Exploring Lean Production in the Flexible Manufacturing Systems Environment:

Some tensions between features of advanced manufacturing technologies and new wave manufacturing strategies

BY

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In the name of God, the Merciful, the Compassionate

In memory of my father

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List of Abbreviations

AMT	Advanced Manufacturing Technologies
APS	Anthropocentric production system
AGV	Automated guided vehicles
AS/R	Automated storage and retrieval systems
CMC	Symbol for compressor manufacturing company
CMN	Symbol for engine manufacturing company
CAD	Computer -aided design
CAM	Computer-aided manufacture
CIM	Computer integrated manufacturing
CNC	Computer numerical control
CAE	Computer-aided engineering
CAI	Computer-aided inspection
CAPP	Computer-aided process planning
CPM	Computerised prevention maintenance
CPS	Production system used in CMN engine manufacturing company
DFA	Design for Assembly
DFM	Design for Manufacture
DNC	Direct numerical control
EBG	Symbol for truck manufacturing company
FMC	Flexible manufacturing cell
FMS	Flexible manufacturing systems
HR	Human resources
HRM	Human resources management
JIT	Just-in-time production
LP	Lean production
LTS	First level machinist certification level used in the Netherlands
MRP	Materials requirement planning
MRPII	Manufacturing resource planning
MTS	Second level machinist certification used in the Netherlands
NWM	New wave manufacturing
PPM	Plant predictive maintenance used in CMN
TPM	Total productive maintenance which aims to eliminate variability in process
TQ	Total quality
TQM	Total quality management
WIP	Work in progress

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

In the new era of Globalisation and open and common markets, the search for competitive advantage has become increasingly more complicated. Stiff international competition and the emergence of dramatically different sets of market demands such as quality, variety and speed of delivery, have led many companies in the West to experiment and adopt new production processes, develop innovative manufacturing systems, and adopt novel work organisation structures. The success of Japanese manufacturers throughout the 1980s and early 1990s led many western companies to adopt and adapt many of the Japanese managerial and organisational innovations that were deemed to be the secret to Japanese success. In the 1990s there has been a proliferation of these new manufacturing innovations, strategies, and systems. Organisational innovations such as 'just in time' (JIT) (Schonberger, 1982) and 'total quality management' (TQM) (Crosby, 1979, 1984; Deming 1986; Feigenbaum, 1983; Hall, 1987; Juran 1988; Oakland, 1989), were adopted in various forms in European and American plants.

These systems were developed into a wide array of concepts with nomenclature such as 'flexible specialisation' (Piore and Sabel, 1984; Sabel 1989), the 'Toyota Production System' (Ohno, 1978; Monden, 1983), 'Toyotism' (Imai, 1986), 'post-fordism' (Roobeek, 1987; Kenney and Florida, 1988), 'New production concept' (Kern and Schumann, 1987), 'lean production' (Womack et al., 1990); 'lean enterprise' (Lamming 1993; Harrison, 1992; Jones, 1994), and 'New Wave Manufacturing' (Storey, 1994; Harrison and Storey, 1996).

Coinciding with the development of these innovations and work organisation structures, was a new technological revolution characterised by the emergence of the microprocessor and the development of programmable controllers and 'smart' sensors. In the manufacturing environment, the impact of the microprocessor was seen through the introduction of Advanced Manufacturing Technology (AMT) and the development of advanced robots which are now applied to mechanical handling, arc and spot welding, paint spraying and many other applications (Greenwood, 1988; Noori, 1990; Ayers, 1990). AMT refers to a family of technologies which includes computer aided design and engineering systems, material resource planning systems, automated materials handling systems, robotics, computer-controlled machines and computer integrated manufacturing systems (Schroder and Sohal, 1999). (see table 1.1).

This thesis will explore the application of lean production to the flexible manufacturing systems environment and investigate the existence of tensions between features of advanced manufacturing technologies and new wave manufacturing strategies in four manufacturing companies in Holland and the United Kingdom.

Derived from the Toyota Production System and adopted by most Japanese automakers, lean production is a production system which uses less of everything compared to mass production: half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever-growing variety of products (Womack et al, 1991, p.13).

Combining advanced manufacturing technologies with flexible work the new wave manufacturing strategies promised to usher in a new productivity technology paradigm with improved operational control, increased flexibility, and drastically reduced lead times. Proponents of this paradigm argued that it is through the coupling of advanced manufacturing technology and new wave manufacturing strategies that the full potential of the technology can be realised to achieve true productivity gains (Bessant 1990; 1993, Clark, 1993). This coupling or linkage between AMT and NWM is seen to maximise the gains from the use of advanced manufacturing technologies.

The proponents who claimed the existence of a new productivity paradigm presented a favourable picture of the fit between the AMT and the NWM. It was assumed that these new wave manufacturing strategies are universal and accordingly are compatible with all the types of advanced manufacturing technologies. In particular, the proponents of the lean production paradigm believed that lean production will supplant all other types of production to become the standard global production system of the twenty-first century (Womack et al., 1990, p.278). Haslam et al., (1996) noted how throughout the 1980s and well into the 1990s, innumerable articles took, as axiomatic, the superiority of this lean production paradigm.

With each new generation of microprocessors, new generations of production equipment and systems were developed, and continue to develop, with a better level of control, increased power, and higher degrees of flexibility and processing ability. These developments dramatically changed the existing norms and structures and hence, researchers saw a new 'techno-economic paradigm' emerging based on the advances in microelectronics (Dosi et al, 1988; Freeman et al, 1993).

Jones (1990, p. 291) saw a 'new technological paradigm' which 'resolved the traditional incompatibility between efficiency and stable forms of productivity growth, on the one hand, and continuing innovation on the other'. Table 1.2 describes in detail the organisational differences between the old and new paradigm and presents the characteristics that are at the heart of the new wave manufacturing strategies and lean production.

Other researchers recognised this new paradigm in the apparent move from 'inflexible division of labour' towards a 'comprehensive system design' (Trist, 1981; Jurgens et al, 1986). Roobeek (1987) pointed to a crisis in the traditional mass production or Fordist model and to the emergence of a new technological paradigm. The Fordist production system was increasingly viewed as cumbersome, inefficient, unable to respond rapidly to changing consumer tastes, and wasteful of the creative potential of production workers (Womack et al., 1990; MacDuffie, 1995; Adler and Cole, 1993; Adler, 1992). Technology in the old paradigm was regarded as fixed, unchangeable and as determining the remaining factors within the company, while in the new paradigm there is 'common optimisation of the technical and social systems' (Salvendy and Karwowski, 1994). The installation of advanced manufacturing technologies did not seem to resolve the existing productivity and performance problems of the mass production system. With all their potential to reduce lead time, improve quality, and increase throughput, the performance of the AMT has been disappointing to many manufacturing companies (Kalb, 1987;Long, 1989; Uzumeri & Sanderson, 1990). Although many reasons have been proposed to explain these difficulties, inappropriate organization and human infrastructure were put forward as the major contributing factors for the AMT failures (Barley, 1990; Bronder, 1991; Karwowski et al. 1994; Majchrzak, 1992; Unterweger, 1986; Zylstra, 1987). It was argued that for the advanced manufacturing technology to achieve its optimum level of performance, it is necessary to adopt new human resources and work organisation arrangements. Combining flexible production technologies with flexible work (i.e. lean production) promised to usher in improved operational control, increased flexibility, and drastically reduced lead times.

1.2 Need for the Study and Choice of the Research Questions

As Harrison and Storey (1996) indicated, a gap in the literature on new wave manufacturing strategies exists in that few studies have elaborated on the implementation of NWM beyond the traditional surveys which generally fail to grasp the nuances and the true dynamics of the implementation, while single case studies lack comparative value.
Thus, by choosing a multiple case studies format for examining the interaction between NWM and AMT, this study attempts to add comparative value while at the same time engaging both the technical and organisational (social) arrangements side of the literature. As Harrison and Storey indicated, the literature on new wave manufacturing strategies has remained largely 'locked into two camps: operations management and organizational behaviour' (Harrison and Storey 1996, P.71). Accordingly, by focusing on the interface relationships between the technical side of production in the form of the

FMS and the organisational side in the form of lean production systems, this study hopes to further explore the dynamics of interaction between the two in the hope of contributing new insights into this debate.

The dissatisfaction as a result from not fully realising the benefits of the technology has been discussed in a number of studies (Rosenthal, 1984; Voss, 1985; Jaikumar, 1986; New, 1986; Tarnfield and Smith, 1989; Bessant *et al.*, 1993; Udo and Ehie, 1996; Lei *et al.*, 1996; Sohal, 1996).

The original ideal vision of the combination of lean production and satisfied workers has been rejected by many researchers who examined changes in the quality of work life under lean production (Parker and Slaughter, 1988; Klien, 1989; Fucini and Fucini, 1990; Sewell and Wilkinson, 1992; Graham, 1993, 1995; Babson, 1995; Delbridge, 1995, Landsbergis et al., 1996; Nishiyama and Johnson, 1997; Lewchuck and Robertson, 1997). Other researchers questioned the claims that lean production practices necessarily lead to high manufacturing gains. Lowe et al., (1997) looked at the performance of 71 'first tier' automotive components plants based in Europe, North America and Japan and their data did not support the notion that work organisation and human resources policies associated with the production model represent a universal "best way" for achieving high manufacturing performance.

In the Worldwide Manufacturing Competitiveness Study, Oliver et al., (1994) found that high productivity was virtually uncorrelated with human resource policies intended to modify the attitude of workers towards their employers. They noted the successful lean plants are controlled plants and that worker empowerment is secondary. This focus on control stands in sharp contradiction to the picture painted by supporters of lean production who argue that authority will become more diffuse within the organization and that workers will be empowered to improve their working lives. The Oliver study appears to argue quite the opposite.

Table 1.1: Overview of new computer –aided technologies (based on Groover and Zimmers, 1984; Meredith, 1986; and Boer, 1991)

Technology	Acronym	Description
Computer-aided design	CAD	The use of computers to assist in the creation, modification, analysis, or optimisation of product design
Computer-aided engineering	CAE	Computerised software for engineering analysis
Computer-aided process planning	CAPP	Computerised software for determining operations and product routings
Manufacturing Resource Planning	MRP	Interconnected computer software systems for manufacturing, planning, scheduling and control
Computer aided quality control	CAQC	Computerised software for testing and inspecting quality
Numerical Control	NC	A hard-wired (tape driven) machine tool
Computer numerical control	CNC	A soft-wired (mini-or-microcomputer controlled)machine tool
Direct numerical control	DNC	Multiple, machine tools controlled by central computer
Industrial robot	IR	A re-programmable, multi-function manipulator
Automated storage and retrieval system	AS/RS	Computer controlled equipment used to handle, store, and retrieve material
Automated material handling	AMH	Computer controlled material handling using robots, automated guided vehicles manipulators or transport systems
Flexible manufacturing system	FMS	Cells of computerised machine tools and material handling devices.
Computer-aided manufacturing	CAM	The use of computers to plan, manage, and control manufacturing operations
Computer-integrated manufacturing	CIM	The integrated application of computers to all of the operational and information processing functions in manufacturing from order receipt, through design and production, to product shipment

Table 1.2: Organisational differences between the old and new paradigm with the new paradigm encompassing the NWM strategies

The Old Paradigm	The New Paradigm
Technology is fixed and determines remaining factors within a company.	Common optimisation of technical and social systems.
Jobholders are assigned to machines.	Application of materials and equipment matched to capabilities and requirements of jobholder.
Jobholders with lower qualifications can be exchanged with one another.	Jobholder capabilities regarded as a resource to be developed.
Maximum subdivision of tasks with simple repetitive job requirements.	Extensive combination of tasks, many comprehensive skills.
External control by supervisors or specialists.	Internal control (self-regulatory subsystems).
Many levels in the hierarchy, complex organisation structure.	Fewer levels in the hierarchy, simple organisation structure.
Authoritative style of leadership with individual decision-making.	Participative style of leadership.
Excessive competitive thought.	Teamwork, work with colleagues.
Only counting the objectives of the organisation.	Consideration of the objectives of the jobholders and community as well as the objectives of the organisation.
Alienation.	Knowledge and command of the technical and social relationships within the company.
Reduced willingness on the part of the company to take risks.	Willingness on the part of the company to innovate.

(Source: Salvendy and Karwowski, 1994, pp. 23-24)

James-Moore and Gibbons (1997) and Oliver et al. (1994) also noted that the focus of lean production research was primarily on high volume automobile and automobile components and some electronics plants. James-Moore and Gibbons (1997) questioned its applicability to other types of industries without modification.

These previous studies identified a discrepancy between the theory and actual results on the shop floor suggesting that the combination of lean production and the FMSs may be problematical and point to potential tensions or contradictions in the emergent new paradigm. This study aims to explore the fit between lean production and its application to the flexible manufacturing systems (FMS). A FMS is a type of production process conversion technology that uses computers to aid the manufacturing process (Gerwin and Kolodny, 1992). It is defined as a group of workstations integrated by automatic material handling equipment and controlled by a central computer (Chin, 1996).

The marriage of advanced manufacturing technology and lean production including new human resource policies is certainly a new phenomenon and one which has come on the heels of a large body of research that pointed to the disappointing results of AMT implementation (Udo and Ehie, 1996; Sohal, 1996). The high failure rate of AMT implementation in the 1980s was mainly attributed to non-technical, people related organisational reasons (See Rosenthal, 1984; Voss, 1985; Jaikumar, 1986; New, 1986; Tarnfield et al., 1989; Bessant et al, 1990, 1993). Womack et al. (1990) found that the automation levels did not account for the wide differences in performance between lean and traditional plants. They noted that *'what is truly striking is that- at any level of automation- the difference between the most and least efficient plant is enormous'* (Womack et al., 1990, p.94).

Although recent improvements in U.S. competitiveness was thought to be the result of closer match between computer technology and innovative administrative solutions (Gleckman et al., 1993), there were major differences in human resources practices and work organisation. Saraph and Sebastian (1992) stated that between 50 to 75 per cent of

AMT implementation in US firms had failed mainly as a result of 'their neglect of human resource factors'.

This led to an increased focus on ways to develop appropriate structural, organisational, human resources and personnel policies to achieve better results from the new technologies (Wall et al, 1987; Campbell and Warner, 1992; Clark, 1993; Storey, 1994; McLoughlin and Clark 1994). Other studies indicated that plants that effectively combined technology improvements with a human orientation achieved higher levels of productivity (Horte and Lindberg, 1994). Thus, the development of lean production as one the tools to address the organisational issues seemed to offer practitioners the answer to their AMT problems.

At the heart of lean production is the powerful combination of just-in-time manufacturing (JIT) and total quality management (TQM) and the development of consistent bundles of human resource practices (MacDuffie, 1995) that deploy teamwork, multiskilling, continuous improvement, increasing worker autonomy and empowerment. The introduction of lean production is presented as the path to achieve optimised performance from the Advanced Manufacturing Technology including flexible manufacturing systems.

Certainly, many of the adopters of these approaches did experience significant improvements from this coupling with AMT (MacDuffie 1991, 1995; Adler and Cole, 1993). However, closer scrutiny of this formula points to a significantly more complex interaction relationship between the two. This interaction requires a deeper level of analysis and evaluation that goes beyond the mere statement of the need for such organisational changes and the subsequent expectation of significant productivity and flexibility gains once the lean production system is implemented.

There have been appreciable increases in productivity and flexibility as a result of the introduction of lean production. Nevertheless, in many cases, these productivity and flexibility gains do not appear to be extensive enough or sizeable enough to justify some of the far reaching claims of the emergence of a new paradigm and the associated revolutionary change.

To date, the issue of AMT and the new organisational arrangements still occupies a significant portion of the interest of researchers and practitioners alike. Manufacturing companies are continually facing new challenges that call for an ongoing process of analysis and examination of the core competencies and contingencies necessary for their survival. Choices are being made about advanced manufacturing technology and new organisational arrangements, structures and systems are being adopted and adapted in an effort to maximise these competencies and achieve and maintain competitive advantage.

The key aims of this thesis are:

- to outline the interaction between lean production and flexible manufacturing systems;
- to explore the extent to which the characteristics of flexible manufacturing systems and lean production systems features are compatible or incompatible;

and the key research questions to be addressed are:

- are their any tensions or inconsistencies in this tight linkage between lean production and flexible manufacturing systems?
- if there are tensions in the relationship and interaction between FMS and lean production are these the result of a logical inconsistency: an inherent contradiction at the conceptual (design) level?
- alternatively, if there are tensions in the linkage between lean production and its application to the FMS, are these tensions the result of an internal factor such as actions by management or employees resulting in a mismatch in the coupling between the two? Are these tensions the result of a flaw in the application of the lean production system?

These questions will provide a platform for the examination of the dynamics of lean production and its interactions in the flexible manufacturing environment. This relationship will be examined in terms of the assumptions associated with the coupling of both these techniques and systems in four European manufacturing companies.

This study will address in detail, the critical dimensions of interaction between lean production and flexible manufacturing systems and will give evidence to reveal the points of tension and their consequences.

1.3 Organisation of the Study

This thesis is presented in eight chapters. Following this introduction, chapter two will review the literature on AMT and NWM, and will describe these two sets of phenomena in more detail. It will attempt to address why these AMT systems have been put in place and what caused managers to introduce NWM and will address lean production systems and FMSs in particular. It will also present the key dimension chosen for the analysis of the case studies. Key potential issues concerning the existence of inconsistencies and contradictions between AMT and NWM are examined.

Chapter three further clarify the research questions and describe the theoretical framework and methodology of this study. On the basis of the literature review and actual reports from field study, complexity, integration, regulation, and flexibility will be chosen as the focus dimensions for investigation in the field. In reporting the case findings, information will be reported on each of the key dimensions identified as important in the literature review. These key dimensions are further discussed in the concluding chapter.

Chapter four presents the case of EBG a Dutch truck manufacturing company and examines the application of lean production to its FMS environment. Chapter five studies a Dutch aircraft manufacturing company (Fokker Aircraft) in the period before its closure and focuses on one fabrication and components plant which utilised FMS and lean production. Chapter six, switches to yet another Dutch, but smaller size company which manufactures refrigeration compressors. And finally, chapter seven presents a UK diesel engine manufacturing company that also adopted both lean production and FMS systems.

These case studies were chosen because certain key similarities suggested that any observed differences may be due to the combination between lean production and FMS rather than other features of organisational context. All four companies process or machine common materials consisting of metal components (ferrous and non ferrous). All four companies had introduced lean production and the FMS systems in relatively close periods of time to each other. All four companies are subsidiaries of large foreign corporate parents. Semi structured interviews and a questionnaire were used to investigate these companies over a period of four years.

Chapter eight will analyse the results of the field research in these four companies and will compare, summarise and present the general conclusions of the thesis including some recommendations for possible future research directions in this area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

As the title of this thesis indicates, the core of this study addresses the interaction between lean production systems and the flexible manufacturing systems (FMS) and its environment. The literature on FMS and lean production is a subset of the broader body of knowledge related to technology, work organisation and human resources structures. This chapter will present a review of the literature associated with the interaction between technology, work organisation and human resources structures and interactions. This chapter will be divided into three sections: the first section will introduce the definitions and key concepts used in this thesis, followed by a review of the criticism associated with lean production. The second section presents the key dimensions of complexity, integration, regulation, and flexibility as the characteristic features of FMS. The third section will present a general overview of the technology-organisation interaction literature.

The original ideal vision of the combination of lean production and satisfied workers has been rejected by many researchers who examined changes in the quality of work life under lean production (Parker and Slaughter, 1988; Klien, 1989; Fucini and Fucini, 1990; Sewell and Wilkinson, 1992; Graham, 1993, 1995; Babson, 1995; Delbridge, 1995, Landsbergis et al., 1996; Nishiyama and Johnson, 1997; Lewchuck and Robertson, 1997). Other researchers questioned the claims that lean production practices necessarily lead to high manufacturing gains. Lowe et al., (1997) looked at the performance of 71 'first tier' automotive components plants based in Europe, North America and Japan and their data did not support the notion that work organisation and human resources policies associated with the production model represent a universal "best way" for achieving high manufacturing performance.

Disappointment resulting from failed of AMT implementation (Udo and Ehie, 1996; Sohal, 1996). was mainly attributed to non-technical, people related organisational reasons (See Rosenthal, 1984; Voss, 1985; Jaikumar, 1986; New, 1986; Tarnfield et al., 1989; Bessant et al, 1990, 1993). Womack et al. (1990) found that the automation levels did not account for the wide differences in performance between lean and traditional plants. They noted that *'what is truly striking is that- at any level of automation- the difference between the most and least efficient plant is enormous'* (Womack et al., 1990, p.94). In many cases increasing automation lead to a decreases rather than an increases in plant flexibility (Upton, 1995), the high failure rate of technology implementation was mainly attributed to non technical, people related organisational causes (Rosenthal, 1984; Voss, 1985; Jaikumar, 1986; New, 1986; Tarnfield and Smith, 1989; Bessant et al, 1990, 1993). AMT refers to a family of technologies which includes computer aided design and engineering systems, material resource planning systems, automated materials handling systems, robotics, computer-controlled machines and computer integrated manufacturing systems (Schroder and Sohal, 1999)

As Karwowski and Salvendy (1994) pointed out, the importance of the human issues behind the implementation of manufacturing technology should not be underestimated.
Additionally, the importance of effective operator interaction with the machine has been widely recognized in the literature (Bailey, 1989; Schneiderman, 1992; Johannsen et al., 1992; Ruge et al., 1995). This part of the broader body of knowledge indicating the need to balance increased automation with improvements in human resources management (Horte and Lindberg, 1994). Beaty (1992) suggested that AMT implementations have their own unique "process and logic" and researchers have only just begun to understand the entire phenomena.
Chen and Small (1996) Studied various companies that implemented shopfloor automation and found that top management support and employee participation were among the key factors that lead to AMT success in addition to vendor relationships, product-process dependence, and manufacturing strategy.

2.2 Flexible Manufacturing Systems

An FMS can manufacture assorted products using the same group of machines linked by automated materials handling systems and controlled by a computer system. Automated and pre-programmed workstations are linked for different operations, ensuring that all members of a family of parts can be produced whenever needed. It is a form of advanced manufacturing technology where the production machines (computer numerical control) are interconnected by a transport system. The transporter carries work to the machines on pallets or other interface units so that work-machine registration is accurate, rapid and automatic. A central computer controls both machines and transport system (National Bureau of Standards, in Upton, 1992; 1994). The key in an FMS is that the coordination of the work flows is carried out by a central control computer. This computer performs functions such as: scheduling jobs onto the machine tools; downloading part-programs (giving detailed instructions on how to produce a part) to the machines; and sending instructions to the automated vehicle system for transportation (Upton, 1992).

The machines use numerical control which is a generic term describing machine control technologies that use numerically coded instructions to guide machining operations. A numerically controlled machine tool has (1) specifically equipped motors to guide the cutting process and (2) a controller. The controller receives numerical commands and translates them into electrical impulses that operate the motors, guiding the metal cutting process.

There has been a number of papers indicating that the economies of scope expected in the implementation of the FMS will not be achieved unless they are matched by organisational changes (Adler, 1988; Chang, 1989; Chen and Adam, 1991; Elango and Fried, 1993; Gephart, 1995; Goldhar & Lei, 1995; Graham & Rosenthal, 1986; Hayes & Jaikumar, 1988; Jaikumar, 1986; Maffei & Meredith, 1994, 1995; Mueller et al., 1986; Nemetz & Fry, 1988; Nemetz, 1990; Parthasarty & Sethi, 1992; Sethi & Sethi, 1990; Teresko, 1995; Walton & Susman, 1987).

Since human resources are central to an administrative system (MacDuffie, 1995; Maffei & Meredith, 1995; Majchrzak, 1988), the extent to which FMS achieve economies of scope is expected to be a function of the extent to which human resources change to meet the requirements of FMS.

Taheri (1990) asserts that parts which have similar physical configurations or can be partitioned into distinct product families, and which require similar machine operations on similar machines are prime candidates for FMSs. The above requirements provide an explanation for the proliferation of FMSs in metal working operations for the manufacture of machining components.

2. 3 The Lean Production System

The concept and acceptance of lean production as a set of principles is now fairly rooted in the literature (Womack et al., 1990; Karfcik, 1988; Monden, 1983). Haslam et al., (1996) noted how throughout the 1980s and well into the 1990s, innumerable articles took, as axiomatic, the superiority of lean production. Although the distinctive "logic" of flexible production in auto assembly emerged from the experiments of Japanese companies in the 1950s and 1960s (Monden 1983; Cusumano 1985; Ohno 1988), the study of JIT as a conscious manufacturing strategy in the West was spearheaded by researchers like Abernathy et al. (1981), Hayes and Wheelwright (1981). Detailed descriptions of the way in which the production systems based on the Japanese just-in-time principles such as the elimination of waste, reduction of production cost, total quality control and recognition of employees' abilities can be found in specialised texts: Shingo(1981) and Ohno (1978, 1982, 1988) explained the development of JIT in Toyota while Monden (1983), Schonberger (1982, 1984, 1986) discussed various philosophical and implementation issues of JIT. Schonberger analysed the adaptability of JIT practices by the Western manufacturing firms and provided a systematic framework for the JIT principles. There have been a considerable number of books and papers which have reviewed the JIT literature (Berkley 1992; Golhar and Stamm, 1985; Harrison, 1992; Hallihan et al., 1997; Keller and Kazazi, 1993; Singh and Brar, 1992; and Sohal et al., 1993) however, it was primarily the study of the Japanese auto industry by Womack, Jones, and Ross (1990) preaching the gospel of lean production as offering the promise of tremendous improvements that the total concept became popular.

In simple terms lean manufacture was defined by Womack et al. (1990), as follows:

- integrated, single piece production flow, small batches, just-in-time giving low inventory;

- defect prevention not fault rectification;

- production pull not push with smoothed demand;

- flexible, team-based work organization with multi-skilled workforce and few indirects;

- active involvement in root cause problem solving to maximize added value;

- close integration from raw material to customer through partnership.

Krafcik and McDuffie (1992) and Womack et al.(1991, p.13) noted its emphasis on 'lean' for its use of less of everything compared to mass production: half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever-growing variety of products.

Womack et al. (1990) argued that lean production represented a dramatic shift from the traditional Taylorist and Fordist principles of mass production such as detailed division of labour and fragmentation of jobs, deskilling, and centralised managerial and supervisory control (Braverman 1974, Giordano 1992). They presented lean production as the historical successor of the mass production: *"... we believe, lean production will supplant both mass production and the remaining outposts of craft production in all areas of* *industrial endeavor to become the standard global production system of the twenty-first century"* (Womack et al., 1990, p.278).

In addition to the just-in-time low inventory levels and just-in-time delivery driving the the detection of error sources, A key element of lean production is its vigorous focus on quality management compared with the traditional mass production approach (Levy, 1997). A number of authors identified the core features of the total quality management used in the lean production framework and the practice and ideologies that comprise it. On the practical side, these included (Garvin, 1987, 1991, 1993; Crosby 1979, 1984; Juran 1988, 1992; Deming 1986) who attempted to provide managerial insights on the effective 'management of quality'. These books provide recipes or principles (see Powell 1995 for summary) based on the vast experience of leaders in the field such as Deming, Juran, and Ishikawa.

Lean production is often referred to as a combination of just-in-time manufacture and total quality management (TQM). TQM is a management strategy that is intended to produce continuous improvement in work processes. Logically flexible production technologies are needed to support continuous improvement (MacDuffie & Krafcik, 1992). The term flexible technology has been used in the past to describe programmable production equipment that can be easily reprogrammed to produce customised products to meet customer demand (Jaikumar, 1986). The *technology* is also flexible because production workers can stop machines if quality problems arise. Hence, an organisation that implements TQM has to have flexible *technology* in order to achieve continuous quality improvement.

The key emphasis in lean production was on successive quality control integrated in the production process and the integrated approach to quality management that lean thinking emphasises (Lamming, 1993; Womack & Jones , 1996) conducted by all actors through design for manufacture by integrating product and process engineering, team work, quality circles, and company wide information sharing, and directly by workers through preventive maintenance where shop-floor workers have maintenance roles; statistical process control; standardised procedures at all levels and in all functions (Womack et al., 1990; Clark and Fujimoto, 1991) in addition to more recent trends which include self assessment through internal quality audits, and focus on administrative routines for quality improvement (Soderquest and Motwani , 1999). Lean production has been extended to encompass the whole spectrum of activities in the business such that world-class companies are seeking to become lean enterprises (Lamming 1993; Harrison, 1992; Jones, 1994). Burcher and Dupernex (1996) notedThat the underlying philosophy can be applied universally within manufacturing, but the tools used to enable the philosophy need to be applied in a context-sensitive manner.

The lean production methodology encompasses the organisational structure, systematic education and training, and the use of Japanese manufacturing principles, such as: systems design; supplier integration; teamwork for continuous improvement; flexible and simple systems; attention to detail; inventory elimination; set-up reduction to facilitate batch size reduction; systematic de-bottlenecking; total quality; preventive maintenance to eliminate unscheduled breakdowns; eradication of non-value-adding activities.

2.4 Criticism of Lean Production

There has been considerable criticism of the lean production system. The primary argument against lean production is that these lean plants achieve much of their productivity by "sweating" workers through faster work pace, standardised jobs, social control via peer pressure, and stress from lack of buffers in the production system and Kaizen efforts that emphasise the labour input (Parker and Slaughter 1988; Fucini and Fucini 1990; Graham 1993). Even Womack et al., cited criticism by the UAW (United Auto Workers union) who call lean production "management by stress" because managers continually seek to eliminate "slack" from the system (Womack et al., 1990:41). Researchers like Bennett Harrison (1997, p.38) referred to this as the 'dark side of flexible production' while others like Turnbull (1988, p.18) observed the British experience in operating JIT and saw it as illustrating " both the degree off work intensification involved and the added stress that is endemic to the system". Klien (1991) questioned the motives of employers who promise "autonomy" when what they really intend is for workers to deliver an unprecedented level of cooperation.

A key element of the criticism of lean production is its claim of productivity gains. Lowe et al., (1997) examined the hypothesis that lean production practices necessarily lead to high manufacturing. Studied the performance and management of 71 'first tier' automotive component plants base in Europe, North America, and Japan. Their data did not support the notion that the work organisation and human resource policies associated with the lean production model represent a universal "best way" for achieving high manufacturing performance. Rather, the findings emphasise the importance of context, specific plant characteristics, and choice for understanding the performance of manufacturing organisations.

Another key criticism of lean production system was that LP implicitly require different approaches to managing human resources, Womack et al. did not explain how human resources practices are integrated into these different production systems, nor did they test the relationship between these practices and performance. While work practices and human resources policies are considered central to the Japanese production system and the success of the Japanese automobile industry (producers (Womack et al., 1990; MacDuffie, 1995; Pil, 1996), the original book by Womack dealt with the human resources management aspects of lean production in a relatively elementary way. There was a need to explore the role of human resources in the "organizational logic"(MacDuffie, 1995) of lean production system and for further elaboration of the "social arrangements of production" (Harrison and Storey, 1996).

MacDuffie (1995) argued that an 'organizational logic' of lean production underpins three generic collections of bundles of organizational practices. These are: factory practices (related to the minimization of buffers, for example through the reduction of inventory levels and minimization of repair space), work systems (related to teamwork and the development and application of employee knowledge and skill on the shop floor) and human resource management (HRM) practices (concerning the encourgement of high commitment and motivation of the workforce).

Harrison and Storey (1996) pointed to five areas in which were considered as prerequisites for successful implementation:

'first to overcome the barrier of treating NWM approaches as simply a series of technical fixes; second, the need to improve integration; third, the need for premium levels of commitment from employees; fourth, the need to widen the managerial agenda beyond the firm to encompass the entire supply chain; fifth, the need for change in company culture.' (Harrison and Storey, 1996, p.66).

In the next section, I will discuss the key research dimensions associated with the flexible manufacturing systems in particular

2.5 Research Dimensions

At the conceptual level, it is possible to identify a set of dimensions which encompass certain characteristics associated with flexible manufacturing systems (FMS). Using Mintzberg's (1979) dimensions for the technical system employed by the organisation, Krabbendam (1988), Boer (1990), Boer and Krabbendam (1991) identified six key dimensions to these production technologies: complexity, integration, flexibility, automation, regulation and expensiveness (Boer, 1990:30).

In order to develop a frame of reference and consistency in the investigation of the interaction between lean production and the flexible manufacturing systems used, the same dimensions used by Krabbendam (1988) and Boer (1990) (complexity, integration, flexibility, automation, regulation, and expensiveness), will be used as measures for exploring the relationships between the lean production and its application to the flexible manufacturing systems used in the case companies.

2.5.1 Complexity

Kuhrana (1999) categorised the various *complexity* concepts into four types - technological, logistical, organisational, and environmental *complexity*. (1) Logistical *complexity* is the result of a high volume of transactions or tasks, or product proliferation; (2) Technological *complexity* is related to the inherent *complexity* of the system and its technologies (for both products and processes; (3) Organizational *complexity* pertains to the organisational structures, forms, and procedures that make organisations complex.

There are several factors that determine the overall manufacturing system complexity. A main set of factors relates to the manufacturing processes being supported by the system: the complexity of the supervisory tasks performed, the complexity of the operators tasks, and the complexity of the required operators behaviours (Martensson and Stahre 1992). Another major determinant of the overall manufacturing system complexity is the complexity of the system in terms of the number of product types manufactured, number of manufacturing operations involved, and the amount of systems maintenance necessary.

In an FMS system, the technology introduces new levels of complexity to the work environment by virtue of the software and hardware requirements. Its introduction increases the number of interrelated elements in the system compounding the level of complexity. FMS complexity reaches a stage were it becomes necessary to use special diagnostic equipment and process planning as well as decision making and tool / part management software in order to maintain control over the production process.

This complexity is also evident from the high, on-line, computing power requirements (including a large stored part program inventory) which means that there is a need for extensive preparation and implementation requirements (Luggen, 1989). In contrast to this complexity, new wave manufacturing focuses on simple work organisation and restructuring approaches i.e. human centred approaches (Ebel, 1989) which characterised the Japanese style production methodologies and systems. This simplification approach was clearly evident in the case of lean production (Womack et al., 1990) in the car industry.

An FMS is a complex, automatic system in which many failures must be anticipated and catered for. The software for controlling medium/large FMS has to handle the tremendous complexity of scheduling and dispatching multiple products through a variety of processing routes, transporting them around the system and recovering from any failures in system components. Failures such as tool breakage, machine and vehicle failure are fairly common. In such circumstances, methods for recovering from the faults must be built into the central control software which adds to the complexity of the control software (Upton, 1994).

In this thesis, the discussion is limited to the production environment in each of the factories studied where the relevant dimensions include technological and logistical complexity. Both dimensions, when viewed from the perspective of the users of the technology, relate to overall job complexity. Job complexity is a measure of autonomy, variety and feedback derived from the Job Diagnostic Survey (Hackman & Oldham, 1975). The model developed by Hackman and Oldham showed that outcomes such as internal motivation, quality performance, satisfaction, absenteeism, and turnover were the result of five core job dimensions: skill variety, task identity and task significance, autonomy, and feedback.

2.5.2 Integration

A second comparative criterion between FMS and lean production is the degree of overall integration of resources and processes. Krabbendam (1988) considered integration as a key characteristic of FMS technology. He defined integration as ' the extent to which the system is able to perform different types of operations, to change tools, to transfer and load work pieces, and to download part programs and production schedules from a central storage' (Krabbendam, 1988 in Boer, 1990, p.101). This definition could be expanded to include the ability to perform and harmonise the various operations within the system and is done through the use of special hardware/ software linkages.

This need for integration is of no less importance lean production systems. The difference is that this integration is often achieved not through dependence on the technology, but through developing internal cooperation and teamwork mechanisms, as well as developing proper communication structures.

Therefore, considering the relationship between the FMS and lean production along the integration dimension, we can see that the need for integration mechanisms is necessary in both cases. The use of FMS increases the need for organisational coordination and integration (Kaplinsky, 1984). A number of authors looked at the need for integration within manufacturing and found that the use computerisation and advanced manufacturing technology increases the complexity and internal interdependence which in turn increases the need for greater integration (Kaplinsky, 1984; Haywood and Bessant, 1990; Gerwin and Kolodny, 1992). Coupled with the lean production structures, AMT can act as a catalyst which increases and promotes overall organisational integration by improving 'the accessibility and speed of information capture and display across different levels and areas of operation' (Clark, 1993, p.11).

2.5.3 Regulation

Regulation is defined as the influence the system exerts on the work of operators, process planners, production planners and maintenance engineers (Krabbendam, 1988; in Boer (1990, p.101). It closely relates to formalisation (the extent of written rules, procedures, and instructions) which is a central feature of Weber's bureaucratic ideal type and an extensively researched dimension of organizational structure (Pugh and Hickson, 1976; Mintzberg, 1979). The degree of formalisation can be conceptualized in the conventional terms of the Aston group (Pugh and Hickson, 1976) as the extent of formalised rules governing work behaviour and the extent to which they are enforced. Arches (1991) found formalisation negatively associated with job satisfaction, and Kakabadse (1986) found formalisation of tasks and work processes positively associated with feelings of powerlessness and self-estrangement. Organizational researchers have noted that people particularly resent what they consider "bad" rules, while "good" rules are taken for granted and rarely noticed (Perrow, 1986, p. 24).

Lawler (1994) pointed to the existing tensions between employee involvement and the TQM focus on codification of the work processes. Applebaum and Bart (1994) described the existence of contradictions between the 'lean' and 'team' approaches.

Based on contingency theory, negative attitudinal outcomes attributed to formalisation are often due to a misalignment of task requirements and organisation and job design. Employees will react positively both when high levels of formalisation are associated with repetitive or routine tasks and when low levels of formalisation are associated with more task variety and complexity (Adler and Boryes, 1996). However, lack of autonomy and control will create negative feelings and act as a de-motivater.

Scott (1992, p 31) noted that structure is formalised to the extent that the rules governing behaviour 'are precisely and explicitly formulated and to the extent that roles and role relations are prescribed independently of the personal attributes of individuals occupying positions in the structure'; formalisation thus 'serves to objectify the structure'. Formalisation procedures provide organisational memory that captures lessons learned from experience (Levitt and March, 1988; Walsh and Ungson, 1991). Formalisation codifies best-practice routines so as to stabilise and diffuse new organisational capabilities (Nelson and Winter, 1982). Adler and Boryes(1996) pointed to two types of formalisation: the enabling and coercive. This idea of an enabling type of formalisation is consistent with Blau's (1955) finding that "good" procedures are those seen as valuable resources that help professionals meet clients" needs.

Coercive type of formalisation, procedures fit Walton's (1985) characterisation: They are a substitute for, rather than a complement to commitment. Instead of providing committed employees with access to accumulated organisational learning and best-practice templates, coercive procedures are designed to force reluctant compliance and to extract recalcitrant effort.

This assumption was re-enforced by a number of studies which confirmed that simply investing in advanced technology did not guarantee successful performance and productivity gains (Bessant et al, 1992; Burnes, 1988; Waterlow and Monniot, 1986). It became clear that these AMTs were not being used effectively (Tarnfield and Smith, 1989; Saraph and Sebastian, 1992), and that the original promises of increased productivity and flexibility were not being fulfilled (Bessant et al, 1990; New, 1986; Voss, 1985). Because organisational rather than technical reasons were given for the disappointing AMT performance (Rosenthal, 1984; Jaikumar, 1986; Callerman and Heyl, 1986), there was a trend towards adopting many of the Japanese techniques and other work organisation initiatives which). An army of industrial and business consultants helped in the dissemination of these new work organisation and management techniques such as JIT and TQM.

2.5.4 Flexibility

There are many kinds of flexibility and indeed a sizeable literature devoted to competing typologies of the various kinds of flexibility (see overview by Sethi and Sethi 1990). Upton (1994) defined flexibility in abstract general terms as " the ability to change or react with little penalty in time, effort, cost or performance" (P.73). Adler and Goldoftas (1999) noted that from an organisational point of view, all forms of flexibility present a common challenge: efficiency requires a bureaucratic form of organization with high levels of standardisation, formalisation, specialisation, hierarchy, and staffs; but these features of bureaucracy impede the fluid process of mutual adjustment required for flexibility; and organizations therefore confront a trade off between efficiency and flexibility (Knott 1996, Kurke 1988).

Slack (1991) identified two critical factors for judging the flexibility of process technology: 'range flexibility' which indicates how far an operation can change, and 'response flexibility', which indicates how fast the operation needs to change. Generally, flexibility is defined as the ability of a company to respond to market demands and react to market changes with few penalties with regard to time, effort, cost or performance (Upton, 1993a) There are four types of flexibility: mix flexibility, product flexibility, volume flexibility, and delivery flexibility (Slack, 1989; 1991). The desired flexibility associated with the introduction of certain types of AMT are seemingly introduced to achieve inter alia any one of these flexibilities depending on the overall strategic and manufacturing objectives of the organisation.

Although FMSs introduce technical flexibility through the reprogramable control of operations and integration mechanisms, developing the necessary manufacturing flexibilities is not limited to the choice of production process but also involves organisational and infrastructural transformation throughout the organisation. Operational advantages are not automatically achieved through the introduction of these AMTs. Adaptations in areas such as production, process planning, quality control, and maintenance are essential if the technology is to lead to operational advantages (Boer, 1990). These adaptations are key elements of the new wave manufacturing strategies. It is assumed that coupling these NMW strategies with these technologies will lead to gains in the overall flexibility of the manufacturing function. The flexibility associated with the new wave manufacturing approaches revolves around the organisation of work and the optimisation of labour productivity, skill, and training and the use of 'functional flexibility' which involves job range and task enlargement (Atkinson and Meager, 1986, Pollert 1991a).

There are many existing factors associated with the technology which affect the manufacturing flexibility. For example, in an empirical study on the flexibility of 61 plants in the paper industry, David Upton (1993b, 1995) found that actual day to day flexibility was severely limited by the existence of a high degree of computer integration:

' There is a consistent, strong, negative relationship between computer integration and range, particularly integration aimed at automating grade changes.' (Upton, 1993b, p.25)

Upton presented two plausible explanations for his findings: (a) that 'system designers are conservative, and complex automation systems require a clear understanding of the range of control tasks requires', or (b) that 'firms only install computer integration systems on those systems which have a limited range' (Upton, 1993b, p. 26). Both of these involve infrastructural or organisational/ managerial rather than technical implications.

