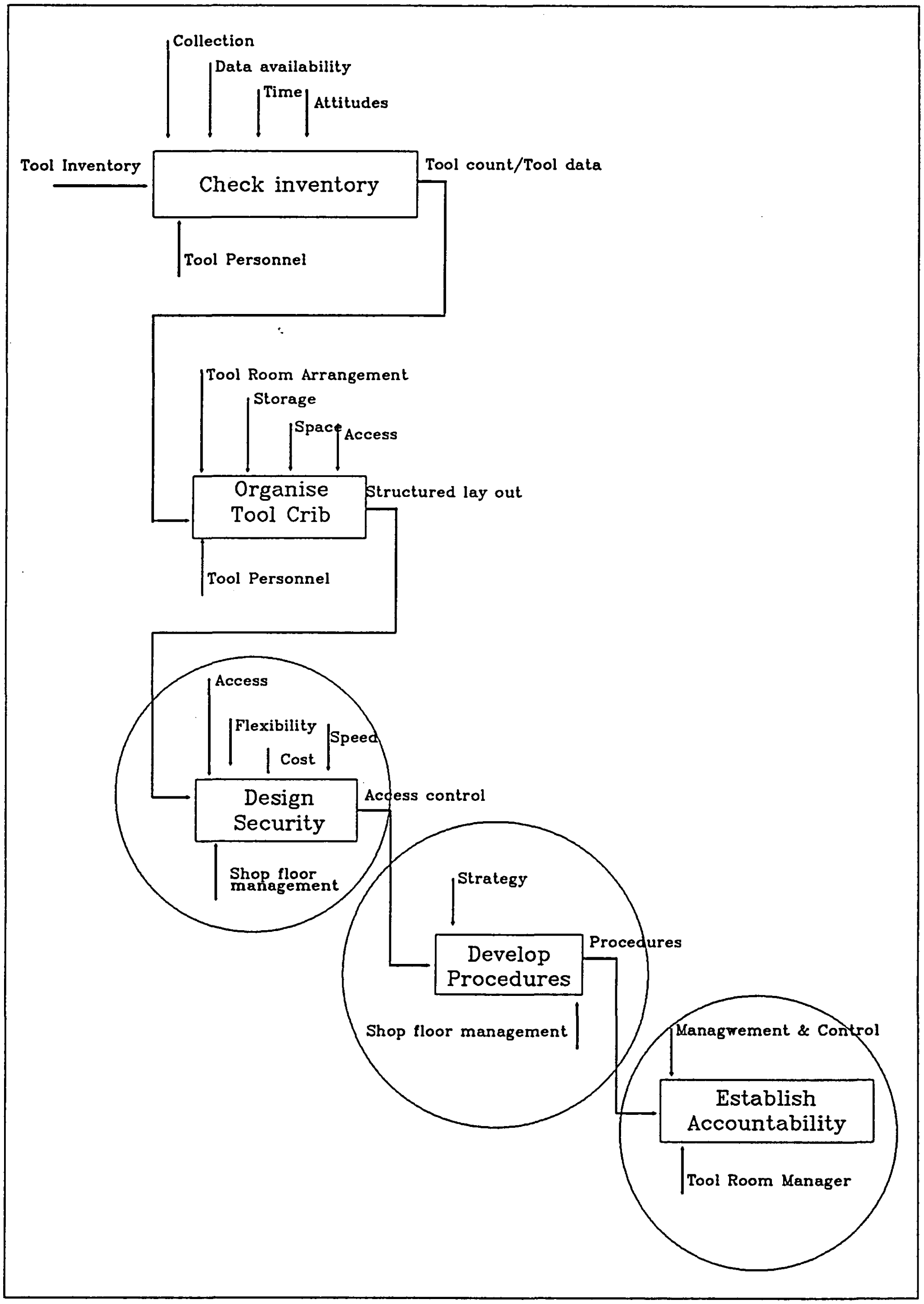


Fig 7.3: Tool Audit

7.4.2- Assessing the policies and procedures concerning the management and control of tooling resources;

Procedures and policies concerning the management of tooling varies in different companies. However, decisions on tooling assignment, tooling levels, tool procurement, tool dispensing, tool maintenance, tool tracking and control, can affect the flow of production and the subsequent costs in any manufacturing environment. But, it is also important to avoid the introduction of unnecessary complications into the system. The main procedures regarding the flow of tools within a manufacturing plant are described as follows;

Generally tool(s) in good condition are released from the tool room against some form of signal indicating the need for specific tool(s). There must be a procedure governing the transfer of responsibility from the tool room to the shop floor (operator, machine, or work station). A return date may then be established. This date is usually determined by whether or not the tool is disposable. The returned tools are then checked for condition and changes in status. The changes are recorded, the tools can then be assigned to another work station, dispatched to tool maintenance, or finally stored in their location, in any case the decision should be recorded Fig 7.4.

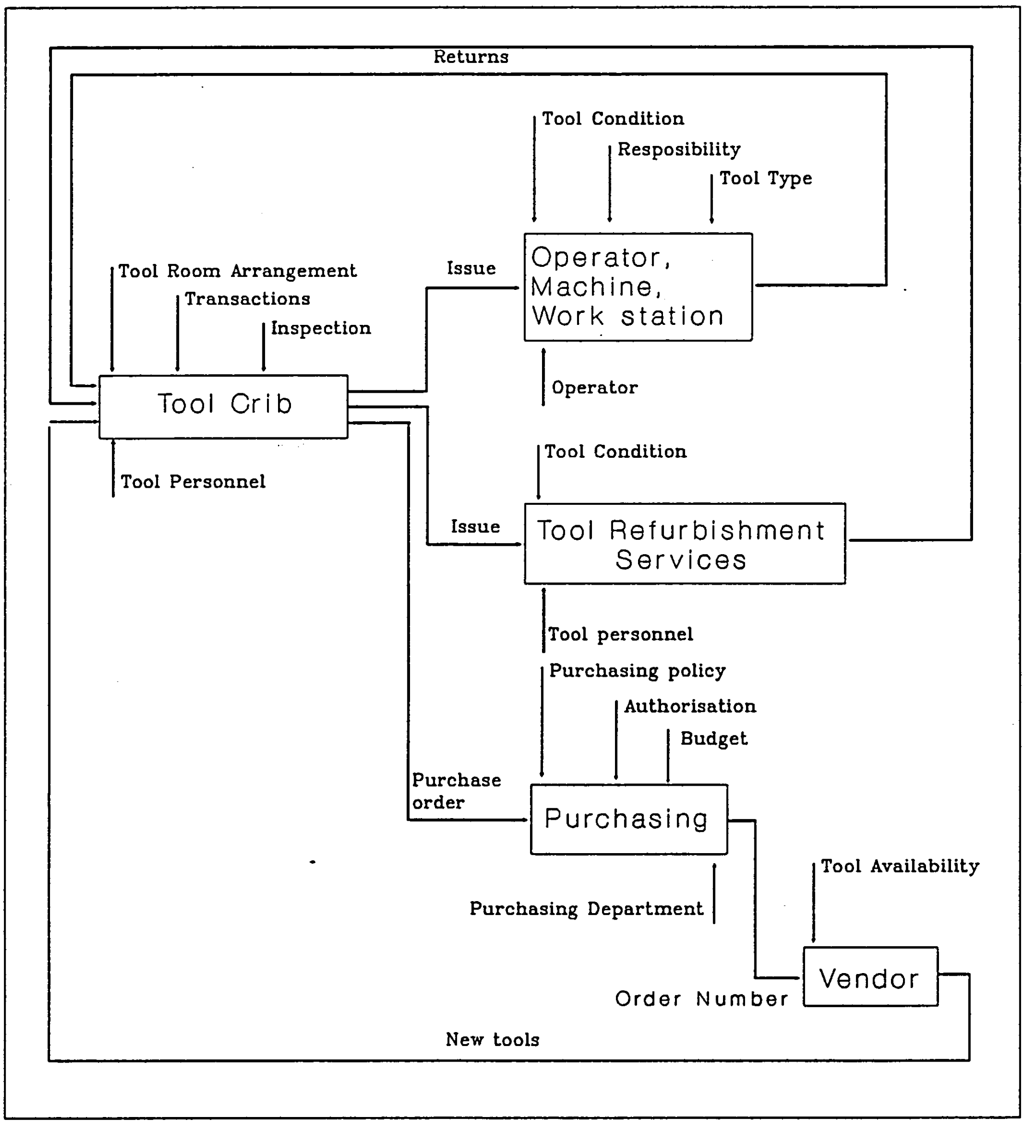


Fig 7.4: Tool Flow

Tool refurbishment services is concerned with the maintenance and enhancement of the quality of existing tools within the system. Disposable tools are usually subjected to inspection upon the end of their expected life. The tool room manager or an authorised operator should then decide to weather or not to scrap the tool. But, with non disposable tooling, the procedure is similar to that of tool issues. However, all maintenance activities should be recorded by the tool room personnel Fig 7.4.

An accurate method of determining tool requirements often ensures the availability of tooling and eliminates the cost of hot purchases. However, the signal indicating the need should be the function of a systematic procedures adapted by the tool management system. The authority of tool purchases often lies with the purchasing department where tools are purchased on price instead of quality and productivity. Therefore it is essential that tool specification is carried out by the tooling or production department where the knowledge lies. A basic purchasing cycle is illustrated in Fig 7.4. where minimum tooling levels are identified through daily/weekly reports from the tool crib. A tool order is created identifying the tool code, type, size, quality, required date, and quoted prices. The vendor is then identified in the formulation of purchase order form.

7.4.3- Addressing the organisational structure

When dealing with tool management, often the management of people/operators is at the centre of any problem intended to solve or simplify. Therefore education and training is a crucial factor in the success of any system. Further, participation of the employees and their contribution to the existing system together with the open channels of communication can account for the significant improvements in the efficient management of tooling resources. Division of responsibilities and accountability for the management of tooling resources on the shop floor can also enhance the success of operating system. In manufacturing environments the management and control of tooling resources crosses many functional areas, and both individuals and departments must bear part of the responsibility. However, the responsibility of managing tool crib rests with the tool room manager, and he is accountable for it. But, once a tool been issued, the responsibility remains with the operator or a work canter. A systematic transaction procedures is widely recommended, and unauthorised tooling should be prohibited at all times. A locked tool crib may be a good idea as long as it can effectively and efficiently support the production activities.

Tool room personnel are most suitable to carry the responsibility of identifying a company's tool inventory. However, it is important that the recorded data are correct and up to date. This is by no means an easy task and must be conducted by people with some tooling knowledge. It requires; commitment, time, and resources. It should be carefully planned with specific targets and realistic compilation date, further, it should be monitored to ensure progress.

7.4.4- Addressing the control procedures;

Control over tooling in manufacturing companies is an integral part of any tool management system which is vital to the success and efficient management of tooling resources. Apparent costs of; tool loses, delays in production schedules, time spent expediting tools, and the hidden costs of; hot purchases, scrap, waste, and rework, excessive tool inventory, and obsolete tooling has been frequently associated with the lack of control over tooling. Therefore it is essential that the flow of tools through the manufacturing plant is monitored objectively and inefficiencies are meet with corrective and preventative measures.

7.4.5- Propositions:

1b Companies who experience sever difficulties in the management of their tooling resources are the frontiers in the introduction of computerised tool management system

1c The bigger the company, and its manufacturing activities, the higher the extent of its tooling problems.

2a Companies who identify the underlying causes of tooling problems prior to purchase, or development of a Computerised Tool Management System (in-house), significantly improve the chances of successful implementation.

2b Companies who develop a set of requirements and specifications for the computerised tool management system, often achieve their objectives regarding the implementation of CATMACS.

2c Knowledge of CATMACS concept often facilitates the development of the system requirements.

3a Justification for system/investment is an indication of the level of interest, and often leads to reasonable expectation.

7.5- Phase 3:- DESIGN

A committee made up from various departments within the company should collect data regarding the requirements/specification for the software from their perspective departments who will be affected as a result of CATMACS implementation. After approval the devised specification should be documented. The above procedure eliminates the need for outside expertise in identifying the software requirements and further, provides a criteria for assessing the various vendors.