Although the Upton study was specific to the paper industry, it served to indicate that claims of flexibility associated with computer integration may be misleading. The focus of the technology management literature in the past few years on the need for structural and organisational changes in conjunction with AMT introduction serves to support Uptons' conclusions on the lack of empirical evidence to support there is a positive relationship between flexibility and computer integration. Slack (1989) referred to these structural and organisational changes as 'infrastructural resources' which are needed to achieve the desired levels of flexibility. They included the 'systems, relationships and information couplings which bind the operation together' (Slack, 1989).

2.5.5 Automation

By definition, the use of advanced manufacturing technology implies an increase in the level of automation within the company. In terms of the FMS, Automation is defined as the degree to which operations such as workpiece transfer, loading and unloading and fixturing, tool change, machine tool control, cutting tool control and quality control, are performed by the system without human intervention" (Boer, 1990). On the other hand, the lean production systems focus less on the technology as they focus on the overall organisational and structural arrangements of work. The use of teamwork, multiskilling, continuous improvement, training, and increasing employee autonomy, and developing a motivated workforce, are the key components of these systems organised around the existing production technology.

2.5.6 Expensiveness

Expensiveness is defined as 'the costs incurred in the investment in, and the operation, maintenance and regulation of the system ' (Boer, 1990). In terms of the research question, expensiveness is of interest as a dimension only in terms of the effect the high cost of the technology (the FMS) has on the actions of management (and/ or the production staff) in deciding the degree of operator freedom in the operation of the FMS. Expensiveness is an issue in terms of managerial (specifically the manufacturing / production managers and staff) that the expensiveness of the equipment makes it imperative to increase the control over haw the FMS is used and limit operator discretion as not to ruin the equipment. This also related to fear of production line down time and stoppage if there was crash in the FMS operation

The preceding dimensions directly relate to the interaction between the FMS technology and the organisational structures and approaches that characterise lean production. These dimensions were used as the mechanism to collect evidence at the point of interaction between the FMS and the lean production system at the shop floor. While the original intention was to collect evidence on all these dimensions (Complexity, integration, regulation, flexibility, automation, and expensiveness), expensiveness of the FMS did not seem to be an issue to the actors on the shop floor and even through some of the managers used the expensiveness of the equipment as a reason to maintain tighter control over the process. For the majority of operators, supervisors, production and manufacturing staff, the expensiveness dimension did not solicit any interest. Accordingly, the dimension of expensiveness was not pursued further. As for the automation dimension, the very core of this study is AMT and the FMS in particular which meant that the focus of the thesis is automation anyway and is not limited to viewing it as only one dimension out of six. Thus, the key dimensions used to explore lean production in the FMS environment are: Complexity, integration, regulation, and flexibility.

The overall framework of the lean production and flexible technology is a subset of the theoretical debate that is part of a long history of debates on technology and automation and its impact and role in the workplace. In order to put these interactions in perspective, the next section will present a brief history of the debate and the key developments in the strategy, technology, and organisation triangle.

2.6 New technology and the Emergence of a New Paradigm

'New technology' in the work place has always attracted the attention of researchers and practitioners. With each new technological innovation new assumptions are made and old ones recast, about the role and impact of new technology on the organisation and structure of work. The debate can be traced to the introduction of automation to the workplace in the 1950s, and has continued to resurface throughout the past four decades whenever a new form or a new generation of technology is introduced in the workplace. The number of these studies continued to grow as the pace of innovation and technical development surged to new heights, mainly as a result of the development of the microprocessor and its proliferation at all levels of the organisation. With each new generation of microprocessors, new generations of production equipment and systems were developed with a better level of control, increased power, and higher degrees of flexibility and processing ability. These developments dramatically changed existing norms and structures both at the macro and micro level and hence, researchers from various schools of thought saw a new paradigm emerging as a result of these technological changes. The new paradigm was seen to discard the old mass production (Fordist) model which dominated the economies of the West for most of this century, and to usher in a new 'techno economic' model (Perez, 1985; Freeman, 1990; Dosi et al, 1988; Freeman et al, 1993). Translated at the micro level within the production (factory) environment, the model became a 'new technological paradigm which resolved the traditional incompatibility between efficiency and stable forms of productivity growth, on the one hand, and continuing innovation on the other' (Jones, 1990). This paradigm was also seen in the move from the 'inflexible division of labour' towards the 'comprehensive system design' (Trist , 1981; Jurgens et al , 1986). The old ways where technology was fixed, unchangeable and determined the remaining factors within the company were gone and a new entity based on the common optimisation of the technical and social systems of the organisation was formed (Salvendy and Karwowski, 1994).

At the macro level, the debate between 'demand pull' and 'technology push' that were used to explain the technological revolution as far back as the late 18th century was at the heart of the innovation theory school developed by Schumpeter (1950) and recast by modern researchers such as Rosenberg (1982), Dosi (1982), Pavitt (1984) and Freeman (1990), who now form a neo-Schumpterian school (Schumpter, 1950; Harris, 1997). This neo Schumpterian school viewed the successive waves of technical change as the new force for economic growth. The dramatic changes resulting from the new technological advances did not fit into the traditional economic models that were based on the profit maximising imperatives and the workings of markets and the speculative activities of investors (Harris, 1997). A new 'techno-economic paradigm' (Freeman and Perez, 1988; Dosi et al, 1988; Freeman et al, 1993) was seen to be at work precipitated by the dramatic developments in microlectronics and its application in all sectors of the economy. This was a new paradigm which ushered in the decline of the traditional industrial economy and the development of new engines and entities for economic growth. Nelson and Winter (1982) saw 'technological trajectories' derived partly form the possibilities inherent in these new technologies (Harris, 1997, p.28).

2.7 Making Choices about Technology and Organisational Arrangements

This 'deterministic' (or structural) account of technical change and its opposing views championing the role of human agency, organisational processes, and social choice have dominated the debate over the past fifty years and is at the heart of the story of technology and work. In the 1950s and 1960s the debate focused on the 'impact' of technology on work organisation and worker's behaviour and skill as well as on its impact on managerial control (Woodward 1958, 1965, 1970; Sayles, 1958; Blauner, 1964; Thompson, 1967). Thompson (1967) focused on the co-ordination requirements of technology making an important early contribution to our understanding of the relationship between technology, structure, and work design.

Research by Burns and Stalker (1961) approximated the working of organisations into 'mechanistic' and 'organic' systems of management which were seen to be determined by internal factors such as the strength of personal commitment and managerial ability, and external factors such as the rate of technical and market changes (Burns and Stalker, 1961, p.209). This research was influential in the development of 'Contingency theory' that saw organisational structure as a function of the firm's environment (Lawrence & Lorsch, 1967,1969) and was influenced by the Tavistock studies development of the sociotechnical systems approach which recognises among the key principles of the sociotechnical model: human resources development, response to the environment, innovation, cooperation, commitment, and joint optimisation of both social and technical dimensions of the organisation.

The 'technological impact' approach dates back to the Tavistock studies and the socio-technical systems view of organisation (Trist and Bamforth, 1951; Emery, 1959; Touraine, 1962; Trist et al., 1963). This approach viewed organisations as systems of interrelated structures that are affected by the environment in which they operate, the technology being utilised, and the sentiments of the users. Although these studies focused on the technical characteristics of the production systems, in their seminal work on the Durham coal mine (Trist et al, 1963) as Brown has indicated 'they did not see technology as having direct effects on workers' attitudes or behaviour, nor as determining a particular set of work and social relations (Brown 1992, p.74).

One of the most influential representatives of the 'impact of technology' school was Joan Woodward (1958, 1965). Woodward was the first to empirically disseminate that technology is an important variable that contingently interacts with structure to influence organisational performance. She believed that there was 'a particular form of organisation most appropriate to each technical situation' (Woodward, 1965, p.72). The theoretical framework for this view laid the foundation of 'Contingency theory'. She saw 'technology' as the key contingency factor affecting organisational structures as well as the behaviours of individual actors within organisations. Focusing on the production technology of manufacturing firms, she observed that the technical complexity and the level of predictability of production tended to increase as one moved along the production spectrum from the unit and small batch production to the continuous flow production processes. Woodward observed that there was a linear relationship, an increase in the level of authority and bureaucracy as technical complexity increased. She also pointed out that at the unit production and process production ends of the spectrum, firms had less bureaucratic and more flexible structures than mass production due to the need for innovation (a curvilinear relationship) in product development for unit production technology and in marketing innovation for process production. Thus, her conclusions were that there was a strong relationship between the type of production technology and the managerial and organisational systems and structures being used. Achieving the optimum organisational performance was seen as contingent on using the appropriate organisational structures with the appropriate production technology. A number of other writers reached similar conclusions and asserted that technology does have an influence over organisational structure (Harvey, 1968; Kotter & Schlesinger, 1979; Boddy & Buchanan, 1986; Helfgott 1988; Fry, 1992; Parthasarthy & Sethi, 1992).

Woodward's findings about the relationship between production systems and patterns of management were tested by Thurley and Hamblin (1963) in a study focusing on supervisory jobs. Their conclusion was that the relationship between technology and the supervisor's job was a complex one affected by factors such as: the degree of planned variation in the operations (related but not identical to the type of production system); the degree of complexity of the operations supervised; the degree of mechanisation of the process; and the organisation of supervisory systems. Blauner (1964) also saw technology in a deterministic light with different forms of technology leading to different forms of control. He argued that technology was the cause of workers' alienation and not the social relations of production. Accordingly, technology determined the social organisation of the factory and workers behaviour. Blauner saw automation as the way to end workers isolation and alienation associated with assembly line work, and took the chemical and oil refinery production technology processes as the model for the automated factory replacing mass production.

Overall, the work of these authors had a considerable influence on the study of industrial organisations. For example, Woodward (1965) and Burns and Stalker (1961) considerably weakened the arguments for 'a one best way' to organise and manage organisations, and gave credence to the impact of the environment and associated social and technical systems, specifically the different demands that technical systems exert on these organisations. Later, a number of researchers based at Aston University further developed the previous approaches by focusing on the organisational structures of the organisations under study, and investigating, inter alia, the relationship between organisational structure and technology. Pugh and Payne (1977), and Pugh and Hickson (1976) related the variability in organisational structures to the overall organisational 'climate' and context of these organisations. They identified six primary dimensions of organisational structure: specialisation of activities; standardisation of procedures; formalisation of documentation; centralisation of authority; configuration of positions; and flexibility (Pugh and Hickson, 1976). They developed quantitative scales for measuring and comparing organisational characteristics and the relationships between variables (such as scales for measuring variation in the operations technology).

By the 1970s, the 'organisational choice' thesis was put forward as a counter argument to the 'impact of technology' school. Its adherents rejected the view that technology has an 'impact' on organisations and instead argued that the link between the technology and organisation is essentially the result of a political process that reflected choices that are based on managerial perceptions (Child, 1972). Child argued that managers will normally have several goals in mind, for example, when introducing new technology. He identified four management objectives which were prominent in new technology introductions: reducing operational costs; increasing efficiency; improving quality; and improving managerial control (Child, 1984). Other authors such as Clegg and Dunkerley (1980) stressed the role of strategic choice in skill decisions.

Technological change was seen as primarily an opportunity for various social forces to play out another round in their rivalry. This argument was reinforced by research showing that implementation is typically accompanied by modifications that adapt the technology to local technical and social conditions (Sahal, 1981; Leonard-Barton and Sinha, 1993). A plausible middle ground was charted by Corbett (1992), who argued that some technologies, and some aspects of any given technology, are less organizationally constraining and more technically malleable than others; he therefore characterized the nature of the impact of technology on work organization as "soft determinism."

This technological determinism versus organisation choice debate continued to fuel the interest of researchers throughout the 1970s and 1980s (See reviews by Buchanan and Body 1983; Huczynski and Buchanan, 1991; Adler 1992; Gerwin and Kolodny 1992). By the late 1980s and early 1990s, following the spread of new microprocessor technologies into the workplace, a middle ground of 'technological imperatives' was introduced (McLoughlin and Clark, 1988). It argued that although technological change involves a process of choice and negation which provides the actors a role in the change process, technology does generate its own imperatives for work and skill in a variety of ways.

Other researchers argued for even a 'softer' form of technological determinism which is being brought about by managerial insistence on optimising the returns on the heavy investments in new technology (Adler, 1992). Adler then went on to posit that the heavy investment in Advanced Manufacturing Technology, both in time and financial resources, led managers to adopt new and novel work organisation and human resource initiatives in order to achieve an optimum return on their technology investment.

As managers have become more and more aware of the influence of social system characteristics on performance, a general move away from the belief that technology alone should determine the task environment the focus has expanded to include the social system, as well (Astley, 1985; Ford & Randolph, 1992; Scott, 1992).

2.8 Skilling, Deskilling and Employment Debates

Skilling and deskilling is another traditional area of the debate concerning new technology. The debate in the 1950s and 1960s was dominated by authors who saw automation as leading to the broadening of jobs and upgrading of skills relative to the limited job requirements of the 1950s assembly line (Adler, 1992). By the 1970s, inspired by Marxist labour process analysis, new technology was seen as leading to deskilling due to 'capitalist' insistence on lowering production costs and achieving greater control over the labour force (Braverman 1974; Kern and Schumann, 1970; Beynon and Nichols, 1977). Supporters of this view believed that human know-how is increasingly being incorporated into the new technology (Braverman, 1974; Wilkinson 1983). Other authors such as (Nobel, 1979; Shaiken, 1984) viewed this new technology as a real threat to craft work and as the cause of a drastic reduction in worker control over labour processes. This reduction of worker control over the labour process was exemplified in the introduction of Direct Numerical Control (DNC) machines which separated the programming function (i.e. control) from operation (Wall, Clegg, and Kemp, 1987). On the other hand, Hirschhorn (1983) saw automation as leading to the creation of new technically oriented and upgraded jobs. Hirschhorn's work was based on the socio-technical systems theory discussed earlier, which defined technology as the key feature in determining new work designs.

With the development of new technologies, these arguments saw a revival in the late 1980s and early 1990s. For example, Kern and Schumann 1992, revised their 1970 study of German automation. In the original 1970 study their conclusion was that automation seemed to be associated with deskilling and 'skill polarization'. Yet in their 1992 study, Kern and Schumann pointed to a skilling and workforce upgrading trend. In the data collected from the auto, machine manufacturing, chemical, and electrical and electronic industries, they noted, as an example of the upgrading trend, the emergence of a new 'Systems controller' job category (Kern and Schumann, 1992).

Another group of researchers saw technological change aimed at increased productivity requiring higher levels and broader varieties of skill from the work force (see Spenner 1982 and Barley 1988). They saw new microelectronic process technologies as creating skilled tasks and altering the relationship between the conceptual and sentient skill while eliminating unskilled work (Adler and Borys 1986; Attewell 1987; Hirschhorn 1984; Zuboff 1988). They suggested that conceptual activity replaces physical labour, and continuous learning becomes the core of new work. Accordingly, systematic learning should be instituted to prepare workers to intervene in cases of failure in automatic systems (Hirschhorn 1984)

Other authors noted that with the introduction of new production technologies, there would be a 'hybridisation' of skills, with workers gaining several new skills with greater emphasis on trouble shooting skills and a shift towards the multi-disciplinary worker (Campbell and Warner, 1987; Campbell and Warner 1992).

Other research into skill levels continued to support the new evidence pointing to a distinct net up grading trend (Adler, 1992). This debate over skilling and deskilling makes it clear that there are choices in the design and implementation of new technology which carry implications for both productivity and the quality of working life (Gerwin and Kolodny 1992).

Employment is another angle to the historical debate closely linked to the skilling and deskilling arguments. AMT is assumed to have lead to high displacement of labour at a ratio between 7:1 to 9:1 (Lund and Hansen 1986). Others reported that in CNC-based shops in engineering, reductions of 30 to 50 percent occurred in the number of operators and setters (Bessant and Senker 1987, Daniel 1987). Nevertheless, there seems to be a general agreement that automation as a whole will lead to a gradual transformation of the employment structure. Forester (1989) argued that most of the evidence showed new technology as creating jobs rather than increasing unemployment, and improving quality of working life instead of deskilling. For example, A United Nations report on FMS trends in 1986 indicated that while there was a 'decrease in direct work', there was also 'an increase in indirect production-support'. In the short term, unemployment may occur as workers shift from jobs lost to jobs created by the new technology (Noori, 1990). However, in the long run the net effect of this transformation will be minimal (Cordell, 1985).

This debate over the effects of new technology introductions also involves an industrial relations dimension. Both management and labour unions would have to negotiate a common framework and a clear understanding of the new technologies. This framework is contingent upon the existing organisational context and the level of antagonism between management and the labour unions.

Inter alia, these debates over the role of new technology in organisations are centred on the relationship between an organisation's competitive strategy, its technology, and the organisational structures and transformations needed to achieve that strategy. Changes in market demands and increased competition are the key factors that helped the trend towards AMT implementation. These changes were instrumental in the development of a new competitive strategy based on product differentiation and innovation (Porter, 1980 and 1985; Tidd, 1994). When this competitive strategy is translated into 'order winning criteria' (Hill, 1985), matching this criteria to a proper manufacturing strategy will require changes in the manufacturing / production processes, as well as in the organisational infrastructure. The use of advanced manufacturing technology can help firms to adapt their existing resources to suit the desired 'order winning criteria' and accordingly lead to the successful implementation of the designated strategy. In the next sections, a more detailed analysis of the relationship between strategy and technology will be presented.

2.9 Factors that led to the push for AMT

The move towards the new paradigm was precipitated by a number of factors arising over a long period of time. At the micro level, in addition to the technological advances, dramatic changes in the market place, increased competition, and even social factors were instrumental in pushing Western firms to adopt new production technologies and systems in their quest for competitive advantage. These factors are described in the following subsections.

2.9.1 Technological Advances in Microprocessors

The changes in the nature of competition were coupled with a significant number of technological innovations and inventions, chief among them was the emergence of the microprocessor. In the manufacturing environment, the impact of the microprocessor was seen through the introduction of Computer Numerically Controlled (CNC) machines used for component production and the development of advanced robots that are now applied to mechanical handling, arc and spot welding, paint spraying and many other applications (Greenwood, 1988). Other developments included Computer Integrated Manufacturing (CIM), and new production planning and scheduling systems such as Management Requirement Planning (MRPII), and Computer Aided Design (CAD) and Computer Aided Engineering (CAE) in the Design and Engineering functions. As new and more powerful generations of microprocessors continued to be developed, the span, power, flexibility, and ability of the resultant new generations of equipment and systems continued to grow.

These advances in the technology gave the companies that utilise Advanced Manufacturing Technologies the potential to effectively respond to the challenges of the market place through improved operational control, increased flexibility and quicker response time.

2.9.2 Changing Market Conditions

The survival of any firm is dependent on its sensitivity to market demands. As market demands change, companies have to reorient their manufacturing process accordingly. Bolwijn et al (1986) suggested that market demand evolved through a series of phases. The first phase, which lasted until the late 1960s, had price leadership as the key competitiveness criteria. As companies competed on the basis of price, efficiency became the key performance factor in the manufacturing process. Improved manufacturing efficiency would reduce production costs allowing the company to reduce its price per unit manufactured and hence increase sales. The second phase of market demand changes began in the early 1970s through increased customer awareness of product quality. As product quality awareness increased, companies were forced to reorient their manufacturing processes and focus on quality as another key competitiveness criterion. As more and more manufacturing companies began to compete on the basis of quality, customers increasingly differentiated between products on that basis reinforcing the trend towards producing a high quality product at a competitive price. The 1980s ushered in the third phase of market demand changes in which customers began to demand increased product range, product variety (Bullinger et al, 1985), product innovation, as well as faster delivery times. This last stage has led to a new focus on flexibility as yet another critical industrial performance criterion. This was especially true in the supplier-manufacturer relationship where a supplier's performance was primarily determined by its ability to produce a wide range of products, of high quality (defined as meeting or exceeding the customer's expectation), at a competitive price, and to reliably and consistently deliver these products within specified short lead times.

Thus, the basis of competition for manufactured products has expanded to include such attributes as customisation, speed-to-market, flexibility, quality and reliability (Small 1993) and in order to remain competitive in this environment, many manufacturers have installed advanced manufacturing technologies AMTs.

2.9.3 Increased Competition

By the 1970s it had become clear to the majority of Western companies that they were losing market share at a very high rate. The coming of age of the Japanese multinational corporation with its ability to produce higher quality products at more competitive prices and at faster delivery times were warning signs to the West. The success of these Japanese companies had been attributed, inter alia, to the development of new managerial and operational structures, new production planning systems, as well as the use of automation in the manufacturing process. It became increasingly evident that if Western companies were to compete successfully with the Japanese, they needed to radically change their manufacturing processes and structures. By the early 1980s, these companies increasingly began to adopt many of the Japanese production systems and concepts such as the Just-In-Time (JIT) scheduling system and Total Quality Management (TQM) concepts. These systems and concepts became the focus of the new effort to recapture lost competitiveness and the rallying cry for an ever-growing management consultancy industry. While the Japanese companies challenged the West at the high end of the market, lesser developed countries offered another challenge to market share through their ability to achieve high volume production at a much lower cost through the use of cheap labour (Bolwijn et al 1986; Reich 1983). These factors of continuously changing market conditions and increased competition from a variety of sources, have raised the level of uncertainty of product demand (Noori, 1990). Under such an unstable demand environment, a firm's ability to adapt its production processes to the change in the environment became very critical.

2.9.4 Social Factors

In addition to the economic factors, AMT proliferation has also been affected by social factors. Hamid Noori, 1990 referred to three major forces that have contributed to the pressure to automate: first, a continued shortage in skilled labourers; second, a move by employers towards job satisfaction and job enrichment, which has resulted in removing employees from tedious and repetitive tasks; and third, the pressure from governments and unions to free workers from unhealthy and hazardous tasks (Noori, 1990, p.4). These social factors combined with a desire by many companies to be at the leading edge of technology implementation increased the pressure to implement some form of Advanced Manufacturing Technologies.

2.10 Strategy

Strategy researchers such as Kotha & Orne, (1989); Nemetz & Fry, (1988); Parthasarthy & Sethi, (1992) have offered conceptual models which consider some of the linkages between and among manufacturing strategy, business strategy, structure, environment, and performance. Whittington (1993) identified four generic approaches to strategy formulation: The classical approach, which looks at strategy as a rational process of deliberate calculation and analysis designed to maximise long term advantage; the evolutionary approach, which models evolutionary theory (survival of the fittest) on the business environment; the processualist approach, which considers the processes of both organisations and markets as imperfect and 'fallible'; and finally, the systemic approach, which is a relativistic approach which regards the 'ends and means of strategy' as inescapably linked to the 'culture and powers of the local social systems in which it takes place' (Whittington, 1993, p.2). Each of these four perspectives provide widely differing assumptions about the nature of organisations. In the literature on strategic management, the classical and systemic approaches provide the two basic models used for strategy formulation. Tidd (1994) refers to these as the traditional and behavioural models. The traditional model states that corporate strategy is based on analysing market opportunities and competitive threats, and the strengths and weaknesses of the company (Chandler, 1962; Asnoff, 1965; Sloan, 1963; Porter, 1980). The chosen strategy then determines the appropriate manufacturing strategy that in turn determines the appropriate production technology. In contrast, the behavioural model of strategy formulation considers the goals of the different groups within the corporation (such as marketing, finance, engineering, or production) as the key determinants of the strategy and technology. .

An important contribution in the particular area of manufacturing strategy was the work of W. Skinner (1969, 1978, 1985) who identified the strategic role of manufacturing within the organisation. Skinner argued that organisations have to recognise the need for trade offs in the structuring of their factories, as manufacturing can not perform all tasks to the same high standard (i.e. to achieve the same level of optimisation in price, flexibility, quality, and delivery speed). Organisations therefore have to recognise these trade offs in the structuring of their manufacturing organisations and the need to achieve internal consistency and fit between the corporate/marketing strategy and manufacturing strategy. Skinner was one of the first to have emphasised the need for aligning decisions in the "infrastructural" areas with the manufacturing strategy of a firm. Subsequently, Hayes and Wheelwright (1984) and Skinner (1985) argued that strategic thinking about the role of manufacture requires a manufacturing strategy that involves structural and infrastructural decision categories. Among others, production, planning and control and quality management were identified as two potential areas where the choice of systems was emphasised to be consistent with the manufacturing strategy of a firm. These included such decisions as the amount, timing, type of capacity, size location and specialisation of facilities, the technology incorporated in manufacturing equipment, the degree of automation in manufacturing process, and the linkages between different stages. Ward, Miller and Rollmann (1988) also found empirical support and wide agreement in the literature for a circumscribed set of strategic choices in manufacturing which included: (1) process technology (2) capacity, facilities, and vertical integration (3) quality systems (4) production planning/inventory management systems (5) work force management, and (6) manufacturing organization.

Skinner (1985) pointed that simply copying the Japanese techniques or other similar practices serves only to keep the adopting company one step behind while the original users or implementers have had more experience and are better equipped to stay ahead of the game. Skinner also noted that many companies were trying to adopt too many contradictory solutions especially tailored by consultants.

A review of the developments within manufacturing strategies indicates that despite differences in terminology, general agreement exists in the manufacturing literature about the dimensions of competitive capabilities or priorities that are generic in manufacturing: cost, quality, delivery performance, and flexibility. This assertion is supported by literature reviews by (Leong et al., 1990) and empirical evidence (Cleveland, Schroeder and Anderson, 1989; Ferdows and DeMeyer, 1990). Looking at its history in the West suggest that until the 1970s manufacturers concentrated on productivity and efficiency based on a strategy of cost leadership. Porter (1980) identified this strategy as one of two basic strategies, the other being differentiation. In the 1980s, spurred by strong Japanese competition and changing consumer taste and demands, there was a shift away from cost leadership towards a differentiation strategy. This differentiation strategy focused on improving product quality. A large number of firms adopted quality programmes during this period including major international corporations such as Ford, General Motors, IBM, Hewlett Packard, Kodak, and Xerox (Shetty and Buehler, 1991). In the 1990s, the shift in the differentiation strategy appears to be concerned with reducing the lead times of product development and offering a wider range of products (Tidd, 1994) implying a further shift from concentrating on quality towards concentrating on increased product innovation plus high quality. The traditional and behavioural models imply that the relationship between the manufacturing strategy, technology, and organisation should be consistent (Tidd 1994). This necessary consistency between the manufacturing strategy and the organisational arrangements, structures, and human resources requires a higher level of linkage between business strategy and human resource strategy. This link was proposed by Lengnick-Hall (1988) who presented a topology for strategic human resource management which emphasised the dynamic relationship and interaction between the competitive strategy and the human resource strategy.

Advanced manufacturing technologies (AMT) offer the technical means for facilitating a strategy based on product innovation and product variety. The flexibility engendered by advanced manufacturing technologies challenged the traditional wisdom about what is possible in manufacturing. For example, Goldhar and Jelinek (1983) pointed out that "economies of scope" are achieved when manufacturers are able to economically produce a number of different product designs appealing to different market segments. The flexibility inherent in the AMT should allow the technology implementers to broaden their manufacturing scope with little sacrifice in production cost. Noori (1989) maintained that while traditional job shop producers (e.g, machine shops) pursue economies of scope and traditional continuous process plants (e.g., paper mills) pursue economies of scale, firms adopting AMTs can pursue a third dimension, economies of integration and simultaneously enjoy scope and scale economies. In other words, AMTs tend to allow even manufacturers of customised products to achieve scale economies, and high volume producers to pursue niches formerly occupied by custom shops.

The successful integration of such a strategy in the production processes depends on the dynamic interaction between the characteristic features of the technology utilisation, such as the flexibility and complexity of the automated processes, and the organisational arrangements, logistics, work organisation and human resource requirements being used. Several studies suggested that technology implementation is more likely to be successful when the technology, organization, and people issues have been designed to complement and integrate with each other and that such integrative planning is rarely done successfully (Preece, 1995; King & Anderson, 1995; Ford & Saren, 1996). Other authors also found that new technology cannot be placed into an organization without carefully attending to a number of human resource issues (Dina, 1994; Kidd, 1992; Unterweger, 1986; Zylstra, 1987). Structure, organisational arrangements, and human resource policies all have a significant bearing on the success or failure of the advanced manufacturing technology implementation (Barton & Kraus, 1985; Fallik, 1988; Wilkinson, 1989; Bessant, 1991; Milkman & Pullman, 1991; Ramamurthy & King, 1992; Noori, 1997).

This failure to realign the organisational and human resources structures to fit with the AMT is seen as the key cause of the failure to achieve the desired efficiency and productivity goals (Bessant et al, 1990; New, 1986; Voss, 1985; Callerman and Heyl, 1986; Tarnfield and Smith, 1989; Noori, 1990; Clark, 1993). In the next section, these work organisation structures and the new organisational arrangements will closely be examined.

2.11 Organisation

In the next section, a brief review of mass production will be presented with the details of the new 'paradigm' being put forth as the alternative to the traditional mass production, Fordist model of work organisation and design.

2.11.1 The Older system of Mass Production

Developed in the car industry by Henry Ford (1922), the mass production system dominated industrial organisation design for most of the twentieth century. The system involved, inter alia, a continuously moving assembly line and highly mechanised production of standardised parts. It relied on large numbers of unskilled or semiskilled workers and focused on the sharp division of labour between management and the workers. Mass production, or 'Fordism' as it later became known, relied on F. W. Taylor's "principles of Scientific Management" (1911). Scientific management, also referred to as 'Taylorism', offered a systemic and logical approach to organisational design through hierarchical control, work specialisation and the notion that the best way to execute a job can be determined scientifically through "time and motion studies"(Noble, 1977, 1979; Hounshell, 1984, Giordano, 1992; Dankbaar, 1997).

Ford coupled the elements of scientific management with the use of specialised mechanisation and dedicated automation to pace work. Time and motion studies were used to determine the manning levels for the assembly line. The machines set the pace of work and a system of strict separation of planning and execution of work was used. This resulted in a very high division of labour in production. Short cycle time, machine-based production work, functional specialisation of support departments, and firm discipline through hierarchical organization became the hallmarks of this system. Stability in the manufacturing environment was achieved through the use of finished goods inventories which decoupled production from market demand uncertainties.

These Fordist principles dominated industrial production of the twentieth century and extended beyond the car industry to consumer goods production and other industries all over the world. Nevertheless, throughout its history, significant criticism of the practices of mass production were put forward by contingency theorists, sociotechnical design advocates, and lean production advocates. In Particular, Womack et al. and the International Motor Vehicle program researchers believed that lean production, developed by the Toyota car manufacturer, will supplant mass production to become the new global standard (Womack et al., 1990).

2.11.2 Reflective Production

Reflective production embodies the principles of the socio-technical systems design (STS). Since the Tavistock Institute studies of the 1950s (Trist and Bamforth, 1951; Emery, 1959, Trist, 1982; Pasmore, 1988), particular emphasis was directed by the proponents of STS towards improving the quality of working life and increasing worker satisfaction through changes to the technical systems and structures on the shop floor.

At the most basic level, the sociotechnical systems perspective considers every organization to be made up of a social subsystem (the people) using tools, techniques, and knowledge (the technical subsystem) to produce a product or a service valued by the environmental subsystem (Shani and Sena, 1994). It viewed people as a resource to be developed through giving workers as much autonomy to perform work tasks as possible based on their knowledge and experience. A key element in this focus on the quality of working life was the search for alternatives to the short cycle work that was characteristic of mass production. Instead of the mass production separation of preparation and execution, reflective production advocated a unity of preparation, execution, and control at the lowest level possible in an organisation (Dankbaar, 1997). The design put much effort in reducing the need for control by reducing the complexity of the organization. In addition, the control capacity of the organization, and especially of the shop floor, were enhanced by the semi-autonomous work groups who are responsible for complete tasks (Hummels and De Leede 2000).

Autonomous work groups were introduced as the basic unit of organisation and were made responsible for their work. Their success depended on the restructuring of production by the creating parallel flows of production where each flow would be responsible for a complete product or range of products (group technology). This involved the elimination of functionally specialised departments in favour of product-flow-oriented groupings of machinery (Sandberg 1982, 1995; Berggren, 1992; Medbo, 1994; Dankbaar, 1997).

Reflective production was developed as an alternative to the mass production system (Berggren, 1992, 1994; Christensen, 1993; Ellegard et al. 1992; Rehder, 1992; Berggren, 1993; Sandberg, 1982; 1995; Benders and van Hooft, 1995; Pot, 1993) emphasising economies flowing from integration of tasks and self-regulation of work groups. It presented autonomous groups as the basic unit of organisation and gave allowance to the lengthening of individual work cycles, job enlargement, and job enrichment (self-regulation) and the Organising of work around parallel product flows (Dankabar, 1997).

This system was perfected in Sweden's car plants at Volvo's Kalmar (1970s and 1980s) and Uddevalla (1989-1993). The Kalmar plant introduced a system of 'parallel manufacture' in which work moved through a series of operations in parallel work stations and used programmable carriers which allowed for a longer cycle time and team-based operations. The Kalmar partial dismantling of the assembly line revealed two problems that barred further progress. First, the longer the work cycle at fixed docks, the more difficult and expensive it became to deliver the store necessary parts at multiple work stations; and second, the more difficult and expensive it became to provide the necessary training. (Sandberg, 1995).

The experiences of reflective production at Kalmar were fine tuned at the Uddevalla plant and a number of researchers such as Berggren (1994) and Sandberg (1995) reported on the its promising success. At Uddevalla the problems were solved by delivering whole-car "kits" on AGVs in formats that corresponded to the assembly sequence rather than delivering parts lineside as a series of separate pieces. This aided learning and eliminated the need for lineside stockpiling. Eventually, team members at Uddevalla were assembling entire automobiles alone in groups of two or four workers (Sandberg, 1997).

The closure of the Uddevalla Plant in 1993 cast a shadow over the claims that it is a viable alternative to mass production. Nevertheless, authors such as Berggren (1994) and Sandberg (1995, 1997) continued to defend this system and stated that the closure of the plant was primarily due to macro-economic, non productivity related reasons. They stated that Volvo continued to use the system in its other plants and in 1995 the Uddevalla plant was restarted as a part of a joint venture with the British TRW Car Company. The reopening of the Uddevalla plant seems to continue the debate on the prospects of this human centred approach to production.

The sociotechnical systems approach traditionally emphasised organisational solutions rather than technological solutions. Nevertheless, its organisational designs adopted technologies that appeared to fit them better than traditional technologies. Flexible Automation, including robotics, appeared to give a new impulse to the use of group technology (the grouping of machines needed to manufacture a specific family of products), which had always been a central element in sociotechnical redesign of facilities for component manufacturing. Advanced manufacturing technology was implemented with emphasis on decentralisation of administrative tasks combined with enriched work content with less fragmentation of work at operator levels (Tryggested, 1994).

Several variations of the socio-technical systems approach were also developed. Concepts such as 'skill-based production', 'human-centred manufacturing systems', and ‘anthropocentric production system (APS)’ were introduced as possible alternative production models to the traditional mass production and as an alternative to the technocentric approach of the unmanned factory (Ebel, 1989; Alasoini et al, 1994). The APS model was viewed as a European alternative approach to production and was chosen as the conceptual basis for the modernisation of industry in the European community. Wobbe (1991, 1992) characterised APS principles as follows: the unity of conception and execution of work; decentralised decision making; flat hierarchies; collaboration between engineers and workers; skill-enhancing job design; and interaction between design departments and the operational level. (Wobbe, 1991, p.5). This system pays special attention to the shaping of the new technologies and focuses on the use of the professional skills of the employees. It strives to improve control by concentrating primarily on increasing the internal flexibility of the companies by means of multi-skilled personnel.

There were serious criticisms of this sociotechnical /reflective production system. Either for its overemphasis on the psychology and sociology of the work place viewed as engineering problems to be solved through the traditional Industrial Engineering department (Gerwin and Kolodny, 1992). The Uddevalla plant represented in many ways the most radical break with Fordism in car production as it eliminated the moving assembly line completely and had a complete car assembled by small groups of workers (Ellegrid et al., 1992; Sandberg, 1995). The lean production advocates saw this as a regression to craft production. They believed that LP will supplant both mass production as well as " the remaining outposts of craft production in all areas of industrial endeavor" (Womack et al., 1990, p.278) to become the standard global production system. Adler and Cole (1993) echoed the same view stating that that however commendable the experiment at Uddevalla was, it could not match the performance of the Japanese lean production plant, such as NUMMI, the GM-Toyota joint venture. Yet, Berggren (1992) drew attention to the many methodological problems in comparing plants that produced such different automobiles, particularly when Uddevalla was producing a more-difficult to assemble model. Also while lean production has been refined over the decades, Uddevalla was still in its infancy, yet has already matched the productivity of Volvos assembly lines in Gothenburg and demonstrated a far steeper learning curve for new model introductions.'

2.12 Gaps in the Literature

With the increase in the pace of new technology introductions (Such as AMT), and the adoption of new organizational innovations and methods of production, a considerable number of researchers focused primarily on the success and failure of organisations in achieving productivity and efficiency gains (Voss, 1985; New, 1986; Ettlie, 1988;

Bessant et al., 1990; Bessant 1991; Noori, 1990; Gerwin and Kolodny, 1992). Many of these researchers correctly pointed out that these failures were due , to a large degree, to managerial and organisational impediments rather than any inherent failures from the new technology introduction (Wall et. al., 1987; Warner et al., 1990). Nevertheless, for the most part, these researchers remained prescriptive in their diagnosis of the causes for AMT failures. Their discourse was limited to alluding to the need for organisational and managerial transformations without going into the details of the necessary organisational, human resources management, and structural changes needed for the success of such a transformation. At the beginning of this research, few studies had elaborated upon the necessary details of these organisational and human resources policies and practices. Storey's (1994) book titled *New Wave Manufacturing Strategies* and Clark's (1993) book *Human Resources Management and Technical change* were two works which attempted to address this gap in the literature. The focus on the organizational aspects of AMT implementation was based on the view that the use of new wave manufacturing strategies and techniques, such as those of lean production (JIT and TQM), with AMT, would lead to achieving the desired optimum efficiency and productivity gains. (Adler, 1988; Chang, 1989; Chen and Adam, 1991; Elango and Fried, 1993; Gephart, 1995; Goldhar & Lei, 1995; Graham & Rosenthal, 1986; Hayes & Jaikumar, 1988; Jaikumar, 1986; Maffei & Meredith, 1994, 1995; Mueller et al., 1986; Nemetz & Fry, 1988; Nemetz, 1990; Parthasarty & Sethi, 1992; Sethi & Sethi, 1990; Teresko, 1995; Walton & Susman, 1987).

Nevertheless, the application of lean production to the flexible manufacturing systems environment in particular remains thinly researched even though it is apparent on the shop floor that the FMS adds additional constraints and variables to the interaction between the technology and the organisational arrangements. The dynamics of the relationship between the FMS and lean production remains unexplored in the literature and its importance to the debate is yet to be emphasised. By focusing on the point of interaction between the FMS and lean production this thesis will shed light on this thinly researched aspect of the debate.

CHAPTER THREE

RESEARCH QUESTIONS, FRAMEWORK AND METHODOLOGY

3.1 Research Questions and Framework

3.1.1 Introduction

This thesis will explore the application of lean production to the flexible manufacturing systems environment and investigate the existence of tensions between features of advanced manufacturing technologies and new wave manufacturing strategies. It investigates the interaction of these lean production (JIT/TQM) techniques and systems within FMS production areas chosen for investigation in this study. This chapter will present the research questions and the overall conceptual framework and major research propositions and dimensions.

3.1.2 Research Questions

As presented in chapter two, in the discussion of the literature on new technology and organisational innovations, there is a new awareness in the organisation and technology literature of the failures of the traditional mass production paradigm to respond to the competitive realities of today's market environment. In addition, increasingly, researchers and practitioners have begun to realise that achieving the desired productivity gains from advanced manufacturing technology application requires adopting new organisational arrangements, work organisation structures, and new human resources policies and practices.

The adoption of lean production, appeared to encompass within its systems the requisite work organisation changes needed for optimising productivity and efficiency. It coupled just-in-time production with total quality management and adopted inter alia, teamwork, multiskilling, increased autonomy, and increasing problem solving skills. Such work organisation innovations seemed to offer a satisfactory response to the advocates of organisational change as a prerequisite to effective AMT implementation and use.

The key objectives addressed in this thesis are:

- to outline the interaction between lean production and flexible manufacturing systems;
- to explore the extent to which the characteristics of flexible manufacturing systems and lean production systems features are compatible or incompatible;

and the key questions addressed:

- are their any tensions or inconsistencies in this tight linkage between lean production and flexible manufacturing systems?

- if there are tensions in the relationship and interaction between FMS and lean production are these the result of a logical inconsistency: an inherent contradiction at the conceptual (design) level?

- alternatively, if there are tensions in the linkage between lean production and its application to the FMS, are these tensions the result of an internal factor such as actions by management or employees resulting in a mismatch in the coupling between the two? Are these tensions the result of a flaw in the application of the lean production system?

These questions will provide a platform for the examination of the dynamics of lean production and its interactions in the flexible manufacturing environment. This relationship will be examined in terms of the assumptions associated with the coupling of both these techniques and systems in four European manufacturing companies.

This study will address in detail, the critical dimensions of interaction between lean production and flexible manufacturing systems and will give evidence to reveal the points of tension and their consequences.

3.1.3 Research Issues

This thesis will explore the application of lean production to the flexible manufacturing systems environment and investigate the existence of tensions between features of advanced manufacturing technologies and new wave manufacturing strategies. It will explore the degree of compatibility between lean production the most widely used form of new wave manufacturing strategies and its implementation to the flexible manufacturing systems (FMS) form of advanced manufacturing technology.

Are there any tensions in the interaction relationship between lean production concepts and systems and its coupling with Flexible Manufacturing Systems.

What constraints exist, if any, to the overall flexibility associated with the application of lean production to the FMS.

What impact will the coupling of the lean production and the Flexible Manufacturing Systems have upon to the productivity gains claimed by the proponents of these new wave manufacturing systems and techniques.

These questions framed the initial approach. In order to avert any ambiguity, these propositions will need to be further clarified as to the specifics of the advanced manufacturing technology (the FMS system) and new wave manufacturing strategies (lean production systems) being used in the manufacturing environment under study.

By exploring any existing mismatch or compatibility in the application of lean production and its coupling with the Flexible Manufacturing Systems form of advanced manufacturing technology.

Although there are a variety of systems and hybrid approaches that fall under AMT and NWM, the focus of this study is on the FMS technology and the implementation of lean production to the flexible manufacturing systems environment. Regardless of the specific name or terminology given, lean production is broadly defined as the combination of just-in-time manufacturing (JIT) and total quality management (TQM) that has been adopted as the key competitive factor in Western manufacturing companies.A large management consultancy industry has mushroomed in relation to the development of, for example, TQM training programs, to help implement these concepts. Similarly, new qualityand work organisation standards were also developed either through large companies attempting to insure a better quality from supplier networks, or through manufacturing and industrial associations and boards developing certifications and awards for insuring standards of quality and efficiency.

3.2 Methodology

This section begins with a general presentation of qualitative research and an account of the choice of qualitative methodology before moving to the specific approach to data collection and analysis chosen for this study.

In line with the established recommendations of Mile and Huberman (1994), the qualitative analysis approach of this study will attempt to be both as systematic and as disciplined as possible in an effort to make it possible to "walk through" the thought processes and assumptions that underline this research.

The choice of qualitative case study methodology for this research attempts to discern and examine how social experience and meaningful patterns and themes emerge in relation to the interaction between lean production systems and their implementation to the Flexible Manufacturing systems environment within each of the chosen companies.

An attempt is made to adequately articulate the standards for assessing qualitative analyses. Knowing that qualitative data can be analysed and synthesised from multiple angles depending on the objectives of the research and the evaluation of the questions being addressed, this relative lack of standardisation provides more versatility to this research.

3.2.1 Choice of Qualitative Methodology

Although it is often the case that the core ontological constructs of research remain implicit rather than being explicitly stated, the aim of methodological roots of this study are derived from action research (Silverman, 1970) and the notion of 'verstehen' (Weber, 1949) were the researcher strives to achieve both an understanding and an explanation of the particular phenomena under investigation. Using Burrell and Morgan's (1979) sociological paradigms, the roots of this study can be positioned within the functionalist-interpretivist paradigms.

According to Yin (1994), it is possible to identify a specific research strategy, that might have an advantage over other strategies, based on the type of research question being asked. In this thesis, qualitative research is seen as more suited to presenting a processual view of social reality. As Miles (1979) suggests, qualitative data preserves the chronological flow, and suffer minimally from retrospective distort. Denzin and Lincoln (1994) noted that qualitative methodology emphasises "processes and meanings that are not rigorously examined, or measured (if measured at all), in terms of quantity, amount, intensity, or frequency". They go on to explain the nature of qualitative research as value-laden and one that emphasises "how social experience is created and given meaning". Similarly, Miles and Huberman (1994) state that in Qualitative analysis *" Meaningfulness is determined by the particular goals and objectives of the project at hand: the same data can be analyzed and synthesized from multiple angles depending on the particular research or evaluation questions being addressed".*

Critics of qualitative analysis question whether a truly rigorous analysis can be achieved in the absence of such universal criteria. They note that qualitative analysis will not specify uniform procedures to follow in all cases. This view mistakenly looks at qualitative analysis as unsystematic, and "purely subjective" which is not the case.

While it is true that qualitative analysis deals in words and is guided by fewer universal rules and standardised procedures than statistical analysis, Guba and Lincoln (1989) and Maxwell (1992) argued for the need to replace the positivist notions of validity in qualitative research with the notion of authenticity. Maxwell (1992) argued that qualitative researchers need to be cautious "not to be working within the agenda of the positivists" in arguing for research to demonstrate "concurrent, predictive, convergent, criterion-related, internal and external validity". Miles and Huberman (1994) noted the distinct differences in procedures and goals of qualitative analysis from quantitative statistical analysis. Nevertheless, they stated that good qualitative analysis is "both systematic and intensely disciplined. If not 'objective' in the strict positivist sense, qualitative analysis is arguably replicable insofar as others can be 'walked through' the analyst's thought processes and assumptions".

In formulating the research questions, a key objective of the questions was to find patterns and common themes that emerge in response to dealing with the coupling of FMS and Lean production. Are there tensions in the interaction between lean production and Flexible Manufacturing Systems? Are there any deviations in these common themes? Are there any factors that might explain these apparent incongruities?

As stated earlier, this framework of the research methodology and case study approach was developed in line with Miles and Huberman (1994) three-element qualitative analysis process (data reduction, display, and analysis). The conclusions and verification from each of the case studies is also in line with the Miles and Huberman (1994) approach.

3.2.2 Case Study Methodology

The aim of the case study methodology is to explore the application of lean production to the flexible manufacturing systems environment and investigate the existence of tensions between features of advanced manufacturing technologies and new wave manufacturing strategies in four manufacturing companies in Holland and the United Kingdom.

Goode and Hat (1952) emphasised the holistic nature of research in organisation behaviour. They defined case study methodology as ' a way of organising social data so as to preserve the unitary character of the social objective being studied' Goode and Hat (1952, P.331). Similarly, Mitchell (1983, p191) described the case study as' a detailed examination of an event (or series of events) which the analyst believes exhibits the operation of some identified general theoretical principle'. Yin (1981, p59) also defined the case study as ' an attempt to examine contemporary phenomenon in its real life context, especially when the boundaries between phenomenon and context are not clearly evident'. Thus the case study method tries to capture the whole, is intensive in nature, and is open-ended and flexible at all stages of the research process (Eckstein, 1975, p.81)

3.2.3 Site Selection Criteria

A number of factors played a part in the site selection criteria. In the initial phase of the research, through a variety of university and personal business contacts, eleven companies in different industry sectors were visited. Initial contacts and first visits to these companies were arranged either through courtesy contacts facilitated by the Human Resources and Change Management Research Unit (by virtue of approved access for other research projects within these companies), or by virtue of personal business contacts (primarily with the marketing or sales organisations of these companies). These contacts facilitated short meetings with either the production manager or the human resources manager of these organisations followed by a guided tour of the plant.

During this initial phase of the research, the issues relating to new wave manufacturing strategies and the use of Advanced manufacturing strategies were still being defined. The purpose of the initial visits to these eleven companies was primarily to explore what type of new technology and work organisation structures were being applied. The questions asked during the tours were general in nature and explored the types of technologies, as well as the type of new work organisation structures were being used in these companies. A table containing a list of popular new management innovations was presented to the interviewees and the presence of any such innovation was checked.

These companies differed in size, shape, and type of organisational arrangements. They included: a high volume producer of consumer products; a manufacturer of electronic PCB assemblies (which are incorporated into other finished goods in the automotive, brewing, domestic appliances and computer industries); a manufacturer of industrial automation products; a major truck manufacturer, one of the oldest aeroplane manufacturers in Europe; a producer of printing and finishing equipment for the textiles and wall paper industries; and a printing company that had earlier introduced digital pre-press computerised hardware/software systems. The exploratory visit to each of the eleven companies had no bearing on this study beyond the identification of four companies which utilise flexible manufacturing systems. Table 3.2 presents a brief overview of these companies and describes the type of products manufactured as well as the type of AMT and NWM that were used. Further access was sought only with EBG Trucks, Fokker Aircraft, CMC Compressors, and CMN Diesel Engines No further information on the other seven companies was developed and accordingly they will not be discussed in this thesis.

The key factors that influenced the choice of the four case studies:

1. Further Access: A practical factor in which the ability to conduct interviews at all levels in the organisation was essential. In addition to the type technology and work organisation structure was the key factor in determining the choice of the focus case studies for this study. Agreeableness of management for conducting the study was also a key element in deciding on the four chosen sites. Particularly as the research involved requiring multiple access and interviews with a cross section of actors within each company ranging from the plant managers, human resources managers (or personnel manager), production managers to shop floor operators. Access to these four companies was facilitated through corporate level contacts facilitated through the help of Professor John Storey (then at Loughborough University) as well as Professor Harry Boer (then at Twente University in Holland). Both professors were generous in securing corporate level introductions to these companies as well as in facilitating middle management support for access for the duration of the study. Consequently, the corporate and middle management support in these companies facilitated cooperation and further access to lower levels of the organisation (particularly on the shop floor) as well as lead to ease of access to documentation deemed helpful for the investigation.

2. Type of technology used: The initial choice for the study was to study companies where both lean production and FMS are being used. A key criteria for the choice of the case study company was the use of Flexible Manufacturing Systems (FMS) - as the new technology change in the manufacturing area. All four sites selected had FMSs as part of the production process in addition to combinations of various types of the CNCs. The existence of similar advanced production technologies in all four plants as well as the relatively similar production environments made the chosen four companies ideal for cross case comparisons within the framework of the research.

3. Type of new organisational arrangements: the presence of organisational innovation was also a key factor in the choice of four sites. In all the four chosen sites, there had

been many organisational changes and human resource development programs. All four companies had passed through a tough recessionary period in the late 1980s and early 1990s and had gone through restructuring and redundancies. In an effort to become more competitive and increase efficiency, all four companies attempted to streamline operations and increase productivity through the implementation of the popular lean production (JIT/TQM) techniques. Thus, the adoption of lean production in all four companies made the four chosen sites viable for the study.

3.2.4 Data Collection

In each of the companies chosen for this research, interviews were conducted with area managers, production managers, production support staff, supervisors, and individual operators. Some of the interviews were conducted with two operators at a time (members of a particular cell).

Primarily the research methodology and data collection were based on the following:

1) Interviews with three types of informants seeking and contrasting their views on the new wave strategies and its implementation: (1) the views of decision makers such as plant managers, production managers, human resource / personnel managers who develop and introduce these concepts; (2) the views of production and manufacturing engineers and support staff such as quality, kaizen, and maintenance engineers; and (3) the views at the shop floor with interviews with supervisors or facilitators, team leaders, operators or team members.

2) Observation through shop floor visits and discussion about working practices as well as changes due to the implementation of the advanced technology and organisational arrangements with both production staff with responsibilities for supporting the FMS environment as well as the direct actors in the FMS environment from supervisors and first line operators.

3) Analysis of documented information such as training manuals, written rules and procedures, improvement charts on quality, productivity and maintenance, memos / communications between management and the various departments especially in the production areas.

4) The Interviews at the corporate level including the human resources managers and plant managers were helpful in two ways. First; as gate keepers, these interviews served as a stepping stone for further access and interviews with a wider cross section within the organisations. Second; they served to provide insight on the managerial perspectives and the associated meanings, patterns and themes that are being put forth by management.

The next section will present the interview schedules and will present some additional comments on interview procedures.

3.2.5 Interview Schedules

3.2.5.1 EBG European Truck Company

Visit Dates	Nov. 1994	June 1995	Nov. 1995	June 1996	May 1997	April 1998	June 1999
Duration	1 day	2 day	1 days	2 days	1 day	1 day	2 days

Informants	Number of Interviewees	Average duration of Interview	Number of interviews (at each position)
Human Resources Manager	1	¾ -1 hour	4
Plant Manager	2	1 hour	2
Area Manager	2	1	2
Manufacturing Engineer	2	1 hour	2
Production Engineer	2	1 hour	7
Kaizen Engineer	2	1 hour	3
Programmers	2	½ hour	3
Logistics/Planning staff	2	1 hour	4
Facilitators	3	1 hour	9
All Rounders (team leaders)	4	1 hour	5
Rounders (Operators)	8	½ -1 hour	9

3.2.5.2 Fokker Aircraft

Visit Dates	Nov. 1994	Feb 1995	June 1995
Duration	1 day	2 days	1 day

Informants	Number of Interviewees	Average duration of Interview	Number of interviews (at each position)
Personnel/Human Resources Manager	2	1 hour	2
HR Staff	1	1 hour	1
Production Manager	2	½ - 1 hour	3
Manufacturing Engineers	2	1/2	2
Production Engineers	2	1 hour	2
Programmers	3	½ hour	2
Programmers	4	½ hour	3
Q.A staff	3	½ hour	1
Group leaders	2	1 hour	3
Operators	8	½ -1 hour	4

3.2.5.3 CMC Compressors Manufacturing Company

Visit Dates	Nov. 1994	Nov. 1995	June 1996	May 1997	June 1999
Duration	1 day	1 day	1 days	1 day	1 day

Informants	Number of Interviewees	Average duration of Interview	Number of interviews
Plant manager	2	¾ hour	4
Personnel	1	1 hour	1
Production manager	1	½	5
Logistics engineer	1	½	1
Technical/ planning staff	2	1 hour	2
supervisors	3	1 hour	5
Operators	9	½ hour	5

3.2.5.4 CMN Engines Manufacturing Company

Visit Dates	Jan. 1995	May 1995	July 1995	June 1997	May 1999	June 1999
Duration	1 day	2 day	1 days	2 days	1 day	2 days

Informants	Number of Interviewees	Average duration of Interview	Number of interviews
Personnel & Industrial Relations Manager	2	¾ hour	3
Plant Manager	2	½	3
Training Staff	1	1 hour	2
Manufacturing Engineer	2	½	4
Production Manager	3	½ - 1 hour	4
Production Engineer	3	½ - 1 hour	6
Kaizen Engineer	2	1 hour	2
Programmers	2	½ hour	3
Logistics/Planning staff	2	1 hour	2
TPM Maintenance Staff	2	1/2 hour	2
Supervisors	3	1 hour	7
Operators	11	½ -1 hour	20

3.2.5.5 Notes on the Interviews and Questions

(a) The interviews were based on semi-structured interviews seeking a stratified sample of views at different hierarchical levels. Primarily seeking three perspectives: managerial, production and support functions staff, and shop floor workers (supervisors and operators). Questions about the production process and environment of the company were posed with particular emphasis on the FMS environment and the various macro and micro issues that related to the FMS.

(b) In the first interview, a tape recorder was used to record the interviews with the permission of the interviewee. The tape recorder made the interview very animated and interviewee responses tended to be short. Additionally background noise on the shop floor made recordings with operators and supervisors unintelligible. A decision was made to discard the tape recording and use hand-written notes instead.

(c) At the beginning of the interview a brief overview of the research project was presented to the interviewee. This was typically followed by providing brief information about the university, a short description of the research, and a brief personal background pointing my engineering background to the engineers and my short experience as a worker in an American manufacturing plant to the supervisors and operators.

(d) The interviewee was assured of the confidentiality of all answers and that the research is not connected with the company in any way. Interviewees were told that the names of the company, business unit, and individuals will be not be used.

(e) Typically, the production or area manager introduced me to the FMS area. The manager would briefly explain the purpose of my visit to the supervisor and once I was introduced to the supervisor, I was then given free access and time on the shop floor for the duration of the day.

(f) Questions that did not apply to the interviewee circumstances and position were not asked. Fact type questions about the process were not repeated in questions to other interviewees unless they related to the discussion.

(g) An attempt was made to cover all the question areas within the time constraints of the interview. The semi-structured format allowed the discussion to focus on different aspects of the research issues that related to the interviewee.

(h) The definition of each of concepts was checked with interviewee to insure agreement on the meanings.

(i) In most instances the discussion did not follow the same chronology as the interview question list and some of the responses were very short. Nevertheless, issues that were at the heart of the dimensions were probed first. The tool of the questionnaire was instrumental in refocusing the discussions back on the key issues. Other peripheral questions were left to be answered in subsequent interviews.

(j) Depending on the position and function of the interviewee, the questions focused on the individuals role and work duties and his views and comments concerning FMS and the lean production techniques as well as how the key dimensions relate to his area of work.

(k) Interview times varied from company to company and from visit to visit. The duration of the interview depended on the production pressures on the FMS during the visit. Some of the interviews were short (between 20 minutes to ½ hour) while others extended beyond that time as other operators were filling in or because there was less work to be done at that particular time. Sometimes interviews would be cut short and resumed at another time during the day. Other interviews were conducted between shift changes usually in the afternoon.

(l) An Interview with an operator would usually start on the FMS were I would observe the operator starting the machining of a new part. The operator would explain every step of the machining process and answer queries related to the operation and the technology. Once the FMS operation is started, the interview would typically move to the quality or team meeting area on the shop floor.

(m)During the interview, a questionnaire was presented to the subject, which focused on the key dimensions relating to FMS and lean production interaction. Although some of the questions were discussed in the interview, questionnaire questions numbers 6, 7, 8, and 9 were presented to the interviewee as a way to seek direct responses on the key measures and as a tool to focus and recap the discussions.

(n) Typically I would go over the questions with the interviewee and would check his responses on the questionnaire form. In the process of asking the questions, I would further elaborate on the meaning of each question to make sure that the interviewee has clearly understood what is meant by each question. This process was helpful to the research as it cleared the different meanings associated with the concepts discussed at different strata in the organisation. Comments and quotable statements were written on to the margins of the questionnaire.

(o) Typically a period of time between 10 to 15 minutes was available between interviews on the shop floor which was used to write follow up notes on each of the preceding interviews highlighting the key comments. This process helped develop and a preliminary and elementary first level analysis and pointed to possible lines of inquiry which were capitalised upon with other interviewees in the same area and explored further with the same subject in following interviews.

(p) As in any research that extends over a number of years, many of the same interviewees were not available for subsequent follow up interviews. A number of the personnel interviewed in earlier visits, particularly staff positions, were made redundant. Follow up interviews were then made with persons working in the same area and at the same level. If, as it was in one of the cases, the area was reorganised and the particular supervisors were moved to different areas of operation, interviews with some of these supervisors were sought seeking first hand accounts on the changes.

(q) In the Fokker case study, Initial visits to the Papendrecht plant were conducted in 1994 and 1995 prior to its dramatic collapse after 77 years in business. Although the investigation of this company was cut short as a result of the closure, enough data was collected to contribute to the examination of the research questions of this study. The drama relating to the questionable survival of the company had shaken the spirit of the organisation and made it difficult to objectively discern the impact of micro-level changes from all the noise generated as a result of the nervousness and anxiety of both management and employees over the future of their jobs. On the other hand, this situation also made it possible for the interviews to achieve a higher level of frankness particularly on questions relating to the management's actions. From middle managers to supervisors to operators, the majority expressed their opinions without reservation and most of the time in a very critical manner of management policies.

(r) In the CMN case study, research was conducted in three plants (Gamma, Delta, and Sigma plants) as all three implemented lean production. A choice was made to disregard the Gamma and Sigma plants and only include the Delta plant as the case study for three main reasons: (1) the data was collected in the Delta plant on the FMS environment exceeded the other two plant as a result of better access opportunities; (2) the Delta plant is the largest of the three plants and possessed the highest concentration of manufacturing conversion machinery including FMS and CNC machines making it the most representative and; (3) to minimise the complexity factors in the research and the analysis process associated with the study of three plants, mixed manufacturing processes, different managerial approaches, and different degrees of adoption of lean production in a single case study. There was no bias towards the content of the data from the Delta plant as all three plants exhibited similarity in the reactions of actors to the application of the same lean production system in all three plants.

3.2.6 Duration of the study

The validity of the qualitative methodology results was also increased through studying the case companies over a period of many years. Three of the four cases were studied through the period from November 1994 till the end of June 1999. The fourth company declared bankruptcy late in 1995 and accordingly the data obtained covers a oneyear period only.

Studying these four companies over a long period of time increased the ability to gain insights over the process of interaction between the new wave manufacturing strategies and the flexible manufacturing systems. By following the processes within these manufacturing companies in over four years period, it was possible to observe the true transformations within these companies and to separate the fads from the true organisational changes. It made it possible to check operators' attitudes over time and to see, first hand, the transformation in these attitudes over the research period. Although the study is not longitudinal, through the four-year duration, it was also possible to pinpoint existing patterns in the relationships between the various actors (from managers to supervisors to team leaders and operators). The duration of the study made it possible to judge the reactions of these actors to the demands of the lean production system over time, as well as the change patterns in attitudes towards the demands of the flexible manufacturing systems.

3.2.7 Interview Procedures

Interviews were conducted with the various participants using a semi-structured format. The informants were selected from a cross section of the plant organization in each of the companies studied. This cross section of informants was necessary in order to provide a balanced view of each of the manufacturing organizations under study as well as to provide a mechanism for confirming the views of the different respondents. Interviewing managers, engineers, supervisors, and operators also helped to add variety to the process and helped add confidence to pin pointing the key issues related to each of the organisations. The number of interviewees in each case ranged from 19 to 30 interviewees as can be seen in Section 3.2.5.

In each of the four companies, the interviews were conducted top-down: initially with managers and then with production engineers and production support staff, and finally to supervisors and shop floor operators. As the focus of the research was on the FMS production environment, follow up interviews concentrated on the shop floor environment through interviews focusing on area managers, production staff, supervisors, facilitators and operators in the FMS areas. Interviews were conducted in different locations: on the line, in group meeting designated areas, in supervisor offices, and on the shop floor. In a number of situations I attended group meetings in FMS cells and in one company an employee achievement award ceremony.

The interviews were based on semi-structured interview process seeking primarily three perspectives: managerial, production support staff, and shop floor Operator's perspectives. Questions about the production process and the production environment of the company were probed with particular emphasis on the FMS environment and the various macro and micro issues that related to the FMS. The FMS environment was not limited to the Flexible Manufacturing Cells only but was usually organised as the cornerstone of a group of CNC machines.

At the beginning of the interview a brief overview of the research project was presented to the interviewee. The interviewee was assured of the confidentiality of all answers and that the names of the company, business unit, and individuals will be changed.

Questions that did not apply to the interviewee circumstances and position were not asked. Fact type questions about the process were not repeated in questions to other interviewees.

An attempt was made to cover all the question areas within the time constraints of the interview. As these interviews were semi-structured, In a number of instances the discussion did not follow the same chronology as the interview question list and issues that were at the heart of the dimensions were probed for further input while other questions (particularly those relating to production related facts) were left to be answered at later interviews.

Depending on the function of the interviewee, the questions focused on the individuals role and work duties and his views and comments concerning FMS and the lean production techniques as well as how the key dimensions relate to his area of work.

3.2.8 Questionnaire

A supporting sample questionnaire was developed in addition to the interview questions. This questionnaire was not designed for purposes of statistical analysis purposes but as a pointer and a general reference to gauge the extent of agreement between the responses in the interview and the actual view of the interaction between lean production and the FMS. The questionnaire was issued to production managers, human resource managers, supervisors as well as operators or team members. The approach taken in using this questionnaire can be described as "nonprobability" sampling, the purpose of which " is not to establish a random or representative sample but rather to identify those people who have information about the process. It is a search not for a 'generalisable person' but for a specific group of relevant people" (Hornby and Symon, 1994, P. 169).

Although the number of questionnaire participants did not constitute a statistically valid sample to prove or disprove a hypothesis, it nevertheless did provide a useful tool as a barometer to gauge the attitudes and feelings of the individuals concerned. The questionnaire posed questions about the new changes both in the technology and the organisational arrangements. It was helpful in showing the discrepancy between the views of managers and operators in relation to these changes.

3.2.9 The Role of the Questionnaire

Although generalisation is not possible from the four case studies and the statistical limitation of the questionnaire, it did provide a framework for focusing the views of the actors on these issues and soliciting additional inputs for further analysis.

In addition to the semi–structured interview questions, the questionnaire consisting of specific questions based on the chosen dimensions (complexity, regulation, flexibility, and integration) provided an opportunity to focus the discussion on these issues in a systematic manner. The questionnaire was administered usually at the end of the interview in an attempt to further focus the flow of the interview in the direction of the key dimensions. In addition to providing a systematic mechanism for capturing specific data relating the dimensions, the questionnaire also provided a replicable instrument in which informants were asked the same questions in a similar and direct manner in each of the chosen production environments of the case study companies.

3.2.10 Details of the Questionnaire

The questionnaire was developed to prepare the interviewees for the nature of the questions

The semi-structured interviews dealt with discovery questions relating to the details of each of the case study companies, the description of the production process, the details of the production technology, the types of work organisation, and the new wave manufacturing strategies being used. In addition, both the interviews and the questionnaire focused on the key research dimensions and the interaction at the shop floor in relation to the Flexible Manufacturing systems and the lean production systems being used.

The informants for the interview and questionnaire were chosen to represent the perspectives of three actors influencing the FMS environment interactions: Managerial perspective, production support staff perspective, and shop floor supervisors and

Operators' perspective. All the informants were asked about the interactions related to the FMS and the lean production approaches in relation to the key dimensions.

The questionnaire asked questions about the elements that define each of the dimensions by assembling data relevant to its convergent and discriminant validity (Campbell and Fiske, 1959). For example, on the measure of regulation, the questions dealt with the changes in the number of rules and procedures associated with the FMS and the lean production systems. The various informants were asked about their view on the need for increased supervision in relation to the FMS, the degree of freedom of the operators to do their jobs, the operators span of control, and the operators freedom to plan the work and so on. The word 'regulation' was used in the interviews but, in order to insure the validity of the constructs used and that the meaning of the term is understood by the users to be the same, the questions focused on the elements of the definition of 'regulation' as used in this research.

The same approach was used in questions concerning the dimensions of complexity, flexibility, and integration. Both the degree of integration and the extent of regulation at the shop floor closely related to autonomy. Accordingly, autonomy is addressed in terms of regulation and formalisation of rules on the FMS. Both the degree of regulation and degree of integration in the process impact the degree of autonomy and span of control of the operators.

By selecting three types of informants (managerial, staff, and shop floor) it will be possible to identify any existing mismatches in the interaction between the FMS and lean production through the identification of potential differences or even contradictions in the views, perceptions, and actions of the three types of informants concerning the same phenomena under investigation.

3.2.11 Qualitative Analysis

There are few agreed-on canons for qualitative data analysis and there are several views on how to perform such analysis. Miles and Huberman (1994), underscored the need for sensible canons of qualitative data analysis to be present in order to establish shared ground rules for drawing conclusions and verifying the sturdiness of qualitative research. They go on stating that any method of analysis that " works- that will produce clear, verifiable, credible meanings from a set of qualitative data" is "grist" for their mill (p.3) in presenting a qualitative approach to analysis.

Patton (1990) also describes the process of analysis as having "no absolute rules except to do the very best with your full intellect to fairly represent the data and communicate what the data reveal given the purpose of the study" (p.372). Coffey and Atkinson (1996) also emphasized that the selection of the appropriate analysis approach should be based on an informed and principled decision.

Lofland and Lofland (1995) maintained that : "even though there are several concrete and even routine activities involved in analysis, the process remains, and is intended to be, significantly open ended in character. In this way, analysis is also much a creative act"(p.181).

Miles and Huberman (1994) defined analysis as "consisting of three concurrent flows of activity: data reduction, data display, and conclusion drawing and verification" (P.10). They viewed the process of data reduction as a continuous process active throughout the study consisting of selecting, focusing, simplifying, abstracting, and transforming the transcripts and written-up field notes of each case study. Data display is defined as "an organised, compressed assembly of information that permits conclusion drawing and action" (p.11). Display includes different types of matrices, graphs, charts, and networks aimed at assembling " organized information into an immediately accessible, compact form so that the analyst can see what is happening and either draw justified conclusions or move on to the next step of analysis the display suggest may be useful"(p.11). The third flow is that of *conclusion drawing and verification.* Patterns and possible explanations start to emerge in the early phases of the data collection. It is suggested that the researcher must keep an open mind and remain sceptic throughout the study. Gradually the patterns will grow more explicit opening for "final" conclusions to be drawn and verified. Thus, Miles and Huberman (1994) underscore that these three flows are "interwoven before, during, and after data collection in parallel form, to make up the general domain called "analysis" (pp.11-12).

Two basic forms of qualitative analysis, essentially the same in their underlying logic, will be discussed: intra-case analysis and cross-case analysis. A case may be differently defined for different analytic purposes. Depending on the situation, a case could be a single individual, a focus group session, or a program site (Berkowitz, 1996). In this research a specific section within the production environment- the flexible manufacturing systems (FMS) area- in four manufacturing companies were chosen as the subjectfor our study and analysis.

Using a combination of deductive and inductive analysis, collected data from each of the case studies was reconfigured and reorganised in a manageable format for further analysis. This approach is in line with the process of data reduction stated by Miles and Huberman (1994) and described as " the process of selecting, focusing, simplifying, abstracting, and transforming the data that appear in written up field notes or transcripts." In each of the case studies, immediately after site visits and or between meetings within each of the companies, the collected data and interview notes were put to preliminary analysis. Interesting comments, statements, behaviours were highlighted for further analysis, follow up and further evaluation.

Side comments were added immediately following each interview highlighting emerging patterns and those comments that seemed to reflect new ideas, concepts, feelings, attitudes, or actions that are of relevance to the research question and that are deemed worthy for later focus in the data analysis.

It is important to note that the choice about which aspects of the data are emphasised and which aspects are minimised or set aside is based on both deductive and inductive process of analysis. While initial categorisations are shaped by the pre-established study questions, dimensions and sample questionnaire, the interview process and collected data was open to the introduction of new meanings from the data available. The four year time frame for study in three of the four cases made it possible to discern lasting attitudes from transient or temporary feelings and impressions resulting from specific incidents.

As stated earlier, data display is the second element or level in Miles and Huberman's (1994) model of qualitative data analysis. Data display goes a step beyond data reduction to provide "an organized, compressed assembly of information that permits conclusion drawing..." A display can be an extended piece of text or a diagram, chart, or matrix that provides a new way of arranging and thinking about the more textually embedded data. Data displays, whether in word or diagrammatic form, allow the analyst to extrapolate from the data enough to begin to discern systematic patterns and interrelationships. At the display stage, additional, higher order categories or themes may emerge from the data that go beyond those first discovered during the initial process of data reduction.

The third element of qualitative analysis is that in the conclusion drawing process an attempt is made to step back from micro picture to consider what the analysed data mean and to assess their implications for the questions at hand.

In order to add an internal verification element to the collected data. The data in each of the case studies under investigation is revisited and the validity and plausibility of the emergent conclusions is followed up through discussions with production and human resource managers during the last set of interviews conducted in June 1999. Additionally follow up phone conversations with two production engineers were made to expand on particular research points or to check validity were possible in two of the four case companies (EBG Trucks and CMN Engines) as a result of friendly rapport developed with these two production engineers during the case study visits. It is important to note that the validity of the conclusions in this context is different from that found in quantitative evaluation were it is a technical term that specifically refers to whether a given construct actually measures what it intended to measure. In the view of this research, validity refers to the credibility of the data and the conclusions being drawn in their ability to defend the resultant explanations.

3.2.12 Data Triangulation

In order to obtain a more comprehensive picture within each of the case studies chosen for this research, information was collected from a stratified sample of views from different sources, actors, and at different places and times within each of the companies. This process can generally be viewed as 'Data Triangulation' in which information relating to AMT interaction can be more reliably obtained (Denzin, 1989).

This process was also used to compare and cross-check the consistency of the data wihin each of the companies within the framework of the case study methodology. The research was conducted through semi-structured interviews and a sample questionnaire administered to plant level managers such as Plant managers, production managers, manufacturing engineering managers, human resources mangers, as well as with area managers, supervisors, team leaders, and production floor employees. The use of these data sources mixture in the case studies was to obtain a more comprehensive, as well as, convergent data bank. Where there were divergent data sources (which is inevitable in triangulation where data are collected from various organisational players), the aim of the research was to look at the various explanations for the contrary, as (Jick, 1979) indicated, it is only by addressing the discrepancy and discords towards the issues being studied that knowledge can be enriched. Patton (1990) recommend that the researcher should study the when and why there are differences from the various data sources. In the four cases investigated, following divergent views in describing the same phenomenon - particularly between managers and shop floor operators- constituted the central approach to the data analysis.

Documentary and archival information such as forms, policies, procedures, quality systems, instructions, and general memos were collected whenever possible at every level within the chain. Yin (1994) saw this use of multiple sources of evidence as useful in "the development of converging lines of inquiry"(P.34). Potential problems of construct validity or subjectivity are also addressed because multiple sources of evidence or data provide multiple measures of the same phenomenon (Yin, 1994).

3.2.13 Relevance of the Methodology

In their article ' Closing the gap: a polemic on plant-based research in operations management', Hill, T., Nicholson, A. and Westbrook, R. (1999) argued that, within the operations management (OM) academic community, there has been a growing call for research of more managerial relevance. They noted that:

'*Given the level of complexity involved in understanding the OM perspective of business issues then the emphasis should be placed on plant plant-based research. Conducting research on-site and investigation through analysis of relevant data, issues, developments and events ensures relevance and a validity essential to making an impact on business practice*' (Hill et al., 1999:139)

Although this thesis does not follow an operations management (OM) perspective, the study follows the recommendation of Hill et al. (1999) in trying to address issues relevant to the practice on the shop floor.

3.2.14 Researcher Credibility

Within the manufacturing management research there has been a tendency to ignore the role of the researcher altogether (e.g. De Filippis, 1994; Ratcliffe, 1997) or to discuss this in purely technical terms (Bagchi and Virum, 1996; Caprihan et al., 1997). Some of this may be as a result of underlying positivist assumptions regarding research. Hence the researcher is seen to be independent and value neutral. Others, like Platts and Gregory (1993) take time in their account of manufacturing strategy to discuss issues of researcher credibility and whether to adapt their research methodology in light of experience during a longitudinal study. Westbrook (1994, 1995) discusses aspects of researcher reflexivity by demonstrating its particular appropriateness for addressing theory building as well as integrative and unstructured problems in manufacturing firms. In this research the role of the researcher plays the key judgement role in the research. An attempt to cancel any potential bias is made through making the process of data collection, reduction, analysis, and drawing conclusions as systematic as possible. The data is tackled with an attempt at maintaining as much as possible value neutrality.

The general results of the research were discussed with the human resources and production managers in three of the four companies studied. The fourth company having gone out of business. In general in the case studies, there was general agreement and recognition of the issues as well as an attempt at justifying why things have changed in the direction they did. The four-year duration of the study made it possible to check the progress of key human resources changes and policies and check the reality of true transformations over time.

CHAPTER FOUR

EBG European Truck Manufacturing Company

4.1 Introduction

This chapter describes the situation at a major European truck manufacturing company EGB in the period between 1994 and 1999. During this period, EGB went through a period of dramatic growth that significantly increased production demands and led to transformations and restructuring in the company and the relationships on the shop floor.

This chapter will focus on the application of lean production to the flexible manufacturing systems environment.. Underlying this interaction between the use of advanced manufacturing technology and the new work organisation arrangements, there are strategic, organisational, and cultural factors that have an impact upon and inform it. This case will serve to highlight the impact of these macro-level forces on the dynamics of this new technology / new organisational arrangements coupling. Investigating four key dimensions: complexity, regulation, flexibility, and integration, this case will establish the existence of inconsistencies in the messages being sent to the users of the new technology. The logic of the new wave manufacturing approaches points to the need for increased autonomy and a consistent drive towards pushing power downward to the shop floor. However, in this case, in spite of declared intentions towards increasing the role of operators, there appears to be a tendency in the implementation of lean production approaches towards increasing the rules and regulations associated with the use of these systems. Complexity and a high degree of integration characterising the use of the FMS is put forward by the manufacturing and production managers and staff as the primary cause for this increase. This will be shown below in three ways: 1) that the implementation of lean production has also introduced mechanisms which increased the degree of monitoring and control over the production process. In this case, the implementation of the 'Lean Enterprise' system has also included with it an 'Objective

Matrix' which is a productivity matrix designed to evaluate the accomplishment of specified goals and objectives. 2) Coupled with the new organisational changes, the number of rules and procedures associated with FMS operation, organisation, and utilisation has increased rather than decreased. 3) The degree of effectiveness of the new organisational arrangements is constrained by prior organisational experiences and developments. In this case, a previous company history of strong, highly independent groups has led to managerial over caution towards any increase in independence and control by the new teams. As time passed, increased pressures on the production system due to a three fold increase in the number of trucks produced led to the hiring of less skilled employees and transformed the relationship between these groups, the new operators, and management. Another aspect of the inconsistencies involved the underlying message associated with the impact of the organisational and cultural change on the company as a whole. When examined at the micro level (the shop floor), the inconsistencies were seen through operational imperatives that sought increased managerial control over the production process. While, simultaneously, an opposing message to increase operator autonomy and level of control was being sent from the human resources department. Production managers, production logistics staff, supervisors as well as operators confirmed that the Four chosen dimensions were key in informing the implementation lean enterprise to the FMS area. These four dimensions of complexity, integration, regulation, and flexibility are used as the criteria for evaluating the consistency between the FMS and the application of 'Lean Enterprise' concepts and techniques to the FMS environment. The details of these relationships will be discussed later in the chapter, but first let us examine the particulars of this company.

4.2 The Company

This company is a major European truck manufacturer with a turnover of approximately £ 503.385 million at the beginning of this study in 1994 with a 6.8 per cent share of the six tones G. V.W. (gross vehicle weight) Western Europe market.

Its core operations comprised the development, production, sale and after-sale service of medium and heavy commercial vehicles. The product range offered to the market consisted of the EBG 45 and the new EBG 65, EBG 75, EBG 85, and the EBG 95 series. The production of these medium and heavy trucks is carried out at this plant in Holland (2416 employees at the start of this study) with the emphasis on engines production and truck assembly which approached 70 trucks/day at the end of 1994 and reached 120 trucks by 1999. In 1994, the company had undergone dramatic structural and cultural changes that were still being defined and implemented at the beginning of this study. This study focused on the operation of what used to be two separate groups: Universal Machining & Gears, and Sheet Metal Components. These two groups were merged and reorganised under a single manager. The reorganisation involved eight production areas: Engines, both large and small; small chassis; large chassis; gears; assembly and test; pipes; paint; and engines overhaul (figures 4.1 and 4.2).

Together the Universal and Sheet Metal groups employed 1050 workers in 1994 including both direct and staff workers. 460 were employed in the Universal/ Gears area. During that time, the company's output rate was around 70 trucks per day (one line producing 8 trucks per hour) in the EBG75, EBG85, and EBG95 model series. By 1999, the number of trucks produced reached 120 trucks per day.

4.3 Organisation and History

EBG trucks was a well established Dutch truck manufacturing company with a work force of about 5000 people operating in a traditional, functionally based, highly bureaucratic environment. Its primary focus was on maintaining and expanding market share in what was referred to as the *'hockey stick'* strategy with its focus on *'more and more volume'*. This focus led to a culture based on this high volume production strategy and the policy of *'expansion at any price, even to the extent of seling trucks at a loss'* as one manager explained.