7.5.1- Vendor Selection and evaluation

The suppliers of dedicated tool management software are limited. However, due to importance of tooling in manufacturing, computer applications is now considered as a solution to the efficient management of tooling resources. Considerable attention from software houses who produce variety of computer application and integrated software for manufacturing industry is now diverted to compete for their market shares. This has made the task of selecting the right vendor more difficult. The selection criteria below is based on number of important issues and was adopted by the majority of participant.

- Vendor reputation and users opinion.
- Company information; market shares, financial stability, engineering expertise, company size, and geographical location.
- Product range.
- Price and payment terms.
- Training, support, and documentation.

7.5.2- System Selection and evaluation

Software selection was generally based on the requirements for system definition by the majority of respondents. However the degree of integration with the existing and future manufacturing facilities did not receive a high priority. In some case the choice of software was limited due to the influence and recommendation of major costumers or parent companies. But, overall, after selecting the potential vendors, the respondent companies considered the following factors in selecting their tool management software;

- Company's computing policy.
- Demonstration by the vendor.
- Technical suitability of the proposed software in relation to application requirements.

- Budgetary consideration.
- Screen layout.
- User friendly.
- Compatibility of the proposed software.
- Up-date and expendability of the proposed software.
- Vendor's commitment to education and training programme.
- Vendor's geographical location, contact, and on-line-support.
- References provided by existing users.

Hardware requirements are considered after the selection of suitable software. Majority of the respondent comply with the vendor's recommendation in selecting their approved and tested hardware. But, some of the respondent benefited from their existing hardware facilities. However, the following questions were raised by the respondent regarding the recommended hardware;

- Technical ability; screen display, size of hard disk, size of memory, reliability, industry standards, back up facilities, and floppy disk type.
- Functional ability; performance, and response time.
- Compatibility.
- Maintenance.

7.5.3- Pilot

A pilot environment was considered to test the systems by the majority of respondents. This had a number of major benefits. first, it reduced the impact of change, second, the success of the pilot boasted the moral of the operators, and thirdly, some minor modifications to the software package provided the company with a system which was operational before the system was in placed.

7.5.4- System Justification

System justification at finance and operational levels was conducted by a small number of respondent. As tool audit has already provided the companies with financial gains and operational benefits, nearly all the responding companies considered their investment to be justified. However, the payback period ranged from three to thirty six months.

7.5.5- People Selection

People's role in the implementation of CATMACS has been recognised as a crucial factor in the success of the project by the majority of responding organisations. A project champion with authority, knowledge, drive, and enthusiasm to lead the project was considered a major factor in the implementation project. The above was generally complemented with selected people form the departments who would be affected as a result of this transformation. Number of companies reported that, formal presentation of the objectives and progress of the company's tool management programme to the shop floor personnel has had a significant part in the success of their system, even though some they may not have been affected. Another area of concern at this stage is education and training. The decisions on length of the time required this activity should be usually based on the degree of computer literacy of the operators, and the complexity of the proposed system.

7.5.6- System Plan

System plan refers to the implementation plan and describes the company's requirements, and the ways in which these requirements are satisfied. Although the responding organisations had different approach to implementation, the following procedures were common amongst them together with time table outlining various activities.

- Project definition.
- Vendor's introduction.
- System installation.
- Defining the scope of the project.
- Defining expectation.
- Agreement.
- Documentation.
- Education and training.
- Data conversion.

7.5.7- Propositions:

4a Companies who utilise a ready made package from reputable software houses, experience little or no difficulties concerning its technical, and operational details.

4b Companies who develop software specification, often demand modification, consequently, improving their chances of a successful implementation.

4c Companies who evaluate the proposed software against their required specification are more successful in the implementation process.

6a Companies who develop an implementation plan are more likely to meet their objectives.

6d The more input from the departments involve, the higher the level of their commitment to the project.

7a To succeed, the champion needs the drive, responsibility, and authority to carry out the task of implementation effectively.

7b Regardless of position, the champion should have the knowledge, and ability to manage the transformation effectively.

7e Champion's contribution to the project is significant, if, he has the management's support.

8c Companies who present the objectives of their computerised tool management system to employees, increase the chances of successful implementation.

9e Participation of management in the education and training process, can only assist the implementation.

9f The higher the level of employee's participation, the higher the likelihood of acceptability, and hence success.

9g Investigating operator's suggestions, increases the level of acceptability of the system, and reduces the chances of failure

7.6- Phase 4- Action

7.6.1- Environmental change

Initial resistance to change through replacing a paper/index card tool management system with a computerised one is quit natural. In some of the responding companies where the operators have gained some degree of computer literacy through their past experiences less resistance to this transformation was reported. However, the majority of the participant companies were of the view that; presentation of the CATMACS objectives to employees, education and training, participation, and the degree of credibility of the new system are the crucial factors in overcoming the barrier of resistance to environmental change.

7.6.2- System conversion

Computerised tool management system becomes operational when tool data is loaded into tool data base. This is a costly procedure, and the length of time required for this process varies in different companies and depends on the size of the company and the number of tools in the system.

The majority of responding companies carried out the above process for different types of tool at any one time. The system and procedures were then transform from the old system to the new system for that particular type of tool. The participant companies benefited from; tool room personnel, shop floor operators, and clerical staff when inputting data into tool data base. A major issue which was addressed by the majority of respondents was the accuracy of data. Without accurate, up-to-date, and reliable data the efficiency of the computerised system becomes questionable and affect its credibility. Some of the responding companies managed to maintain their index/card record by storing them. However, this proved to have number of disadvantages; first, the old system becomes operational by some operators, second, it reduce and prolong the success of implementation, the occupied space for storage can be utilised for other purposes, and, having two system for managing tooling resources reduces the degree of control and effects the efficiency of manufacturing facilities.

7.6.3- System procedures

System procedures should be designed, tested, and agreed by the individuals and department who are affected as a result of this transactions. Some of the responding companies who had reviewed their procedures in tool audit reported very little changes in procedures.

7.6.4- Attitudes

Tool management and control system is a cross functional area and many departments and individuals are affected as a result of CATMACS implementation. As reported by the majority of responding organisations, the success of computerised tool management and control systems relies heavily on user's cooperation. When CATMACS is installed people have to redundant some of their old practices and adopt new procedures. Communication, participation, education and training , and operational efficiency was reported to be the factors that can change the attitudes of the operators in favour of the new system.

7.6.5- Propositions:

6b A well structured implementation plan, provides a means of measuring progress, hence, increasing the likelihood of success.

6c A module/phased implementation plan, provides short term which are visible, easier to monitor, and enhances the chances of success.

6e Modular implementation increases the chances of successful implementation.

7c Implementation is more likely to be successful where the champion exhibits a constant level of commitment and enthusiasm.

7d High commitment of the champion can influence the degree of commitment provided by the user group.

7f A pilot project provides real time data for serious implementation, consequently, its success contributes towards system implementation.

9a Companies who take advantage of comprehensive training offered by the vendor, make better progress than those which take the minimal training.

9b The higher the magnitude of education and training, the higher the chances of success.

9c The higher the degree of computer literacy, the lower the magnitude of training. Consequently, lower degree of resistance to change.

9d The greater the complexity of technology (hardware/software), the higher the level of learning required in the organisation.

10a The companies who use tool room personnel to input data, usually reduce the chances of incorrect entry.

10b Changing tool room layout is an indication of new practices and procedures.

7.7- Phase 5- REVIEW

The objective of post implementation review is to evaluate the project as a whole by comparing planned data with the achieved results. The main areas of concern are;

- **System:** This review is concern with the solution to system project and operational details and the contribution of the new system to overall performance of manufacturing facilities.

- **Implementation:** This review deals with the implementation methodology and the user's acceptance.

- **Budget:** This review assess the actual cost of the project to that of planed budget.

7.7.1- Objectives

This review deals with the expectations and achieved objectives. The post implementation review should ideally be conducted some month after the system has been operational preferably by some one who is not biased towards the system. If the project is considered to be success, a methodology documentation can provide a good source of reference for future project. Otherwise action modification could provide the solution for success.

7.7.2- Propositions:

9h The highest reward for those who are instrumental in the implementation process, is, its success.

11a Companies who embark on the implementation of CATMACS are often successful in achieving their objectives.

12a Unavailability of financial data complicates the financial justification of CATMACS implementation. But, the benefits of such implementation are measurable in measured in financial gains.

12b Average Return On Investment (ROI) of CATMACS is three years.

13a The critical factors in implementation of CATMACS are; management commitment, project champion, employee's participation, education and training, and change management.

7.8- Validation

When developing such a model, it is not difficult to become too involved with the propositions and their interpretation, to the exclusion of the experience. For this reasons, the framework was submitted to people from the companies who participated in our study. The procedure adapted at this part of study was similar to that of the mail survey. Based on the contacts established during the in-company-interviews, twenty people were selected for our sample. To enhanced the efficiently of this sample two software engineers who have developed tool management software for their perspective companies and participated in the implementation process, also took part in this validation.

A mini questionnaire was then designed to assess the validity of the model, and to see this model from the perspectives of the professionals from industry (Appendix 3). To facilitate a better understanding of the proposed model, the definitions, objectives, and a brief description of inputs and outputs, accompanied the questionnaire and a covering letter were posted to the selected sample. Eighteen valid responses were obtained, giving an overall response rate of 90%.

The questionnaire was designed to assist the evaluation process and contained five questions:

1 Does the model addresses the major issues of CATMACS?

2 Does the model addresses any irrelevant issues concerning the implementation of CATMACS?

3 Are the inputs and outputs of every phase sufficient for the implementation of CATMACS?

4 Can a methodology based on the model and accompanied by charts and guidelines be useful in the implementation of CATMACS?

5 In your opinion, could such a model with the presence of a capable champion eliminate the need for outside consultants?

The response was very encouraging with very little or no criticism at all. According to one respondent "The model in its current state covers 99% of the issues associated with the implementation of CATMACS". Another respondent commented; "The model apart from providing valuable guidelines for implementation of CATMACS, it can also be used for similar projects in the field of CIM". However, number of respondents were concern about financial justification. They suggested some form of project cost savings is a pre-requisite when embarking on such investment and should be accommodated for in the first phase of the model. Although majority of the respondents were aware of the importance of the implementation plan during the design stage of the model, nine companies expressed their concern for clear and well defined targets together with a realistic time scale for the project. The model however, was criticised for not accommodating the issues concerning the in-house development of tool management systems.

In response to valued opinion of the respondents, the framework was amended to accommodate their views Fig 7.5.

CATMACS Implementation Model

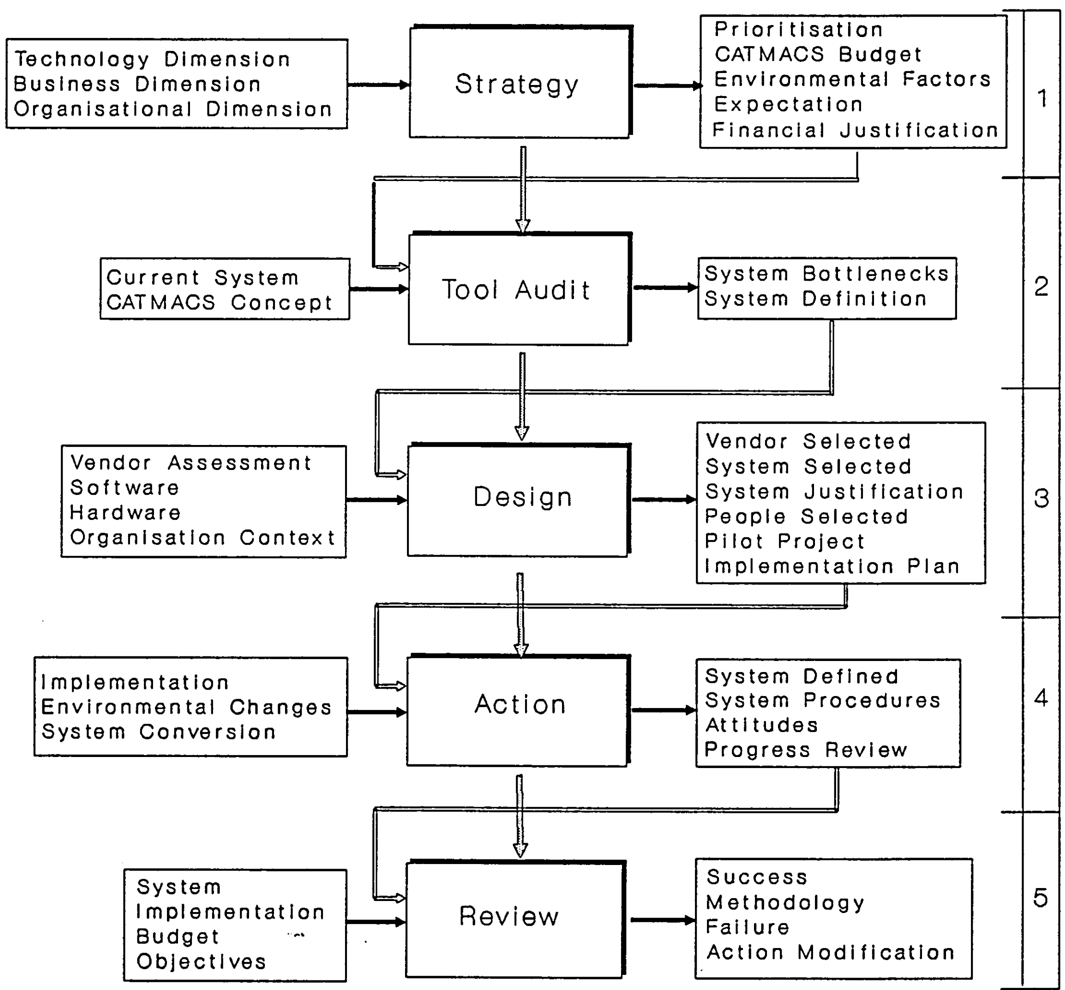
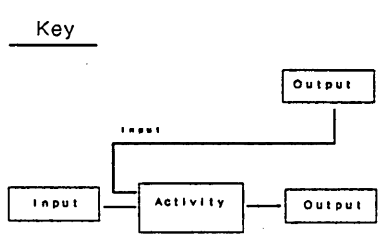


Fig 7.5: Amended Framework



CHAPTER EIGHT

CONCLUSION

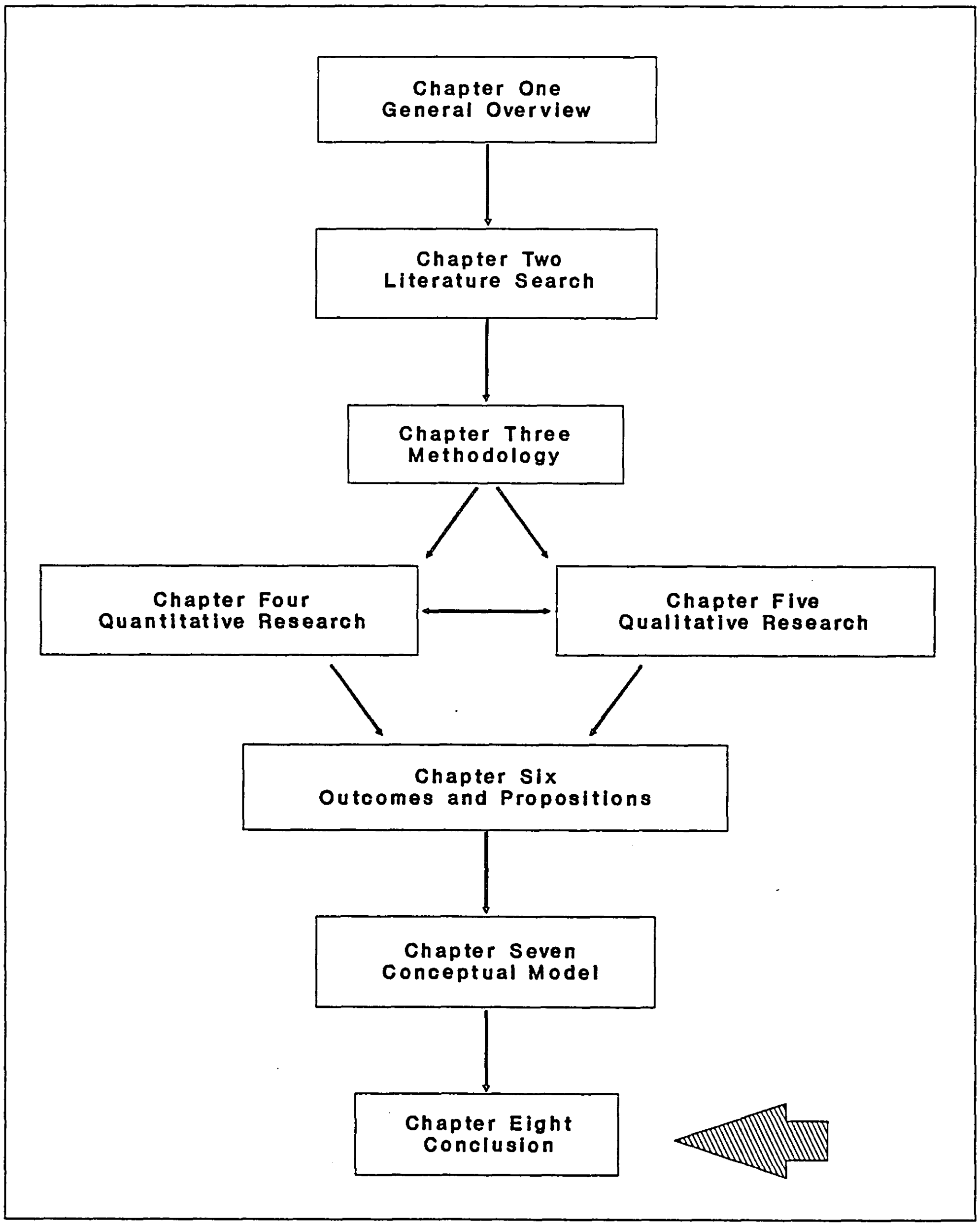


Fig 8: Process of PhD

CHAPTER EIGHT

CONCLUSION

This chapter reviews the main findings of the research and outlines the contribution to theory. The conclusion deals with quantitative and qualitative results separately and is then followed by recommendations for further research.

8.1- Quantitative Results

The quantitative studies focused at the nature and causes of tooling problems in the UK manufacturing industries. It was revealed that 37% of responding organisations considered tooling as a problem in their business unit, 26% saw tooling as an occasional issue, and 37% did not see tooling as a problem in their organisations. Therefore over 60% of the respondents considered tooling as a problem in their companies. It is important to note that the companies reporting no tooling problems (37%) held a limited number of tools and often were unable to provide any information regarding the size of their tool inventory, its value, or the cost of tooling as a percentage of production cost. Therefore, it is dubious whether such companies are not experiencing problems regarding the management of their tooling resources. Hence, the percentage of companies who are experiencing tooling problems could be much higher than 60%.

The study suggests that in general the UK manufacturing industries are experiencing difficulties concerning the management of their tooling resources. The degree of significance of perceived tooling problems varies from one company to another, and to some extent depends on the size of the company and its manufacturing activities.

Tooling problems generally encompasses unavailability of right tooling at the required time, high tool inventory, difficulties in tracking tools on the shopfloor, high tool variety, lack of tool refurbishment services, and cost of tooling.

Due to similarity of average responses (table 4.2 Chapter four) it was difficult to draw any conclusion regarding the priority of the perceived problems; 41% of the respondents considered high tool variety, and high tool inventory; 38% considered tool unavailability; 35% considered tool tracking and control; 31% viewed high tool inventory; 21% viewed cost of tooling; and 17% viewed lack of tool services as their first and second major tooling problems (fig 8.1).

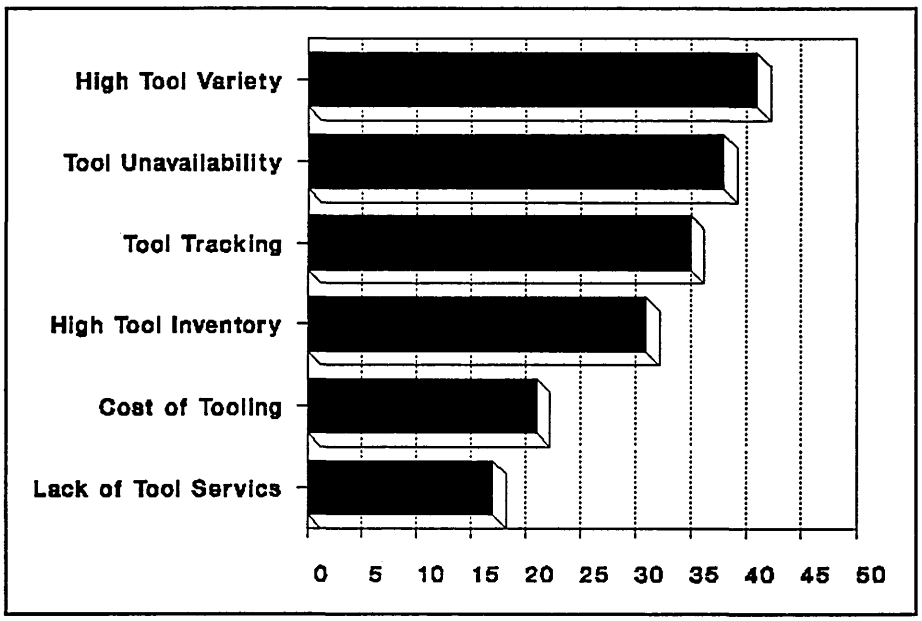


Figure 8.1: Tooling Problems

It may be argued that in statistical terms such representation may not provide a clear picture regarding the importance of tooling problems as reported by the participant organisations. But, since the responding organisations were generally more aware of their immediate tooling problems, it is fair to assume that it is representative.

By and large, it appears that manufacturing companies are faced with a combination of tooling problems which are aggravated by the poor management of this critical manufacturing resource. Such are the "symptoms" of the mismanagement of tooling resources that the underlying causes of tooling problems may be the crucial factor in the current state of tooling within manufacturing industry. This study identifies such factors as follows:

- **Lack of Understanding of Concept of Tool Management**
- **Lack of Strategy for Tooling**
- **Lack of Prioritisation of Tooling**
- **The Degree of Awareness**

The study suggests, on average that UK manufacturing companies spend over £10,000 on cutting tools every month (purchase cost). Whilst this figure may be in line with the figures provided by other authors (chapter one), it does not reflect the costs of poor management of tooling resources. The true cost of tooling is often masked by accounting practices in some companies. However, when added to the costs of mismanagement of tooling resources including the value of excess and obsolete tool inventory, costs of hot purchases, costs of expediting tools, production stoppages, late deliveries and unsatisfied customers and hence, consequent market losses indicates the importance of tooling in today's manufacturing environment, and its impact on the competitive nature of any manufacturing company.

The realisation of such costs, and the impact of tooling on the efficiency of manufacturing facilities which was initially appreciated by companies operating in a high-tech environment is gradually filtering through all sectors of manufacturing industry and has encouraged companies to benefit from the introduction of Computer Aided Tool Management And Control Systems (CATMACS). However, technology lead strategies alone can not solve the problems associated with the management of tooling resources, and if we are to benefit from the utilisation of such systems, considerable attention must be diverted towards the implementation process.

8.2- Qualitative Research

The implementation of computer based systems and models has received a considerable amount of attention since 1970's. However, success stories are matched by implementation failures. The successful implementation of new and particulary integrated technology is seen to be patchy in terms of their success. The root cause of this has been attributed variously to insufficient account being taken of the relationship between these technologies, and the business, and organisational context in which they are located. The successful implementation of CATMACS is more than just placing a computer system and making it operational in the company's environment. It involves getting people to interface with the various faces of the system, to follow procedures, to conform to the data discipline imposed by the system, and to act on the generated information. Therefore CATMACS presents a permanent change in the companies. such changes may be added equipment, technology, tasks and responsibilities, attitudes, and relationships.

To comply with multi-facetted problems of CATMACS implementation, qualitative research (Case studies) provided the opportunity to draw up the propositions which are relevant to successful implementation of CATMACS in different companies. By classifying these proposition into a framework, a methodology for the implementation of CATMACS has been developed.