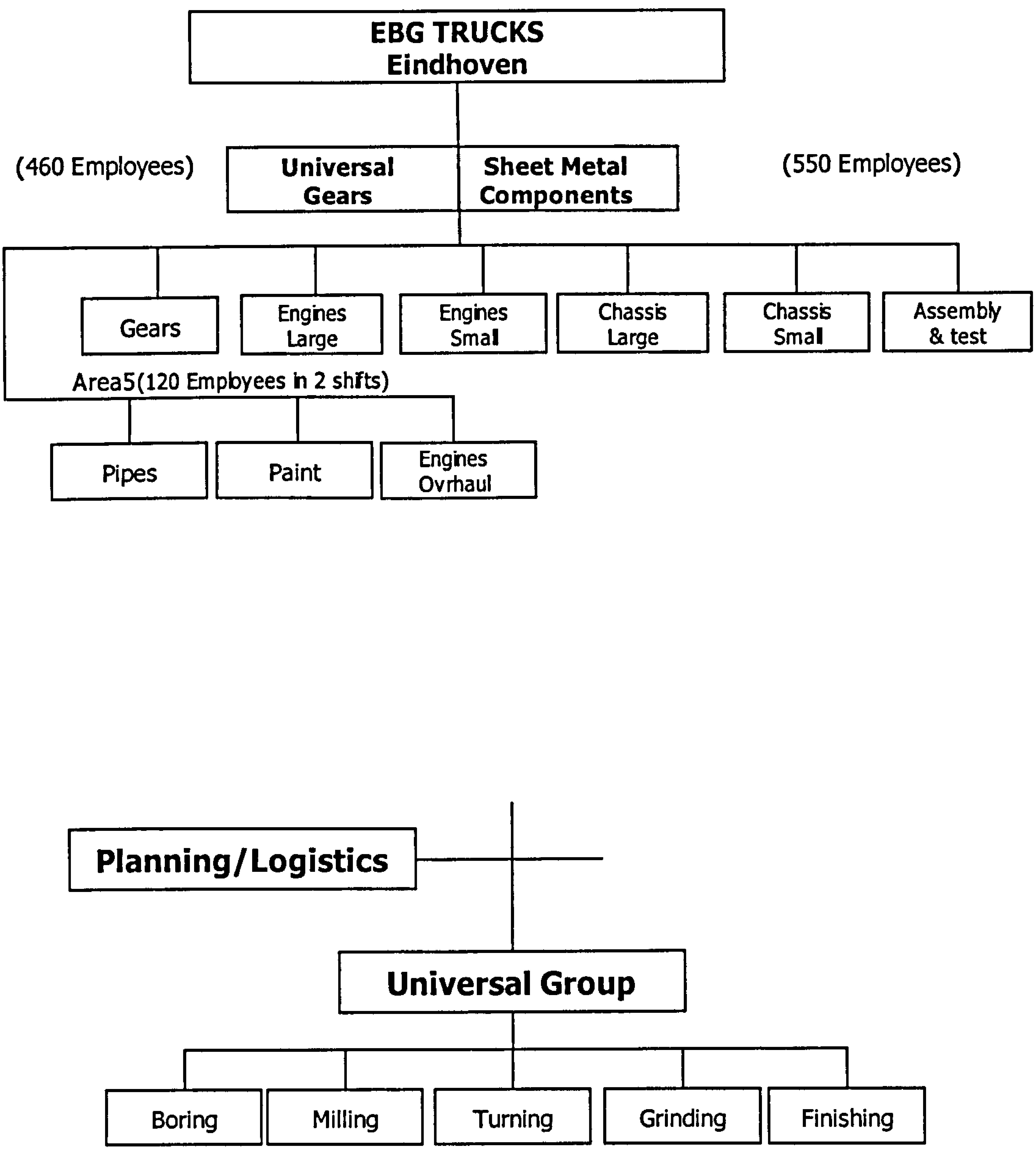


Figure 4.1: EBG Production areas chart

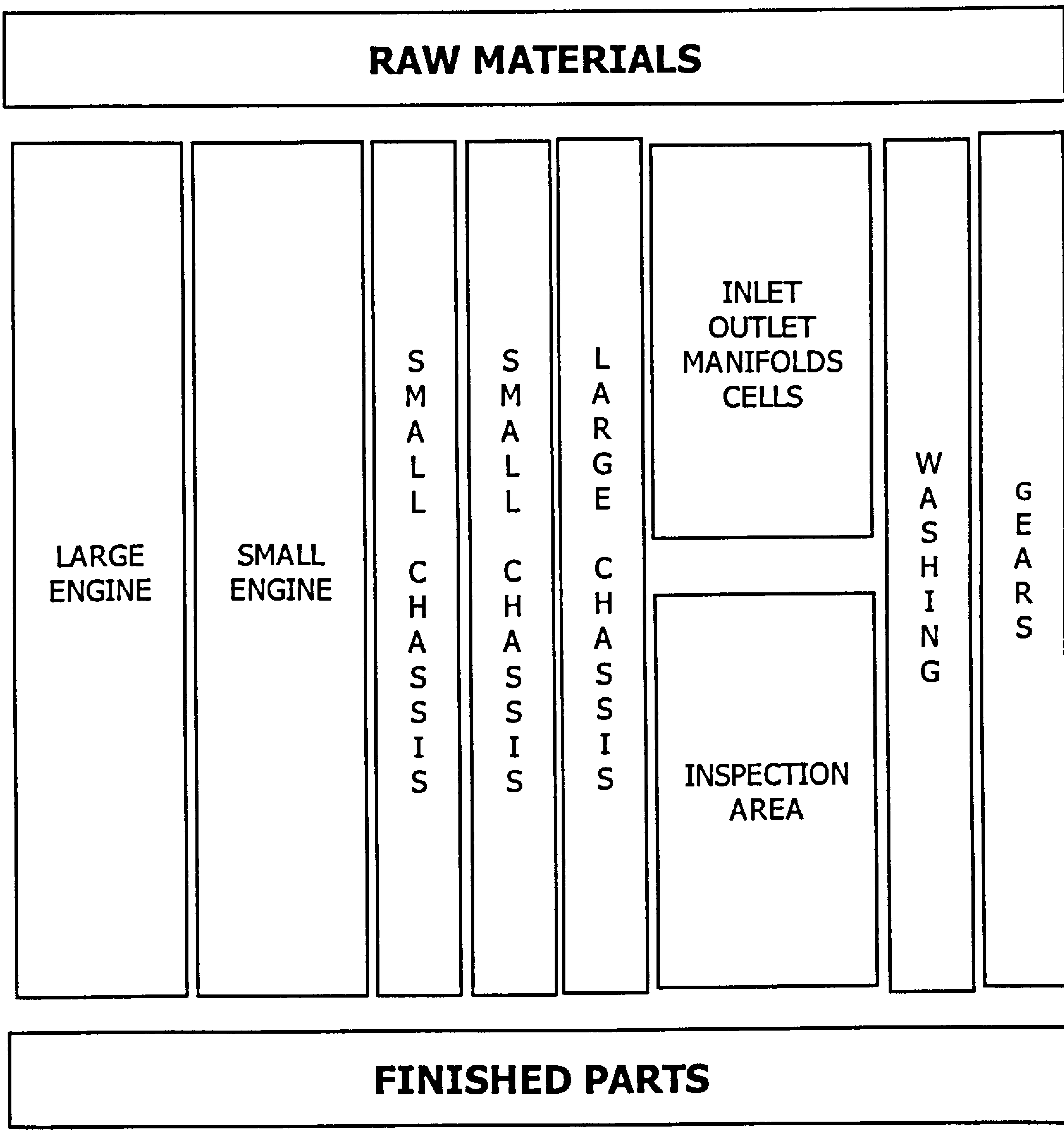


Figure 4.2: Universal / Gears Area Layout at EBG

By the late1980s, and as competition increased, the company continued to face mounting pressures due to decreased sales and mounting operational and production costs. This downward spiral culminated in bankruptcy when early in February of 1993, the board of management of EBG was obliged to institute insolvency proceedings and declare bankruptcy. This bankruptcy came as a surprise to the majority of the employees who were misinformed on the seriousness of the financial situation of the company. It was obvious to the workers that the chief executive had deliberately kept employees and shareholders misinformed in an effort to limit the damage to the company's stock price. Four weeks later, through new financial arrangements with the banks, creditors, private investors, as well as the Dutch government and the workers unions, a new EBG Trucks with a new business plan, was formed to carry on some of the operations of the old EBG. During the weeks preceding this, intensive discussions were held with the unions, which were also faced with tremendous problems under extremely difficult circumstances. Only 50 per cent of the old EBG employees were rehired by the new company which meant that this restructuring reduced the number of employees from 5000 to approximately 2500 people. Agreement was reached on structure and the conditions relating to the selection of the new company's work force. This resulted in a protocol in which the terms of employment for the employees within the new EBG Trucks were set out. The first few months following the start-up were characterised by heavy pressure due to the circumstances under which the company had come into being. Employees had witnessed the redundancy of many of their former colleagues and were confronted with this after joining the new company. A new organisational structure had to be worked out in detail and refined and strengthened, in addition to the need to re-negotiate contracts with suppliers. In the new organisation (which from now on will be referred to as the new EBG) and through these drastic redundancy measures, the company was able to radically transform the organisational structure and work organisation of the whole company and introduce many of the concepts and systems which characterise new wave manufacturing (NWM). The new EBG introduced a 'Lean Enterprise' concept (goal setting, team working, communication, flat organisation, reorganisation of groups, and increased responsibility) taking advantage of drastically reduced resistance to change resulting from the immense bankruptcy shock. What emerged was a more flexible organisation which, as one company document indicated:

'...has an efficient and alert organisation with short lines of communication. We have employees who want to be customer oriented. an organisation which is and must remain lean and as such still has an important lead over many of our competitors.'

One of the key changes which the new EBG has implemented is its reversal of the 'hockey stick' strategy by focusing the marketing efforts on fewer markets and concentrating on servicing those markets. 'Volume' was no longer the magic word to watch for in the new company. 'Profit' and 'Profit Margins' were added to the company vocabulary, and the focus switched to 'making sure we know our own strengths and weaknesses, strong points and weak points and use them in the market'.

4.4 The New Organisational Structure

One of the first changes that the new EBG company undertook was to eliminate a significant number of the middle management positions (at least 30 per cent of the redundancies were in management positions). The new management reduced the number of organisational levels by at least two levels (as can be seen from figure 4.3 and figure 4.4).

From the new organisational chart, we can see that the position of superintendent has been completely eliminated. The position of the supervisors has been transformed into a ' facilitator' position which involved enlarging the span of control and attempting to redefine the relationship between the operators and team members and the supervisor. In addition, the manufacturing manager position has been enlarged and a new position 'Area Manager' has been introduced. All the engineering, production control, quality, and logistics staff necessary for the operation of these areas have been moved down to be under the control of the area managers. This led to bringing the engineering and planning

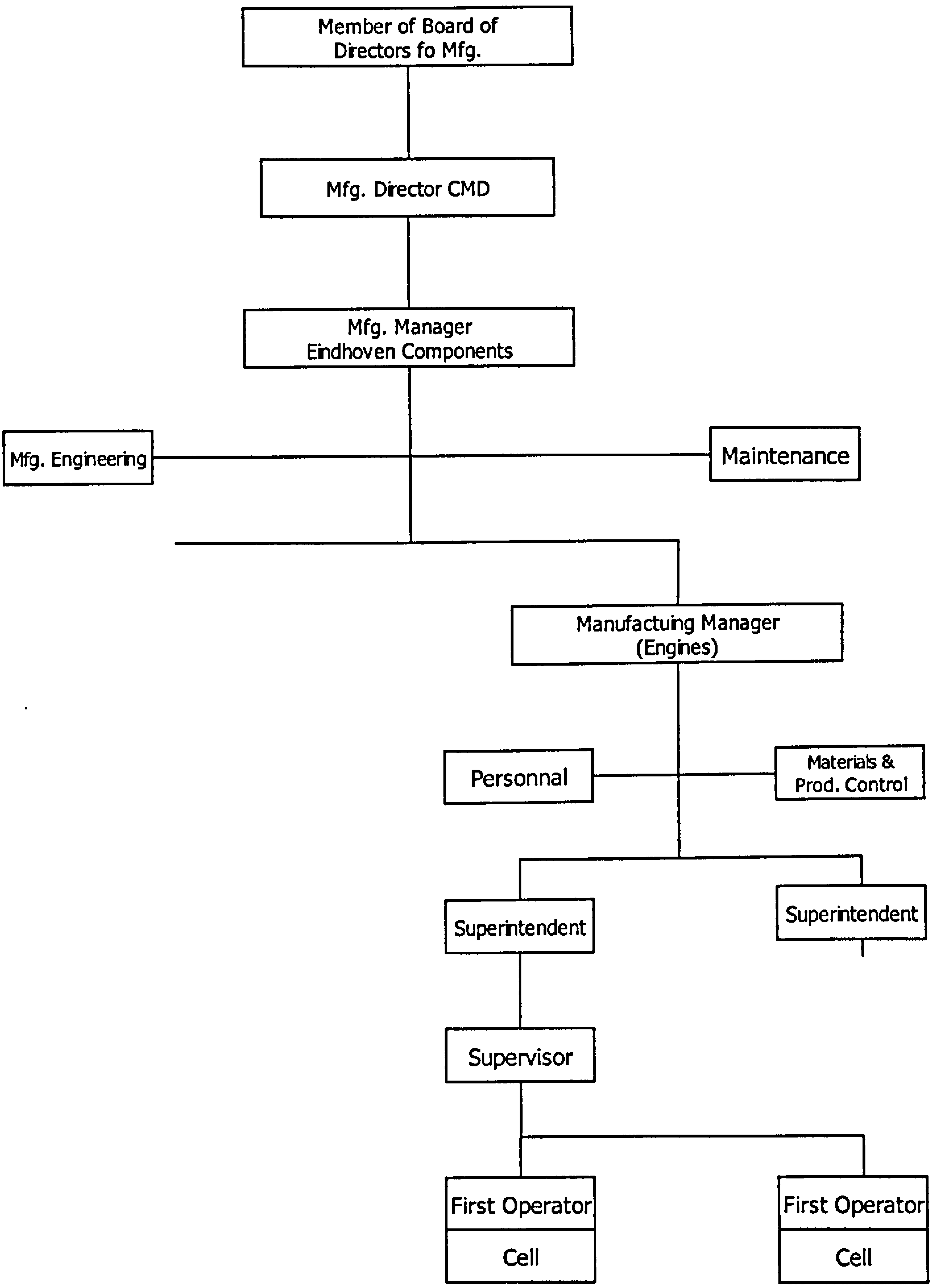


Figure 4.3: Organizational Structure – Old EBG

functions closer to the operation on the shop floor, thus going a long way to transforming the company from a functionally based to a process based organisation.

4.5 New Wave Manufacturing

The transformation from the old to the new EBG and the significant reduction in the work force gave management the ability to dismantle old departments and establish new structures without the level of resistance which is usually expected when dealing with traditional, long established, bureaucratic and usually powerful departments. Although some new wave manufacturing elements were introduced in the old EBG, their introductions were usually seen as half-hearted attempts at change and their effectiveness was severely constrained by the existing bureaucratic, hierarchical culture, and lack of enthusiasm towards such changes. This was especially true when these changes entailed attempts at the redistribution and devolving of power to lower levels in the organisation. With the new EBG, the opportunity arose to restructure the whole organisation in part through the implementation of new wave manufacturing approaches which were deemed essential for achieving the necessary productivity and efficiency for new EBG to survive. A key element in this process was the introduction of the 'Lean Enterprise' concept.

4.6 Lean Enterprise

The lean enterprise concept was introduced immediately after the restructuring with the primary objective of transforming new EBG into a more focused organisation with a leaner, flexible, and more productive work force with 'increased responsibility and accountability'. The new EBG was to become a flatter organisation with increased vertical and lateral communications, goal setting, and team working within a flexible, productive well integrated, cooperative environment. The key drives for the successful implementation of this new wave manufacturing / lean enterprise concept involved the following:

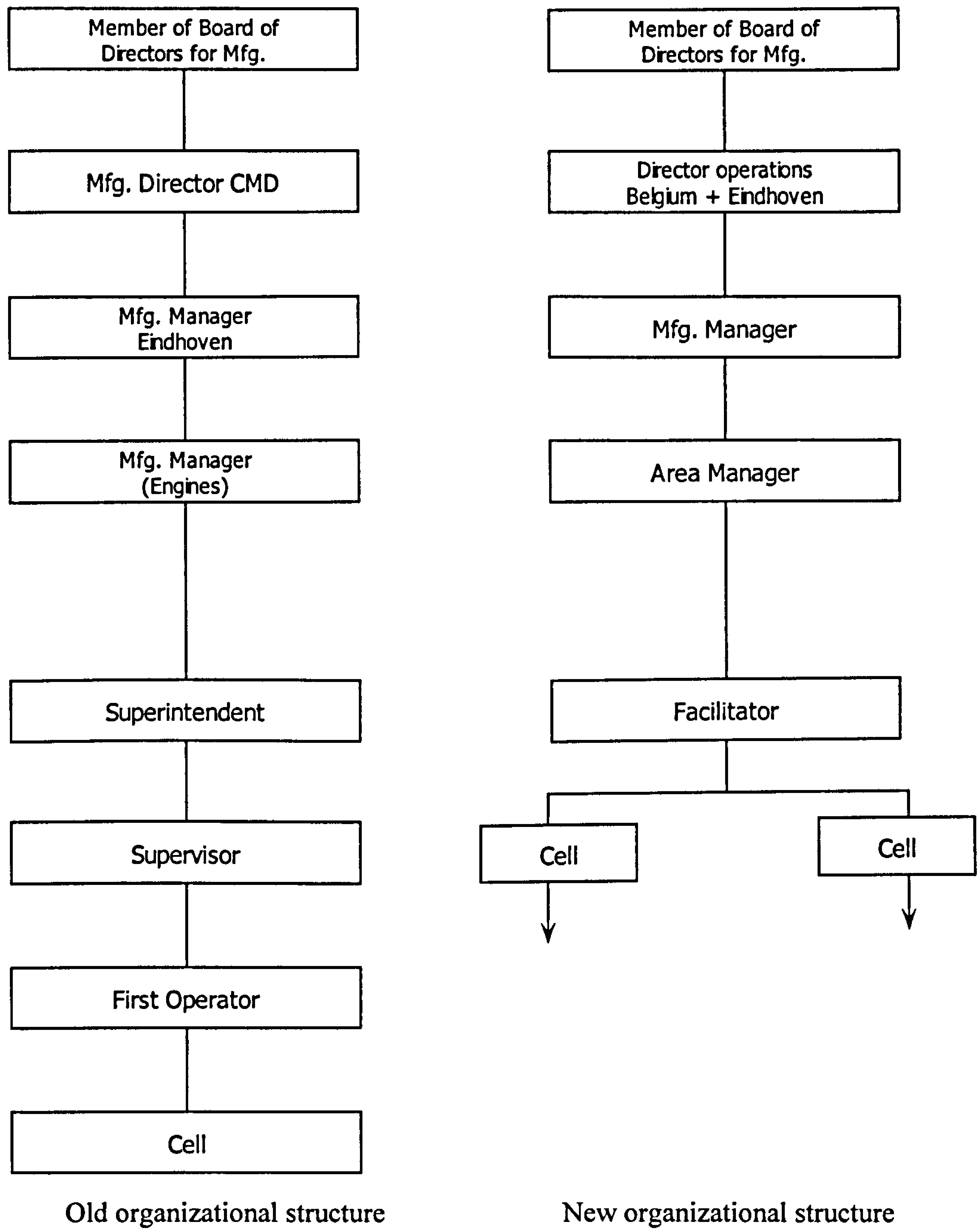


Figure 4.4: changes in the organizational structure

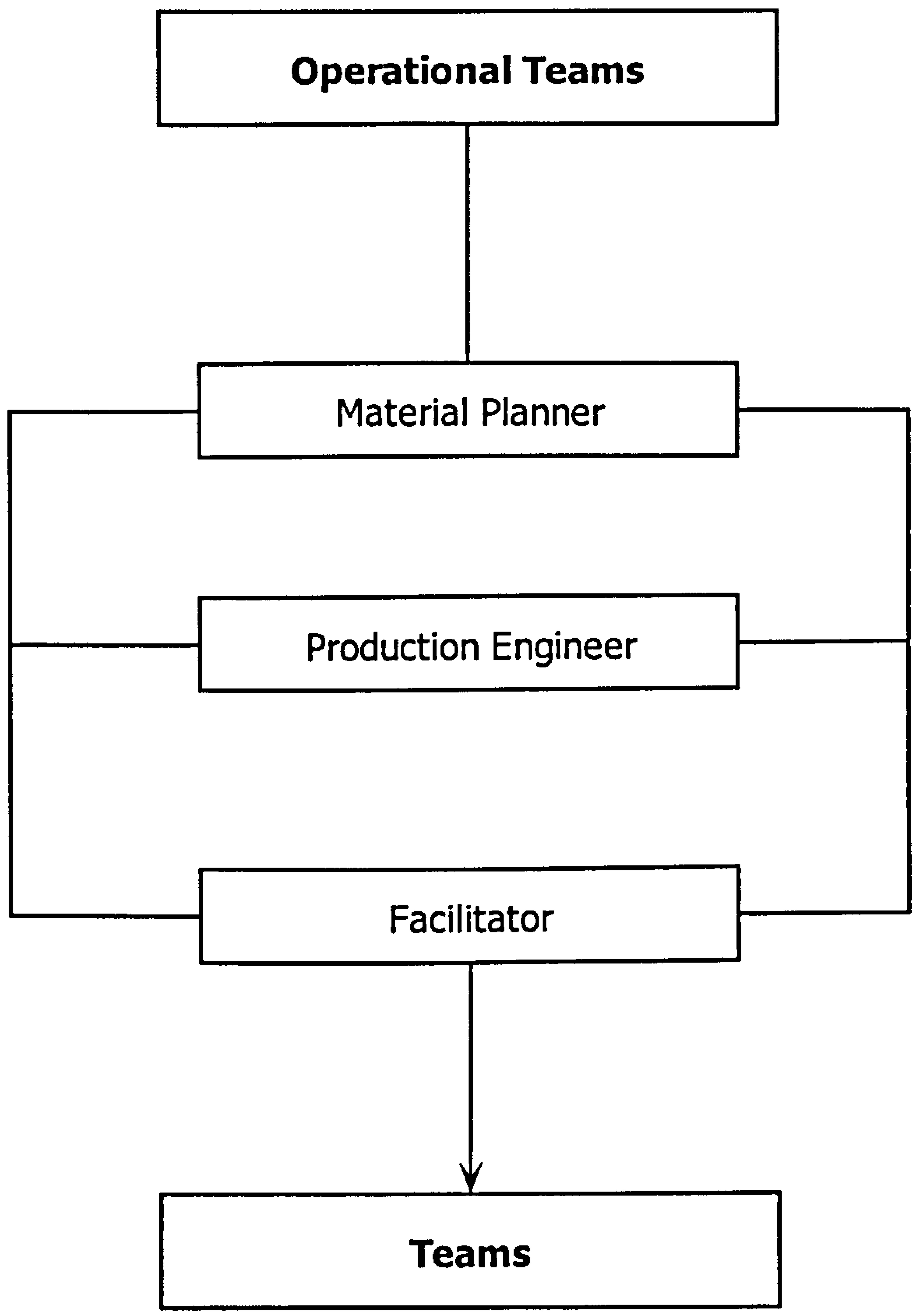
4.6.1 Continuous Improvement

A system for continually improving the production process has been established at all operational levels from Area managers down to the individual cell level. The system involves monthly meetings where production and improvement targets are agreed upon and progress is evaluated in subsequent meetings through target comparison and monitoring. When designated targets are acquired, new objectives are established and the system is updated at all levels on the basis of the new changes and improvements. This new continuous improvement approach was exercised using what was referred to as the 'Objective Matrix'.

4.6.2 The Objective Matrix

An objective matrix established in each of the production areas, focuses on increasing the responsibility of the teams for their own production cell or group of production cells. The key actors are the facilitator (supervisor), a logistics/ material planner, and a production engineer. These three actors designate the teams with the operational mandates which are then translated into very focused team objectives (figure 4.4a). The integration of these production and logistics personnel into the production areas has replaced the old functional structures and has helped to increase the integration within these areas. This close proximity to the production areas lends support to the established teams within each production area, and through the use of regularly scheduled team briefings and the elimination of many unnecessary steps, has helped increase the efficiency of team operations.

The agenda for these team briefings includes discussions of the production targets and the results of actions taken since the previous meeting. These team briefings also include general discussion of the overall production status and issues such as customer complaints, projections, tool usage, illness, and production targets and milestones (see (Objective Matrix chart in figure 4.5). A key aspect of these meetings is planning: a six month production schedule is analysed and changes to the schedule are updated



Operational team functions were in separate departments before the restructuring
Now , these functions are closer to the cells

Figure 4.4a: Operational Teams

	Begr	Periode 01	02	03	04	05	06	07	08	09	10	11	12	13	Cum	Begr	Akties
Quality																	
Klantklachten	96	99.0	98.0	98.0	97.0	99.0	97.0	98.0	99.0	99.3	99.4	99.0			135.3	96	
Celverificatie	99	98.8	98.7	98.7	98.4	98.5	99.2	99.2	99.6	98.9	98.7	99.6			136.0	99	
Procesaudit	93	95.0	95.0	97.0	95.0	99.0	95.5	95.0							95.9	93	
PV Verspaning																	
kwal.Index	96	97.6	97.2	97.9	96.8	98.8	97.2	97.4	99.3	99.1	99.1	99.3			120.0	96	
Leverbetrouwbaarheid (Reliability)																	
Inzetrestrictors (Input restrictions)																	
MBS - VDI	90	99.0	94.0	98.0	98.0	97.0	100.0	100.0	95.0	92.0	98.0	89.0			132.5	90	
Logistiek x fl 1000,= Logistics																	
Ruw Blokken	87.0	226.0	193.0	198.0	114.0	96.0	103.0	103.0	144.0	155.6	163.8	124.2			180.1	87.0	
DLT Ruw (Throughput time)	2.0	5.6	4.7	4.6	2.6	1.9	2.3	2.3	2.8	2.4	2.5	1.6			3.7	2.0	
OHW+Ger	728.0	600.0	539.0	791.0	937.0	820.7	845.0		772.0	1016	965.1	*****			1051.2	728.0	
DLT OHW + Ger	9.5	9.6	8.5	10.6	11.4	9.1	11.2		8.9	9.5	9.4	10.7			12.4	9.5	
Totaal	817.0	826.0	732.0	989.0	1051	916.7	948.0	103.0	916.0	1172	1129	*****			1114.5	817.0	
DLT Totaal	11.5	15.2	13.2	15.2	14.0	11.0	13.5	2.3	11.7	11.9	11.9	12.3			14.7	11.5	
OS Totaal	26.0	26.3	29.6	22.3	20.8	25.7	26.8		27.0	26.6	28.7	26.3			32.5	26.0	
Ruw Lagerkap	24.0	45.0	62.0	61.0	98.0	81.5	103.8		100.0	105.9	95.7	90.7			105.5	24.0	
DLT Ruw	7.0	18.5	21.9	17.7	26.7	19.8	26.7		23.8	21.6	18.7	14.5			26.2	7.0	
OHW+Ger	102.0	104.0	153.0	111.0	124.0	114.3	124.6		134.0	121.4	191.7	154.9			166.6	102.0	
DLT OHW + Ger	13.0	15.7	22.4	16.7	14.7	12.9	16.6		14.3	12.1	18.6	15.2			19.9	13.0	
Totaal	125.0	149.0	215.0	172.0	222.0	195.8	228.4		234.0	227.3	287.4	245.6			272.1	125.0	
DLT Totaal	20.0	34.2	44.3	34.4	41.4	32.7	43.3		38.1	33.7	37.3	29.7			46.1	20.0	
OS Totaal	17.5	20.0	13.4	17.0	13.2	16.3	14.0		11.9	18.5	15.1	17.5			19.6	17.5	
Directen (Personnel)																	
Payroll	25.0	25.0	25.0	29.0	28.0	27.0	27.0	28.0	30.0	36.0	34.0	35.0			36.0	25.0	
Tot Result	73.2	70.8	84.4	90.1	93.9	77.0	84.7	84.2	70.3	85.9	92.1	83.1			101.8	73.2	
Res Aanw	90.4	101.5	102.7	103.6	111.9	94.5	102.9	106.6	96.3	96.4	101.1	90.9			123.2	90.4	
Z Verzuim (Illness)	6.2	7.8	12.7	10.0	14.0	14.5	12.3	10.4	9.2	10.3	9.3	8.7			13.2	6.2	
Normt Ontw																	
Indirecten (Indirect)																	
Payroll																	
Exploitatie (Salary)																	
Loon																	
Ger / Normuur (Tools)	6.77	4.2	4.1	4.1	4.6	7.0	6.2	4.7	7.6	6.3	5.3	5.1			6.6	6.77	
Tot Expl																	
Kwaliteitskosten (Cost/ Man hour)																	
Kosten / Normuur	4.45	1.6	0.8	0.4	0.9	0.8	2.7	3.5	2.5	1.2	0.9	1.3			1.8	4.45	

Figure 4.5 : EBG Objective Matrix Sample Chart

periodically. Mix quantity and material needs as well as improvement initiatives and overtime needs are established in these meetings. In addition, safety and environmental issues as well as the general situation at EBG, including any new activities, projects, investments, or any other communication that management cares to impart to the teams, are also discussed.

4.6.3 Teamwork and Cell Formation

Historically, in the old EBG, while the rest of the organisation was highly functionalised into departments, the production area was organised into cells. The organisation of NC and CNC and other conventional machinery into cells was introduced into the old EBG in 1983. These cell groups were organised around specific functions such as milling or boring. Although the equipment was grouped together into cells, the operators' role was limited and dependent on the planning department's approval of machining operation through the production process. In machining operations, the operator needed to fill in a special form that needed a stamped approval from the planning department (figure 4.6).

With the new EBG, the new organisation set out to move more responsibility to the shop floor and abolish the strict controls exercised by the planning department. Gradually, more control was given to the operators to include functions such as quality inspections and maintenance functions. In order to give operators more control, the first step was to allow operators to do the set-up for the machine they operated. The second step was to let the operator do the first level quality inspection, and the third step was to move the planning function to the shop floor and eliminate the existing, excessively bureaucratic system of control.

4.6.4 Skill Level and Multiskilling

The key characteristic of all new wave manufacturing approaches is their focus on increasing employee skills. Since the production processes involve the use of NC, CNC, and FMS operators, by definition, the operators are required to be skilled in the operation

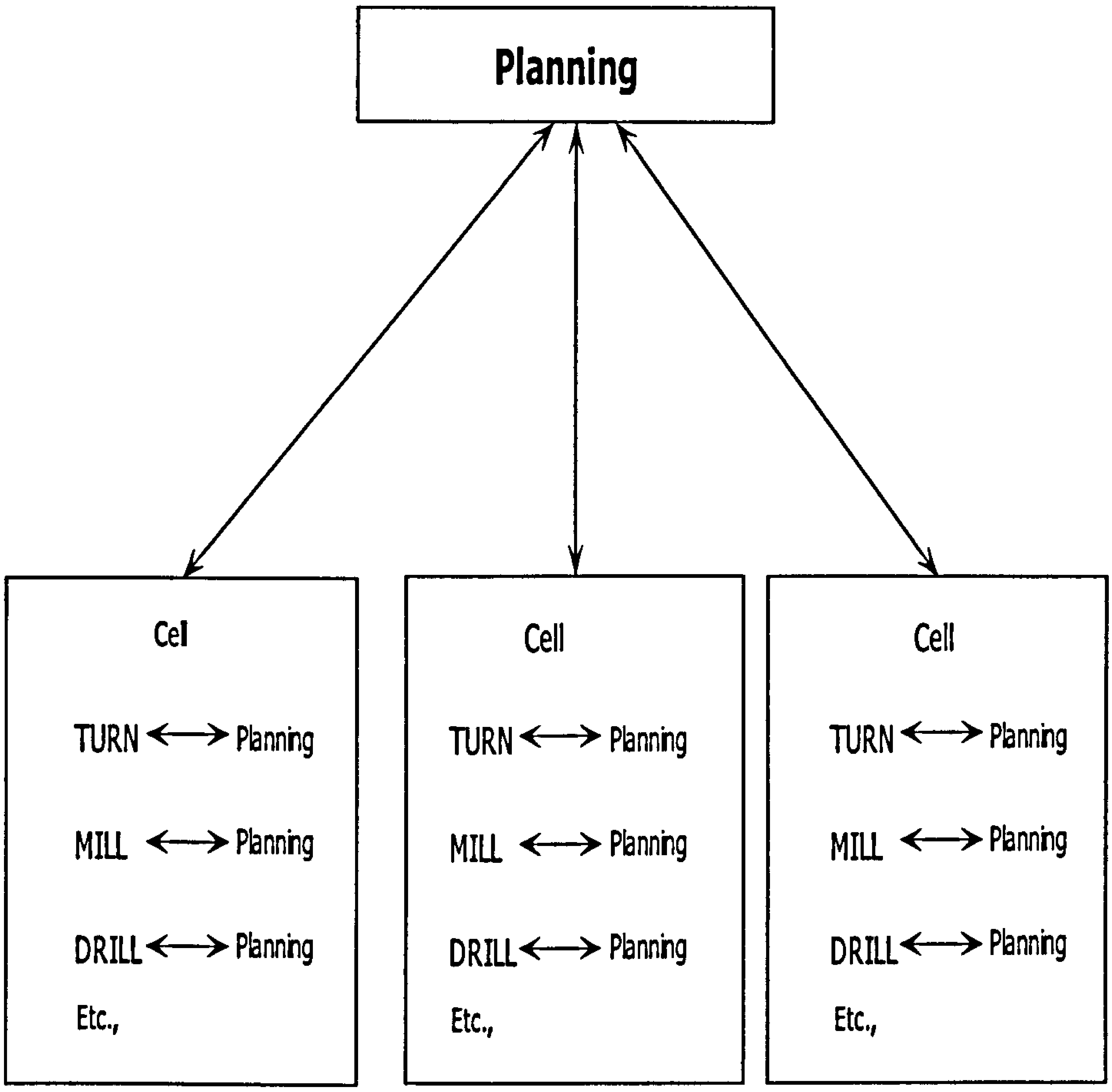


Figure 4.6: Old EBG – High Level of Control

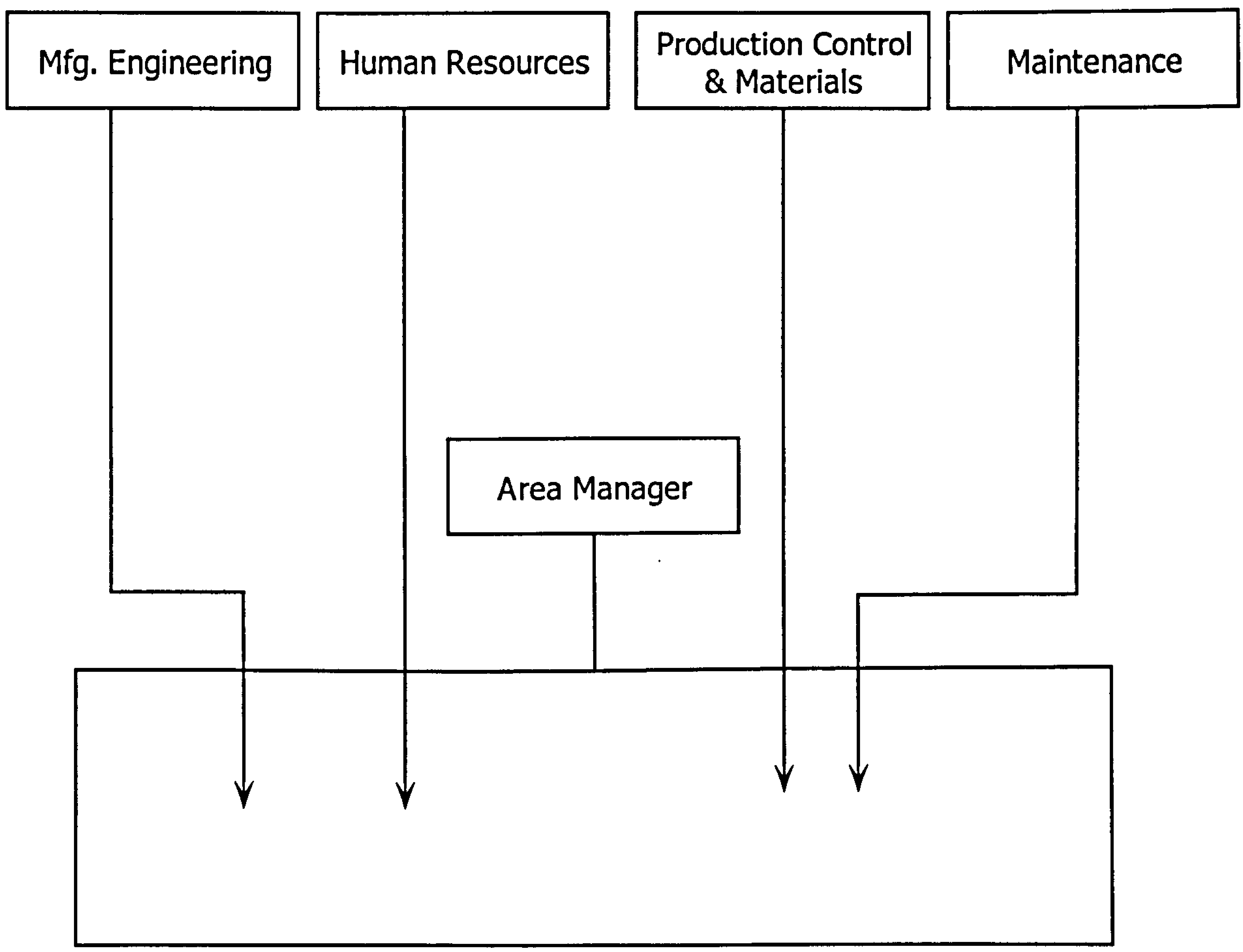
of such equipment. At EBG there are three nationally recognised accredited machine operator skill levels: LTS, MTS, and MTS-Plus. Depending on the accredited skill level, operators are divided on salary scale levels of group 4 to group 7. A group 4 salary level indicates a beginner or a new worker and a group 7 salary level indicates an experienced multi-skilled operator. In the FMS area, about 70 per cent of the operators are at MTS level and about 30 per cent are LTS level. One or two operators were MTS Plus. About two-thirds of the operators in the FMS area are at salary group seven while the rest are at salary Group 6. Group 7 operators are multi-skilled operators who can program the CNC and FMS machinery, while Group 6 operators are only allowed to make correction changes to the written programs while operating the machines.

4.6.5 Delayering

Another key element of the new wave manufacturing approaches is the move towards eliminating as many layers in the organisation as possible. Delayering as an approach is an essential element of the Lean Enterprise philosophy. New EBG restructuring has reduced the number of hierarchical levels in the organisation by an order of two. Thirty per cent of the layoffs associated with the restructuring were in management positions. Many well-entrenched departments such as planning, manufacturing engineering, maintenance, and materials / production control have been dismantled and essential functions in these departments were moved down under the control of the area managers (figure 4.7). This meant that a significant number of the staff level positions had been eliminated. For example, in the Universal Area, the number of materials/ production control employees was reduced from 20 to 8 and eventually to 3 employees.

4.6.6 Communication

Another key element of the new wave manufacturing approaches is the development of clear, on going, dual track communication both vertically between management and employees as well as horizontally between functions and groups. The focus of the new organisation was on developing lateral communication between work areas, operational



Moving away from the functional structure of departments: Integrating these separate functions to become under the control of the area managers

Figure 4.7: New EBG Functional integration steps

teams and groups. The use of operational teams and the productivity matrix was a consistent effort to develop cooperative teams. These teams which consisted of Engineering, Material / Production control (Logistics), and Production facilitators (or supervisors) departments, helped to improve the communication between what used to be competing departments with contradictory sets of priorities: The engineering department with its focus on the smoothness of the processes and the development of new projects; and the Material/ Production control (Logistics) with its focus on lead times and stocks and outputs; and the production supervisors with the focus on, inter alia, quality and productivity.

With the development of the operational matrix and the incorporation of the three functions of Engineering, Logistics, and Production into the same team, management has gone a long way to increasing the communication and cooperation levels between what used to be traditionally competing functions. Through the team approach, with its regular team meetings and briefings, the parties were able to compromise and achieve a trade-off that obtained the maximum benefit for the organisation at the shortest possible time. On another front, following the restructuring and the drastic reduction of workers, confidence in the company had been shaken. However, with the new EBG, early emphasis was placed on building up that confidence, both internally and externally, through the use of regular team briefings, in addition to a series of verbal and written information provided for the work force at all levels. Other efforts to increase communication included the publishing of a weekly newspaper informing the employees about company wide activities and initiatives. Bulletin boards were also used in production areas as well as regular meeting places.

In another step to increase confidence in the new company, plant management arranged general meetings conducted two or three times a year with all the people in the plant in a series of 3-4 sessions throughout the day. Another aspect that helped regain confidence in the new company was associated with the company's marketing campaign which comprised a large advertising campaign across Europe under the watch word 'Buy an EBG'. A three week long 'EBG trucks in Action' event was held on the company grounds attended by over 45000 people, customers, drivers, as well as all the plant's employees showing all the new truck models, as well as the future plans of the company. Although this was mainly a marketing campaign designed to increase customer confidence in the new company, its effects extended to all EBG employees and has helped in informing the workers of the direction of the new company and the investment decisions both in new truck models as well as new equipment and machinery, and emphasising the sound financial position and the potential for growth.

4.6.7 Training

In order to increase the role of operators, and through the on going process of dismantling departments, operators on the shop floor had to learn new skills such as quality control and maintenance, which were the duties of separate department s in the old EBG. The majority of the workers were multi-skilled group 6 or group 7 salary goup which implied that acquiring the new skills did not require extensive training. Nevertheless, a training program was established with sessions on team development and problem solving techniques and a 'HAW-Review' (which included technical machine operation/programming for different machines, as well as quality/ maintenance refresher courses for the operators

Team leader training for every cell of 10-20 people includes management techniques, communication skills, problem solving skills, quality, project engineering, and logistics. A contract was signed with a local training institute to upgrade operator skills. Extensive / accredited training on CNC operation is conducted to nationally recognised standards and an exchange program in which apprentice operators are employed as a part of their skill accreditation program. Many of these trainee students are then employed on a full time basis once they achieve their LTS or MTS or MTS-Plus level certification.
As sales and production of the EBG series trucks increased, the company was faced with an urgent need to hire new skilled employees. For every single truck increase in daily production, the company needed an extra 23 employees on the shop floor to smoothly handle the new demands on the production floor.

Shortages of skilled machinists in the labour market forced the company to hire part timers and less skilled workers through special placement companies. A special introductory, one month training program in elementary mechanical engineering skills was developed both to provide orientation for the new workers as well as to judge their potential as machinists.

4.7 Advanced Manufacturing Technology

The introduction of new and advanced manufacturing technology (AMT) had always been the policy of the old company. With the restructuring, the new company continued to uphold the same policy with the recognition of the need for new organisational arrangements with the introduction of new technology. The introduction of new equipment was viewed as a part of a consistent innovation strategy aimed at increasing the competitiveness of the company as a viable alternative to increased international competition. The introduction of new machinery was also viewed as key in increasing the confidence of employees in the future of the company. In 1994, money investment in new CNC machines and technology had reached $11 million in Machining Equipment and a $7 million investment in Engines. Advanced manufacturing technology has been one of the positive features of the old EBG. Although new technology introduction was often done without the knowledge or cooperation of the operators or even supervisors of the area where the new equipment was to be implemented, the decision about the new equipment and the date and place of installation was made by the manufacturing engineers. As one of the supervisors (otherwise known as facilitators) explained:

' ... in the old EBG we were excluded from the decision on the introduction of new equipment. It happened once in my area when I came in one morning to see huge boxes and technicians unpacking the equipment. I had no idea what these boxes were and why they were in my area. I had to ask many questions of Purchasing and Engineering to get that information.'

Although other supervisors did not have similar experiences, it nevertheless illustrated that the introduction of new technology was clearly a top down decision: engineers had the say on what new technology was needed and where it should be introduced. In 1986, new CNC machinery was introduced with the development of a new truck model.

4.7.1 The Flexible Manufacturing Systems Environment

Called the 'Flexible Bewerking Centrum', this FMS is located in the Engines section of the newly integrated Universal Area. This area includes four machining cells for big and small cylinder blocks and main bearing caps. In addition, many of the CNC and old NC machines, which are still being used, are located in this section. There are 65 direct workers operating in this section organised into teams with one facilitator. Ninety per cent of these workers are direct workers and only ten per cent are indirect. Of the 65 workers, 12 operators are assigned to the FMS. Operating as a team, operations on the FMS are done on a three shift system with four operators on every shift (with one operator acting as an unofficial cell leader) while the rest of the teams in the area operate on a two shift system. The FMS has six working stations used for machining cylinder blocks and cylinder heads. The machining stations are divided into three left-hand side and three right- hand side stations. At the centre between the six stations a carrier machine transfers the blocks to the stations while the loading and unloading of blocks is done manually. These stations are used for machining four types of engine blocks: two types of engine heads for 8 litre engine blocks which require half an hour of machining time per block; and two types of engine heads for the 11 litre engine blocks which require one hour of machining time per block (figure 4.8).