8.3- Qualitative Results

The case studies provided a wealth of information concerning the implementation of CATMACS, and enabled the construction of the 39 propositions. It appears that although the implementation of CATMACS is very much similar to other applications of Advanced Manufacturing Technologies, considerably less attention has been diverted towards the process of change. This may be due to the size of investment and the lack of priority to tooling as a manufacturing resource. Often, with full/partial commitment of the senior management in terms of providing the necessary resources, the success of such system is left with the shopfloor operators. This is indicated by the case of a multinational company in the automotive industry where, after two years of initial introduction of their CATMACS, and despite the presence of a consultant, decided that the system has not yielded its full potential benefits due to the lack of attention to the introduction process.

The successful implementation of CATMACS requires a good analysis of the existing tool management system together with clear strategies, implementation plan with clear and realistic targets, and a review of the progress. However, management commitment, project leader, employee's participation, education and training, system changeover, and system's specifications may be the critical factors in the success of such systems.

Regardless of the degree of success, lower tool inventory, and reductions in obsolete tooling, time spent expediting tools, cost of hot purchases, cost of waste, tooling budget, set-up times, and improvements in store services, tool tracking and control, production schedule and delivery dates, are the benefits that can be associated with the utilisation of a CATMACS. More interestingly, whilst supporting the payback period of within nine months reported by Brown (1991 chapter six), the study reports the payback period of maximum three years. With such attractive returns, regardless of the size of the company, the author recommends the utilisation of such systems, specially with the availability of low cost tool management software.

The development of the implementation model provided by the study is based on the propositions of chapter six and falls into the following five categories:

- Propositions relating to existing features of the company and their situation regarding the management of tooling.
- Propositions concerning the future management of tooling resources.
- Proposition relating to preparation for the implementation of CATMACS.
- Propositions relating to the implementation of CATMACS.
- Propositions relating to outcome.

A review of the propositions suggested an undeniable parallel between their sequence and a morphogenic change (general change model) which addresses;

- Where are we now?
- Where do we want to go?
- How do we get there?
- What action do we take?
- How do we know we are there?

Therefore, if the propositions indicates a structure, by developing such structure to accommodate the propositions, we should conclude with a methodology for implementation. With this in mind, a framework for the methodology has been developed based on five sequential phases:

- **Strategy**
- **Tool Audit**
- **Design**
- **Action**
- **Review**

based upon the developed framework, the study recommends a methodology for the successful implementation of CATMACS. The methodology focuses on the individual elements of each phases of the framework (consecutively numbered), and highlights their contribution. Although the elements (input, and output) to each phase may varies from one company to another, it should not influence the objectivity and importance of each phase.

8.4- CATMACS Methodology

PHASE 1- STRATEGY

The objective of a CATMACS is to reduce manufacturing costs through the efficient management of tooling resources. The elements required of this phase are as follows;

1- Environmental Factors	Company's commitment in improving the management of tooling resources through the promotion of tooling as a manufacturing resource and a source of productivity.
2- Prioritisation	Priority to tooling at various stages of manufacturing (from product design to finished products), and highlighting its impact on the efficiency of production systems.
3- Business Dimension	Improving the competitive edge of the company by setting policies regarding the management of tooling resources from implementation to utilisation.
4- Organisation Dimension	CATMACs is operator's system and its success relies on their acceptance. Therefore considerable attention should be diverted towards organisational issues.

5- Technical Dimension

Technical issues are parallel to organisational issues and are equally as important. However, on the operation side, decisions such as; tool renewal, tool status can affect the quality of the products.

6- Financial Justification

Projected cost savings, and expected benefits.

7- Expectation

Required minimum level of expectation together with any negative expectation.

8- CATMACS Budget

An estimation of the following costs can provide a realistic budget.

- Cost of hardware.
- Cost of software.
- Annual cost of maintenance, and up grading.
- Cost of personnel.
- Cost of education and training.
- Cost of documentation.
- Cost of implementation.

PHASE 2- TOOL AUDIT

The objective of tool audit is to analyse the company's situation with regard to management of tooling resources. The elements required for this phase are as follows;

9- Current System

Company's situation with regard to existing tool management system through the following procedures;

- Checking inventory and its value.
- Organising tool room.
- Designing security.
- Developing procedures.
- Establishing accountability.
- Assessing the policies and procedures.
- Assessing the organisation structure.
- Assessing the control procedures.

10- System Bottlenecks

Uncovering the underlying causes of tooling problems by analysing the flow of tools through the manufacturing system.

11- System Definition

System requirements.

12- CATMACS Concept

Providing the basis for the desired system (system capabilities, system integration, etc).

PHASE 3- SYSTEM DESIGN

Phase 3 is aiming at the development of requirements for software, hardware, organisation context, and action plan.

13- Vendor Selection/Assessment Selecting the most suitable supplier through;

- Vendor reputation.
- User opinion.
- Company information, market shares.
- Product range.
- price and payment terms.
- training, support, and documentation.

14- System Selection Selecting suitable hardware, and Software.

15- Software Selecting software based on;

- Company's computing policy.
- Demonstration by vendor.
- Technical suitability against requirement.
- Budgetary consideration.
- Screen layout.
- User friendly.
- Compatibility.
- up-grade and expendability.
- Vendor's commitment to training.

- Vendor's geographical location.
- Existing user's references.

16- Hardware

Selecting hardware based on;

- Technical ability.
- Functional ability.
- Compatibility.
- Maintenance.

17- System Justification

compliance with the system requirements, and expected results.

18- Organisation Context

Selection of champion and individuals from various departments affected by this transformation.

19- Pilot Project

Reducing the impact of change, boasting the operator's moral, and system efficiency.

20- Implementation Plan

Company's requirements, and the ways in which these requirements are satisfied. It should include;

- Project definition.
- Vendor's introduction.
- System installation.
- Defining the scope of the project.
- Defining expectation.

- Agreement.
- Documentation.
- Education and training.
- Data conversion.

PHASE 4- ACTION

The objectives of this phase is to make CATMACS operational in the company environment.

21- Implementation	Compliance with implementation plan.
22- Environmental Change	Reducing the impact of change through fostering employee's participation, and education and training.
23- System Conversion	Transferring tooling data into the system's databases.
24- System Procedures	Agreement on designed and tested procedures.
25- Attitudes	Compliance with new procedures.
26- Progress Review	Meeting targets.
27- System Defined	Parameters of the new system.

PHASE 5- REVIEW

The objectives of this phase is to evaluate the performance of the project as a whole.

28- Implementation	Review of targets, time scale, and achievements against those of implementation plan.
29- System	Solution to system requirements.
30- Budget	Total cost.
31- Success	System efficiency.
32- Methodology	Future reference.
33- Failure	Problem diagnosed.
34- Action Modification	Corrective measures.

The study makes two major contributions;

1- It provides awareness concerning the management of tooling resources, and highlights its impact on the efficiency of manufacturing facilities, and its importance as a competitive weapon.

2- The model represents a significant step in understanding of CATMACS implementation. It provides guidance on the best way of implementing CATMACS, and forms the basis of an "implementation toolkit" for use by companies and their advisors.

8.5- Further Research

The model described in chapter seven is the basis of an implementation tool which could be useful for companies and consultant wishing to implement a CATMACS. However, whilst suggesting some possible source of materials for inputs, it does not fully address the method of collecting the materials. The next stage may be to produce a workbook consisting of the necessary guidelines regarding the method of collecting materials for inputs. Future research however, may take the form of one of the following;

- The most significant area of research may be to investigate the relevance and applicability of the model outside the environment (case studies) from which it was developed.

- This study revealed that the average payback period of a CATMACS is three years. A research programme devoted to identifying the financial justification of a CATMACS could persuade manufacturing managers to benefit from the introduction of such system.

- The intangible benefits of a CATMACS may be complex and difficult to measure. A research programme aimed at such an area could certainly encourage companies to benefit from the utilisation of such systems.

- The management of change concerning the implementation of CATMACS is in need of much more attention. A study on the best ways of managing change could facilitate the success of implementation process.

- The framework provided by this study presents a general methodology for the implementation of CATMACS. A further study could contribute to the development of the framework in specific sectors.

- A research programme dealing with the implementation of integrated technologies could provide further understanding of their organisational and business implications.

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APPENDIX 1

Questionnaire and Covering Letter

Tool Management and Control Survey

An effective tool management and control system must monitor the status, location, and movement of tooling. It must control inventory and reporting to ensure the right tool is available at the right time, at the right place, in the right condition, and in the right quantity.

This survey is being conducted by Sheffield City Polytechnic to evaluate the current status of tool management and control systems in U.K manufacturing industry.

The questionnaire will take only 15-20 minutes to complete and will provide vital information on tool management systems.

There is no commercial interest, and all answers will be kept confidential. However the aggregated data would be reported.

Your participation means a great deal to us and we would like to thank you in advance for your time and consideration.

If you are interested to obtain a copy of the results, please complete the form below and return it together with the completed questionnaire. An SAE has been provided for your reply.

Yours sincerely,

M.Shafaghi
Research Engineer

Phone: (0742) 533385
Fax: (0742) 738022

NAME	:...
TITLE	:...
COMPANY NAME	:...
COMPANY ADDRESS	:...
	....
	....
	....
COMPANY TELEPHONE	:...

QUESTIONNAIRE

For the purpose of this questionnaire we have defined 'tooling' as, cutting tools and setup tooling such as jigs and fixtures etc.

If your company has many sites, please consider your site when responding.

Please answer the following questions;

1) COMPANY/PRODUCTS/FACILITIES

1.1) What is/are your main product/s?........... ....

1.2) Number of work centres? a) NC machines........ b) Non NC machines........

1.3) Number of employees ....

1.4) If possible,please indicate your annual turnover.

( )Above £100m ( )£100-50m ( )£50-30m ( )£30-10m ( )£10-5m ( )Under £5m

2) TOOLING

2.1) What is the average number of tools your business unit carries in stock? (Over the last twelve months) ....

2.2) Please indicate the proportion of the following categories of tools used?

a) Disposable (eg; C tips/Inserts) ______ %
b) Non disposable (eg; HSS drill) ______ %
Total 100 %

2.3) Please check below the range which best captures the estimated value of your company's tooling stock.

( ) Less than £20K ( ) £20-50K ( ) £50-100K ( ) £100-200K
( ) Other, pleasespecify ....

2.4) Please indicate your annual tooling budget/costs(Approx).

( ) Less than £10K ( ) £10-20K ( ) £20-30K ( ) £30-40K
( ) Other, please state ....

2.5) What percentage increment do you estimate for your tooling budget next year ?............... %

2.6) Please indicate the tooling cost as an approximate proportion of product cost..................%

2.7) Do you consider tooling as a problem in your business unit?

( ) Yes
( ) No
( ) Sometimes

If **Yes/Sometimes** , please go to Section 3.
If **No** , Please go to Section 4.

3) TOOLING PROBLEMS

3.1) Please characterise your company situation with regard to tooling problem:-

a) Not significant ( )
b) Significant but under control ( )
c) Significant and needs more attention ( )
d) Significant and require urgent attention ( )
e) Other, please state ( )
....

3.2) Please rank the following tooling problems in order of importance. The scale is One(1) to Six(6), with (1) being the highest.

a) Lack of right tooling at the required time ( )
b) High tooling inventory ( )
c) Difficult to track tooling (on shop floor) ( )
d) High tool variety ( )
e) Lack of proper tool refurbishment services ( )
f) Cost of tooling ( )
g) Other (please specify) ( )
....

3.3) Please indicate the percentage of obsolete tools (ie, those that have not been used during the last twelve months) in your stock ....%

3.4) Please indicate approximately, what percentage of time is spent expediting tools every week ....%

3.5) What is your usual method of solving tooling problems?

a) Buy more tools ( )
b) Reschedule ( )
c) Expedite ( )
d) Other, please state ( ) ....

4) TOOL MANAGEMENT SYSTEM

4.1) Does your business unit have a formal tool management system?
( ) Yes
( ) No

4.2) Does your company utilise a Computerised Tool Management and control system (TMCS)?
( ) Yes
( ) No

If **NO**,please ignore the rest of the questionnaire.
If **YES**, please identify from the following, how the system was developed.

a) In house ( )
b) Software companies ( )
c) Outside consultants ( )
d) Other, please state ( ) ....

4.3) Please indicate your approx cost of TMCS in terms of (Hardware and Software)

( ) Less than £30K ( ) £30-40K ( ) £40-£50K ( ) £50K & above

5) IMPLEMENTATION

5.1) During the implementation process, did your company have or use any of the following?

1) A formal plan for implementation? ( ) Yes ( ) No ( ) Partially

2) A strategy for implementation? ( ) Yes ( ) No

If **YES**, was the strategy based on one, or a combination, of the following aspects:

a) Organisational aspects ( )
b) Technological aspects ( )
c) Business aspects ( )
d) Others , Please specify ( ) ....

3) Project leader? ( ) Yes ( ) No

If yes, what was his position in the firm?..

4) A formal TMC team? ( ) Yes ( ) No

5) Outside consultant? ( ) Yes ( ) No

6) A pilot project? ( ) Yes ( ) No

5.2) During the implementation process, did your company make any of the following?

1) An alteration to plant layout ( ) Yes ( ) No
If Yes please specify..

2) A formal presentation of the objectives of the company's TMC programme to the employees? ( ) Yes ( ) No

5.3) During the implementation process, did management do any of the following?

1) Specify and publicise in advance an implementation timetable.

Specify	( ) Yes	( ) No
Publicise	( ) Yes	( ) No

2) Allocate the necessary resources to the programme?

( ) Yes ( ) No ( ) Partially

3) Participate in the education and training programme?

( ) Yes ( ) No ( ) Partially

4) Investigate operator's suggestions?

( ) Yes ( ) No ( ) Partially

5) Reward those who were instrumental in CTMS implementation.

( ) Yes ( ) No

IfYes,How(Pleasestate)..

5.4) As a result of TMC implementation,what percentage (A) increase/(B) decrease was achieved?

a) Production schedule	A.....%	B.....%
b) Expediting tools	A.....%	B.....%
c) Obsolete tools	A.....%	B.....%
d) Store services	A.....%	B.....%
e) Tool inventory	A.....%	B.....%
f) Cost of hot purchases	A.....%	B.....%
g) Tooling budget	A.....%	B.....%
h) Cost of rework & scrap	A.....%	B.....%
i) Waste	A.....%	B.....%
j) Tool tracking and control	A.....%	B.....%
k) Set-up times	A.....%	B.....%
l) Quality	A.....%	B.....%
m) Delivery dates	A.....%	B.....%
n) Time lost	A.....%	B.....%

5.4) Please estimate what percentage improvement in Return On Investment (ROI) resulted from TMC implementation ....

5.5) Has TMC implementation been a success?

( ) Yes ( ) No ( ) Partially

If **Yes**, how is it measured?

a) Financially ( )
b) Organisationally ( )
c) Out put efficiency ( )
ie: Reduction in lost time,damaged goods and reworks.
d) Business efficiency ( )
ie: Meeting delivery dates, quality, etc
e) Others,please specify ( )..

If **No**, please indicate the reasons for failure..
....
....
....

5.6) What do you consider to be the three most critical factors in implementation of TMC
....
....
....
....
....
....

5.7) Please enter any additional comments you may have about tooling and its related problems, thank you
....
....
....
....
....
....

Company number	Ave Tooling Stock	% Disposable	% Non Disposable	Tool Value £1000
1	*Supp Store	75	25	Unknown
2	150	80	20	Under 20
3	380	10	90	Under 20
4	600	50	50	Under 20
5	500+	50	50	Under 20
6	600	30	70	Under 20
7	500	5	95	Under 20
8	Unknown	60	40	Under 20
9	100	50	50	Under 20
10	200+	--	100	Under 20
11	60	15	85	Under 20
12	400	70	30	Under 20
13	180	50	50	Under 20
14	Unknown	--	100	Under 20
15	300	15	85	Under 20
16	UnKnown	10	90	Under 20
17	1000	15	85	Under 20
18	200	10	90	Under 20
19	140	20	80	Over 200
20	Unknown	--	100	Under 20
21	Unknown	30	70	Under 20
22	15000	30	70	20-50
23	400	2	98	Under 20
24	Unknown	--	100	Unknown

Table A-1: Tooling stock and their values

Company number	Ave Tooling Stock	% Disposable	% Non Disposable	Tool Value £1000
25	Unknown	20	80	Under 20
26	400	--	100	20-50
27	Unknown	80	20	Under 20
28	20000+	15	85	20-50
29	50	25	75	Under 20
30	Not given	95	5	Under 20
31	1000	20	80	20-50
32	25000	40	60	50-100
33	1000	30	70	100-200
34	5000	40	60	100-200
35	5000	60	40	100-200
36	6000	40	60	20-50
37	10000-15000	25	75	1.5M
38	10000-15000	30	70	20-50
39	100000	50	50	900
40	5000+	70	30	Under 20
41	20000+	70	30	50-100
42	150-200000	25	75	100-200
43	20000+	50	50	1.4M
44	4000	50	50	100-200
45	1420000	46	54	400
46	Unknown	85	15	200+
*Supp Store= Supplier controlled Consignment store				

Table A-1: Tooling stock and their values

Company number	Number of employees	Annual Turnover (£M)	Annual Tooling Budget (£K)	Number of Machines NC	Non NC
1	208	30-50	10-20	4	30
2	30	Under 5M	Less than 10	-	38
3	25	Under 5M	Less than 10	2	61
4	22	Under 5M	Less than 10	1	6
5	36	Under 5M	Less than 10	8	1
6	110	5-10	20-50	5	6
7	25	Under 5M	Less than 10	-	35
8	6	Under 5M	Less than 10	-	2
9	14	Under 5M	Less than 10	-	1
10	42	Under 5M	Less than 10	2	6
11	40	Under 5M	Less than 10	-	8
12	184	5-10	Less than 10	13	56
13	44	Under 5M	Less than 10	-	42
14	73	Under 5M	Less than 10	-	11
15	60	Under 5M	Less than 10	-	3
16	143	5-10	Less than 10	1	4
17	Not given	Under 5M	Less than 10	6	41
18	45	Not given	Less than 10	3	9
19	93	10-30	100-200K	-	-
20	130	10-30	20-30	2	6
21	120	Under 5M	Less than 10	3	10
22	400	10-30	50-60	14	80
23	800	10-30	10-20	1	20

Table A-2: Company profile

Company number	Number of employees	Annual Turnover (£M)	Annual Tooling Budget (£K)	Number of Machines NC	Non NC
24	6	Under 5M	None	1	-
25	350	50-100	Less than 10	-	15
26	23	Under 5M	10-20	5	15
27	800	50-100	100K	33	200
28	400	Not given	Less than 10	15	100
29	30	5-10	Less than 10	-	2
30	110	Under 5M	Less than 10	20	72
31	240	Not given	10-20	20	35
32	60	Under 5M	70K	11	55
33	20	Not given	100K	5	-
34	350	50-100	30-40	35	5
35	400	10-30	150K+	20	350
36	355	10-30	175K	15	120
37	2000	50-100	100K+	35	200
38	650	10-30	300K	30	90
39	2500	50-100	100K	30	60
40	250	5-10	250K	42	8
41	1100	50-100	175K	15	90
42	800	50-100	75K	18	50
43	1000+	50-100	100K	6	200
44	600	30-50	250K	40	100
45	1100	50-100	500K	75	150
46	1000	Above 100M	Not known	80	300

Table A-2: Company profile

APPENDIX 3

Questionnaire and Supporting Notes for Validation of the model

Mathew Shafaghi
School of Engineering
City Campus
Sheffield Hallam University
Pond Street
Sheffield S1 1WB

Phone 0742 533391

Date:

Contact Name:
Address

Dear ....

Further to our telephone conversation, I have enclosed the following literature for your attention.

A model for the implementation of Computer Aided Tool Management and Control System (CATMACS) has been developed based on the analysis of a literature search, a mail survey, and a series of case studies (Fig I. Page A-15)

The model consists of five sequential phases: Tool audit, Strategy, Design, Action, and Review. Every phase is important and successful implementation CATMACS is the function of all these phases.

To ensure the practical relevance of the proposed model, we would like to benefit from your experiences in the implementation of Computerised Tool Management System. Your prespective can contribute can assist in providing a framework and a better understanding of Computerised Tool Management System implementation, as your views will be reflected on the final version of the model).

To facilitate a better understanding of the proposed model, the definitions, objectives, and brief description of inputs and outputs have been provided in the pages (A-16 to A-20).

Five questions have been designed to assist you in the evaluation process so that, the model can be seen from your perspective (Page A-21).

Your participation means a great deal to us and we would like to thank you in advance for your time and consideration.

Yours faithfully

M.Shafaghi
Research Assistant

CATMACS Implementation Model

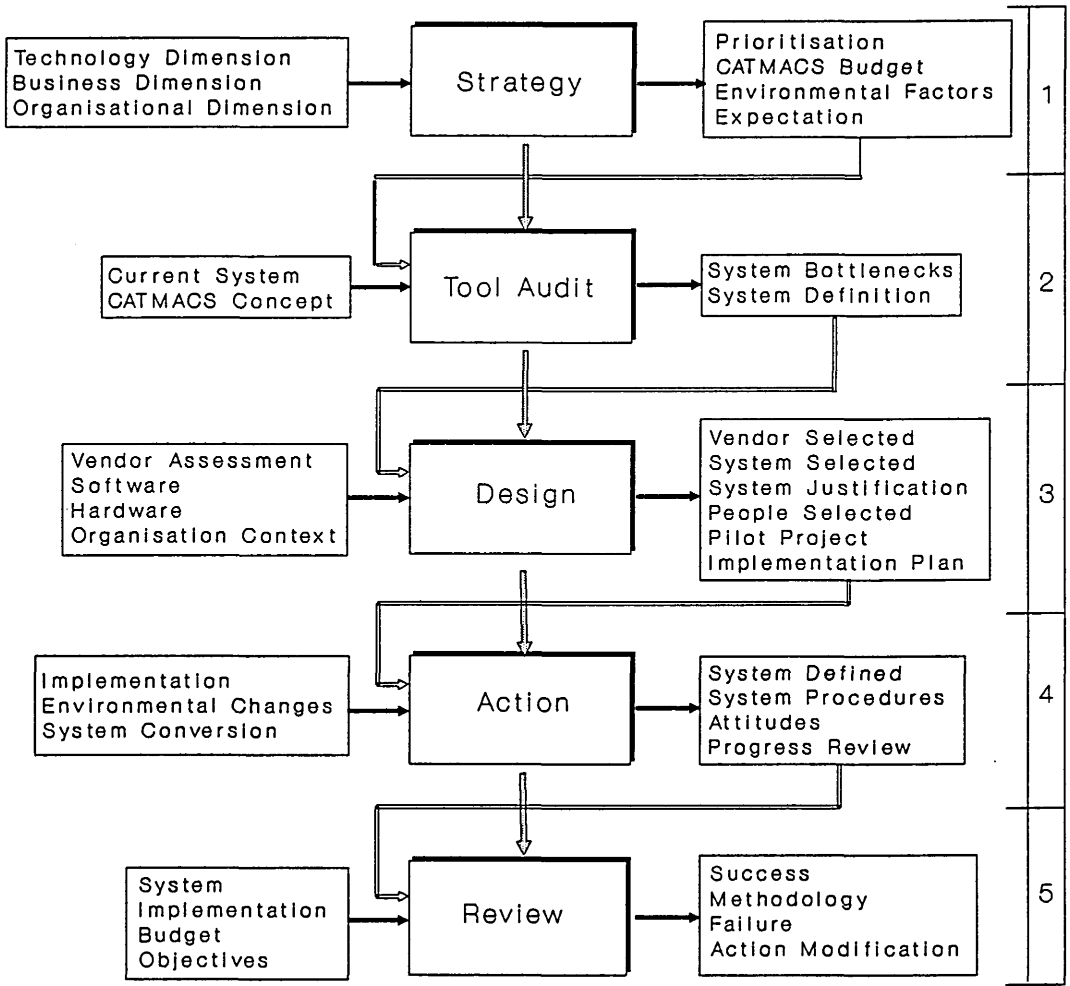
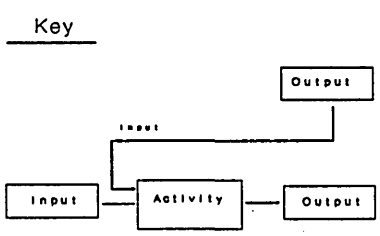


Fig 1: Initial Framework



Phase 1. Strategy

Aim = Improving the management of tooling resources

Terms:

Technology Dimension	Installation strategy.
Business Dimension	Competitive position of the company.
Organisation Dimension	Organisation design.
Prioritisation	Level of priority within manufacturing environment.
Environmental Factors	Commitment of management to the project.
CATMACS Budget	An estimation of the costs involve ie; Costs of hardware, software, maintenance, and up grading, personnel, education ad training, documentation, and implementation.