In addition to the machining of the engine blocks for the new truck model engines, the FMS is also used for the prototype engine work and testing and depending on capacity, the FMS can contract to do machining jobs for customers from outside the company (such as, for example, Mitsubishi and Caterpillar). With the introduction of the new organisational structure, the FMS deals with other EBG groups or teams seeking FMS usage as customers. For example, one such contract focused on design for the production

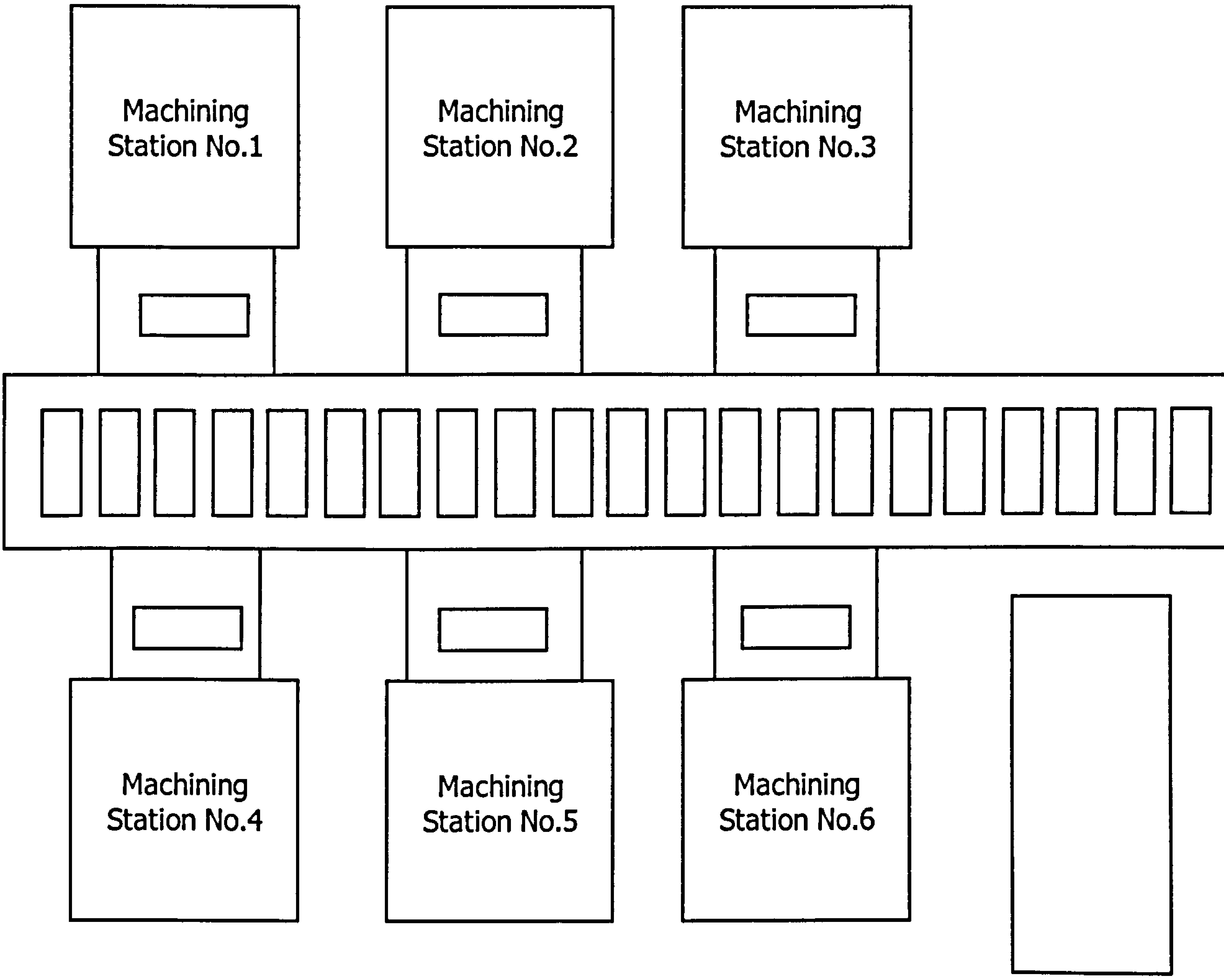
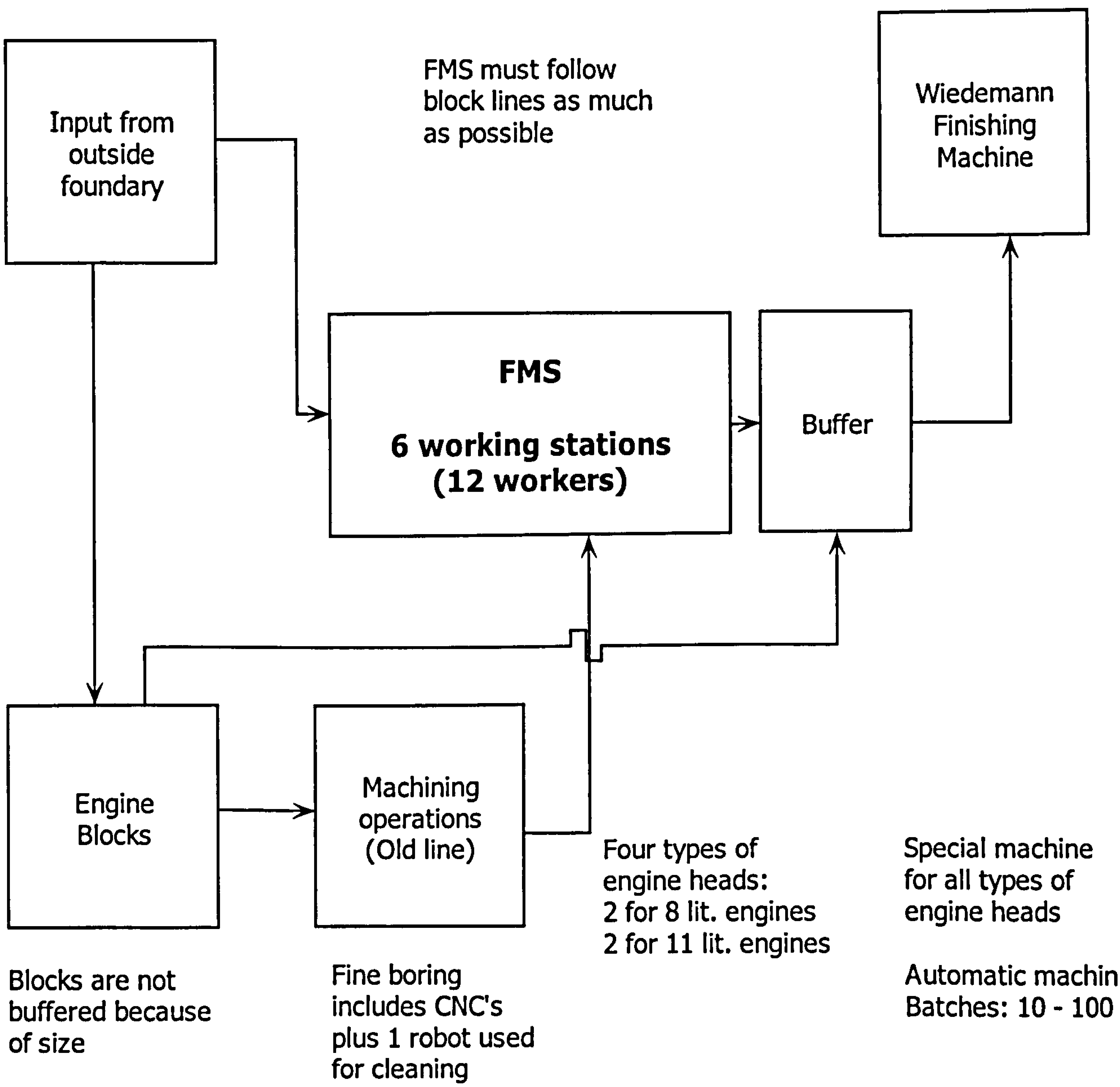


Figure 4.8: FMS machining stations

testing of a 4 valve engine block as well as the designs of different blocks and engine heads prototypes. The development and full production of the EBG95 series has limited the extent of these types of contracts. Currently the FMS operates 17 eight hour shifts per week at 80 to 85 per cent of the theoretical operational level which implies that the FMS is fully operational 22.5 hours a day, a relatively high rate.

The input to the FMS comes primarily from two sources: direct from an outside foundry, and from the machining operations of what is called ' the old line', which has a group of CNC machines which are used for fine boring operations on the engine blocks. There is also one robot used for cleaning the blocks. Once the cleaning is finished, the blocks are then transferred to the FMS stations. Because of the block size, the blocks are not buffered and the FMS operation must follow, as far as possible, the block line. Once the machining operations of the FMS are completed, the blocks are then transferred to a Wiedemann fine boring machine. Because of the different machining times for different engine block sizes (i.e. 8 lit. and 11 lit) a utilisation / scheduling problem arises so as to maximise the usage of all six FMS stations. Figure 4.9 describes the input diagram and integration of the FMS within the engines area. Further detail on the integration problems of the FMS will be provided later in this chapter.

Close to the FMS stations is the tool library area, where the sets of machining tools and spindles are kept. Each tool has its own bar code and a database containing a complete listing of all the spindles and tool parts which can be accessed through a computer terminal in the area. The operators are responsible for the pre setting and tool listing for the job in hand. This also includes testing for and replacing worn-out tools. Tool testing is done separately and not by the operators on a new computer controlled 3D (Three-Dimensional) measuring machine. The operation and programming of the machine is deemed 'very complex' and is operated by quality control personnel. The operators in this engines area are multi-skilled operators with about 70 per cent of them, including the operators of the FMS, in a Group 7 salary group which implies that the operators are capable of writing their own programs. In the case of prototype development and machining, the operators have complete control and do the full programming.



Six working stations on FMS for block line of 4 types of engine blocks:
One 8 lit. block requiring 1/2 hour machining time .
One 11 lit. block requiring 1 hour machining time .

Figure 4.9: Integration, FMS connected to tow lines

4.7.2 The Three Dimensional Measuring machine

This is a new inspection machine with a three dimensional capability. Due to its supposed complexity, only quality control department personnel did the actual measurement on this technically advanced machine. It is said to require an extensive programming knowledge and requires extensive training. Attempts at training the FMS operators about this new machine appear to have failed. Whether this was due to insufficient training or due to resistance from the ex- quality department personnel was not clear. Nevertheless, the facilitators' attitude about the operator use of this machine was that *' the machine was too complex, and very specialised for the FMS operator to operate.'*

4.7.3 Computer Numerical Control (CNC)

The most used type of technology in this manufacturing company is the computer numerical control (CNC) machinery. The company uses a variety of CNC 20, CNC 60, and CNC 100 production machines. These machines are used for all kinds of machining such as milling, boring, drilling, sawing, grinding and finishing, as well as a number of special machines used for bending. Many of these CNC's have multiple spindles and some are 4 - axis machines. Uses include machining of cabin parts, and axles-chassis connections. In the same area, a number of small presses, bending, and cutting CNC machines using Plasma CNC cutting units are present, separated from the rest of the production area and surrounded by a wall to cut the noise down, and have a CAD/CAM interface. Other types of machinery are the new automated 'side member production' (frame that the truck is build on) machines. These new types of machines are large machines which replaced older types of 2000 ton inflexible presses and the new machines can do many operations in one step. An overhead robot conveyor delivers the parts to these machines. Figure 4.10 describes the steps employed to produce the chassis rods.

In the paint area, an ALP automated paint-electrode bath is used to paint the pressed parts. The painting process is complicated by the different paint specifications needed for

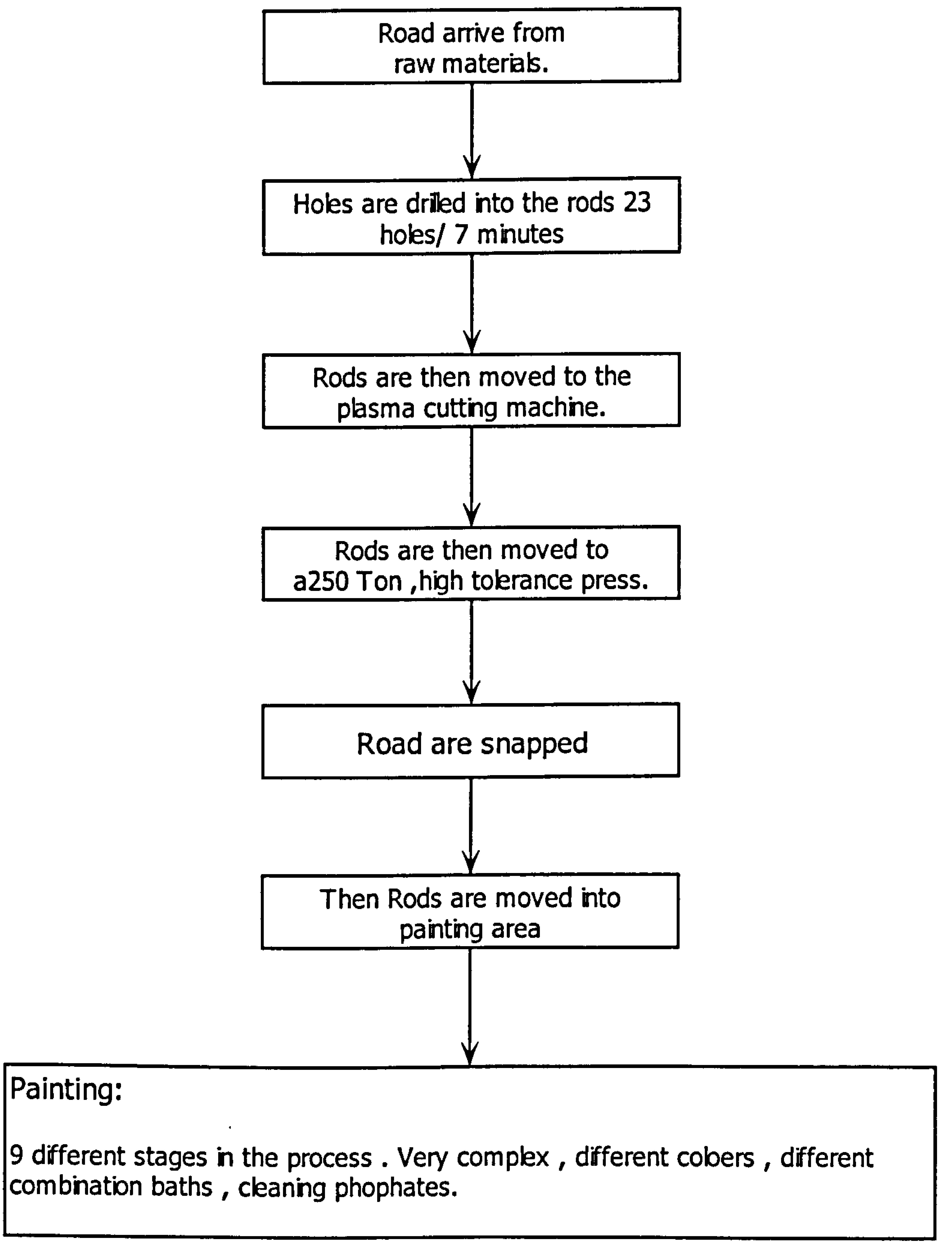


Figure 4.10: Chassis rods operation

different models and orders and colour combinations. The process has nine different stages with different combination baths including cleaning and phosphate baths. At the beginning of this study, the company was in the process of implementing a number of networked personal computers (PCs) on the production floor with a planning module, and a new order release and dispatching module installed within the network. A project group made up of the area manager, a logistics engineer, a production engineer, and a facilitator were overseeing the completion of this project. In addition, an application development program for customising information management and analysis was also established by the development engineers.

4.8 Cultural Change

The dramatic upheavals and transformation of the organisation into a new company with fifty per cent reduction in the work force had a devastating effect on the morale of the employees who survived these cuts. What was of significant impact in this case, was the fact that there were no real warnings of the redundancies. In spite of the rumours about financial problems, nobody in the company realised or expected the company to fold. Two factors helped camouflage the true situation. The first was company size and long standing national prestige associated with it 'nobody expected this large company to go down'. Second was the role of the chief executive in masking the true financial picture of EBG by maintaining a 'business as usual' façade in what appeared to be an attempt to maintain the stock price levels. Because of these factors, rumours of financial difficulty were swept aside, until that fateful February day when the general manager called a company meeting and admitted the seriousness of the situation and announced the filing of bankruptcy proceedings. The shock of this announcement lead to serious confrontation between the manager and the employees '*the manager was heckled and shouted down, it got really nasty, and people were very angry*'.

People were told that they would receive a letter in the mail indicating their future status with the new restructured company. One of the engineers described the experience:

'On that same weekend, you got a letter in the mail on Saturday. If you were one of the lucky ones, you got a two page letter: The first page was from the old EBG company saying that you have been fired due to the bankruptcy, and the second page was from the new EBG welcoming you as a new employee in the newly formed company. The unlucky ones only got a single page letter'

When the chosen employees returned to work, emotions were running high and people *'were walking around in a daze'* everywhere they looked there was evidence of people who were fired. *'desks were empty, and forms had signatures of fired managers or staff personnel or supervisors'*.

It took some time before people adjusted to the new reality, and having passed through this baptism, the attitude of the old entrenched departments and resistance to change had changed. As the human resources manager indicated: *'...with 50 per cent of the employees made redundant, we were able to disable old departments and build new ones'*.

Management moved quickly to fully implement the 'Lean Enterprise' system. External consultants were brought in as advisors to help move the company towards a 'business unit' structural format. In the short period following the restructuring, the employees were kept on a 2-3 day week schedule in an effort to deplete the existing stocks of trucks that were piling up in the plant parking lots. When these stocks were depleted, workers were put back on a full production schedule. As sales increased and production operations went back to normal levels, confidence in the new company began to increase and the climate of uncertainty began to dissipate. Although the new EBG was still licking its wounds, the company was able to continue development of the new truck model (EBG95 Super Space Cab) and achieve full production in less than 60 weeks. At the time of this study, the production level achieved the 50000 trucks mark with significant fanfare from management.

4.9 Organisational Changes

With the implementation of the 'Lean Enterprise' concept (i.e. a flatter organisation with increased vertical and lateral communications, goal setting, team working, continuous improvement, and a 'productivity matrix' within a flexible, productive well integrated, cooperative environment), the situation in the production areas has changed dramatically. A case in point was the move of the planning functions to the production floor. As we saw in figure 4.6, before the company's restructuring, the Planning department was the primary controller of all activities on the shop floor. Before turning, milling, boring, or any other machining operation on a part, the operators had to get the stamp of approval from the planning department at every step in the process, even if the operation involved a single part or component. An example of this high level of control can be seen in the in the pump housings operations in the Universal Area. In the old structure, the pump housings operations used to take six weeks on average before completion of the processing. By moving the planning closer to the shop floor and eliminating most of the unnecessary controls and stamping procedures, this same process under the new 'Lean Enterprise' restructuring arrangements, takes only two days from start to finish. Another aspect of the organisational change on the shop floor is elimination of the superintendent role and the expansion of the duties of the supervisor to include those of the superintendent. Now the supervisor role has been transformed to a 'facilitator' in charge of all the cell teams operational in his area, the name change to 'facilitator' indicating the supportive nature of the supervisor's new role who now reports directly to the area manager (See figure 4.4: The new organisational structure). The other change on the shop floor was the elimination of the first operator position and increase team responsibility for all aspects of cell operation. Increased operator responsibility now means that operators can do quality audits which were the responsibility of the quality department in the old organisation.

4.9.1 Team and Work Group Development

The development of the Lean Enterprise concept with its focus on productivity targets through the use of the Objective Matrix was the key element that helped pave the way for the success of the teamwork groupings on the production floor. To understand the significance of such a change, it is helpful to review the history of team development at EBG.

In the 1970s and 1980s, following the popularity of the Scandinavian autonomous work group, as well as the development of similar socio-technical approaches by a number of Dutch universities, the company adopted these socio-technical approaches to work organisation structure on the shop floor. The work teams on the shop floor gained more autonomy and control to the extent that the area manager indicated:

'... these groups focused too much on labour satisfaction and not enough on goals and productivity .The autonomy of these groups got out of hand to the extent that these cells were setting their own production schedules that often contradicted with those production targets set by management'.

The high degree of autonomy led to a significant increase in group cohesion at the expense of other groups and functions in the organisation (see Figure 4.11):

' ...the increased level of work group autonomy lead to the creation of 'kingdoms' and inward looking groups that decided even on when to have a party. The cells became too autonomous and very inward looking . This created and in-out group phenomenon'.

(Area Manager)

As another manager indicated, by the late 1980s, with the coming of a new manufacturing manager, the excesses in the work group issue was tackled head on. The new manager '*adopted an anti QWL*' posture and forced a move towards '*focusing on the numbers*' and accountability for achieving production targets. The new manager focused purely on results. With the coming of the Japanese production techniques and their

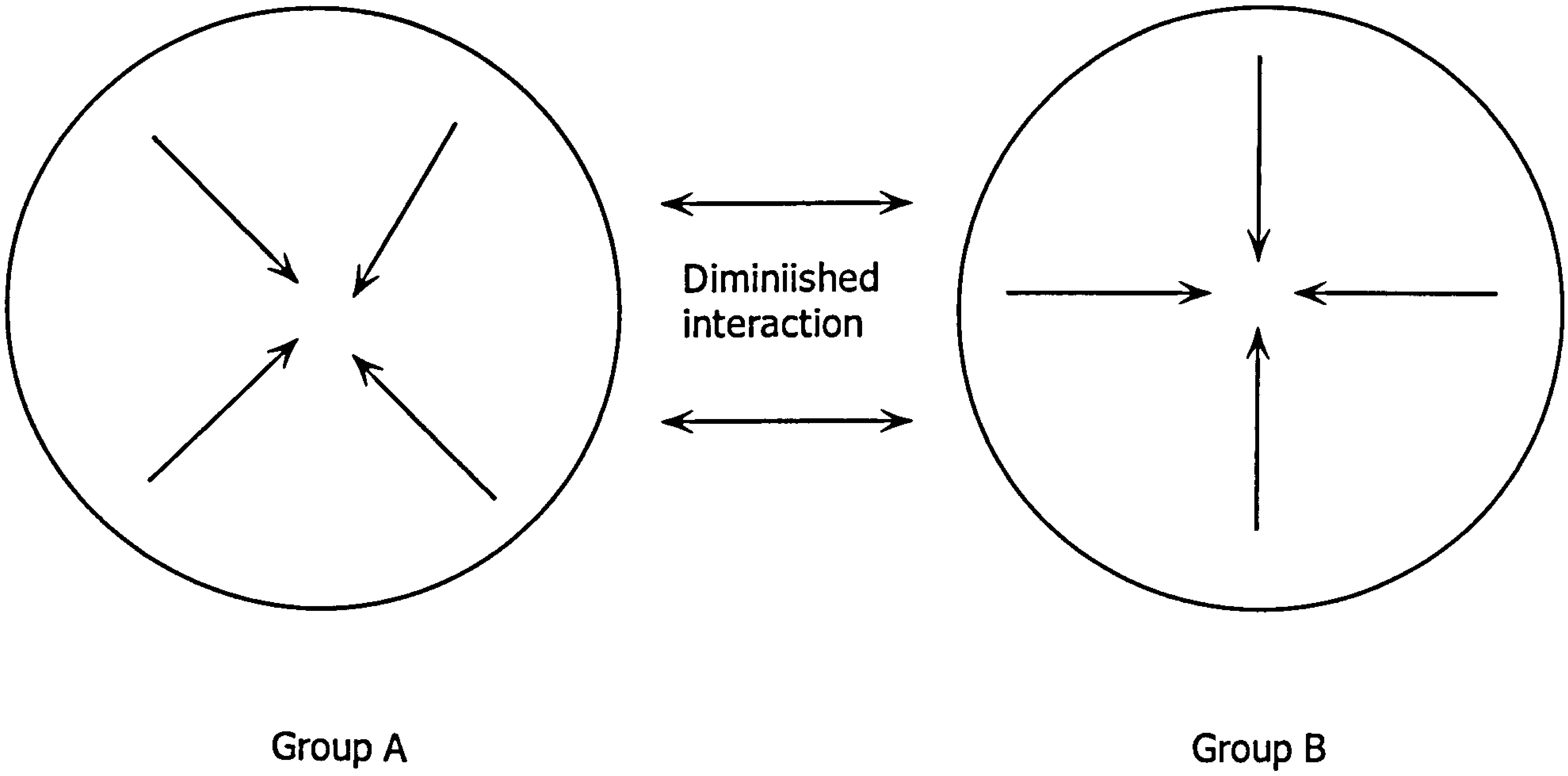


Figure 4.11: ***Drawing by one the area managers indicating the cohesiveness of the autonomous groups. The groups were focused inwardly without interacting with other groups.***

increased popularity and success in other companies, the company's board of directors, believing in the need to adopt similar systems as a way to revitalise the company's declining productivity, kept pushing the manufacturing manager to adopt similar approaches. However, believing that such programs were *'a waste of time'* and recalling the previous experience in the autonomous work groups fiasco, the manager continued to resist the introduction of any such systems.

' This manager held back these modern concepts. and just before the bankruptcy and as a way to save his skin, he moved to introduce the Lean Enterprise concept at the last minute'.

In spite of the introduction of Lean Enterprise, commitment to it remained limited. Yet, with the restructuring and the formation of the new organisation, the Lean Enterprise concept was adopted wholeheartedly and more fully throughout the new organisation, with full managerial support.

The development of the Objective Matrix under the Lean Enterprise concept helped the company avoid repeating its previous experience with teams. By including a production engineer, a logistics engineer, and a facilitator as a part of the team approach, and focusing on a goals and achieving set objectives and production targets, the Lean Enterprise was able to achieve productivity improvements. Other aspects of the Lean Enterprise involved developing integration within areas and moving all the production-related functions closer to the shop floor. Some functionality still existed at higher levels in the organisation but at area levels these have been integrated at shop floor level.

4.10 'Lean Enterprise' in the Flexible Manufacturing Systems Area

A key element of the lean enterprise initiatives was the attempt at 'devolving more responsibility and control to the shop floor'. This was done, as the human resources manager indicated, by focusing on the development of teams (cell groups), developing training in techniques such as problem solving, and adopting continuous improvement through the use of the 'Objective/ Productivity Matrix' and focusing on continuously improving production goals and objectives.

Improving competitive advantage through the implementation of new technology was also the policy new EBG. In this case, the company adopted FMS systems on the shop floor in addition to the CNCs, as the production technology needed to help maintain the company's competitive advantage. Together, the development of 'Lean Enterprise' and the continued introduction and usage of advanced production technologies were seen as the key weapons for insuring the competitiveness of the organisation particularly in today's increasingly unforgiving market place. This view was confirmed in the interviews by the human resources manager, the plant manager, the Area manager, production engineers, supervisors and operators alike.

In the flexible manufacturing systems production area, interviews were conducted with facilitators and operators ('All Rounders' and 'Rounders') on the shop floor which examined the details of the lean enterprise arrangements at the FMS and the perceptions of the facilitators and operators of the degree of success of these arrangements.

On the surface, the issue of whether lean production is applicable to the FMS area was not a question that was entertained by the actors in the organisation. Lean production or in this case 'lean enterprise' was presented and adopted in the company on the assumption that it was applicable to all aspects of the production processes including the FMS environment.

Probing further into the relationships relating to lean enterprise application to the FMS area, three points of views emerged in the interviews:

The first viewpoint, interviews conducted at the managerial level (particularly the human resources manager and the plant manager) pointed to an emphasis from these managers on their commitment to the principles of lean production including the commitment to giving shop floor operators more responsibility and control over the production process.

In the words of the human resources manager, this commitment also included 'pushing power downward to the shop floor'.

The second viewpoint, interviews conducted with the area manager, manufacturing, production, and logistics engineers pointed to acceptance of the lean enterprise, but with emphasis on the importance of the objective/productivity matrix (Figure 4.5) characterised by focusing on team objectives, production targets and on the need for tighter control of the production process. 'Complexity' and critical 'Interdependence' of operations especially in the FMS area were cited as the reason for the need for tighter control of the process.

And the third viewpoint, based on interviews with facilitators and operators pointed to an apparent increase in rules and regulations that are being applied to the FMS in particular in conjunction with the objective matrix. The view of the operators of the lean enterprise indicated a perception on their part of decreased control over the production process as a result of the demands of the objective matrix.

Thus, based on these three viewpoints, inconsistencies relating to the perception of the role of lean enterprise and its applicability to the FMS environment in particular were detected. These inconsistencies were seen in the message associated with FMS operation and that of the lean enterprise organisational arrangements.

Underlying the messages associated with lean enterprise is the impact of organisational and cultural change on the organisation as a whole. This impact, when viewed at the micro level, is translated through designated operational imperatives which seek increased control over the production process. While simultaneously sending an opposing message, also associated with the new work organisation structures which are supposed to increase the degree of autonomy and span of control of the workers.

What emerges from the interviews is that these efforts at increasing the levels of autonomy and authority on the shop floor were moderated by three factors:

1) Increases in monitoring and control through the 'Objective Matrix';

2) Increases in the rules and procedures associated with the operation and utilisation of the FMS;

3) Prior managerial experiences of loss of control over group developments causing over-caution on the part of the area manager and production staff to the independence of teams. This heightened sensitivity to group development was conveyed to the facilitators (supervisors) as well.

These three factors appear to present a conflicting picture of the nature of the new organisational innovations and their relationship with the FMS. They cast a shadow over the compatibility of the operational imperatives associated with FMS use and those of the lean production approaches. In the next section, these inconsistencies will be examined more closely using four characteristic dimensions associated with the flexible manufacturing systems as key criteria for evaluating these inconsistencies.

4.11 The Key Dimensions

As was discussed in chapter three, it is possible to use some of the characteristics primarily associated with the flexible manufacturing systems (FMS) as the dimensions for evaluating the compatibility between FMS and lean production. The key chosen dimensions are: complexity; integration; regulation; and flexibility. These four dimensions were confirmed by the area manager, production and logistics engineers, supervisors (or facilitators), as well as, operators as factors that have informed and impacted the use of the FMS. These dimensions will similarly be used as the research tool for evaluating the consistency or tensions between 'Lean Enterprise' concepts and its application to the FMS environment.

These questions were developed to prepare the interviewees for the nature and scope of the questions and to gain insights on the key dimensions under study. The information was collected and coded based on the four key dimensions. All the data collected was grouped on the basis of the key dimensions of complexity, integration, regulation, and flexibility and were analyzed accordingly. The grouping of the responses was done through cut and paste approach.

Typically following each interview a brief period of time was used to review the responses of the interviewee and to highlight the key points and comments expressed by the respondent. By writing up the impressions of each interview, it was also possible, using keywords highlighting the focus of each interview, to group and organize the responses on the basis of the chosen dimensions. By grouping the responses based on the key dimensions it was possible to identify the central points as they related to each of the respondents and his individual experience on the interaction between lean production and FMS.

4.11.1 Complexity

Based on the interviews with facilitators and FMS operators, at least two levels of complexity associated with the FMS operation are evident. The first level involved tool management and tool kitting needed for the operation of the six FMS stations. This process is further complicated by the fact that at least two types of engine (an 8 litre and an 11 litre engines) and four types of engine heads are being machined at these stations. Operators have to go through a series of steps and operations which involve tool set-up and tool kitting, using an extensive tool library database and, depending on the type of machining process needed for that operation, a computer assembly print-out is produced. Assembling the tools is done with the help of a bar code system, and the tools are preset and loaded into a carrier (tool magazine). The second level of complexity involves the inter-relatedness between the elements of the six stations of the FMS and the machining operations preceding it. Coming from two different areas: one type of engine block coming directly to the FMS (referred to as the 'block line'), and another type of engine block coming directly to the FMS from other areas. As one facilitator indicated,

'There is so much to do for the operators. [in FMS], they have to make sure that capacity is achieved through the correct mix of engine types [8 litres and 11 litres] as well as the

engine heads. The FMS is a bottleneck and mistakes are costly. Operators have to make sure that the correct choice is made other wise the incoming blocks will accumulate and since they are large in size, there is not enough room to buffer these engines.'

Because of their large size, engine blocks are not buffered; which implies that the FMS must follow the block line as much as possible to avoid bottlenecks. Because there are two types of engines (8 and 11 litres), and four types of engine blocks (with the 8 litre engine needing half an hour machining time and the 11 litre engine needing a full hour), increased complexity arises in organising the timing and planning of the capacity for the four types of engine blocks. For example, the 8 litre engine block line 4 machines in the FMS following the block line. With two spindles less, the operator needs to calculate the rate changes between the 4 and 8 litre blocks so as to ensure that the timing and the capacity are at an optimum mix (refer to figure 4.10).

The results of the semi-structured interviews and the questionnaire administered to the facilitators and operators confirmed that, owing the high level of complexity associated with the FMS (compared to the requirements of operating regular CNCs), FMS operators were trained to be multi-skilled and were given salaries at the higher end of the operator salary scale (group 7 salary level). These operators have been trained (for periods between 6 to 12 months) on all aspects of the FMS operation and tooling, in addition to other training associated with team development in techniques such as problem solving, quality checks, first level maintenance, and so on.

Another aspect of the complexity involves actual programming and operation of some of the machinery related to the FMS. An example can be seen in the operation of a newly introduced 'Three-Dimensional Measuring Machine'. This type of machine is a computer numerical controlled (CNC) machine used in conjunction with the FMS primarily for testing tool tolerances.

Based on the interview and questionnaire to the area manager and production and manufacturing engineers dealing with the FMS area, two different perceptions relating the complexity of the production technology emerged:

While the both managers and operators viewed the technology as complex, a significant part of the complexity was seen by the operators in terms of the increase in the interrelatedness of the system and the increase in capacity of the FMS. The complexity was reflected as much as in the use of the technology as it is reflected in the increase in pressure on the operators. While characterised as complex by all the operators interviewed, the actual programming of the FMS did not appear to present a problem particularly to the All Rounder (LTS level, multi-skilled) operators. This view was manifested in terms of an apparent sense of pride in their programming abilities. For example, during the interviews, when describing the complexity of the FMS, the operators were also pointing to the significant role that they play in the process and the high skills and abilities that they needed to have in order to operate the FMS.

This operators' view of complexity contrasted with the views of the area manager as well as the views of the manufacturing, production, and logistics engineers who saw a higher degree of complexity in the FMS environment. Responses by the area manager and production engineers to the questionnaire on the issue of complexity scored relatively higher than the responses of supervisors and operators. Complexity and the interrelatedness of operations were scored as 'significantly increased' by the production and logistics engineers while the supervisors and operators scored "increased' rather than 'significantly increased' in response to the same questions.

The difference in the perception of complexity was much more pronounced when the interview questions referred to the complexity of the 'Three-Dimensional Measuring' CNC. This new CNC measuring machine could be considered as a part of the FMS system as it is used to measure FMS tool tolerances insuring the proper operation and quality of the FMS machining operations. Two divergent perceptions of its complexity were detected: Production and logistics engineers saw the 3D measuring machine as '*too complex for the FMS operators to operate*' and accordingly its operation was left to a specialist quality control engineer. On the other hand, the Facilitator and a number of the operators did not see this machine as '*any thing special except for the controls and that* *its programming is similar to those of the FMS although it takes only tolerance measurements'.*

Thus, the perception of the degree of complexity of the 3D machine differed considerably between the operators and the production and logistics engineers. This discrepancy pointed to issues of control over the production process and the differences in terms of the expressed viewpoint of the production engineers of the need for tighter control in the FMS as a result of its complexity.

The view of the 'need for tighter control over the production process' contrasted with the stated views of the human resources manager and the plant manager. The responses of these managers to interview questions on the role of lean production clearly pointed to an expressed commitment towards increasing the degree of shop floor operators' autonomy and giving shop floor operators more say and control over their individual areas

Shifting to the interviews with facilitators and operators on the same issue, responses to the interview questions confirmed that the role of teams has been enlarged as a result of lean production. Yet, equally, control over the FMS process was still being exercised primarily by the area manager and production and logistics engineers through the vehicle of the 'objective matrix' and team meetings. Operators indicated that the operational objectives of the teams or cell groups are strictly specified in the team meetings, and that the 'what, when, where, and how' of operations are thus established. A key component of this 'Objective (productivity) Matrix' review is the assessment of productivity levels and the achievement of set objectives. Accordingly, two apparently contradictory circumstances appear to be in operation here and that the complexity of the FMS system is being presented as the justification for its existence.

4.11.2 Integration

The integration dimension in the FMS production area can be seen operating on two levels: the first involves the degree of FMS integration within the overall production function, while the second involves its harmonisation within the total system including the organisational arrangements and its internal cooperation mechanisms (such as teamwork). In the Universal / Engines area within which the FMS is located, the CNCs are integrated into cell groups organised around teams. These teams are responsible for all the activities in their cells including engine block machining operations prior to their transfer to the FMS stations. Accordingly, there is a high degree of interdependence between the operation of the six stations of the FMS and the preceding operations as seen in figure 4.10. When viewed in totality, we can see that a high level of integration between the operation of the CNC cells and the operation of the FMS exists. The new organisational arrangements through their focus on eliminating the functionalism of the past and fostering lateral communication between teams and groups within the various work areas, help to develop the internal cooperative mechanisms between groups and make it possible to manage the various interdependence relationships within these areas.

A significant organisational factor which helped support this integration within the production area was the elimination of many well entrenched departments (such as planning, manufacturing engineering, maintenance, and materials / production control), and the transfer of key personnel in these functions closer to production under the control of the area managers.

4.11.3 Regulation

A key aspect of the dimensions characterising the FMS is its influence on the work of operators and team members. This influence, owing to the high degree of complexity and integration in the FMS area, is seen through the rules and regulations incorporated by the system.

Historically, EBG was highly functionalised with the planning department controlling every aspect of FMS operation. With the transformation of the company into new EBG, and the adoption of lean production (including the call for increasing employee autonomy), it seemed logical to expect that the degree of regulation associated with the FMS would also be positively affected by the new organisational transformations.

However, responses of facilitators and operators to interview questions about the increase or decrease in the number of procedures and rules indicated that the number of rules and regulations associated with the FMS has increased rather than decreased since the introduction of the lean production. This in spite of an overall, organisation wide move to devolve more power and control to the shop floor including the FMS area. As the FMS facilitator indicated :

'...With the new company and the lean enterprise system... it made things more difficult, with more responsibilities for the operators and more rules for the area.'

These circumstances point to an apparent contradiction between the message of the lean production system adopted by new EBG (calling for devolving more responsibility and control to the operators), and the actual operational imperatives of the FMS. These operational imperatives were characterised an increase, rather than decrease, in the number of rules and regulations associated with the FMS operation. The interviews indicated that there was indeed a development in the role of FMS operators particularly within the new teamwork structures and an apparent expansion of operator roles to include quality control and maintenance functions. But coupled with this increase in operator responsibilities, there was also an increase in the operational rules and regulations governing the detailed execution of these new responsibilities. Added to this increase in rules, is the demands of team meetings and the establishment of the 'Objective Matrix' as the instrument for setting immediate goals and objectives for each of the cells. From the operator's perspective, the objective matrix appeared to be acting as a measuring device to insure compliance to the specified goals and objectives as well as the adherence to the new rules. From the area manager and production engineers viewpoint, the justification for this increase in rules and regulations is the need for tighter control over the production process. Based on the interviews with the area manager, the production engineers and the logistics engineers, the need for tighter control of the system is internalised in the need limit any possible disruptions to the operation and flow of the production system. This was emphasised by the area manager as especially true at 'this critical juncture in the development of company', and the imperative need to increase production and maintain tighter control over the production process. This is reflected in statements such as *'...operators have freedom as long as they follow the block line'*, indicating the limit of operator control over the process. The high complexity and integration perceived to be associated with the six FMS stations and the production of 2 x 4 (two types of engine x four types of engine heads) was deemed enough to justify the need for the increase in regulation.

In the early interviews, both the area manager and the FMS facilitator were asked about the 'degree of operator freedom to do the job' in the FMS area. Both responded enthusiastically and positively indicating that 'operators have a greater freedom to do jobs now (with the introduction of the lean production) than they did before in the control culture of the old EBG. However, when the question is shifted to the 'degree of operator freedom to plan the work' both responded was less enthusiasm (although still indicating that in their view 'it was still high'). On the other hand, interviews with the FMS operators, both 'All Rounders' and 'Rounders', responding to the same question of 'degree of operator freedom to do the job' pointed to positive responses. Thus confirming the high degree of operator 'freedom to do the jobs' (owing to their high skill and training levels). The response to the planning aspect of their job indicated that it was about the same or slightly better than it used to be in the old EBG. As one operator indicated: *'directives on what, where, and how, are still being dictated from above'*. The fact that operators indicated that in spite of the organisational changes and the efforts made towards increasing the level of operator control over their work, when it comes to the planning aspects of that work, the new organisational arrangements did not alter the existing relationships. In fact the general view of operators pointed to an increase in the degree of control.

4.11.4 Flexibility

Under the new organisational arrangements, the new company concentrated on increasing overall flexibility of the organisation with the intention of improving its competitiveness and maintaining production costs at competitive levels. The new focus was primarily on labour flexibility with flexible working hours and longer operating times. The company also adopted a 'build-to-order' philosophy and reorganised the manufacturing functions through the adoption of new wave manufacturing techniques such as 'lean enterprise' with the objective of increasing flexibility, reducing lead times, as well as coping with the changing environment and future demand. In the FMS area, the focus was on mix flexibility. Responses to the interview questionnaire by operators indicated that the overall flexibility of operations associated with the lean production in the FMS area appears to have remained at the same level. Because the FMS operators were Group 7 salary group, i.e. highly skilled and experienced workers, the ability of these workers to exercise judgement and make 'on the spot' operational changes remained the same. Probed further is subsequent interviews, it was noted that the implementation of operational teams and the Objective Matrix appears to have put certain constraints on the operators' discretion. On the other hand, by virtue of increased flow of information between production areas and increased knowledge of incoming production changes and targets, operators are better able to organise their work and alter their operational schedules to better advantage and hence increase their flexibility.

4.12 Increased Production Demands and Lean Production

Between 1994 and 1999, the company experienced considerable, dramatic growth in its market share and increased the production of the EBG95 truck from 40 trucks per day to 120 trucks per day. This three-fold increase in the pnduction volume while essentially maintaining the same work organisation and structure, had a tremendous impact on the production environment and created new challenges and difficulties on the production line and in the FMS area in particular.

This increase in demand was not limited to the company, but was also a reflection of the positive economic environment in the manufacturing sector. As a result, overall demand for skilled CNC operators increased, which led to shortages in skilled operators. The company had to hire technical school graduates, as well as low skilled workers to cover for the shortfall in the number of operators. According to the human resources manager, for every increase in the production of EBG95 by a single truck, EBG needed to hire 23 new people on the shop floor. Accordingly, the increase in the production of the EBG95 truck led to increases in the complexity of the system and created new sets of problems for management.