Objectives:

The objective of the strategy is to improve the efficiency of manufacturing facilities through better management of tooling resources, and hence, the competitive edge of the company by improving quality and reducing costs. Setting policies and defining procedures regarding the management of tooling resources can assists in reducing the manufacturing costs. Decisions such as; tool replacement/renewal point, tool status, tool life, minimum and maximum stock levels, and order levels can contribute towards the costs of waste, rejects, reworks, and can affect the quality of the products. However, with strategic management of tooling resources such costs can be avoided. A major issue that has to be addressed at this stage is the prioritisation of tooling within the manufacturing environment.

Phase 2.	Inputs	Outputs
Strategy	Technology Dimension Business Dimension Organisation Dimension	Prioritisation CATMACS Budget Environmental Factors Expectation

Phase 2. Tool Audit

Aim = To analyse the company's situation with regard to tooling.

Terms:

Current System	Existing Tool Management System.
CATMACS Concept	concept of computer aided tool management and control system.
System Bottlenecks	Underlying causes of tooling problems.
System Definition	Requirements for the perceived system.

Objectives:

The objectives of a tool audit may be summarised as follows;

1-To establish quantitative measures (Ientifying tool types, locations, stocks, and stock value.
2-To provides the basis for building a tool data base, based on accurate and up-to-date data.
3-To assist in identifying the underlying causes of tooling problems by analysing the flow of tools throughout the manufacturing system objectively, and to study the current operational practices (Fig.II)

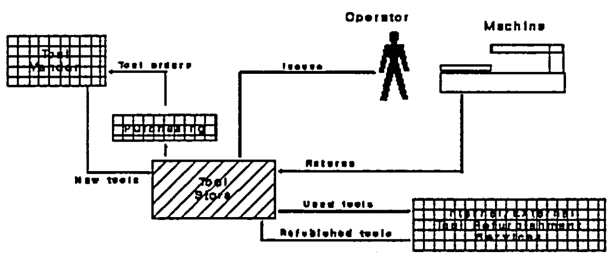


Fig II. The flow of tools within manufacturing system

The approach in which the objectives of tool audit are achieved is, through:

A-Identifying the size and value of existing tool inventory.
B-Assessing the policies and procedures concerning the management and control of tooling resources.
C-Addressing the organisational structure.
D-addressing the control procedures.

Phase 1.	Inputs	Outputs
Tool Audit	Current System System Concept	System Bottleneck System Definition

Phase 3. Design

Aim = Development of requirements for software, hardware, organisation context, and action plan.

Terms:

Organisation Context Department, and people who would be affected as a result of new system.

Objectives:

The objectives of the design stage is to develop an action plan. Data should collect regarding the requirements/specification for the proposed software from the departments and individuals who will be affected as a result of CATMACS implementation. This eliminates the need for outside expertise in identifying the software requirements and further, provides a criteria for assessing the various vendors.

The selection criteria regarding the software vendor was generally based on; Vendor reputation and users opinion, Company information, Product range, Price and payment terms, Training, support, and documentation. However, the following questions arose when selecting the recommended hardware; Technical capabilities, Functional ability, Compatibility, and Maintenance.

System selection is based on the requirements for system definition, and a pilot environment to test the systems was generally considered by the majority of responding companies. However, system justification at finance and operational levels was not conducted by all participants.

People's role in the implementation of CATMACS has been recognised as a crucial factor in the success of the project by the majority of responding organisations. A project champion with authority, knowledge, drive, and enthusiasm to lead the project was considered a major factor in the implementation project.

Although the responding organisations had different approach to the actual implementation process, there was majority agreements on most procedures together with time table outlining various activities.

Phase 3.	Inputs	Outputs
Design	Vendor Assessment Software Hardware Organisation Context	Vendor Selecte System Selected System Justification People Selected Pilot Project Implementation Plan

Phase 4. Action

Aim = Making CATMACS operational in the company environment.

Terms:

Environmental Change	Internal changes.
System Conversion	Replacing the manual system by computerised tool management system.

Objectives:

Initial resistance to change through replacing a card/index tool management system with a computerised one is quit natural. However, the majority of the participant companies were of the view that presentation of the CATMACS objectives to employees, education and training, participation, and the degree of credibility of the new system are the crucial factors in overcoming the barrier of resistance to environmental change.

Computerised tool management systems become operational once tool data is loaded into tool data base. This is a costly procedure, and the length of time required for this process varies in different companies and depends on the size of the company and the number of tools in the system. The majority of responding companies carried out the above process for different types of tool at any one time. The system and procedures were then transform from the old system to the new system for that particular type of tool, and tool room personnel, shop floor operators, and clerical staff when instrumental in inputting data into tool data base. System procedures were then designed, tested, and agreed by the individuals and department who were affected as a result of this transactions. Some of the responding companies who had reviewed their procedures in tool audit reported very little changes in procedures.

Tool management and control system is a cross functional area and many departments and individuals are affected as a result of CATMACS implementation. As reported by the majority of responding organisations, the success of computerised tool management and control systems relies heavily on user's cooperation. Communication, participation, education and training , and operational efficiency was reported to be the factors that can change the attitudes of the operators in favour of the new system.

Phase 4.	Inputs	Outputs
Action	Environmental Changes System Conversion	System Defined System Procedures Attitudes Progress Review

Phase 5. Review

Aim = To evaluate the performance of the project as a whole.

Terms:

System Review	Assessing the suitability of the selected system in response to the system project and includes reviews such as; **Performance, Functional,** and **Organisational.**
Implementation	This refers to the system implementation. It is important that; **plans, procedures, progress,** and **methods** are reviewed and compared with originals plans and expectations.
Budget Review	This review is aimed at establishing the cost of the project in relation to allocated budget.

Objectives:

To compare the achieved results against the original plan.

The post implementation review should ideally be conducted some month after the system has been operational preferably by someone who is not biased towards the system. If the project is considered to be a success, a **Methodology documentation** could provide a good source of reference for future and similar projects, otherwise, **Action modification** could provide the answers for failure.

Phase 5.	Inputs	Outputs
Review	System Implementation Budget Objectives	Success Methodology Failure Action Modification

Questions

1-Does the model addresses the major issues of Computerised Tool Management System?

....

....

....

2-Does the model addresses any irrelevant issues concerning the implementation of Computerised Tool Management System?

....

....

....

3-Are the inputs and outputs of every phase sufficient for the implementation of Computerised Tool Management?

....

....

....

4-Can a methodology based on the model and accompanied by charts and guidelines be useful in implementation of Computerised Tool Management System?

....

....

....

5-In your opinion, Could such a model with the presence of a capable champion eliminate the need for outside consultants?

....

....

....

Comments:

We would be grateful for any comments, recommendations, and criticism. please use the space provided below.

....

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Table A-3: List of Tables

Table A-4: List of Figures

Analysis of Tooling Problems in Discrete Manufacturing Industry

Shafaghi M, Perera D T S,
School of Engineering, Sheffield Hallam University

Tranfield D R,
Sheffield Business School

INTRODUCTION

Traditionally, men, machines, and materials are viewed as critical resources for continuous flow of production, with little or no concern for tooling. But, with the diversity of work and complexity of modern manufacturing systems, management and control of tooling becomes a crucial issue. Although tool unavailability can affect the efficiency of production systems, it seems that there is a lack of understanding about the role of tooling in manufacturing environments.

Tooling has been identified as a critical element in planning and operation of Flexible Manufacturing Systems (FMSs). Ranky (1), Perera and Carrie (2), Bell and De Suza (3), Perera (4) addressed different aspects of FMS tooling problems. Having recognised the impact of tooling on efficient operation of FMS's, considerable attention has been diverted to the management and control of tooling resources in traditional manufacturing systems. However, there is little formal research concerning the identification of tooling problems in UK manufacturing industry and their consequences and impact upon productivity.

Mason (5) was the first to provide an insight into typical tooling problems in traditional manufacturing environments. He identified several key tooling problems and their magnitudes in some American companies. Mason (6), Jablonowski (7), and Melnyk (8) discuss basic concepts of tool management and identify primary features of computerised tool management systems, and Albert (9), Hollingum (10), and Mason (11) report their experience on the use of computerised tool management and control systems in typical manufacturing environments.

Some businesses have attempted to solve their tooling problems by investing in computerised tool management and control systems. Whilst supporting the idea of computer based tool management and control systems, we are of the view that some of the main benefits of such investments may go undetected if the underlying causes of tooling problems are not identified beforehand.

This view has been developed from the weight of evidence accumulated concerning similar and sometimes related applications of advanced manufacturing and information technologies into manufacturing environments. Typically, applications of new and particularly of integrated technology are seen as patchy in terms of their success. The root cause of this has been attributed variously to insufficient account being taken of the relationships between these technologies and the business and organisational context in which they are located. These fundamental problems are often experienced and have been reported as problems manifest in the introduction and implementation of new technologies [Voss (12), Waterlow and Monniot (13), Ingersoll Engineers (14), Bessant and Haywood (15), Tranfield and Smith (16), Maull, Hughes, Childe, Weston, Tranfield and Smith (17), Kirkwood, Smith and Tranfield (18)].

This paper presents the results of a survey carried out to identify typical tooling problems in UK manufacturing industry. The survey is the first phase of a three year research programme[1] on organisational and implementation issues of computerised tool

[1]This research programme is funded by the Science and Engineering Research Council, and the School of Engineering, Sheffield Hallam University.

management systems which aims not only to identify the problems, but also to produce a prototype methodology for effective introduction.

Tooling covers a wide variety of items, and is generally referred to as whatever is required to manufacture the product, besides the men, machines, and materials. However, in this paper tooling refers to production tooling; i.e. cutting tools, jigs and fixtures, gauges and so on.

METHODOLOGY

A questionnaire was designed to collect data concerning the underlying causes of tooling problems, and was piloted on both academics and managers, the latter being responsible for the management and control of tooling resources in their respective companies. Each academic and manager reviewed the proposed questionnaire for concepts and clarity, and a redesigned questionnaire was produced.

The structure of the questionnaire was divided into four interdependent areas; company background, tooling information, tooling problems, and implementation of computerised tool management system, if applicable. Three hundred questionnaires were targeted to a mixed cross section of UK companies chosen from manufacturing directories. The overall response was 15%.

To complement the breadth of data from the survey, follow-up-data was obtained form eighteen companies. These aimed to investigate the issues associated with the management and control of tooling resources. The interviews were carried out on-site, each interview averaging approximately two hours. The interviews were held with two company directors, one production manager, one company buyer, and fourteen other personnel directly related with manufacturing departments. The questions focused directly upon the management of tooling resources and other relevant issues, However in many cases, the interviewees requested participation in the interview from others who dealt with different aspects of tooling within the company. This provided the opportunity of recording additional perspectives on tool management within the company. Table I. shows the overall functional area of interviewees.

Functional area	% of respondents
Top management	5.5
Purchasing	3
Manufacturing	86
Design	5.5
Management level	
Top	8.3
Senior	3
Middle	19.4
Junior	28
Supervisory	8.3
Shop floor	33

Table I. Functional area of interviewees

SAMPLE CLASSIFICATION AND PROFILE

This research is exploratory, and the variety of responding companies (Table II) gives an interesting and indicative perspective on the nature and extent of perceived tooling problems.

Manufacturing industry	No of companies
Aerospace	2
Air conditioning	1
Coach,cabs body	2
Construction equipment	1
Defence systems	1
Electric motors	1
Engineering components	4
Gas turbine	1
Hoists	2
Industrial casting	1
Industrial and razor blade	1
Injection moulding components	1
Motor cycle	1
Motor vehicle	3
Parts for motor vehicle	8
Plumbing products	2
Process heater	1
Refrigerator	1
Satellite dishes	1
Screen printing equipment	1
Shoe machinery	1
Textile machinery	1
Tool (Cutting/Hand/Machine/Press)	6
Traction equipment	2
Total	46

Table II. Classification by industry

The sample for this study was not geographically structured, and the range of products varied. The responding organisations varied in size from less than 100 employees to more than 1000, and annual turnover ranged from under £10 million to over £50 million (Table III.a, III.b). The responding companies benefited from annual tooling budget of under £10K (lower limit), and over £50K (upper limit), and the number of machines utilised by the companies had a range of under 50 to over 200 (Table III.c, III.d).

No employed	% of respondents
Under 100	41
100-500	34.8
500-1000	15.2
Over 1000	9

Table III.a

Annual tooling budget (£K)	% of respondents
Under 10	32.6
10-50	26.1
Over 50	34.8
Unknown	6.5

Table III.c

Annual turnover (£M)	% of respondents
Under 10	50
10-50	19.6
Over 50	21.7
Unknown	8.7

Table III.b

No of machines	% of respondents
Under 50	56
50-100	20
100-200	11
Over 200	13

Table III.d

Table III. Profile of the Sample

SURVEY RESULTS

Approximately 1 in 3 of the responding companies considered tooling as an ongoing problem in their business unit, with approximately a further 1 in 4 seeing tooling as an occasional issue, and only one third of the responding companies did not see tooling as a problem in their organisation (Fig.1). Therefore, over 60% of the responding companies saw tool management as a problem.

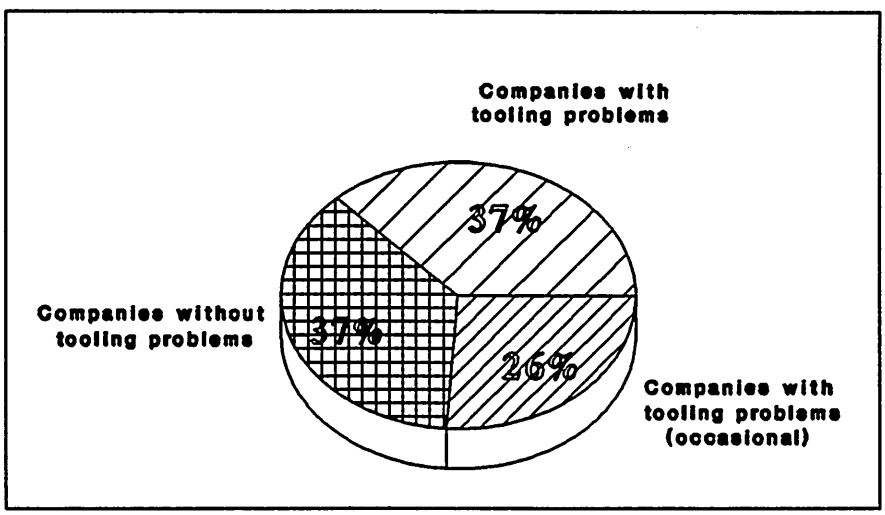

Fig I. Classification of respondents by tooling problems

Fig II, and III shows the average number of employees, and the average number of machines in relation to the annual turnover of the sample. The percentages of companies with tooling problems within the specified range of annual turnover can be seen in (Fig IV).

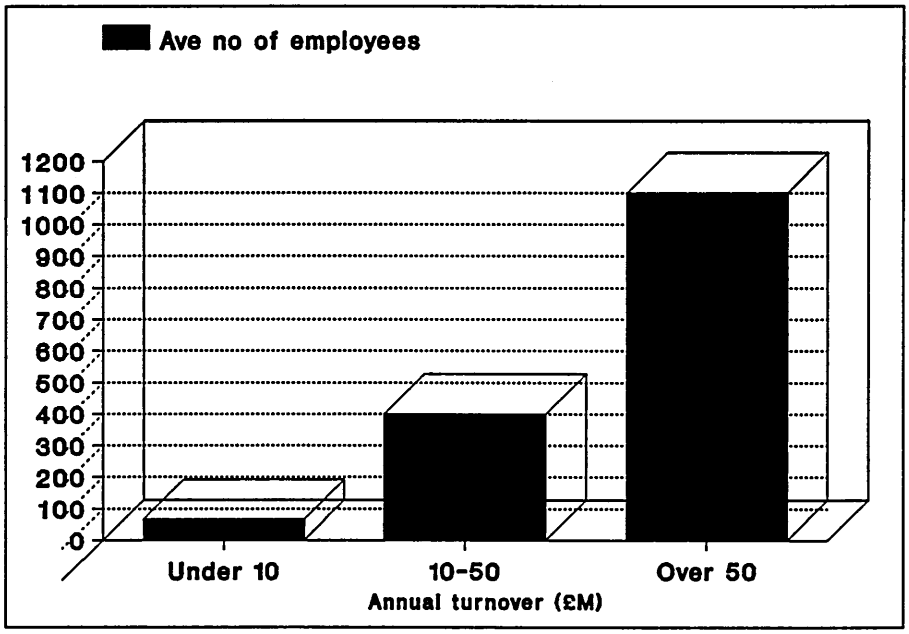

Fig II. Number of employees verses annual turnover.

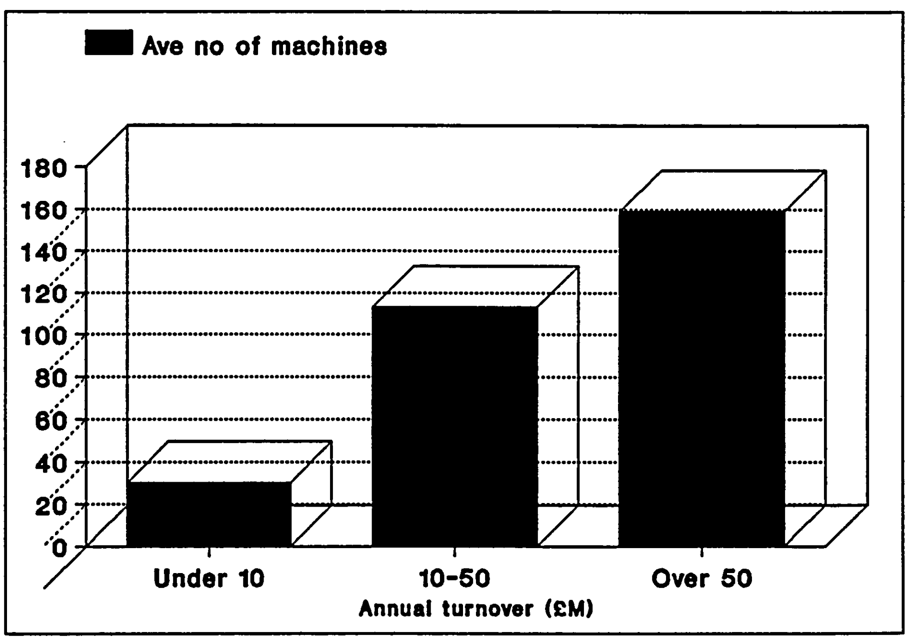

Fig III. Number of machines verses annual turnover.

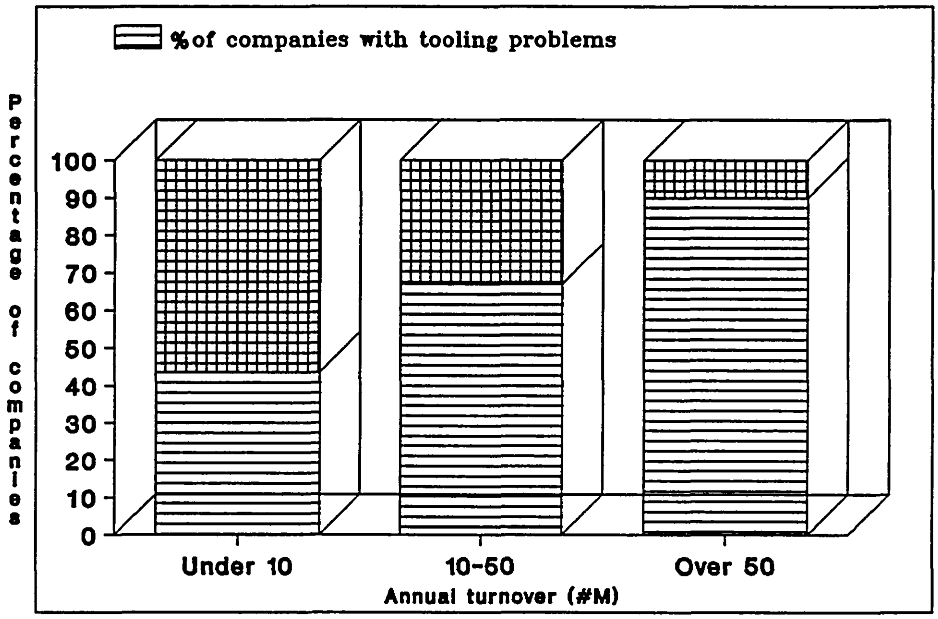

Fig IV. % of companies with tooling problems verses, annual turnover.

Not unpredictably, large manufacturing companies with high staff numbers, numerous machines and high annual turnover reported more difficulties associated with the management of tooling resources. This awareness could be due to the complexity of the manufacturing environment or the results of poor management of tooling resources. Over 40% of the companies with annual turnover of under 10 million reported having problems with the management of their tooling resources, compared to 67% of companies with annual turnover of between 10 and 50 million, and 90% of companies with the annual turnover of over 50 million. It would seem that whilst tooling problems are not unknown in smaller companies, they escalate as companies grow in size. This is reinforced further by the findings illustrated in Figures V, and VI.

Fig V shows the number of NC, and non NC machines in relation to tooling budget. Although large manufacturing companies may benefit from a bigger tooling budget, their management of tooling resources requires far greater attention. Fig VI highlights the extent of perceived tooling problems across the represented sample within the specified tooling budget.

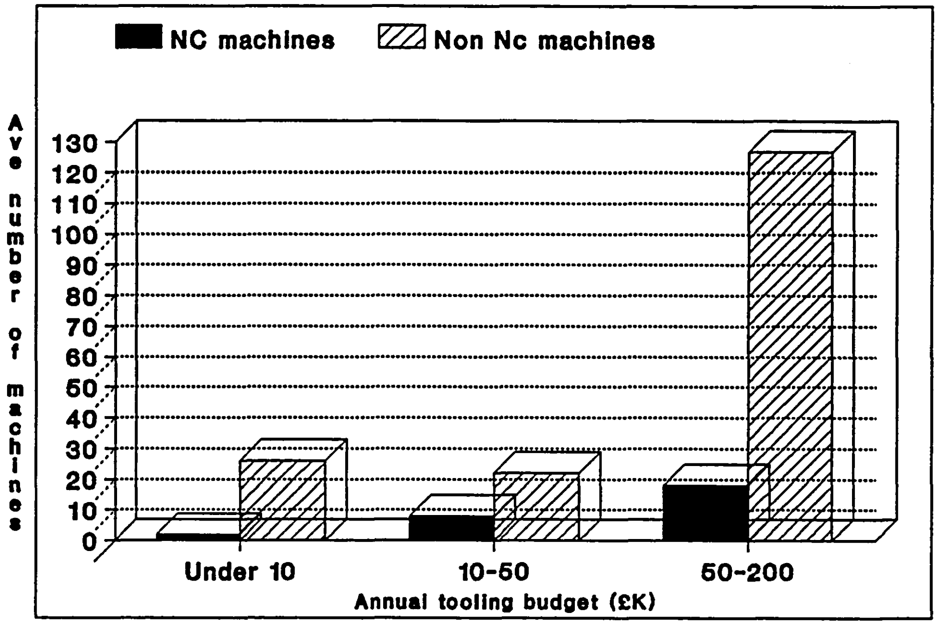

Fig V. Number of NC, and non NC machines in relation to annual tooling budget.