4.13 Operational Issues

One of the key obstacles which faced operational teams was the traditional engineering staff's view of the production area as their sole domain. Add to that the need for the engineering staff to show how indispensable they are to the production process, a problem arose where production and logistics engineers, even in their role as team members, would exercise too much control and seize the operational team as a vehicle for the execution of their agenda. To correct this imbalance, management tried, as the plant manager explained:

'... to make it clear to the engineers that acting on behalf of the team is not welcome...for example we do not want to see only the engineers delivering presentations about team activities, but rather we want to see the whole team acting in concert , and that the responsibility is that of the team as a whole including production and logistics functions'.

Another problem which become visible through the development of the operational teams was the problem of ownership due to long-standing different cultures associated with membership to traditionally different specialities. For example, the different objective criteria for the Logistics with its focus on lead time, Production with its focus on quality and output, and Engineering with its focus on the smoothness of the process and the introduction of new projects. These conflicting objectives for each of the group member speciality had to be reconciled.

A third problem the area managers and production engineers' insistence on increased regulation and control in conjunction with the lean production changes pointed to a managerial (particularly the production management point of view) which made a distinction between the concept of autonomy and that of responsibility. Managerial emphasis on the responsibility of workers indicated a degree of lack of trust probably stemming from past experience with autonomous work groups. Although new EBG adopted lean production, the approach to its implementation, as seen on the FMS shop floor can be discerned to still follow the traditional approach of the company old or new that emphasised tighter control and specification of work roles and structures.

The above three issues were evident in the interviews conducted at the managerial, staff, and shop floor levels. Their existence raised doubts concerning the validity of new EBG true compliance with the lean production philosophy and the commitment to the stated changes.

4.13.1 Changes to the Teamwork Structures

In the last visit to the FMS area in 1999, the production supervisor (facilitator) was in charge of 70 workers working in three shifts. Of these, almost 70 per cent were new employees with limited manufacturing experience. The new employees were also of different nationalities (nine different nationalities were present on the shop floor including British machinists). This created an additional dimension to shop floor problems as a number of these operators did not speak Dutch. This meant that production supervisors had to deal with the language barrier as well as limited skills when working with these new operators.

Looking deeper into the team structures in this area, in the three shifts numbered 71, 73, and 74, we can see that in this area, the structure was based on three major teams with each team consisting between of 7 to 8 operators. The teams' leaders were of a grade 7 scale. i.e. multi-skilled operators who were given the name 'All Rounders' a term used to emphasise the fact that they were senior operators with experience on all the machines in the area and who had the skill and experience to work on every aspect of the manufacturing operation. Of the 70 workers in this area eleven, operators were 'All Rounders'. In addition, each of the teams had one programmer with the responsibility for programming the CNC machines (This constituted a new development on the shop floor which will be discussed in the next section). The rest of the operators were apprentices or new operators with an average experience level of one year or less. These new operators had LPS and LTS technical education level (figure 4.12).

4.13.2 Tensions and Stresses: Lean Production in the FMS

The increase in production from 40 trucks to 120 trucks per day exasperated the interaction between the FMS and the use of lean production. A number of problems developed as a result of the increased pressures, as well as the hiring of new operators with limited skills. For example, in shift number 71, the lean enterprise format was leading to problems relating to:

1) Sick leave time, and the scheduling of holidays: Because holiday scheduling was one of the responsibilities devolved to the teams to decide on by themselves, problems occurred over the scheduling of holiday time for each member of the cell, particularly with the increased production pressures and the shortage in 'All Rounders' or multi-skilled operators. Essential personnel were taking leave at the same time causing disruptions to the production schedule.

2) Machinery breakdowns: This related to the role of the maintenance department. According to the lean enterprise model, the operators of the FMS and other CNC machines were supposed to be conducting first level maintenance of these machines, However, in reality, it appears that this function was left to the maintenance department. Operators did not do any of the required first level maintenance.

3) Division of Labour within the teams: The new teams having both multi-skilled and semi-skilled operators, began to show divisions in the execution of tasks within the team. The multi-skilled operators became the strong members of the teams exercising considerable influence over the team and choosing to do the easy tasks or 'nice jobs such as programming or materials planning while leaving the dirty work to us' as one semi-skilled team member explained.

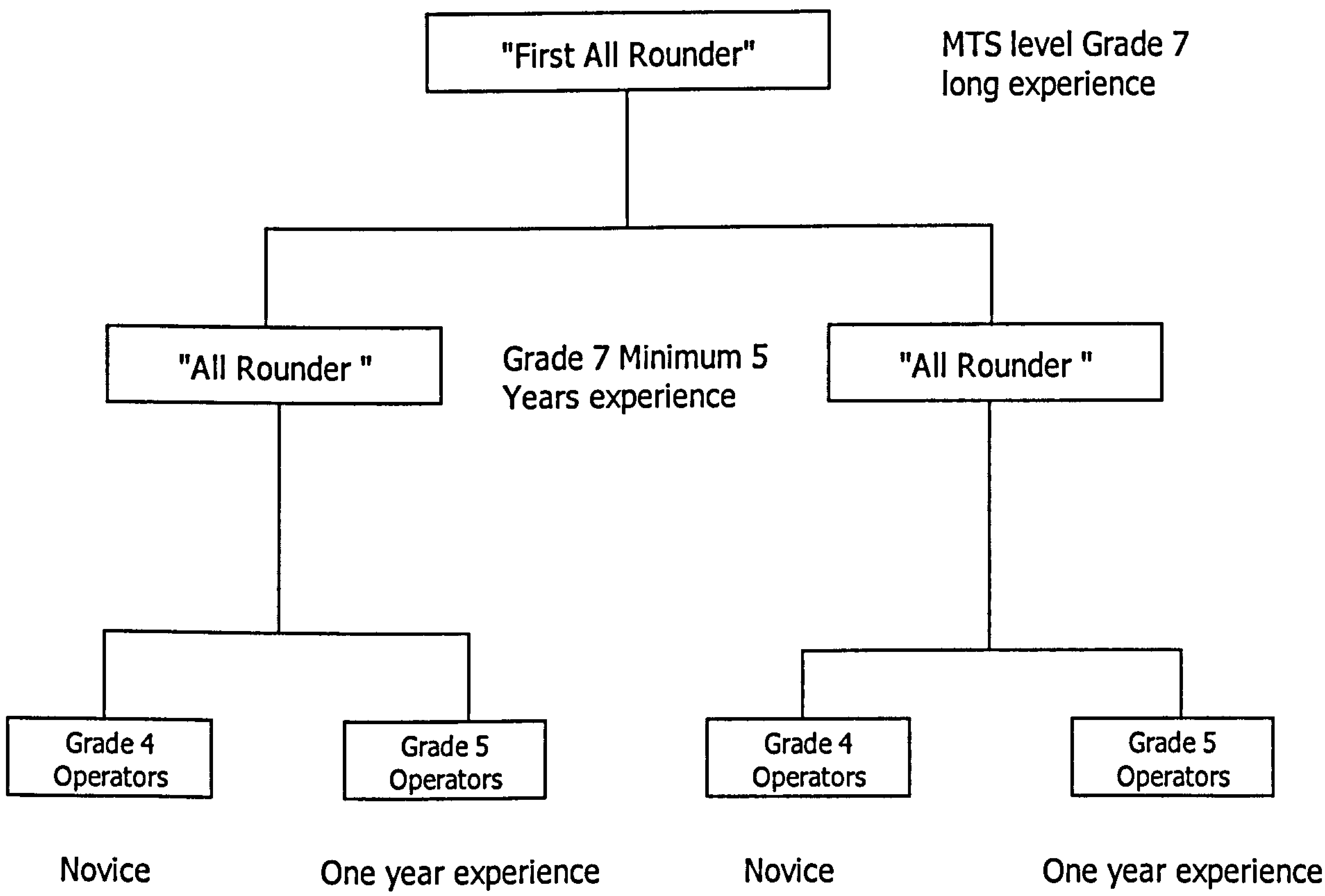


Figure 4.12: FMS area new teams hierarchy (by skill level)

These attitudes dramatically influenced the work of the teams to the extent that the area supervisor decided to reorganise the team structure into a functional format as can be seen in figure 4.12. The new team structure was divided into three hierarchical levels: A 'First All Rounder' level a grade 7 or grade 8 level with a lot of experience; an 'All Rounder' level which is an MTS grade 7 level with a minimum of five year's experience; and the rest of the operators and new operators from grades 4 and 5. For the programming, a grade 7 programmer is also included in the structure, taking charge of all programming needs of the cells. This programmer has at least 2-3 yars experience and is of a high technical educational level (MTS).

4) Increase in the rules and regulations on the FMS: Overall, the complexity of the operation on the FMS increased. For example, while early in this study, this area machined two types of timing cases, by the end of this study in 1999, they were machining 10 types of timing cases. Problems resulting from this increase in production affected the MIS system of the company with increased system breakdowns, in addition to typical problems such as machinery breakdowns and some quality problems associated with the semi-skilled operators' work. In response, management instituted new rules and regulations throughout the production areas and focused in particular on the FMS area.

Some of the new rules and regulations were general in nature relating, for example, to the holiday schedule within the FMS teams discussed earlier in this section. In the old system these holidays were decided within the team. However, with the new regulations, holidays are currently only possible through a two week notice request by the operator which is then put on a holiday request list and is 'frozen', i.e. the schedule on the list is fixed and is subject to the approval of the area supervisor.

The new team structure seen in figure 4.12 could also be viewed as a part of the increase in regulations at the FMS. It institutionalised the differences between the semi-skilled and multi-skilled operators and created an elite group of core multi-skilled operators who were flexible, moved from place to place on the production line depending on the need at the time, and gave directions and mentoring to the new semi-skilled operators. Yet, when it came to the specific production activities, management increased its control by focusing on 'departmental efficiencies' and a 'paper system' with 'performance indicators' detailing the set targets and the variability between them and what is actually being done on the shop floor. This 'paper system' related to all aspects of the operation including worker utilisation, maintenance, machine breakdowns, machine utilisation, training, and others.

What is significant is that the general focus in the company has shifted from the traditional issues of quality, delivery, and price which were the key terms in 1994 to 'man utilisation' as the key term that is consistently the focus of EBG management. Targets are now set top down based on managerial estimates and weekly controls are instituted through this 'paper system' to check on the targets.

The complexity of the FMS operation and the increase in the number of semiskilled operators was given as one of the reasons why management opted for the new bureaucratic structure. Either way, the result was a definite move away from the original principles of the Lean Enterprise and a shift back to the traditional modes of operation which can be characterised as following the traditional 'mass production' or 'fordist' philosophy referred to in chapter two of this thesis. These new arrangements led to a decreased level of the satisfaction of operators and even a decrease in the response to the set targets as well as requests from other functions. This was precisely due to the lean enterprise concepts of continuous improvement where the management continuously optimises the process and sets new, more difficult targets once the old targets are achieved without any recognition of the operators efforts in achieving the set targets.

The return to the traditional older mass production model of operation was not limited to the advanced manufacturing areas (i.e. FMS and CNC production areas) but it also extended to the engine assembly. Driven by the decrease in multi-skilled assemblers/operators a number of quality problems arose as a result of the inexperience of the new workers. Management moved to reorganise the assembly area and separate the work into simpler tasks within the cell so as to minimise the risk of quality defects.

4.14 Human Resources

At the beginning of this study, the human resources department played a key role in organising and facilitating the new team structure. What developed was a 'successful' team model that was viewed to exemplify the 'best of the new wave manufacturing' approaches. With the new 'build to Order' system, the teams were made up of a core of multi-skilled operators with increased control over their individual production areas as well as using lean enterprise tools to their maximum advantage. The result was the successful production of a high quality product with significant potential for future sales. Demand for this new truck increased and production soared from 40 trucks per day to 120 trucks per day.

The message of the human resources department in this case was in tune with what was being practised by the area supervisors and production managers. The obstacles at the early stages of the research revolved around the strong influence of the planning staff over production and finding the right balance between the planning function and the autonomy of the teams.

The Lean Enterprise teams were given more autonomy and the strict control of the planning department was decreased. Teams became more and more independent particularly at the FMS. To some extent, the HR department worried that these teams were becoming too independent to the extent that it affected the production line. For example, the issue of holiday scheduling which was decided upon internally within the teams led in a number of instances to having two or more essential 'All Rounders' taking time off at the same time and affecting the production schedule. The response to this increased independence was an increase in the number of rules and regulations on the floor.

As complexity increased, particularly at the FMS, the human resources department and planning department used this complexity as the reason to institute new rules and regulations. The transformation of the make up of the new teams from what was strictly multi-skilled operators to a mix of multi-skilled and semi-skilled operators, has changed the dynamics of the relationship internally between team members and externally between the management and the teams.

The internal dynamics within the teams created a new phenomena of what looked like a two class system: the multi-skilled operators acting as the elite within the teams, and the less skilled operators. The multi-skilled operators doing mostly the easy jobs of material planing and programming, while leaving the rest of the labour intensive jobs such as cleanup and first level maintenance to the less skilled (new) operators.

Eventually, maintenance functions were withdrawn from the operators and even the first level maintenance function, which was part of increasing the autonomy of operators, was left to the maintenance department. As the human resources manager stated:

'Now we have two worlds in the cells, multi-skilled operators who are in control and those who are less skilled, on a temporary contract, and without any control.'

The increase in pressure and the atmosphere of the two worlds led to a high degree of turnover in the new 'part timers'. 10 to 15 workers left every week primarily because of the high degree of pressure on the shop floor, high competition for new recruits from other manufacturing companies and the reluctance of management to make these operators full time employees or to put them on 'permanent contract'.

For the human resources department, this new division within the teams created a serious challenge to the original ideas of lean production and the new wave manufacturing approaches. But as production demanded relief from the increased production pressures and demanded the hiring of new operators, human resources did not address this problem head on and shifted to the issue of hiring of new workers.

By 1999, The role of the human resources department was transformed and focused on two key strategic issues of concern: 1) How to hire and keep people who are fit for the job. 2) How to deal with the issues of work related stress. Both of these issues were the result of the increased production demands due to the increase in sales of the EBG95 series engine. For every one truck increase in vehicle production, human resources need 23 more workers on the shop floor.

The Human Resources departments' policy was to fix the number of permanent contract workers- i.e. those who enjoy the full benefit package of EBG and a guaranteed employment contract, at a level sufficient for 40 trucks per day. As production dramatically increased, HR increased the number of fixed contract operators to be enough for the production of 75 trucks per day. The rest of the people were on a short-term contract basis or were hired as temporary operators through external hiring agencies. This limit on the number of full time operators reflected the sensitivity of EBG's management to its pervious history of large-scale redundancies. Full time workers enjoy extensive benefits and job security that make it very difficult to have labour flexibility.

The decreasing pool of technical school graduates of the LTS and MTS educational levels compounded the skilled labour shortage problem at EBG. Left with no choice but to hire less skilled workers, the HR department developed a new four-week training program on the elementary mechanical engineering skills needed in production. This new program was also used as a selection tool to judge the fitness of the new recruits.

4.15 Summary and Conclusions

In this chapter, the compatibility between advanced manufacturing technology and new wave manufacturing strategies was investigated in terms of the specific case of the application of lean production to the flexible manufacturing systems environment. Semi-structured Interviews with a cross section of managers and employees in company were conducted with particular emphasis on the manufacturing organisation and the FMS production area. Interviews and a questionnaire were administered based on an interview schedule (see Appendix) which included the human resources/ personnel manager, the plant manager, the manufacturing (area) manager, manufacturing, production, and logistics engineers, supervisors (facilitators), as well operators of the flexible manufacturing systems area.

The findings of these interviews and questionnaire pointed to the existence of inconsistencies in the interaction between elements of the 'Lean Enterprise', the name given to the lean production system implemented in this company, and its application to the FMS environment. These inconsistencies related to the perception of the role of 'Lean Enterprise' and its applicability to the FMS. Three factors appeared to present a conflicting picture of the nature of the new organisational arrangements and their relationship with the FMS:

First, the stated commitment and efforts by the human resources department to deploy lean production and increase the levels of operator autonomy on the shop floor were moderated by Increases in monitoring and control by the area manager and production staff. Second, increases in the number of rules and procedures associated with the operation and utilisation of the FMS were detected in relation to the lean production arrangements. Third, other factors such as prior negative managerial experiences with strong groups appeared to be behind the cautious, conservative attitude on the part of the area manager and production staff towards the teams.

Four out of the six characteristics primarily associated with the flexible manufacturing systems (FMS) were chosen as the key dimensions for evaluating the compatibility between FMS and lean production. The dimensions were: complexity, integration, regulation, and flexibility. These four dimension were seen as the key actors in the FMS environment from the point of view of the users while automation and expensiveness were viewed as self evident and did not solicit appreciable responses.

Based on the interviews with facilitators and FMS operators, at least two levels of complexity associated with the FMS operation were evident.The first level involved tool management and tool kitting needed for the operation of the six FMS stations. The second level of complexity involved the inter-relatedness between the elements of the six stations of the FMS used in this case and the machining operations preceding it. The results of the semi-structured interviews and the questionnaire administered to the facilitators and operators confirmed that, owing the high level of complexity associated with the FMS, the operators were truly multiskilled and were given salaries at the higher end of the operator salary scale (group 7 salary level). Two different perceptions relating FMS complexity emerged: First, while both managers and operators viewed the technology as complex, a significant part of the complexity was seen by the operators in terms of the increase in the interrelatedness of the system and the increase in capacity of the FMS. Second, The complexity was reflected as much as in the use of the technology as it is reflected in the increase in pressure on the operators. While characterised as complex by all the operators interviewed, the actual programming of the FMS did not appear to present a problem particularly to the All Rounder (LTS level, multiskilled) operators. This was manifested in terms of an apparent sense of pride in their programming abilities. The view of complexity by the operators contrasted with the views of the area manager as well as the manufacturing, production, and logistics engineers who saw a higher degree of complexity in the FMS environment. Responses by the area manager and production engineers to the questionnaire on the issue of complexity scored relatively higher than the responses of supervisors and operators. Complexity and the interrelatedness of operations were scored as 'significantly increased' by the production and logistics engineers while the supervisors and operators scored 'increased' rather than 'significantly increased' in response to the same questions. This was particularly evident in the perception of the degree of complexity of the 3D Measuring CNC used in the FMS area which differed considerably between the operators and the production and logistics engineers. This discrepancy pointed to issue of concern over who should have control over the production process. Clear differences emerged between the expressed viewpoint of the production engineers for the need for tighter control in the FMS as a result of its complexity and the views expressed by the plant manager and the human resources manger. Both managers emphasised the principles of lean production and the move towards increasing operator autonomy and control.

The view of the 'need for tighter control over the production process' contrasted with the stated views of the human resources manager and the plant manager. In interviews with facilitators and operators on the same issue, responses to the interview questions confirmed that the role of teams has been enlarged as a result of lean production. Yet, equally, control over the FMS process was still being exercised primarily by the area manager and production and logistics engineers through the vehicle of the 'objective matrix' and team meetings. Two apparently contradictory circumstances appeared to be in operation here and the complexity of the FMS system was being presented as its justification.

On the dimensions of integration and regulation, responses of facilitators and operators to interview questions about the increase or decrease in the number of procedures and rules indicated that the number of rules and regulations associated with the FMS has increased rather than decreased since the introduction of lean production. This in spite of an overall, organisation wide move to devolve more power and control to the shop floor in line with the stated 'Lean Enterprise' precepts. Coupled with this increase in operator responsibilities, there was also an increase in the operational rules and regulations governing the detailed execution of these new responsibilities. In the FMS area, the high complexity and integration perceived to be associated with the existing six FMS stations and the production of 2 x 4 (two types of engine and four types of engine heads) was deemed enough to justify the need for the increase in regulation.

By the end of the investigation of this company in 1999, some reversals in the application of the lean enterprise modes were evident. The complexity of the FMS was presented as one of the reasons for the regression from earlier new wave manufacturing strategies and the return to traditional forms of operation albeit more enlightened and less ridged than the older mass production approaches.

CHAPTER FIVE

AN AIRCRAFT MANUFACTURING COMPANY

5.1 Introduction

This chapter focuses on Fokker N.V. the pioneering Dutch aircraft manufactuer. Fokker Aircraft had a proud history with a long tradition of introducing new technologies to its manufacturing environment. Its acquisition by the German Daimler-Benz Aerospace group (DASA) in 1992 provided the company with a new direction that emphasised increasing overall efficiencies and productivity through the implementation of lean production systems. Fokker had introduced lean production approaches to its manufacturing operations at the Papendrecht components and parts fabrication plant. The plan for this case study was to investigate the interaction between the lean production implemented at the time as a part of an overall dramatic restructuring within the company and its application to the FMS environment (which included a variety of new CNCs and FMS) in the fabrication plant.

Additionally, this case study contributed to the research by illustrating a fundamental point for this and other research, namely that companies do not operate in a vacuum. While the primary focus of this research dealt with micro-level issues (the interaction between lean production and the FMS), macro level events often have an incomparable impact that overwhelms the tactical aspect of operation within the company. In this case, the big issue was that of the lack of job security and the layoffs of large numbers of workers. This fact loomed large in the factory during the research and had a dramatic impact on the morale of managers, supervisors, and operators making it difficult to evaluate the nuances of the micro-level changes.

At Fokker Aircraft, the company's financial position had deteriorated significantly (at the time of the second visit in 1995 losses had reached NLG 651 million or approximately

$325 Million). On the day of the last visit to the company, the company announced a further reduction of 500 employees before a scheduled meeting with one of the manufacturing engineers. The meeting turned into an hour and half session in which the interviewee let off steam and went into a lengthy, angry description of 'what is wrong with the company'. Although his views were coloured by the unfortunate circumstances, it nevertheless generated new insights on the true picture of the organisation.

Taking into consideration the above situation, we nevertheless can still examine the interaction between lean production and the FMS environment. At the components and parts fabrication area, the four major dimensions of complexity, regulation, integration, and flexibility were used as the measures to investigate the dynamics of interaction between the lean production arrangements and its usage in the FMS area. But first the details of the company will be examined

5.2 The Company

This case study focused on Fokker Aircraft's main Aeroplane components fabrication factory in Papendrecht, Holland. This factory employed 2644 employees of whom 980 employees were from a previous restructuring in which Fokker went through bankruptcy proceedings and was able to restructure following the DASA bailout. At the time of this study, the factory had recently experienced yet another reduction in the number of employees by about 30 per cent.

Parts fabrication ranged from the production of small parts (8mm long) to the fabrication of aluminium sheets, titanium, and anti corrosion steel-composite materials fabrication. These parts were used in all Fokker aircraft models such as the F50 and F100, as well as for other aeroplane manufacturers such as the Boeing 747, Airbus, Gulfstream and older Fokker aeroplane models such as the F27 and F28 that were still in service.

In the early 1990s the company increased its capacity based on higher demand expectation for the F50 and F100 new models. For example at the Farnborough annual air show of 1990, the company had preliminary orders for between 100-150 planes of the F100 type. Accordingly, based on the projected potential orders for all models, the company increased its production capacity. The total demand for the F100 model was expected to be at least 100 planes per year but the actual demand for the F100 did not exceed 40 planes per year. This created a problem of over capacity while the company was 'rolling out' (producing) one F100 plane every 3 days and later, as a result of lean production and increased productivity, one F100 plane every 1.5 days. High manufacturing costs - with each plane costing $20 million, declining profits, and the high expense of 'green space'(daily rented parking space for produced aircraft), compounded the financial woes of the company. In 1992 Fokker suffered the largest financial loss in its history and, unable to pay its creditors, declared bankruptcy. DASA, the German aerospace company stepped in and took control of Fokker and restructured the business units through the elimination of the excess capacities and layoffs of large numbers of Fokker employees. After the restructuring, Fokker management endeavoured to recover the confidence of the market and did improve the efficiencies within the new restructured company. Nevertheless, the company did not fully recover and orders were still less than needed number. Finally, in late 1995, with losses mounting and Fokker unable to find new investors and pay its loans, the company's credit line expired and after seventy-seven years in business, Fokker Aircraft went into final receivership and all 5664 employees were sent a letter giving written notices of final dismissal.

5.3 Organisation

The new structure following the DASA bailout made every effort to improve the competitive position of the company as the plant manager indicated:

'... It was important to establish an organisational structure that would allow Fokker Aviation to operate efficiently and flexibly.'

In the case study plant at Papendrecht, and as a part of the new lean production approach, management decided to integrate two units (Fokker Special Products and Fokker FAE) into a single unit. Both units operated largely in the same markets and with the same customers. Combining forces was therefore a logical step and a plan of action for integration was introduced which resulted in a new business unit that eliminated duplication. The new unit developed as a self-supporting business unit, and supplied products for the aircraft, space, defence and industrial markets.

The plant was divided into two main sections: sheet metal & parts and Assembly. The sheet metal and parts was divided into four 'Production Technical Specialist' (PTS) sections with responsibilities for: welding, sheet metal, chemical and paint, and production (figure 5.1).

The production operation included batch manufacturing of engine parts for the left and right wings of the F50 and F100 (20 parts batch for the left wing and 20 parts batch for the right wing). In addition, the plant manufactured special contract jobs for external customers such as machining the F19 fuselage-engine ducts for NATO military planes, as well as a special contract for the Boeing company BA747 components. The manufacturing area had 70 operators on the shop floor who were divided into teams of between 15 to 18 operators each team led by a group leader or supervisor.

5.4 Advanced Manufacturing Technology

Fokker Aircraft had a long tradition of introducing new technologies to its manufacturing processes. The focus on technology was clear throughout the company. In interviews with managers, when questioned about the use of new technology it was clear that they viewed 'technology as number one' reflecting management's pride in consistently introducing new technologies. This attitude was also evident in practice at the shop floor through the presence of many new generation CNC machines. Fokker was particularly strong in specialised technologies for aeroplane manufacturing and new and advanced technology acquisition was viewed as key for maintaining a competitive edge. Management's objectives were to expand the company's niche of specialised equipment and maintain a high technology level while at the same time eliminating jobs that can be duplicated else where by other companies.

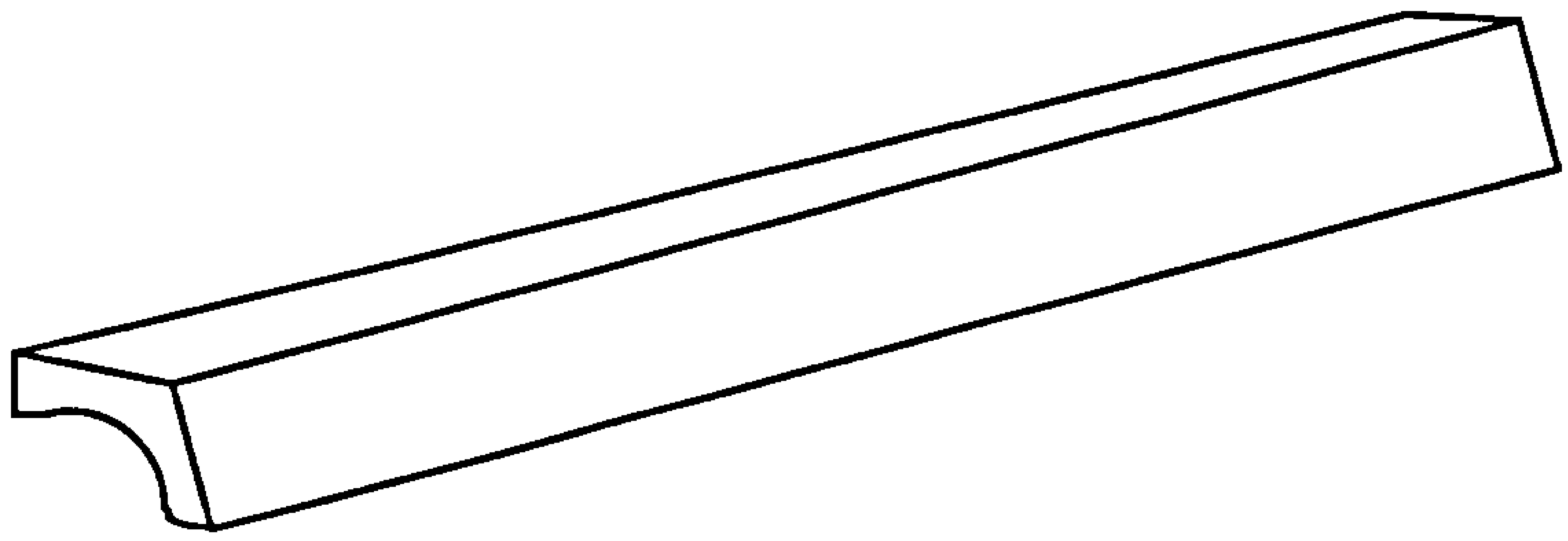


Figure 5.1 : Formed extrusions, one of the many parts manufactured in the Papendrechet plant

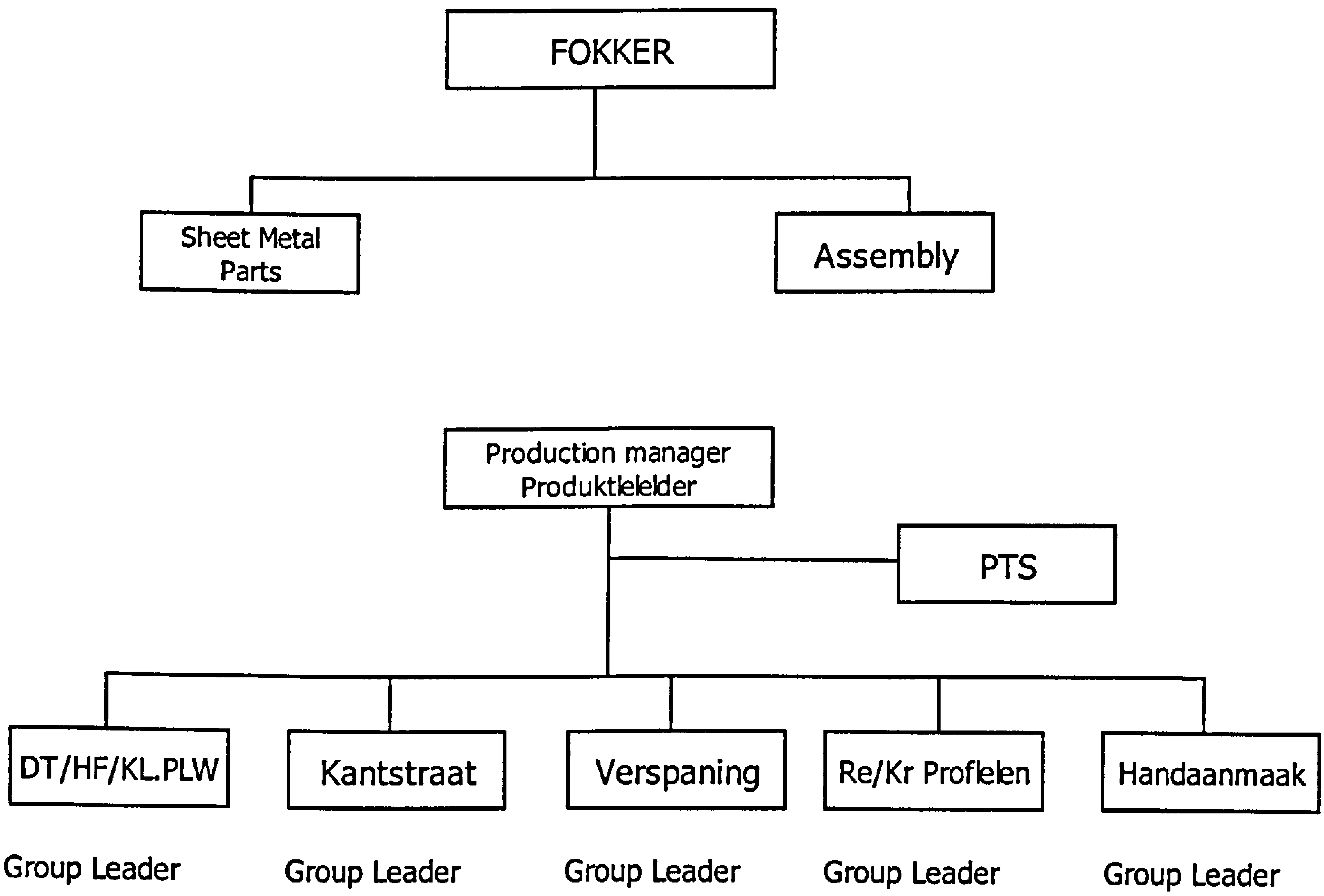


Figure 5.2: Organizational chart – Papendrecht plant

5.4.1 The FMS Environment

At the start of the production process metal sheets arrived at the plant to be processed on the machine tools. The hub of activity revolved around the 'Profile Beworking Machines (PBM)', a Flexible Manufacturing Systems production technology in which 15000 different parts of different shapes and sizes were machined. In the same area various new CNC machines used primarily for the F100 and F50 models were used among them: A JOMACH 25, a 'Three Dimensional' milling machine. This was an Italian-made CNC machine that was operated by four multi-skilled operators.

Another CNC in the FMS area was an LGIRE– ACB 6-axis machine introduced to replace the hand forming process. Also a six tools CORTNI L 300 SB CNC and a TRUMATIC 260 BFS CNC machine tool programmable from a central database. Programs for this CNC were pre set and were called from a central database in a DNC network. Operators typically called up programs from a menu and had the ability to change programs in coordination with the 'technical services' Programmers. Other machines included automated ABK riveting and boring machines. In addition, an AS/AR automated magazine system.

The machined parts were then fed into the Grading (Grinding) machines to eliminate sharp edges. After the Grinding, the parts were then ready for forming on big presses on five high-pressure press machines (980 Bars pressure).

5.5 Cultural and Organisational Change

Historically, Fokker was used to being a traditional bureaucratic organisation with a long history and a proud tradition. It was thought of as paternalistic and as one of the older operators stated 'a job at Fokker meant a job for life'. The dim prospect of closure and failure was a far-fetched proposition considering its long history and position of pride in the national psyche of the Netherlands. But times changed, and as the news of its losses and potential bankruptcy filtered down through the organisation, employees began to seriously worry about the future of their jobs. The bailout by the DASA group- although was a shot in the arm, did not solve the mounting problems of the company and the continued decline in revenues. To reduce capacity, the new management offered employees a generous retirement package. As the human resources manager stated, the plan was to reduce the number of workers between the ages of 57.5 and 65. But what transpired was that about 85 per cent of the people between the ages of 55 and 65 took the offered package set at 87.5 per cent of their last salary. This increased the company's social benefits and pension costs and eventually contributed to its inability to meet its outstanding debits.

The issue of over-capacity and the mishandling of the layoffs also contributed to the general atmosphere and sense of impending demise. The production manager described the situation that faced the workers in dramatic terms:

'Without prior notification, the plant manager stood at the gate early in the morning and directed those who were to be fired to a separate gate while those who were lucky and be spared were allowed to pass to their regular places of work'. He then added ' The scene was very dramatic and there was a lot of shouting and it was not one of Fokker's great moments.'

The effects of the trauma of the last two massive layoffs were still having their effect on the operation of the company. One of the manufacturing engineers described the situation in his work area as follows:

'... It is like walking into a graveyard, every where you can see that most of your friends have been made redundant. You look at the paper work and you see someone's signature who is no longer here.... You have a question about a certain order so you dial the extension to discover that the engineer who made the order no longer works here... look around and its empty offices.'

Employees at every level in the organisation were not given a chance to adjust to the new situation and for those who survived, managerial attempts at creating a new culture which focused on cost reduction and 'lean' production only served to remind them of the dark prospects of the company. The demands of the new structure and its emphasis on lean production and the new work organisation structures exacted its toll on workers and managers alike.

5.6 Tensions and Stresses: Lean Production in the FMS

The new wave manufacturing approaches used at Fokker centred on the use of lean production techniques as a way to improve efficiency and productivity. On the shop floor, the lean production approaches included giving operators more autonomy through multiskilling and attempts at job enlargement, increasing the skill level of operators, job rotation and training. A number of the key lean production recognised approaches were introduced. These included Kaizen, TQM, SPC, Zero defect programs and it was also noted that the plant had BS5750 certification.

The new management put forward lean production to be its central focus with emphasis on 'lean' as the key objective reflecting the management's strong desire to reduce capacity and improve productivity. Management expected strong resistance to the introduction of lean techniques owing to the prior bureaucratic, traditional history of the company. Yet, resistance to the introduction of lean production approaches seemed to be minimised as a result of the recent layoffs. Operators were less resistant to the introduction of these new organisational arrangements following the shock of the drastic reductions in the number of workers on the shop floor and the realisation of the ongoing threat to the company's future. Acquiescence to the new organisational arrangements cut through all levels of the production organisation. Younger operators in the FMS appeared to be more at ease with the new changes and expressed opinions of their willingness to adapt to the lean production approaches more readily than the older operators. This diminished resistance was also evident with the production staff programmers who traditionally had a separate culture as staff employee programmers. Initially, they resisted efforts to move them to the production area considering that prior to lean production, the programming function was a separate function with a separate manager and freedom and control over all the programming decisions on the FMS and new CNCs. With the introduction of lean production, this department was dismantled and many of the programmers were made redundant. Those who remained were moved and integrated to the shop floor under the direction of the production manager as 'technical services'.

The company was going through a traumatic period of change and uncertainty. Layoffs, early retirement packages, union relationships and arrangements, and the implementation of the new restructuring policies, were all issues that the organisation as a whole needed to handle and the human resources department was the leading player in all these matters. Consequently, when the human resource manager was interviewed and was questioned about the issue of interaction between the lean production approaches and its implementation in the FMS environment, it was clear that it was the furthest thing from his mind.

The threat of company failure loomed large over the Fokker organisation as a whole. This feeling was in sharp contrast to the earlier lax, overconfident atmosphere that traditionally characterised the attitude of the organisation and its employees. The shock of the bankruptcy and the restructuring of the organisation after the German DASA group bailout created a new atmosphere in which the reality of the situation became clearer to all Fokker employees, and the unthinkable (i.e. the demise of the company) became a real possibility. Further restructuring as a result of the over-capacity led to another wave of layoffs that created an additional atmosphere of suspicion and resentment through-out the company and on the shop floor in particular. Under these circumstances, the human resources department had the difficult task of charting its way through these changes and implementing 'lean production' as the new wave manufacturing approach to transform the company into a more efficient and productive organisation.

The lean production policies implemented by the human resources department included an emphasis on increasing employee autonomy through multiskilling and upgrading of operators skills, developing continuous improvement, teamwork, increasing training, flattening the organisational chart by reducing the number of levels within the hierarchy and moving the production, programming, and quality assurance staff closer to the production floor.

The reorganisation involved the elimination of many mid level management positions and reducing the number of organisational levels. In the production area, the number of organisational levels was reduced from 5 to 3 levels as part of the shift towards lean production (figure 5.3). This reduction in organisational levels was possible through the following:

A) The elimination of the Director of Manufacturing Operations and transferring the responsibility along unit structures position to a Unit Manager;

B) The elimination of the Manufacturing director position;

C) The combining of the team leader and Group leader positions on the shop floor.

In addition, management moved towards transferring quality functions to the shop floor and the elimination of the quality department as a separate unit from production. Traditionally, the quality department was also separate from production and quality personnel regularly checked the production machinery through spot visits to the shop floor. With the new lean production, this responsibility was moved down to the team leaders and operators on the shop floor. The position of quality control team leader was eliminated and the quality teams personnel were moved to the production floor closer to the FMS.

Previously, the programming of the FMS and other CNCs was traditionally separate from production. This separation was more poignant because the programming was done in a separate building creating significant communication problems and led to de-coupling and minimum interaction between the programmers and operators. As stated earlier, as part of the new restructuring the production manager changed the structure and moved programming to the same area of production. Later the operators were given increased roles in the programming with the view that '*the operators are better able through training and multiskilling to write programs*'. For example, access to the DNC network on the shop floor was granted to the operators. This change allowed the operators to call up from the central database the program menus to be used on particular CNCs in the

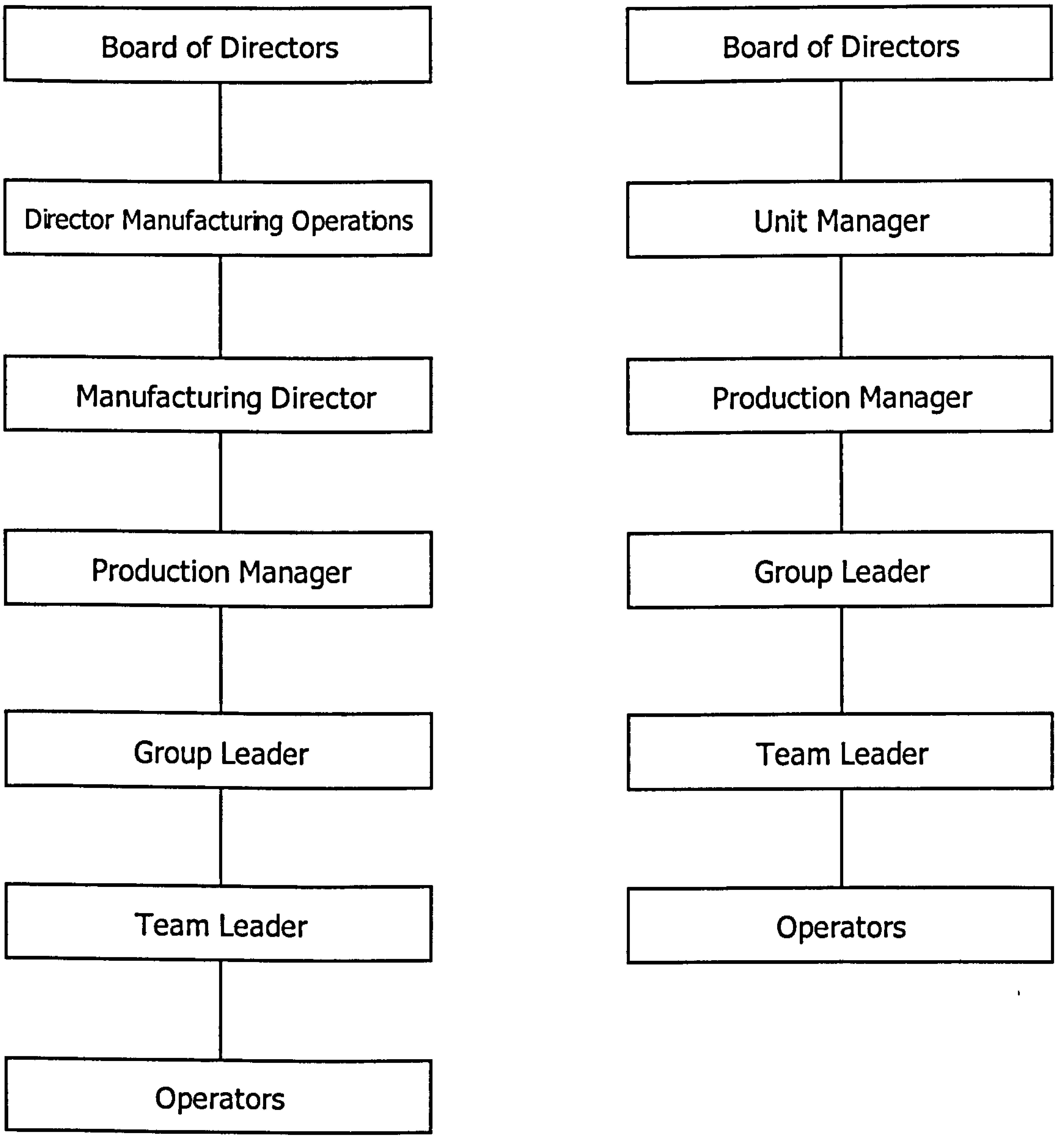


Figure 5.3: Changes to organisational chart, Delaying

area. Prior to this change, programs on the menu could only be changed with the programming department's approval.

In general, following the strong push by management for lean production, the production manager was not satisfied with the overall performance of operators on the shop floor. He reflected on the situation at the shop floor as well as the on the staff functions as traditionally having *'a lax culture that still lacked the sense of urgency necessary to move the company out of its crises'*. This view was directed specifically at the programmers who appeared to have adopted a passive approach to the new changes. In the interviews with the Programmers on the shop floor, it was clear that they had had a separate culture. They saw their job as having an intellectual content and clearly as a staff position. They resented the move to the shop floor. When questioned about the lean production almost all of them expressed negative opinion about the changes. But when probed further for additional explanations, it was clear that they viewed the move to the production floor 'as *the first step in eliminating our jobs*'. Six of the seven programmers who have been moved to the shop floor expressed this pessimistic view and it was clear that it was a key driver of the expressed low motivation.

5.7 Human Resources

The human resources department sought to introduce the new ideas through developing educational programs focusing on increasing technical skills and the problem solving techniques of operators. These programs were welcomed by younger operators and were faced with scepticism by older more experienced operators reflecting their overall dissatisfaction with the new measures. This dissatisfaction explained in part the rush by older operators to accept the early retirement package in large numbers.

Driven by the human resources department, the new unit manager had separate meetings with the production manager, group leaders and team members of the unit presenting the new plans of the company and the lean production strategy. The unit manager introduced the LP concepts and requested that all working groups should use brainstorming exercises focusing on ways to reduce costs each in his individual area. In addition, the unit manager started a process of on-going discussions with the group leaders on the cost reduction strategies of the company and how best to implement them at the shop floor. Similarly, team leaders were expected to repeat the process with the rest of the operators.

Reorganisation at the shop floor level has been an attempt at job enlargement and increasing the skill level of workers through job rotation and an in house training program. The training program focused on developing an educational program covering both technical as well as social skills and problem solving techniques.

5.8 Teamwork

Initially, teamwork started with the introduction of the autonomous work group concept prior to the DASA group bailout. But, as the production manager indicated, *'these were half-hearted attempts at increasing the role of operators on the production floor'*. With the new restructuring and the introduction of lean production, the focus was on decreasing manufacturing costs and lead times. The unit manager sought to involve the operators in contributing their ideas on cost reduction and productivity improvements. The human resources department introduced a 'Cost Reduction Program' that used cash rewards as an incentive for employee participation. A percentage of the money saved through the cost cutting ideas was given to the team or person who suggested the best cost saving idea. During the second visit to the flat sheet metal area, I participated in a short ceremony in which three workers were given 14000 Guilders for a cost reduction idea that suggested a specific wood type change for the wood used on tooling for the F50 wings. The new suggestion reduced the cost of the operation by 30 per cent, a significant reduction in cost for the company. Indicative of the increased autonomy, the workers did their own research into the types of wood and the amount used in tooling. They contacted suppliers on their own and presented their proposal for the change and were rewarded accordingly. But, these types of rewards were rare and most of the cost reduction ideas were not viewed as significant enough to merit similar rewards.

Team development did not appear to be a concentrated effort in introducing the best team practice strategies of the organisation. Instead, it was basically the reorganisation of the operators into teams around each of the function units and supervisors were simply given the new title of group team leaders. Quality control personnel were moved closer to the shop floor and became part of the teams (figure 5.5). The teams were reorganised in groups of 10 to 15 people per unit with a minimum LTS technical education level. Before lean production, in one of these team units of 15 operators only 4 were skilled enough to change between the different machine tools especially those with different programming parameters. But, with the introduction of lean production approaches, most operators became multi-skilled through in house training and job rotation and accordingly became more flexible.

The production manager communicated the importance of various performance dimensions and defined targets through regular meetings with the team leaders. Production targets were posted in the FMS area for operators to see. The team leaders organised 'what should be produced and which tools to use' in each particular area based on a set schedule. For example, in the FMS area, a chart showing the progress in lead-time reduction from 8 days to 3 days was posted during the second visit to the area. The sign was available for all to see and by the last visit to the same area, they did reach their target of a lead-time reduction to 3 days.

5.9 Key Dimensions

The use of technologies such as FMSs and CNCs has always been the policy of Fokker as a way to maintain its technological edge. Coupled with lean production approaches, improvement in efficiency and productivity were expected. Looking at the FMS environment, the four key dimensions of complexity, regulation, integration, and flexibility associated with the characteristics of the FMS, as defined by Krabbendam (1988) and Boer (1990), were also used in this case.

The semi-structured interviews and the questionnaire shown in the appendix were used to investigate the lean production approaches implementation to the FMS area. The interviews were conducted with the human resources manager, the PTS unit manager, the production manager, two manufacturing /production engineers, 2 supervisors or group leaders, as well as with operators. In addition, shorter interviews were conducted with 7 programmers. Four of the programmers on the shop floor were interviewed together and the questionnaire questions were answered collectively by the group. Additionally, two quality assurance engineers were also interviewed. These interviews were conducted during three visits between November 1994 and June 1995 prior to the closure of the company.

5.9.1 Complexity

Taking a closer look at the FMS environment, it was evident that, individually or collectively, the technology used was complex: a 'Profile Beworking Machines (PBM)', a Flexible Manufacturing Systems in which parts of different shapes and sizes were being machined; a visibly new three dimensional JOMACH 25 milling CNC with sleek LCD display monitors; a six tools CORTNI L 300 SB CNC and a TRUMATIC 260 BFS CNC machine tool programmable from a central database; a LGIRE – ACB 6axis machine and so on. Interviews with the supervisor and operators in area confirmed this initial view complexity. The complexity was evident from the fact that operators had to undergo extensive programming training by the vendors as well as through in house multiskilling technical training programs.

Responses to the question on general operational complexity pointed to mixed opinions with the majority of respondent indicating that it 'remained the same' and only one operator indicating that it has 'increased'. There was general agreement that complexity in the FMS area did not exhibit any appreciable change as a result of the introduction of the lean production approaches. Responses to the complexity questions in the questionnaire regarding the degree of interdependence between work stations, the need for increased coordination between the FMS and other stations and areas, did not point to any appreciable changes as a result of the introduction of new organisational changes.

Programmers on the other hand, having recently been moved to the production floor near the FMS, did agree that the complexity of the FMS played a role in justifying the need to increase supervision of the FMS and monitoring the use of the specialised CNCs and the DNC database.

From the human resources manager perspective, the complexity of the manufacturing process and by extension the FMS has been handled through increased training and multiskilling of the operators. By introducing lean production approaches, and giving operators more control over the production process, he expected the teams to handle the complexity depending on the instructions of the production manager and the group leaders. On the other hand, the responses by the production manager indicated that the degree of complexity in the FMS did not appear to increase appreciably. He indicated that he '*had and continues to exercise firm control over the production process*' and that with lean production, because set objectives are closely measured and are consistently evaluated, he expected any complexity problems to manifest themselves quickly and be taken care of very early. He also expressed the view that by transferring the production, programmers, and quality staff to the production area and by monitoring team actions, particularly in relation to cost cutting measures, he made it easier for the teams to seek help in any arising complexities.

5.9.2 Integration

The levels of integration in the FMS increased as a result of the lean production approaches. Production units were physically moved closer to each other. Group leaders and operators clearly perceived an increased interaction and coordination between functions. The production manager also pointed to the tighter coupling of the production process and considered it to be at the heart of the lean production philosophy. This increased integration was consistent with management efforts to capitalise on lean production and reduce lead times driven by a sense of urgency and the realisation of the need to show concrete results.

In the 8 moth period between Nov. 1994 and June 1995 the lean production approaches seemed to take route and gain increasing acceptance by the supervisors, operators, and even the programmers on the shop floor. The teams were showing increasing signs of cohesion and increased confidence. Operators clearly stated that they felt that they had more autonomy in spite of the high degree of regulation that typically existed on the shop floor.

One reasons put foreword by the group leader (supervisor) of the FMS group for the increase in autonomy was, in part, due to the reduction in the number of engineering and production staff 'dictates' as a result of the redundancies. Mid-level staff positions suffered the largest percentage of cuts and the ratio of salaried employees to the total number of employees was reduced to ratio of 1:3 from a ratio of 1:1. Although by the standards of lean production systems this 1:3 ratio was still high, the change was considered to be significant.

By the last visit to the Papendrecht plant, apparent resistance to increases to operator autonomy by the production staff declined. The production managers' attitude in respect to the existing high degree of regulation and control over the shop floor was transformed into a recognition of the need to give operators and teams more freedom and control over their individual work areas. Group members also perceived an increase in the cohesiveness of the groups and saw themselves as better able to distribute tasks and increase their ability to control the process. Yet some functions such as maintenance remained separate and maintenance staff still followed a prescribed preventive maintenance program.

5.9.3 Regulation

By virtue of the critical safety aspect of the aviation industry, the company had traditionally adopted a high degree of regulation in the manufacturing of aircraft parts and components. Over the years the company developed a highly functionalised bureaucracy that oversaw the establishment of rules, regulations and procedures. Prior to the introduction of lean production approaches, the company had a ratio of one salaried employee (staff) for every worker on the shop floor. Although the number of salaried staff positions has been reduced under lean production to a ratio of one staff for every three workers, as the Fabrication Unit manager stated 'the organisation had a long way to go and still suffered a high degree of red tape'.

The situation in the FMS area of production appeared to be similarly highly regulated. Every aspect of production had to follow a set of prescribed rules and be documented appropriately. According to the production manager, 'Fokker developed a bureaucracy with rules and regulations for every aspect of the production operation'. The extent of the 'red tape' as it was described by the group leader and operators at shop floor was so pervasive that it was estimated that for one '15 cent part the paperwork costs $150'.

The extensive degree of regulation in the production area was further increased following a joint Fokker-Boeing project for a BA 747. Both companies had extensive, well established, bureaucracies that added to the demands on documentation at the production floor. Of the 66 parts produced, 324 changes were made. The contract for B747 required, as per the conditions of the Boeing's company, extensive sets of rules and regulations governing the operation on the shop floor. Differences in part names and part numbers for the same manufactured items between the two companies led to complications and defaults in the paper work which caused the large percentage of parts changes. As one of the group leader stated:

'Production is OK but there are problems in the regulation associated specifically with one Boeing contract. Too much regulation and red tape applied from both sides Fokker and Boeing.'

Another shop floor problem revolved around the bureaucratic delays between engineering and the manufacturing cells concerning the new parts manufacturing. It took weeks to complete the manufacturing process for a single new part as a result of 'delays and excessive red tape' between engineering and production in finalising the manufacturing process for a non-recurring part (i.e. a part that is manufactured as a single order part). While for the manufacture of a recurring part, there was on average a five-day delay as a result of the same paper work (figure 5.4). This problem is multiplied significantly if we take into consideration the large number of parts required for each assigned job.

The high degree of regulation was reflected in the supervisors and operators responses to the interview questions concerning the number of procedures regarding operations, process planning, production planning, maintenance, and the degree of paperwork. There was a general agreement that the set work procedures and the number of rules and regulations relatively remained the same. Yet even with the increased operator autonomy and multiskilling, the regulation was still seen as very high.

Programmers responses to the same questions on regulation and the degree of control over the FMS operation indicated that they generally accepted the existence of high number of rules and procedures but that they viewed it as necessary for the efficient and proper function of production. The complexity of the FMS being used as one of the reasons for the need for the regulation. The Complexity of the three dimensional milling

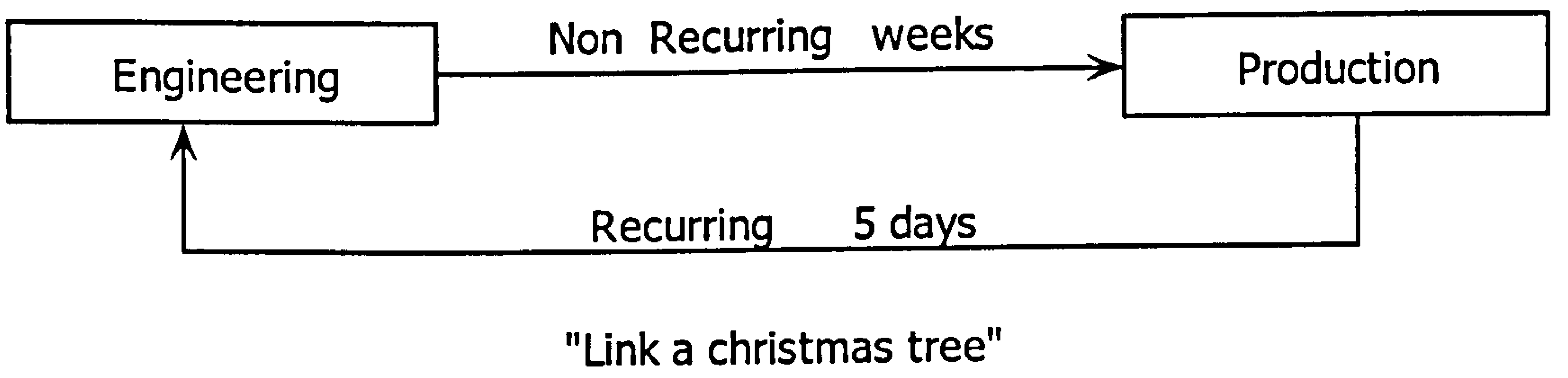


Figure 5.4: Increased regulation and delays for two types of parts production recurring and non – recurring

machine and the possibility of programming errors was one example put foreword by 4 of the programmers interviewed.
The high degree of regulation and tight control over the production process was even confirmed by the production manager 'to be excessive'. When questioned about the degree of control, he indicated that he felt that:

'There is certainly a need for less control by moving responsibility down to the operators... I don't care how they [the operators] do it as long as the job gets done and on time'

Nevertheless, as testified by the group team leaders and operators, he continued to exercise control of the process through set team objectives that were closely measured and consistently evaluated.

5.9.4 Flexibility

The overall flexibility of the production system benefited from the lean production approaches. As the operators in the FMS were organised into teams of 10 -15 of multi-skilled operators and with the participation of staff programmers and quality personnel in addressing production problems, the flexibility of the system improved considerably. By its very nature, the flexibility of the FMS system and the CNCs in the area operated by multi-skilled operators, made possible for the company, in times of low manufacturing activity, to offer its production capacity to external clients. These FMS services were offered for other aviation companies as well as to the military. During the research, the two contracts in operation were for NATO as well as for the Boeing Aircraft company.

Production efficiencies and flexibility continued to be viewed by the group team leaders and operators as having been improved since the introduction of lean production. The responses to the questions on the degree of flexibility; the ability to adjust at any moment to changing market conditions; and the ability to change production parameters and make

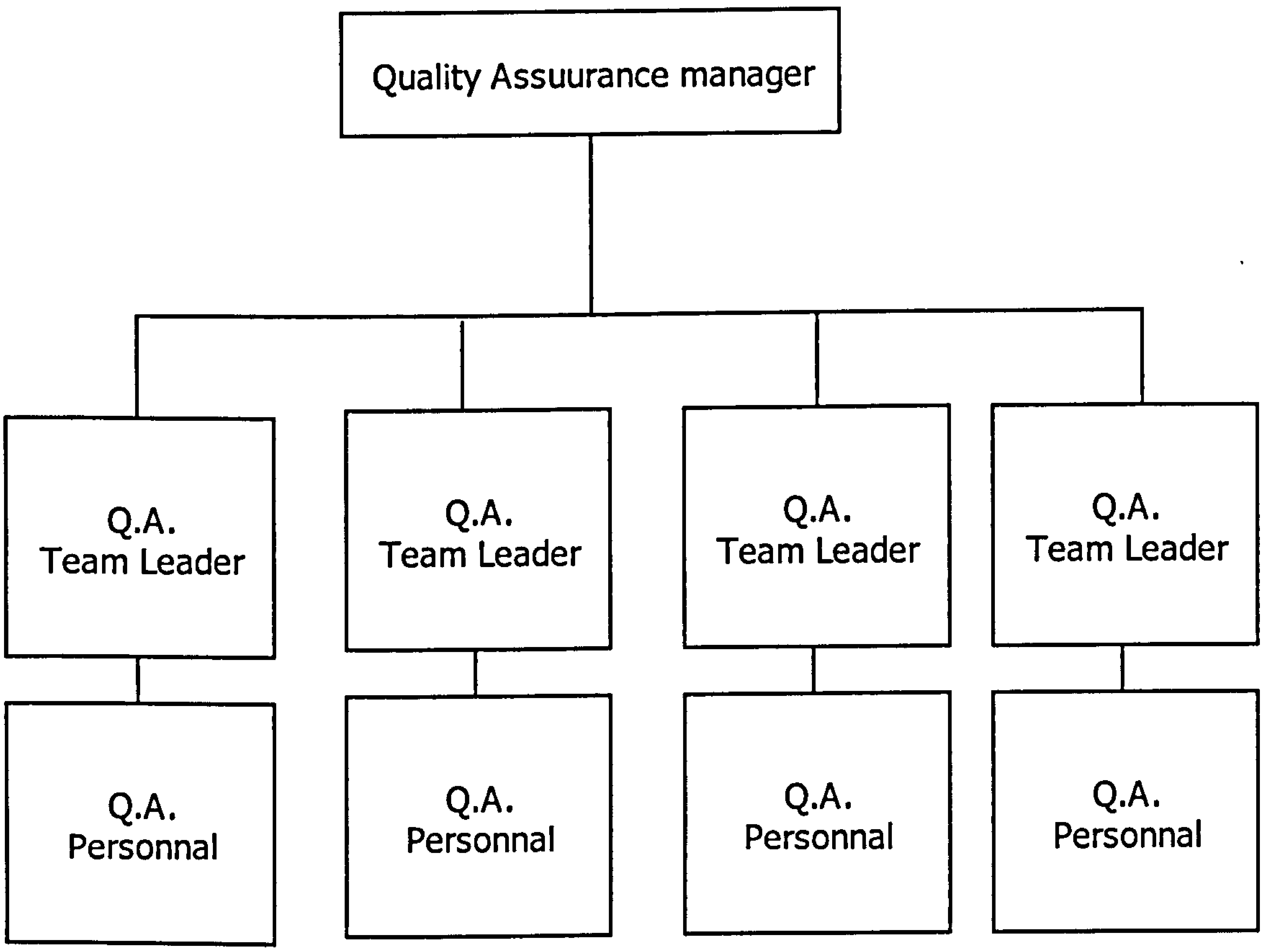


Figure 5.5: Quality Assurance (QA) department used to be separate from the shop floor. Then the QA team leader position had been eliminated and the QA personnel reduced and transferred to the production area.

design changes scored positively by all respondents (ranging from increased to significantly increased).

5.10 Analysis and Discussion

The objective of this case study was to investigate the application of lean production approaches to the FMS environment in an aircraft manufacturing with a reputation of high utilisation of advanced manufacturing technologies. Fokker Aircraft did utilise various forms of new production technologies including FMS and new CNCs in addition to adopting lean production approaches. The result of the interaction between the two, as indicated by the actors in management and on the shop floor, did point to improvements in productivity and efficiency.

The human resources department played a key role in trying to increase the degree of autonomy and control of the operators through the introduction of teamwork and multiskilling, and problem solving techniques. On the other hand, Plant managers and the production manager in particular focused on reducing costs, eliminating waste, and especially reducing capacity.

Yet, the company reminded burdened with over-capacity as a result of decreased demands for its products. In addition, Fokker carried the baggage of a complacent and inflexible bureaucracy that regulated every aspect of the production process. The restructuring of the company and the introduction of lean production played a major role giving the company a second chance. Nevertheless, the company needed to become leaner and while the financial position worsened, Fokker continued to eliminate excess capacity and reduce the number of employees. Given this state of flux, the points of stress exhibited in the FMS area as a result the lean production approaches were overshadowed by the larger stresses of possible job loss. These stresses played a role in reducing the level of engagement by the operators on the shop floor. The perceived high degree of regulation resulting from lean production added to these tensions and re-enforced the view of lack of confidence in the company's management.

The central issue on the minds of all the actors in the company was 'job security' and the uncertain future of the company. This fear over job loss was compounded by media reports detailing the ups and downs of the management and the dire financial position of the company (particularly after DASA declaration of its intention not to continue to 'bankroll a sinking ship' as was quoted in the local paper and widely talked about on the shop floor). Given this pessimistic outlook and the continued stream of layoffs, it was almost impossible to instil the desired new culture and the ability to solicit cooperation in all areas of operation was diminished.

Looking at the production floor and the FMS in particular, the dramatic impact of all the layoffs had severely impacted the atmosphere and the attitude of operators and staff alike. The issue of tensions relating to the application of lean Production to the FMS environment were not a concern for Fokkers' managers and staff. Yet Their was a realisation by the production manager of the need to give operators more freedom and to increase operator autonomy on the shop floor. If the lean production appraoch is to succeed. This view was manifested in the reorganisation of teams on the shop floor and multiskilling of operators through increased training.

Additionally, the production manager also viewed the reduction in the number of production staff and programmers as 'in a way increasing operator autonomy'. Also, by rationalising manufacturing/production, programmers and quality staff and moving the remaining staff closer to production he saw this move as adding assets to the production teams and increasing the efficiency and productivity of the teams.

Yet, the operators on the shop floor pointed to tensions related to the use of the DNC network and the tool programming database. While operators were allowed access to the program menus and given the autonomy to make changes, programmers considered this action as a direct challenge to their roles. Add to that the general uncertainty in the company and the overriding fear of job loss, this led to friction with the operators and group leaders. The situation remained unresolved up to the time of the last visit to the company. The actual exercise of the changes to the programmes remained with the 'technical services' Programmers and changes were done under their direct discretion.

Based on the interviews with the human resources and production managers, the perception was that both followed the general principles of the drive towards lean production and both appeared to espouse to giving operators in the production floor more control and autonomy over their work. Nevertheless, tensions in the application of these lean production approaches were seen in the perception of the degree of actual application of the lean production approaches. While the human resources manager viewed the new changes as a great leap in terms of Fokker's compliance with the lean production philosophy, The production manager applied the same principles within the traditional operational paradigm were the new changes give him an improved ability for monitoring and continuously evaluate the performance of production teams. However, these apparent incongruities relating to the FMS would have to be put in perspective as they were overshadowed by:

1) An overriding tension between management and operators about the future of their jobs and a distaste for the lean production approach which they viewed as the instrument for eliminating their jobs.

2) The continuation of the pervasive bureaucracy and high degree of regulation in spite of the lean production approaches being practised on the production floor and in the FMS area.

Even as the human resources department was developing the lean production techniques to be implemented on the shop floor, the company's financial position continued to decline and management continued its cost cutting crusade through additional layoffs. The publicity associated with the dire straits that the company was going through, made Fokkers' possible demise after 77 years in business the overriding issue at every level in the company. The impact on the morale of the organisation as a whole was severe. Under these circumstances, the research questions of this study dealing with micro developments on the production floor became insignificant and the operators' interaction with the FMS and the lean production techniques become mute.

CHAPTER SIX

CMC Compressors Manufacturing Company

6.1 Introduction

So far in this study, we have seen the implementation of the lean production system to the flexible manufacturing systems environment in two relatively large manufacturing companies: truck manufacturing and aircraft manufacturing company. In these core companies we saw that there were inconsistencies in the interaction between application of these lean production approaches to the FMS environment. These inconsistencies were the result, in the case of EGB Truck, of the contradictory messages being sent from the human resources department (calling for increased autonomy and empowerment) and the production and planning departments introducing more regulations and control over the process through the lean production procedures. While in the second case, Fokker Aircraft, the inconsistencies were due to a pervasive bureaucracy and high degree of regulation particularly at the FMS area as low motivation due to job uncertainties. In this chapter, the focus shifts to a smaller size manufacturing company that has also introduced lean production to its flexible manufacturing systems environment. The results from this company will point to an example were the tensions predicted and found in the other larger manufacturing companies were less visible in this case. As the discussion of CMC will show, The general impression from the responses of managers and operators interviewed points to an apparent good fit in the application of lean production to the flexible manufacturing systems where the lean production system was deployed.

This is a Dutch compressor manufacturing company that was in the process of introducing lean production to the production environment including its Flexible Manufacturing Systems (FMS) area. Five visits were made to this company in the period between November 1994 and June 1999. Semi structured interviews and short questionnaire were administered to a cross section of plant employees and staff. These included interviews with the Plant manager as well as Personnel, production, logistics, technical and planning staff. Focus of the interviews was on the 'Mechanical Department' which contained all the manufacturing functions in the plant. An interview schedule can be seen in the Appendix.

6.2 The Company

CMC is one of the world leaders in industrial refrigeration particularly for the food and fishing industries. A subsidiary of a German multinational corporation, CMC manufactures reciprocating and screw compressors, NH3-chillers, pressure vessels and other related components. Its products are high quality, reliable, low energy consumption refrigeration compressors that can be applied in almost every industrial refrigeration process (see figure 6.1 for a picture the type of compressor manufacturing at CMC).

Historically, CMC has been the traditional leader in the compressors manufacturing and industrial refrigeration business and was the first to introduce large welded steel reciprocating compressors to the market. In 1993, CMC was acquired by a large German multinational corporation specialising in all aspects of the refrigeration business. The new owners opted for minimum interference in CMC yet encouraged CMC management to adopt lean production techniques. The minimum interference policy of the parent company was primarily based on its business philosophy of 'group decentralisation' through what they termed as the 'FEF-programme' an abbreviation of the words 'focused, efficient, and fast'. The FEF-programme objectives were to encourage the development of leaner, smaller, and decentralised subsidiary companies in an effort to 'avoid losing market shares to smaller, specialised and efficient competitors' as the parent company literature stated.

In addition to the parent company's encouragement to CMC to develop the lean production approaches, they also provided CMC with additional investment funds directed at CMC's Research & Development (R&D) department as well as for investment

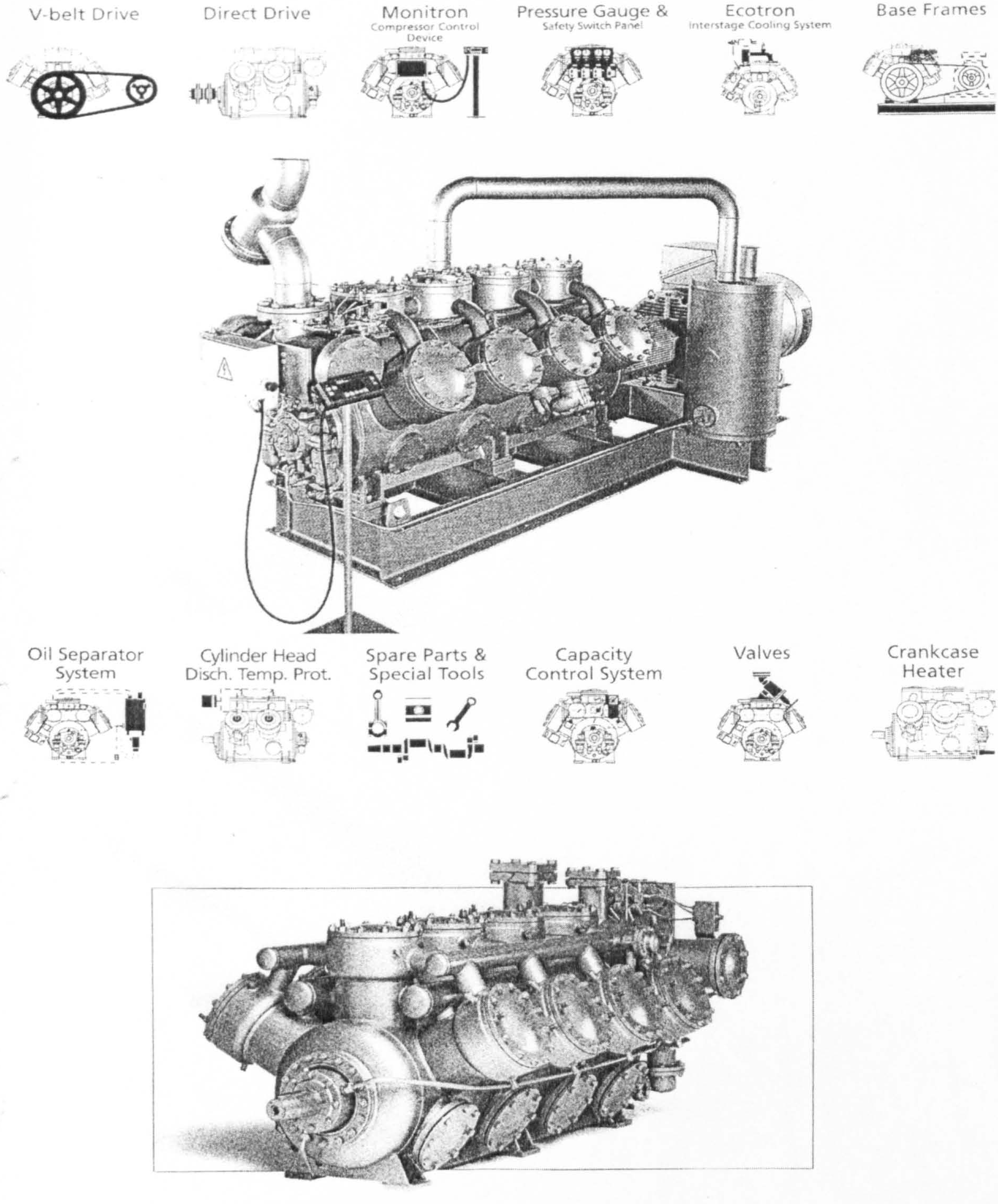


Figure 6.1: Picture of CMC Compressors

in new machinery. This infusion of capital helped CMC to complete the development of a new compressor design and increased overall confidence in the future of the company.

In January 1998, CMC began production of a new series of screw-type reciprocating compressors that were designed to meet new regulatory demands for environmentally friendly refrigeration. The new compressor design had a bore of 160 mm and a stroke of 110 mm used in six single stage and nine two-stage models. These new compressors were high quality; heavy-duty reciprocation compressors designed to operate with ammonia.

The successful introduction of the new compressor series came on the heel of significant organisational and technological transformation in CMC. Over the five-year period since the initial visit to the company in November 1994, CMC experienced increased growth in sales, which reached 616 million-DM in 1996, and by 1998, totalled 676 million-DM. The company was also successful in streamlining its production and logistics operation, increasing its productivity as well as managing the introduction of new compressor design with the minimum of difficulties. In the next sections, I will describe these developments and focus on the production area where lean production techniques were applied.

6.3 The Organisation

Prior to the company being acquired by the German multinational, CMC was organised along traditional lines (figure 6.2) with the 'Technical/Planning' department being the nervous system of the organisation taking charge of planning activities, scheduling, and even maintenance. This departments' focus was on the production operation with its staff micromanaging activities on the production floor.

Although the parent company did not want to interfere in the details of the production environment at CMC - considering that CMC's management had the necessary experience in its product area and that the company was successfully producing well established compressor products, nevertheless, they still wanted the company to actively pursue the adoption of a lean production strategy. The new owners were very keen on innovations made popular in the productivity and quality management literature and accordingly encouraged their subsidiary companies to adopt lean production as driver for future growth and success in the market place. CMC's management agreed with the parent company on the need to implement these changes and proceeded in 1994 to implement a pilot program based on the recommendation of a Japanese consulting company hired to help the company to adopt the lean production system. As a result of the success of the pilot program, CMC's management decided to adopt lean production albeit at a "gradual pace" as the plant manager indicated during the first interview in 1994.

By the end of 1995, the parent company was not satisfied with the 'slow pace of change' at CMC and decided to appoint a new president of operations. The new president was younger, had an industrial engineering background, and was fully committed to the new lean production philosophy. His extensive managerial experience in another innovative, high profile, electronics manufacturing company immediately established his credibility throughout CMC.

With this change in leadership and its stated commitment to lean production, the implementation of lean production took on increased urgency and gave company workers and staff a strong signal to pursue lean production to its full advantage.

6.4 The Production Process

The production process of CMC compressors is designed as follows: raw materials are immediately transported to the welding area where welding robots are used to do the initial welding of the compressor housings while the rest of the welding operations are completed by skilled welders. Prior to the introduction of lean production, welded compressor houses were done in series. As a result of lean production changes, housings are welded based on customer orders only (one-piece flow production).

Once the compressor housings are completed, they are then transferred to the heat treatment and cleaning section. Once the cleaning is completed they are then transferred

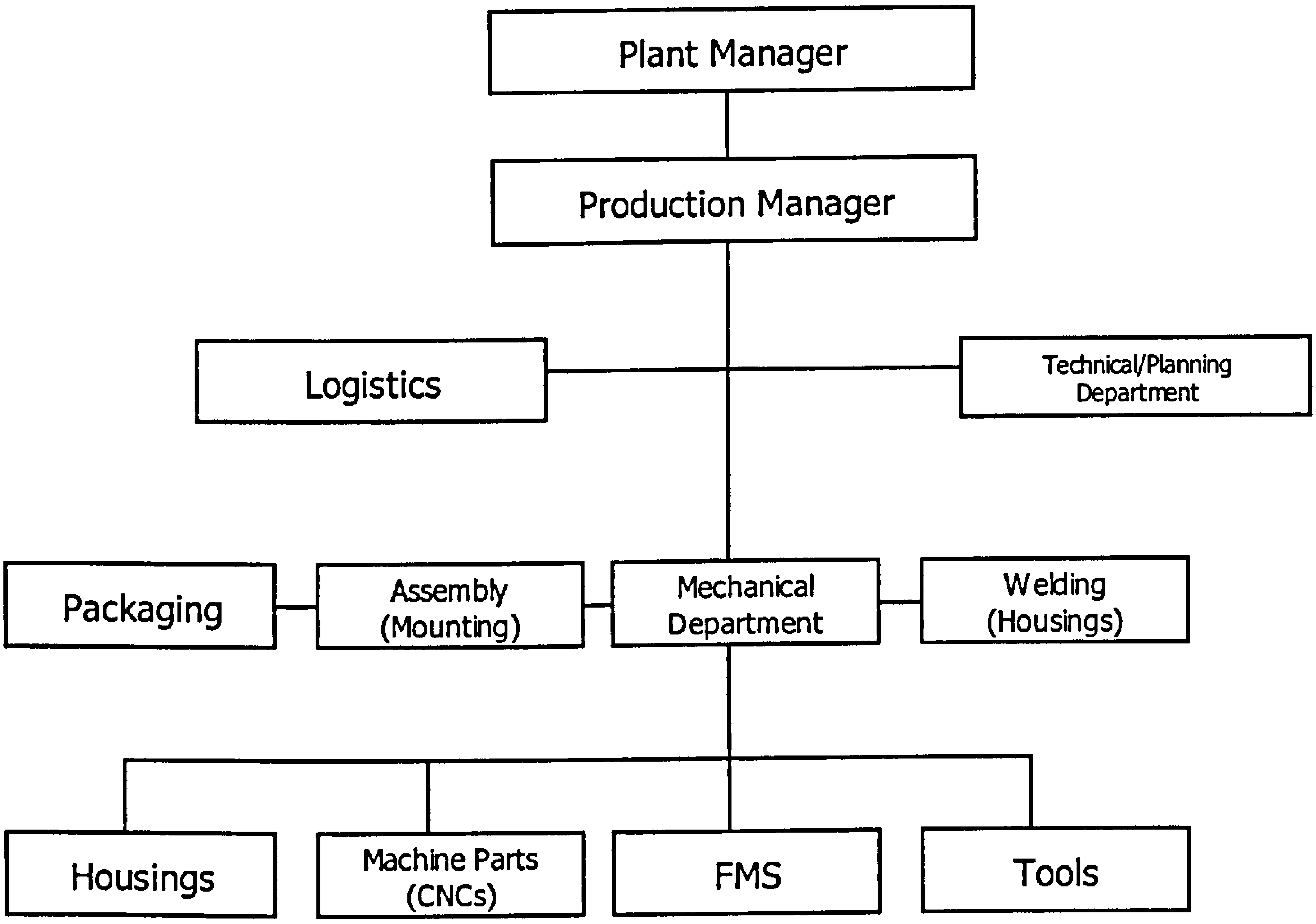


Figure 6.2: CMC Compressor organisiational chart as it relates to production

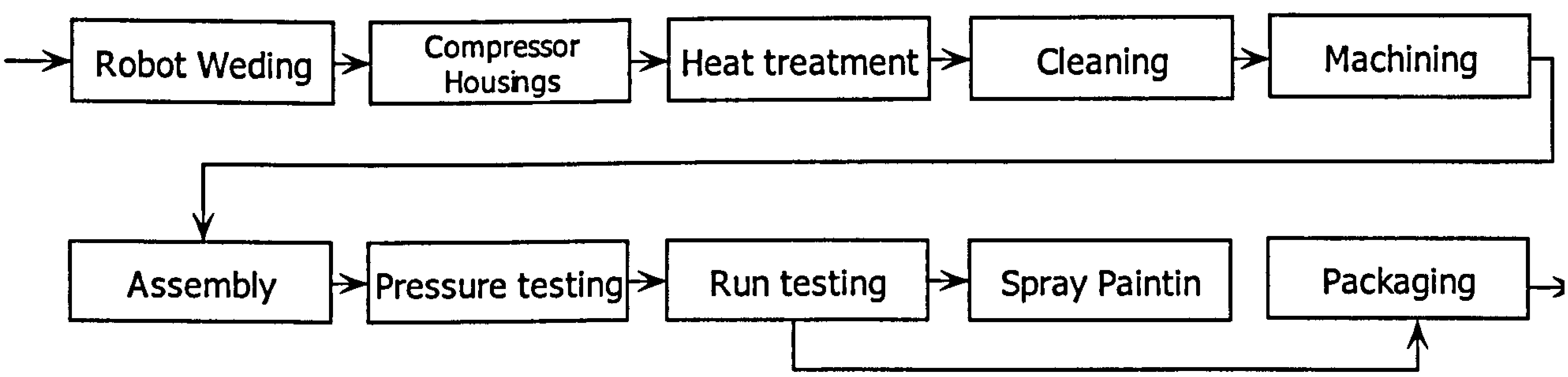


Figure 6.3: CMC Compressor production process

to the machining area which includes the FMS and CNC machines for turning, boring, drilling, and grinding processes, or the machining of crank shafts, cylinder liners, connecting rods etc., (see figures 6.3 and 6.4). The machining area has nine multi-skilled operators per shift. Once the compressor is machined, it is then transferred to Assembly. In Assembly, 20 workers do the assembly of compressors which are assembled 'one- at-a- time' with the full assembly being the responsibility of individual workers who have to personally sign for the assembled compressor once it is completed. During discussions with the assembly operators on the floor it was clear that they viewed this part of the job the most rewarding because of its variety and high skill requirement. It also offered the added satisfaction associated with 'working by hand'.

Once the assembly is completed, the compressor is then sent to the Pressuretest and run-test area where it is fully tested and is then sent to the spray paint robots and/ or to packaging depending on the customer order.

6.5 Key Organisational Developments

During the first visit in late 1994, the company was in the process of introducing lean production techniques including Just-in-Time, continuous improvement (*Kaizen*), and total quality.

The reorganisation of CMC and the adoption of lean production were based on a new business reorganisation strategy encouraged by the new owners. CMC's management proceeded to improve the organisational efficiency through introducing teamwork, improving logistics, and reducing inventories. As the plant manager indicated in the first interview, the objectives were set out as *"increasing efficiencies through reducing over-capacity, achieving a significant shortening of throughput times as well as achieving significant reductions in inventory"*.