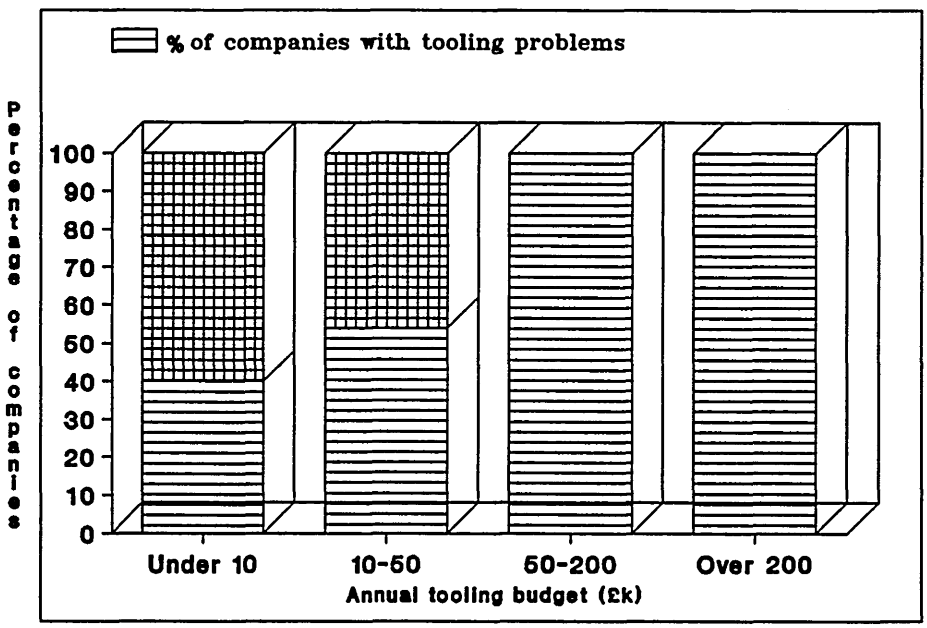

Fig VI. % of companies with tooling problems verses annual tooling budget.

Zuin (19) suggests on average, that British manufacturers spend around £15,000 on cutting tools every month. Our survey reveals that on average the responding organisations spent around £10,000 on cutting tools every month. However, we tend to believe that the true figure may be much higher for two reasons. Firstly, this figure does not take account of the costs incurred as a result of poor management of tooling which will be discussed later in this paper, and secondly, in some companies, accounting practices make it possible for the cost of tooling to be diverted to other accounts.

Overall, more than half of the responding companies (56%), provided figures relating to the cost of tooling as a percentage of production cost. On average tooling accounted for over 3.5 percent of production costs (with 0.2% and 10% representing the range of response). However, it is important to note that the companies reporting no tooling problems (37%), held a limited number of tools and often were unable to provide any data regarding the size of their tool inventory, its value, or the cost of their tooling as a percentage of production cost.

It is fair to assume that companies with a large proportion of disposable tooling and those who utilise press tools, customer's tools, and consignment tool stores (where the firm is billed for the tools used from the supplier's tool consignment), may experience fewer difficulties in managing their tooling resources. However, this should not undermine the importance of tooling, its relevant costs, and its effect on efficiency of manufacturing facilities. Although 63% of the responding companies characterised their company situation with regard to tooling problems as significant, the specific nature of the tooling problems they faced varied in different companies.

TYPES OF PERCEIVED TOOLING PROBLEMS:

The companies were asked to rank six major tooling problems in order of importance within their business units. The response suggested that perceived tooling problems varied.

Tooling problems	Rank							Total
	1	2	3	4	5	6	*	
Tool unavailability	21%	17%	7%	17%	3%	21%	14%	100%
High tool inventory	14%	17%	31%	10%	7%	7%	14%	100%
Tool tracking and control	14%	21%	17%	17%	21%	7%	3%	100%
High tool variety	31%	10%	7%	17%	7%	14%	14%	100%
Lack of tool services	14%	3%	7%	10%	21%	24%	21%	100%
Cost of tooling	14%	7%	21%	17%	14%	10%	7%	100%
* companies not responding to this problem								

Table IV. Ranking of tooling problems by responding companies

Table IV. shows the ranking of tooling problems by different companies. These problems were ranked from one to six, with (1) being the highest. For example, (31%) of the respondents ranked "high tool variety" to be their major tooling problem, whereas (21%) of the responding companies ranked "tool unavailability" to be their biggest tooling difficulty.

High Tool Variety

High tool variety refers to variants in tool sizes and differs from tool inventory. 31% of the respondents rated "high tool variety" to be their number one priority when considering tooling problems. This is mainly due to lack of consideration for tooling at design stages of products. However, an effective tool management and control system can help to negotiate a manageable quantity of tools to reduce tool variety.

Tool Unavailability

The importance of this tooling problem is highlighted by 21 percent of the companies who ranked "tool unavailability" as their main tooling problem. Tool unavailability is referred to as the unavailability of tools at the right time, at the right place, in the right quantity, and in the right condition. This definition is very broad in a way that it encompasses the outcome of all tooling problems. However, further understanding of the nature of this important tooling hurdle is needed in order to eliminate the unnecessary cost and expense.

Cost of Tooling

14% of the responding companies considered the costs of tooling to be their major tooling problem, 17% ranked this problem second and fourth, and 21% ranked this problem third in their list of priorities when dealing with tooling. This relatively low ranking may be due to the fact that the cost of a single tool is relatively small in manufacturing terms, and further, accounting practices can sometimes distort the true costs of tooling in some manufacturing companies. The cost of tooling may be categorised into Apparent and Hidden costs. Apparent costs are associated with the purchase and utilisation of tooling resources. They are easily identifiable, can be measured, and their effect on manufacturing cost is quite apparent. They may be classified as;

Purchase cost

This refers to the actual cost of tool purchase, cost of hot- purchases, and the cost of making the tool (where the tools are made in-house). These costs could be reduced utilising a tool purchasing policy.

Utilisation costs

Unsystematic issues, returns, and stocking, lack of proper tool refurbishment services, lack of faith in the tool management system by the operators where more tools are taken out than needed, and self service tool cribs are some of the utilisation cost and are contributory factors in reducing the productive time.

Control costs

Inventory losses due to poor control, over stocking, tool shortages, hidden stock, and tool status monitoring are some of the factors influencing the cost of tooling.

The Hidden costs, however, are the result of poor management and control of tooling resources. According to responding organisations they include, time spent expediting tools, long set-up-times, lost time due to tool unavailability, wastage due to wrong tool usage, poor quality products, and delays in delivery times. All of these can severely affect the flow of production in any manufacturing company.

Tool Tracking and Control

There is clear evidence that all responding organisation were familiar with this aspect of tool management and its effect on tooling costs. The prerequisite for an efficient tool tracking and control system is either a computerised or manual tool database. This database should contain the records of all tools, their number, location, status, and their transactions. Although this is fine in theory, in practice, productive time is affected because the tool is not where it should be, it is not in the right quantity, it is not in good condition, it is not the right tool for the machine, or it has not been ordered. In some cases, a tool control and tracking system exists when the tool room is manned by only a tool crib person, but the system cannot be operational when the tool room is unmanned. The solution may be a set of systematic and recorded procedures complemented by a training programme for all the shop floor operators affected by tooling.

High Tool Inventory

14, 17, and 31 percent of the responding organisations ranked this common tooling problem either their first, second, or third major tooling problem respectively. It may be fair to assume that, since the majority of responding companies were not aware of their actual tool inventory (allowing a margin for error of 10%), the true figures may be much higher. Excessive numbers of tools, storage, obsolete tooling, and waste, can contribute towards the cost of product and may relax the degree of control needed for efficient management and control of tooling resources. Companies with a rationalisation programme can reduce the size of their tool inventories by identifying their obsolete tools which have been accumulated over the years.

Lack of Tool Refurbishment Services

With only 10% of the responding companies considering the lack of tool refurbishment services as a most important problem in their business unit, this potential tooling problem received a low priority. However, although accommodation for this service can be made internally or acquired externally, without a clear policy and control procedures the lack of refurbishment services can severely interrupt the flow of production.

FIELD WORK.

Whilst complementing the survey, the in-company interviews were aimed at further understanding the nature and the extent of tooling problems in UK manufacturing industry. The findings from the interviews will be discussed under four headings:-

1- Tooling concept.
2- Tooling strategy.
3- Prioritisation.
4- Awareness.

1- Lack of Understanding of Concept of Tool Management

Tool management and control describes all activities required for the effective management of tooling resources on the shop floor. However, in many companies, it is often viewed from an engineering, production, and inventory perspective instead of a total system perspective. This lack of system perspective may be due to the traditional perception of the low-tech nature of tooling, and lack of integration of tooling within the context of the entire system within the company. However, tooling is a manufacturing resource, and successful completion of any production order depends on the availability of men, machines, materials , and the right tools throughout the whole of the manufacturing process. Several functions are involved in solving the tooling problems, and it is this which makes tooling a genuinely integrated ie, multi-functional issue.

2- Lack of Tooling Strategy

The absence of a clear, well defined strategy regarding the management of tooling resources is often evident across the responding group. In many companies decisions such as; tool replacement/renewal points, tool status, and tool life are made by the machine operators. Such decisions can contribute towards the cost of waste, rejects, reworks, and can affect the quality of the products. Some companies have realised the need for the strategic management of tooling resources. Further, the development of such vision is often rewarded in financial terms.A production manager reported that, "tooling strategy has been a major factor in reducing the cost of tooling by determining; the tooling levels and relevant costs, tool replacement, and tooling assignment."

3- Lack of Prioritisation

Tooling is often regarded as a manufacturing residual by many companies, and little consideration is given to its effect on the efficiency of production systems. A manufacturing engineer said, "the only time tooling receives any priority is, when there is a problem involving tooling". He reported that lack of prioritisation to tooling at design stages of products could be a contributory factor in the size of their tool inventory, 142000 tools.

4- The Degree of Awareness

The degree of awareness of tooling problems appears to be influenced by the size of the company and the management of its tooling resources. The impact of tooling on efficiency of production systems and manufacturing costs is underlined by the majority of respondents. Delays in the production schedule, delivery dates, set-up times, and the costs of expediting tools, store services, rework and scrap, waste, tool tracking and control, time lost, and tool inventory frequently were reported. However, very little is known about the true nature of the perceived problems and their specific effect on manufacturing costs. For example, calculating the tangible and hidden costs of poor management of tooling resources is by no means a simple task, for improvements and savings are only noticeable when an efficient tool management and control system is installed.

SUMMARY AND RECOMMENDATIONS

Enhancing competitiveness and market opportunities have encouraged U.K manufacturers to recognise the importance of advanced manufacturing technologies, but widespread reports of patchy success rates is pointing up the importance of strategically managing the introductory process. However, the management and control of tooling resources still tends to receive less attention than other aspects of the production system. Some medium and large companies, by investing in computerised tool management systems, have attempted to overcome their tooling problems. However, without a clear strategy for tool management, the benefits of such systems may go unrealised, with the resulting high levels of production overhead and general inefficiency which detracts from the competitive performance of UK manufacturers.

The cost of a single tool may well be small in manufacturing terms, but when added for example, to the value of tool inventory, cost of expediting tools, cost of tool losses, cost of delays in production schedule, value of obsolete tooling, and cost of hot purchases, poor tooling can account for a significant part of production cost. At a time of increasingly global competition, where the effects of poor tooling can impact directly on the competitive dimensions of cost, quality, delivery and lead times, companies without a tooling strategy, structure and system will find themselves missing a significant opportunity to improve their competitive position.

The key issues regarding the management of tooling concerns the lack of tooling strategy, lack of prioritisation, the degree of awareness, and the lack of understanding of the concept of tooling and, its importance as a source of productivity. This is perhaps hinted at in the case of the 37% of the responding companies who reported not considering tooling a problem in their business unit, yet, could not provide any data regarding the size of their tool inventory, its value, or their annual tooling budget. However, 67% of respondents considered tooling as a production bottleneck and are of the view that, an effective tool management and control system can improve productivity and , assist in improving the competitive edge of their organisation.
Computer aided tool management and control systems (CATMACS) are now seen by many as the solution to tooling problems. The identification of underlying causes of tooling problems and the analysis of current tooling practices is a critical factor in the introduction of any tool management system. The lack of prioritisation, and strategic perspective often taken by management appear to be important factors affecting the

introduction of CATMACS. The complexity of the issues involved particularly concerning the cross-functional nature of the implementation process requires the development of a systematic model for the effective implementation. Such a model needs to take account of the fact that the introduction and maintenance of such systems is an organisational as well as engineering issue.

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