The key focuses in that early stage was primarily on cost reduction and the elimination of over capacity. The plant manager made it clear that there were some tough decisions ahead which he had to take. That meant that the company was planning to reduce the size

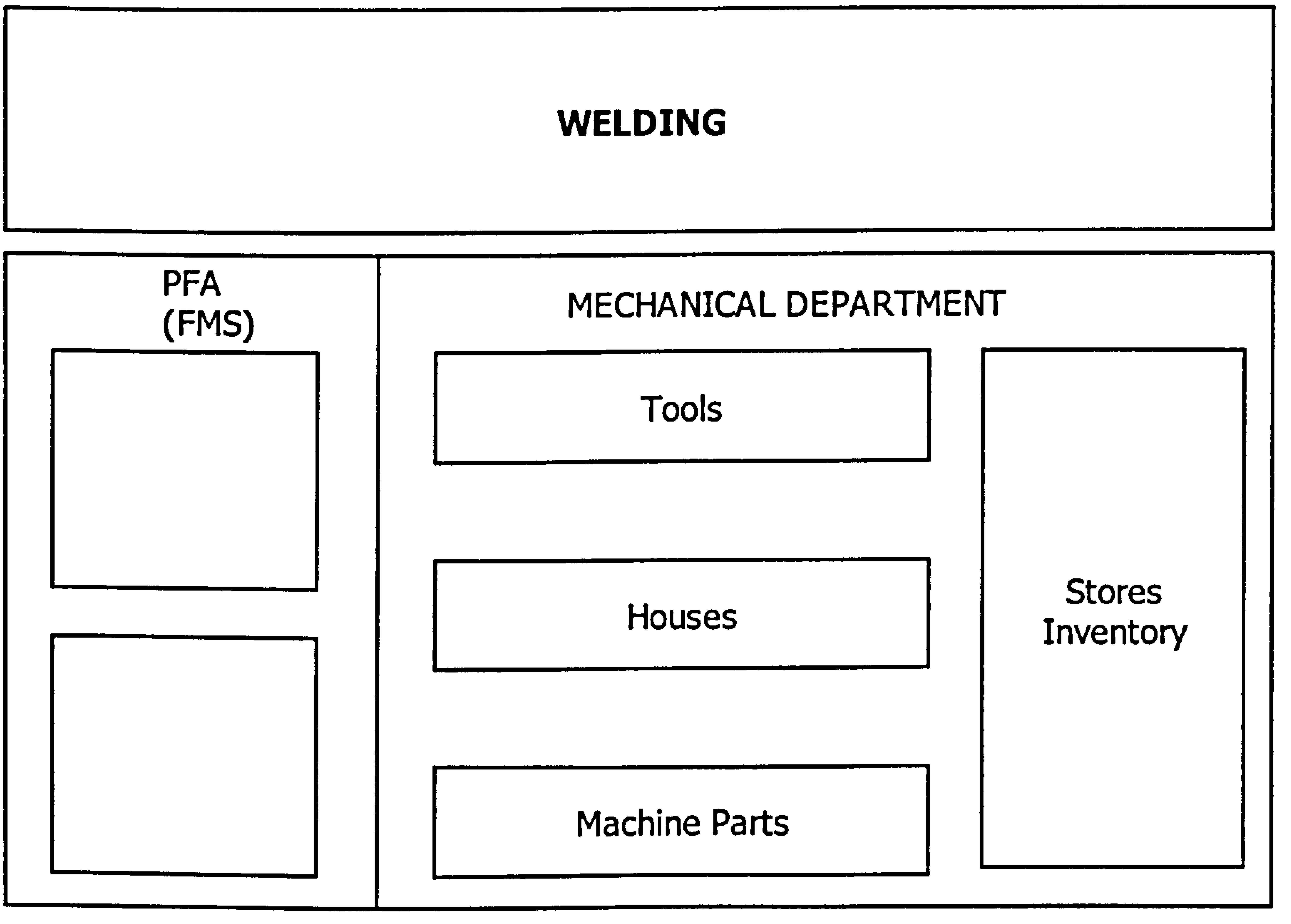


Figure 6.4: Layout of the mechanical department and the FMS

of its labour force and as expected, within eight months from the initial visit, management had reduced the size of its workforce from 350 employees to 180 employees. Nevertheless, the organisational structure remained relatively the same with the most noticeable reduction being the reduction in the number of employees by fifty per cent from every department with the exception of the welding area whose experienced welders were deemed indispensable.

By 1998, following the lean production philosophy guidelines and the adoption of multiskilling and selective hiring practices (particularly the hiring of young technical diploma MTS and LTS qualification graduates), CMC still maintained the number of employees around its 'lean' 1995 levels.

Up until 1995, CMC had traditionally manufactured all the components of the compressor housings using a variety of CNC machines. Management commissioned a complete audit that examined every aspect of the manufacturing operation. As a result of the audit, which was heavily influenced by lean production guidelines, the company decided to 'farm-out' small parts production and focus on its core competency of compressor housings. The decision to subcontract small part production was based on a 'make or buy' matrix cost analysis. The presence of reliable suppliers in the region as well as the company's ability to achieve a good supplier relationship as a part of the CMC group of companies made the decision to adopt Just-in-time logistics a practicable proposition. Today, small parts production is subcontracted to suppliers using JIT delivery. The fact that CMC is located near a major transportation artery and that most of its supplier companies are within short driving distance made the JIT system a success.

As indicated before, the introduction of lean production into CMC was done primarily through the help of an external Japanese consultancy company that introduced CMC to the use of *Kaizen*, Just-in-Time/TQ techniques and principles. As the production manager stated *"with just in time we were able to reduce througput time considerably and almost totally reduced stocks".* This convinced management of the utility and effectiveness of lean production and accordingly proceeded to fully adopt it as a company wide strategy. The plant manager referred to the Japanese Consultant Company as a "sparring partner" reflecting the degree of intensive discussions and interaction with CMC's management team as well as production and logistics staff and multi-departmental meetings. All the lean production ideas and practicable steps were discussed and analysed thoroughly before deciding to implement them. The implementation of these Lean production concepts involved a pilot program that proved the validity of these concepts and thus were implemented throughout the company.

With the help of the Japanese consultant and through the establishment of a multi-departmental work group, the company slowly changed its production philosophy to adopt the JIT methodology. By 1998, CMC had moved towards a onepiece flow production system that was based on customer orders as an alternative to the old demand forecasting method. This transformation was particularly poignant because, in a number of cases, the forecast method proved inaccurate. For example, the original decision to buy the FMS unit was primarily based on a demand projection of strong sales in the U.S. market. Later US sales proved to be much less than projected. Although the decision to adopt FMS to the production of the older type compressors was for the wrong reasons, it nevertheless proved to be a good decision as the FMS proved its effectiveness in increasing production flexibility.

One of the important lean production transformations was the break-upof the Technical-Planning department. Prior to lean production, the production function in all its aspects was highly centralised through this department. This led to dissatisfaction from other departments, as well as from supervisors on the shop floor. Even the plant manager admitted that *'this department had too much power and it controlled every aspect of the operation from planning to programming and even to maintenance'*. Thus, a decision to break it up and transfer many of its functions to the production floor was taken. The earlier decision to downsize the company helped make the break up process smoother.

In addition, the production manager had two assistants to handle all aspects of production operation. The division of labour was haphazard and depended on the particular job at hand and the needs of each department. This created a problem particularly for the supervisors who felt that many of their duties had been taken over by these managers creating the feeling that there was an undue over control by the technical department.

With the break up of the Technical/ Planning functions, each of the teams did its own planning. Although this gave each team a strong degree of autonomy, it nevertheless led to considerable delays and confusion between the departments. This process 'was taken a step too far' according to the production manager and the department teams became 'too independent and led to variances and confusion in the planning times'. As a result from these perceptions of team over independence (put foreword primarily by the production and logistics staff), it was later decided to re-centralise the planning function for all departments by deciding on an end time for each team. Accordingly, the planning for the departments was re-centralised under the direction of the production manager. Now, working in teams with the aid of transparencies, each team's 'end-time' is set for every department. The production manager looks at efficiencies 'of the total rather than the old method of measuring efficiency for each team' (see figure 6.5).

The plant manager opted for increased efficiencies through, inter alia, 'a lean core of multi-skilled workforce' rather than semi-skilled labour even though, as the production manager stated, that *'for the majority ofthe time, you only need push button people'*. The decision to retain a leaner, multi-skilled workforce was a strategic decision that was said by the plant manager to "have helped the company become more flexible and adaptable to changing market conditions". This made it possible for the company to weather the shift in the industry towards new environmentally friendly compressors. New environmental regulations could have had considerable negative impact on the performance of CMC. But having retained a well trained, knowledgeable, multiskilled workforce, it was easier for CMC to introduce the new compressor design to the production floor with far less problems and with much less 'growing pains' than would have been traditionally encountered had the work force been less qualified.

OVERZICHT LEVERDATA

Datum: 10-5-99

Ordernr.	Klantnaam	Type	Aantal	LEVERDATUM Compr.	Unit	Compr Week		Huis Lasserij	Scharn.	Mont.	Contact persoon
9134705	GI- RUSLAND	RCU912	2	4-mei	19-mei	919		ok	ok	ok	GBOUMAN
9137725	IND.SYSTEMS	RCU69	1	5-mei	19-mei	919		ok	ok	ok	BMOONEN
9156701	SAMIFI	RCU429	2	5-mei	19-mei	919		1x ok	1x ok	1x ok	BVDBRAND
9126716	ILERFRED	RCU49	1	10-mei	26-mei	919		ok	ok	ok	BVDBRAND
9136723	[redacted] IBERICA	RCU49	1	10-mei	26-mei	919		ok	ok	ok	BVDBRAND
9155102	ARCOFIL	RC69	2	10-mei		919		ok	ok	ok	BVDBRAND
9165131	KINARCA	RC429	2	10-mei		919		ok	ok	ok	BVDBRAND
9156708	[redacted] GMBH	RCU49	2	11-mei	27-mei	919		1x ok	1x ok	1x ok	GBOUMAN
9154813	[redacted] CHINA	RC412	1	11-mei		919	E	ok	ok	ok	GBOUMAN
9155303	[redacted] UK	AC680R	1	11-mei		919		ok	ok	ok	GBOUMAN
9184716	[redacted] PHIL.	RCU2112	1	12-mei	26-mei	919		ok	ok	ok	MVOVERVELD
9184717	[redacted] PHIL.	RCU4212	1	12-mei	26-mei	919		ok	ok	ok	MVOVERVELD
9134701	[redacted] PHIL.	RCU412	1	12-mei	26-mei	919		ok	ok	ok	MVOVERVELD
T278601	QUICK REACT	RC611	1	12-mei		919		nvt	nvt	ok	RSCHIPPERS
T278678	QUICK REACT	RC611	1	12-mei		919		nvt	nvt	ok	RSCHIPPERS
T300166	QUICK REACT	RC66 F	1	12-mei		919		nvt	ok	ok	RSCHIPPERS
9146802	[redacted] GMBH	RCU66 F	2	ok	10-mei	919	E	nvt	ok	ok	GBOUMAN
9084720	[redacted] GMBH	RCU412 /2-pack	1	ok	11-mei	919		ok	ok	ok	GBOUMAN
9125705	[redacted]	RCU29	2	ok	12-mei	919	P	ok	ok	ok	BMOONEN
9164701	[redacted] GMBH	TRCU612	1	17-mei	31-mei	920		ok	- 5-mei		GBOUMAN
9164708	GRENCO IBERICA	RCU9312	1	17-mei	1-jun	920		4-mei	5-mei		BMOONEN
9164724	GRENCO IBERICA	RCU412	2	17-mei	1-jun	920		4-mei	5-mei		BMOONEN
9154725	GRENCO IBERICA	RCU212	1	17-mei	1-jun	920		ok	ok	ok	BMOONEN
9154814	[redacted] CHINA	RC6312 syst. B	1	17-mei		920		ok	ok	ok	MVOVERVELD
9124815	GRENCOBEL	RC612	3	17-mei		920	*E	ok	ok	ok	BMOONEN
9166702	[redacted] IBERICA	RCU49	1	18-mei	1-jun	920		5-mei	6-mei		BMOONEN
9154825	[redacted] INC	RC4212	1	18-mei		920		ok	ok	ok	MVOVERVELD
9154828	[redacted] INC	RC612	1	18-mei		920		ok	ok	ok	MVOVERVELD
9155127	[redacted] INC	RC429	1	18-mei		920		5-mei	6-mei		MVOVERVELD
9154723	ARCOFIL	RCU412	1	19-mei	1-jun	920		6-mei	7-mei		BMOONEN
9166812	[redacted] GMBH	RCU46	3	19-mei	2-jun	920		nvt	7-mei		GBOUMAN
9155320	[redacted] UK	SAC780R	1	19-mei		920		ok	ok	ok	GBOUMAN
9165107	GRENCO IBERICA	RC29	1	19-mei		920		6-mei	7-mei		BMOONEN
9164706	[redacted] UK	RCU4212	3	21-mei	7-jun	920		10-mei	11-mei		GBOUMAN
9166749	NORSKE KJOLE	RCU69	1	21-mei	7-jun	920		10-mei	11-mei		HBOGER
T277693	QUICK REACT	AC1080R	1	21-mei		920		10-mei	11-mei		RSCHIPPERS
T278755	QUICK REACT	RC611	1	21-mei		920		nvt	nvt	ok	RSCHIPPERS
T305750	QUICK REACT	AC680R	1	21-mei		920		ok	11-mei		RSCHIPPERS
9124003	ADEAREST	RCU312E	1	ok	12-mei	920	*E	ok	ok	ok	GBASTIAANSEN
9125704	[redacted]	RCU69	2	ok	17-mei	920	*P	ok	ok	ok	BMOONEN
9114723	GRENCOBEL	RCU312	1	ok	17-mei	920	*E	ok	ok	ok	BMOONEN
9114725	GRENCOBEL	RCU312	1	ok	17-mei	920	*E	ok	ok	ok	BMOONEN
9114726	GRENCOBEL	RCU212	1	ok	17-mei	920	*E	ok	ok	ok	BMOONEN
9114707	KYLDELAR	RCU7212 ec. B	1	ok	18-mei	920	P	ok	ok	ok	BVDBRAND
9114724	[redacted] GMBH	TRCU3112 st. B	1	ok	18-mei	920	P	ok	ok	ok	RSCHIPPERS
8504010	GRENCO	RC7212E ec. B	2	ok	18-mei	920	*E	ok	ok	ok	BMOONEN
8504011	GRENCO	RCU312E /monitr	2	ok	18-mei	920	*E	ok	ok	ok	BMOONEN-
9134706	GI- SURINAME	RCU412	1	ok	19-mei	920	P	ok	ok	ok	GBOUMAN
9156729	GRENCOBEL	RCU429	1	ok	19-mei	920	P	ok	ok	ok	BMOONEN
9114749	GRENCO BORN	RCU2112	1	ok	21-mei	920	*P	ok	ok	ok	BMOONEN
9114703	GI- RUSLAND	RCU312 /monitr.	2	ok		920	*E	ok	ok	ok	HVUUREGGE
9133704	GI- RUSLAND	RCU412 /monitr.	2	ok		920	*E	ok	ok	ok	HVUUREGGE
9155324	[redacted] CHINA	AC480R	1	25-mei		921		12-mei	13-mei		MVOVERVELD
9174741	GRENCO IBERICA	RCU612	1	26-mei	7-jun	921		13-mei	14-mei		BVDBRAND
9146710	[redacted] UK	RCU69	2	26-mei	9-jun	921		13-mei	14-mei		GBOUMAN
9184001	RITEL	RCU312E	3	26-mei	9-jun	921		ok	2x ok		BVDBRAND
9165122	[redacted] INC.	RC219	6	26-mei		921		13-mei	14-mei		MVOVERVELD
9165123	[redacted] IBERICA	RC29	1	26-mei		921		13-mei	14-mei		BMOONEN
9164730	GI- THAILAND	RCU1212	1	27-mei	10-jun	921		14-mei	17-mei		MVOVERVELD
RESERV	THERMAX	RC69	2	27-mei	—	921		14-mei	17-mei		BVDBRAND
9124714	NYSSEN	RCU412	3	28-mei	11-jun	921		ok	ok		BMOONEN
T278832	QUICK REACT	RC611	1	28-mei		921		17-mei	18-mei		RSCHIPPERS
T308298	QUICK REACT	RC429	1	28-mei		921		17-mei	18-mei		RSCHIPPERS
T311135	QUICK REACT	RC429	1	28-mei		921		17-mei	18-mei		RSCHIPPERS
9134603	GRENCO	RC69 CHILLER	1	31-mei	23-jun	921		ok	ok		BMOONEN
9174001	POST	RCU412E	1	31-mei	14-jun	922		18-mei	19-mei		BMOONEN
9174002	POST	RCU612E	1	31-mei	14-jun	922		18-mei	19-mei		BMOONEN
9164720	[redacted] UK	RCU4212	1	1-jun	15-jun	922		19-mei	20-mei		GBOUMAN
9185104	GRENCO IBERICA	RC49	1	1-jun		922		19-mei	20-mei		BVDBRAND
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9165328	[redacted] GMBH	AC680R	1	2-jun		922		20-mei	21-mei		GBOUMAN
9165329	[redacted] GMBH	AC880R	1	2-jun		922		20-mei	21-mei		GBOUMAN
ORDER	GI-ADEAREST	RC66 F	2	3-jun		922		nvt	24-mei		GBOUMAN

Figure 6.5: CMC Compressor orders and production sequences

6.6 The Flexible Manufacturing Systems Environment

CMC utilised a Dorress-Sharman Flexible Manufacturing System. In addition, CMC also introduced two Welding robots. Ten CNC machines (Crankshaft turning and milling machine, Vost Alpine Stienel, WNC 500 S Millturn, Mazzak) and other types were also used. The company introduced the Flexible Manufacturing System late in 1993. The original reason for the purchase was primarily based on the expectation of significant increases in the US market demand for the CMC compressors.

The FMS was used for machining compressor housings and other parts. It was made up of two flexible manufacturing cells with a pallet-changer. With one of the cells used mostly for the housings. (See figure 6.6: picture of FMS). The Cells are operated on a 24-hour basis in three shifts with the third shift unattended. A single skilled operator (with programming skills) works each FMC. Once housings or components are machined, finishing is done by hand. The operator does the loading and unloading of the compressor housing, and has the freedom to change the program and has the choice in priority procedures for each individual job. The FMS also has an associated robot tool wheel. This robot replaces tools, which are pre-set in the pre-set department. Another operator in the tool department is in charge of the setting up and calibration of tools. This calibration is done by a Zoller H 4000 machine, which also requires special training. The operator calls up the tool list from the tool library and tool storage racks. The parts list is outputted from the computer once the list is completed, the operator then assembles the tools together and the tools are then put on the tool wheel.

The FMS machining centre area was used for small compressor housing with 6 pallet stations (figure 6.6). In addition, as part of the new organisational changes, FMS maintenance (including preventive maintenance) was subcontracted. In case of defaults or breakdowns, operators cooperate with the external maintenance specialists to solve particular FMS problems as well as in order to increase operator familiarity with the machines.

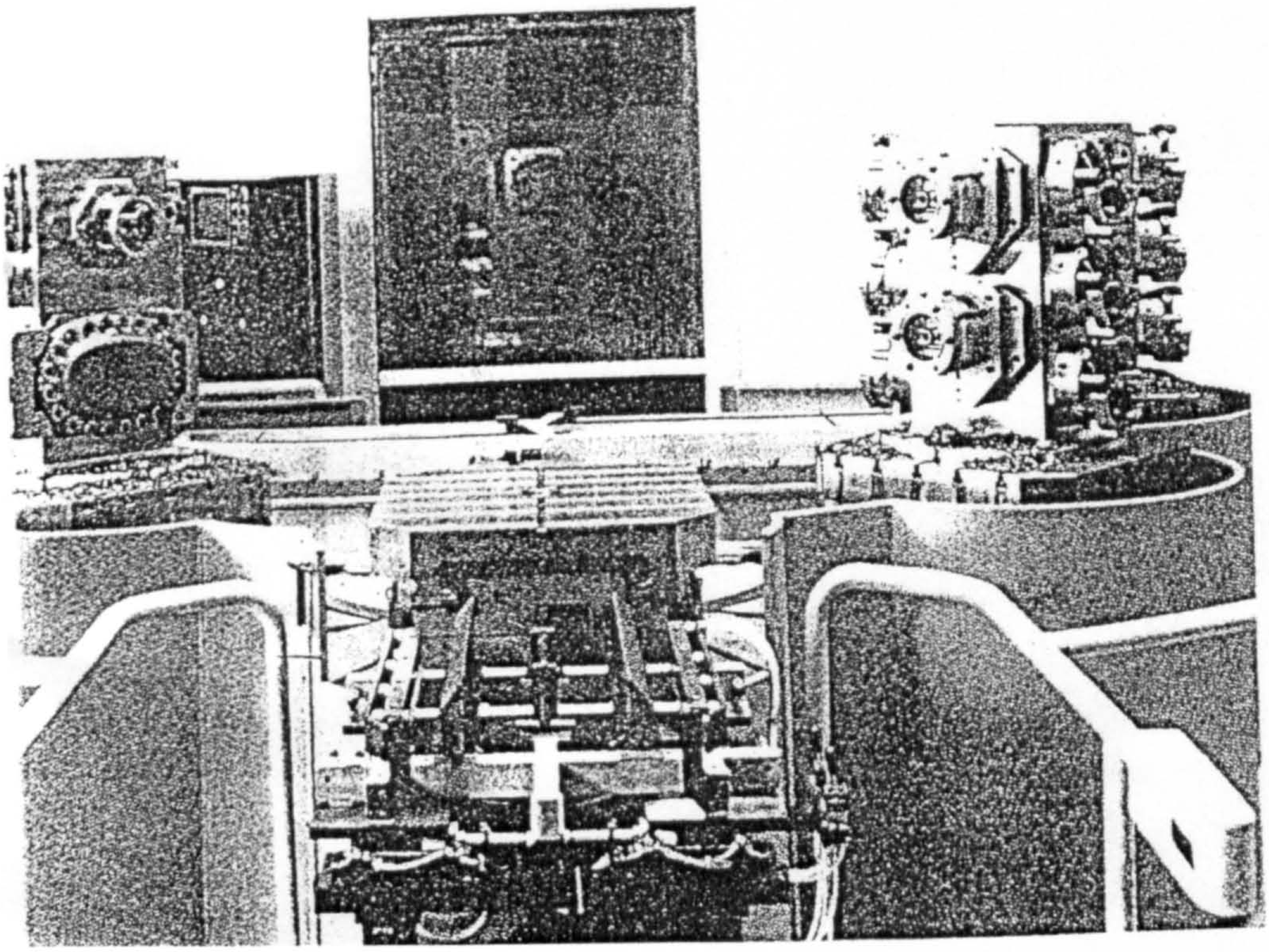


Figure 6.6: CMC Side view of the FMS

6.7 Lean Production

The implementation of lean production through a specialist Japanese consulting company with experience in lean production implementation in European manufacturing companies (particularly in Germany) significantly followed basic JIT and TQM approaches discussed in chapter two of this study. The measures adopted by CMC following a long process of discussions and analysis at all levels in the company included the following:

1. Stream lining the company by reducing over capacity and cutting the workforce by more than half;
2. Adoption of just in time logistics internally and externally with significant reductions in inventories over time;
3. A move towards 'make-to-order' production;
4. The adoption of total quality techniques including preventive maintenance, problem solving techniques;
5. The development of continuous improvement (Kaizen);
6. The adoption of teamwork using flexible multi-skilled workers.

Additionally, outsourcing small part production functions of non-core activities which could be produced more economically by external suppliers, simplified the production process.

The plant and production managers viewed the implementation of lean production measures as a success. Initially these measures were tested in a pilot program and later fully implemented to all areas in the company. The strong enthusiasm of the plant manager for lean production was a key driver in the transformation of CMC from a traditional organisation into the lean production paradigm.

As the new plant manager stated during the first interview, his previous experience in lean production at his previous employment at an electronics manufacturing company, was a key factor for his strong commitment to lean production. This was in sharp contrast to the views of the pervious plant manager. In the interview conducted with the previous plant manager during the first visit to the company in November 1994, no such enthusiasm was detected. In a following interview with the production manager who survived both regimes he indicated that:

" *one of the reasons the old plant manager was removed was because he did not believe in these changes and he only implemented a pilot program as a test to buy time*"

Senior or corporate CMC management apparently saw the plant manager as taking too much time to adopt lean production and owing to other undisclosed reasons he was removed. What was clear from the interview with the new plant manager and the production manager under the new leadership is that the initial slow adoption of these new organisational changes encouraged by senior management was a factor in his dismissal. However, with the change in leadership and the expressed deep commitment of the new manager to the lean production philosophy, the transformation of the company was seen to accelerate.

As a result of lean production changes, the organisational format of the welded compressors housing was changed from a series production to an 'order by order' production format. According to the Mechanical department charts, lead-times were reduced from 22 weeks (from start to finish for the production of a complete compressor) to seven weeks and eventually, at the end of 1998, to four weeks lead time.

6.7.1 Kaizen

The initial pilot program at CMC started with the formation of a kaizen team. This team was started in the mechanical department axle manufacturing CNC area. The team was trained to use fish bone diagrams and brainstorming problem solving techniques. The result was the development of immediate improvements in the area. Sample improvements involved the development of a raised platform to ease the strain on operators as well as the reorganisation of the layout of the machinery and a general tidying up of the area.

A full program for the implementation of Kaizen and teamwork was introduced. Twelve teams were formed and training was provided through a one-weekintroduction program, which involved a two-day lean production/ kaizen theory training while the rest of the week focused on JIT and other practical aspects of the new structure.

6.7.2 Teamwork and Multiskilling

Although prior to the introduction of lean production operators were organised ingroups or teams, these teams were not fully implemented. As the new group facilitator explained 'groups were formed but only on paper'. One of the supervisors added that 'in the old days the production manager talked about the need for workers to be organised in groups but on the shop floor there were no group activities'.

With lean production, teams were given full support and commitment particularly by the new management. For example, group meetings were conducted during work hours and a special team debriefing room was established near the production area for use by teams. The new confidence given to the experienced operators led to the resolving of many problems in the area and as the FMS team leader stated ' quality problems that had existed for a long time were solved in a very short period of time'.

An example of such a quality problem involved the variability of the circular shape of machined cylinders, the team was able to fix the problem by changing the sequence in the manufacturing process as well as developing a quality check prior to the succeeding operation. The teams would regularly meet once or twice a week depending on the status of production. With some group members operating in different shifts, some of the team meetings are held between shifts. The primary item on the agenda was usually related to technical and quality issues.

This view of the success of teamwork was confirmed by the responses to the interview questions and the special questionnaire. Operators scored "significantly increased" on all items related to operator 'freedom to plan their work' and 'operators span of control over work assignments'. Responses by operators to questions on 'degree of flexibility', and 'ability to adjust at any moment to changing market conditions', also scored 'increased' by the operators. Although the question on the ability to adjust to market conditions is primarily a managerial question, it was important to gauge the operators understanding of the company competitive priorities. The ability to respond to 'changing market demands' was understood by operators in terms of their overall production flexibility.

An important factor in the view of the success of the teams was that most of the operators were skilled operators with the flexibility to work on different machines. In the machining area for example, of the nine operators working per shift, five were multi-skilled operators who could operate every machine in the area. The other four were in the process of learning the other machines.

6.7.3 Communication

One of the key changes introduced by lean production was an increase in the flow of information between the various groups and departments. Departmental chiefs met once a week, supervisors once a day and a general meeting with operators and managers was held once every 6 weeks. Near the FMS, a special area was made available for teams to meet. The room had bulletin boards and a variety of charts, diagrams and tables describing the various aspects of production and associated performance levels (figure 6.8). The room was relatively large and both workers and staff had access to it. Teams met in this room at least twice a week depending on the work schedule and need.

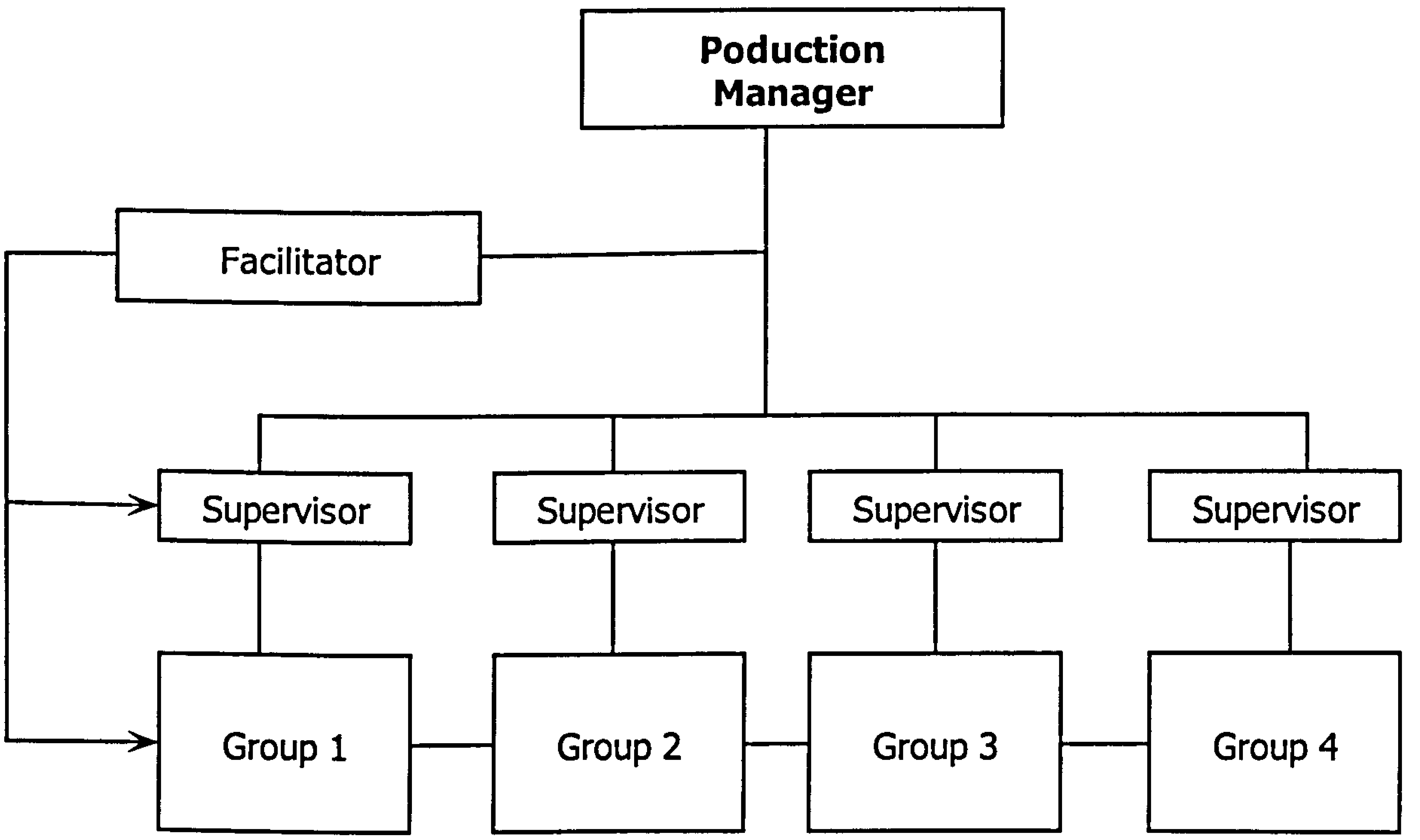


Figure 6.7: CMC Compressor facilitator role and the new team arrangements in production

6.7.4 New position of Facilitator

This was a new position created in cooperation with a local university. The position was designed to complement the lean production philosophy adopted by CMC. In particular, the group facilitator role focused on enhancing group/ team development in the production area as well as throughout the organisation (figure 6.7).

The fact that CMC had established a cooperative relationship with a nearby university (particularly in an area other than R&D which is typical of the type of cooperative relationships with academia within manufacturing companies) is indicative of the extent of commitment by the new plant manager to lean production strategies and their full implementation in the company. It can be viewed as a clear statement that lean production adoption was a genuine attempt at improving the performance of the company. By 1999, CMC had streamlined its operations and as the plant manager indicated *'we have successfully introduced a new compressor design to production with the minimum of problems using a core team of multi-skilled, experienced, and efficient workforce'.*

6.7.5 Supervisor as team leaders

The new plant manager also introduced changes to the staff positions, one of the key new organisational restructuring decisions was to dismantle the technical/planning department. The reasons given for this drastic action were that the technical/planning department had assumed 'too much control' over the production process and in the FMS area in particular.

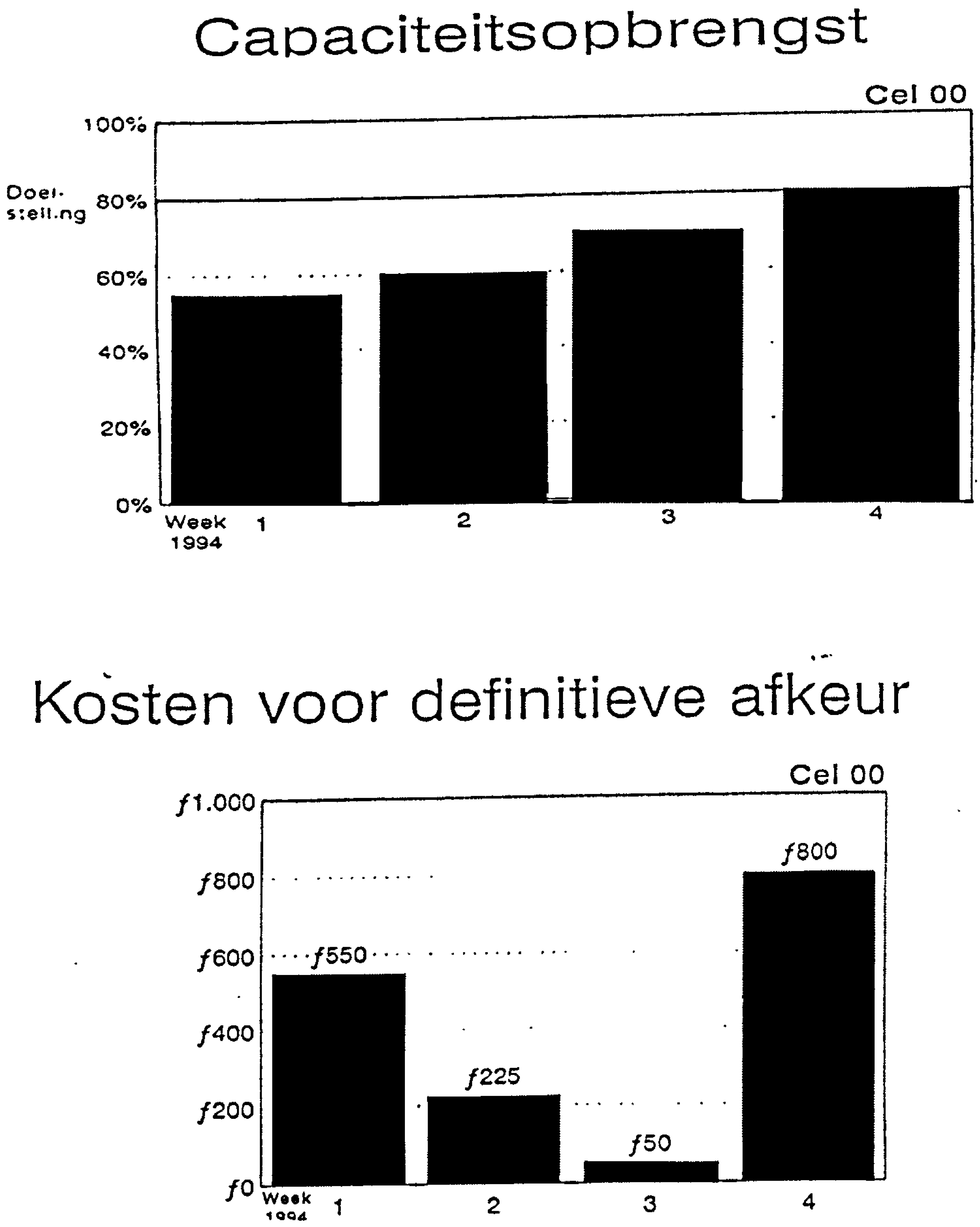
In interviews with two of the Mechanical Department supervisors had pointed to a degree of dissatisfaction with the existing work organisation structures. In Interviews conducted in November 1994, the key issue for the supervisors was the degree of the technical department's control over the production process and the FMS area in particular. Supervisors and Operators saw the technical department as exercising 'micromanagement of work on the shop floor'. Supervisors openly referred to as 'the heavy department' reflecting its perceived over-control of production. This department was responsible for all functions related to the production process and had operated in a highly centralised manner. Areas such as quality control, maintenance, planning, as well as production were all micro-managed by the staff of the technical/ planning department. In Interviews with the engineers in the technical department the need avoid mistakes was given as the key reason for the tight control. In responding to questions on the Complexity of the FMS it was agreed that complexity was a factor. Supervisors and operators on the other hand did not see complexity as having an impact on their work.

Another problem encountered at CMC, which could be viewed as a reaction by the supervisors to earlier perceptions of lack of control, was the perception by operators working in the newly created teams that team leaders 'are doing more work' than anyone in the teams. This observation was particularly expressed in relation to work tasks associates with the FMS.

Interviews with the production manager and operators confirmed this development in what could be viewed as a planning staff-supervisors-operators interaction triangle. The production manager referred to this problem as:

' a tendency by the team leaders [supervisors] not to delegate work tasks'.

As the team leaders (supervisors) also worked with other operators on the shop floor, they tended to do other team members' tasks. This was coupled with what could be interpreted as anxieties over the changes resulting from lean production. In follow up interviews with the two supervisors in the Mechanical Department, they confirmed that during the early stages of the lean production implementations and the firing of a number of colleagues, they were worried about their individual job prospects. The realisation of managerial plans to downsize and the fact that they did not see themselves as 'indispensable' - particularly as the company was implementing the new lean production techniques, made them work harder. In later interviews, they reflected on this early



Afkeurpercentage	5%	8%	1%	10%

Figure 6.8: CMC Compressor sample Capacity and Cost diagrams used in the FMS

period and saw it as 'chaotic'. As the company completed the restructuring, and through affirmations of job security from management and with a strong hint from the production manager for the team leaders to delegate more, the supervisors became more relaxed and delegated more work to the rest of the team members or operators.

6.7.6 Outsourcing

A key point which was viewed by the plant manager as contributing to CMC's success was a new focus on the 'core competitive advantage' i.e. its manufacturing skills. Following the introduction of lean production and the reorganisation of the plant, management decided to outsource those functions that were deemed as lacking in added value to the company. Small parts production in particular was seen more costly than outsourcing thus it was subcontracted to external companies. The decision to outsource was made based on a 'make or buy' matrix cost analysis. The analysis showed that many of the small parts produced at CMC could be bought from external supplier companies at much lower prices per part produced. The suppliers benefited from economies of scale and were able to produce high quality parts at a much lower price than CMC would be able to produce them. Reliability of supply was helped by the fact that more than one supplier for the parts existed and that the company was able to achieve good supplier relationship through the linkages with other sister companies in their group of companies. Additionally, the fact that CMC was located near a major transportation artery and that most of its supplier companies were within short driving distance made the decision to adopt JIT logistics a practical proposition.

Another novel idea introduced in an attempt to ease the effects of the downsizing of the company (i.e. the layoff of workers), was to 'farm out' the maintenance functions of the FMS and CNC machinery to an outside company in return for the contracting company hiring released CMC operators. The idea was taken seriously by the new maintenance company and a number of CMC operators were hired to work for this company.

6.8 Key Dimensions

In this section, the interaction on the implementation of lean production to the FMS environment at CMC's Mechanical Department will be discussed based on the chosen dimension of Complexity, integration, regulation, and flexibility.

6.8.1 Complexity

With the skilled machinists and the relatively simple machining tasks required for the compressor housings, complexity of the FMS did not seem to be a key issue. The use of tools and fixtures as well as the programming of the FMS was viewed as 'relatively standard' by the operators. In their view, once operators achieved familiarity with the system, the FMS operation became easier. Accordingly, no increases in complexity were detected in this case. Operation of the FMS by the skilled operators was 'not so difficult' and tools and fixtures were seen as universal. In addition, as mentioned earlier, the two programmers who were retained from the technical / planning department and had been moved closer to shop floor, provided support to the production teams on the shop floor by checking the FMS and CNC programs.

In early interviews with staff engineers in the Technical/planning department two of the respondent did agree that the complexity of the FMS was a factor in theirdecisions to keep a closer watch over the operation of the FMS. Yet in later interviews post the dismantling of the technical / planning department, responses to questions about the changes in the degree of complexity, there was general agreement that it remained relatively unchanged.

6.8.2 Regulation

With the full implementation of the lean production philosophy, the degree of autonomy of operators working through teams has been increased. This was reflected in operator responses to questions on the number of rules and procedures as 'decreased' and the degree of operator discretion as 'significantly increased'. Subsequent discussions with the operators and team leader in the FMS area informed the following:

Operators concurred that there has been a significant increase in their ability to do the work and their control over the production process as compared to the situation prior to the managerial change and the implementation of lean production. Similarly, with multiskilling and job rotation as well as the ability of the production teams to take corrective actions when necessary made it possible for CMC management to claim that the operators were 'partners' and not merely employees.

The operators are either LTS level or MTS level operators which means that the MTS level are capable of doing the programming of the machines from scratch while the LTS level are capable of doing changes to an existing program. About 50 per cent of the operators on the production floor can do program changes to the CNC and FMS. Between 20 to 30 per cent of the operators are capable of writing a totally new program from scratch. This is a relatively high ratio and is reflective of the Multiskilling approach adopted by CMC.

The ability to program the machines including the FMS by the operators gave CMC an additional advantage in simplifying the steps it took from planning to programming to machining and corrections. Operators were given the freedom to do their own programming and accordingly increased their confidence in their skills. The programming was traditionally the role of the technical / planning department. However, with the dismantling of this department and the elimination of most its staff jobs, skilled operators were allowed to do the programming. Two of the original staff programmers are now working with production teams and providing help to the operators in checking their programmes, potential errors were significantly reduced.

Nevertheless, as a result of this increased autonomy being granted to teams, some problems arose in the sequencing of jobs. However, the production manager developed a sequence and delivery time list for the teams in each area to follow. The operators had to follow the sequence to maintain the delivery schedule. The sequence was also visible on a 'planning board' which served as a reminder of the details of the production process.

6.8.3 Integration

Responses by operators to questions on changes to the interdependence of work flows and degree of interdependence between work stations as a result of the introduction of lean production did not point to any discernable trends. Responses by operators indicated that it 'remained about the same'. Nevertheless, lean production was seen by most operators to have standardised the operation in the FMS area through a set of rules and measurements introduced in the reorganisation.

Lean production team development had given the teams the freedom to decide on sequencing and delivery schedule. This resulted in sequencing and time delivery problems and confusion between departments. The production manager indicated that these problems were encountered in the as a result of the independence of the teams and existence of this problem was confirmed by the team leader and operators of the FMS.

This process *'was taken a step too far'* according to the production manager and the department teams became *'too independent and led to variances and confusion in the planning times'*. As a result from these perceptions of team over independence put foreword primarily by the production and logistics staff, It was later decided to re-centralise the planning function for all departments by deciding on an end time for each team. Accordingly, the planning for the departments was re-centralised under the direction of the production manager. Now, working in teams with the aid of transparencies, each team's 'end-time' is set for every department. The production manager looks at efficiencies 'of the total rather than the old method of measuring efficiency for each team'. The guidelines according to the production manager where that:

'...workers are given more autonomy but we make sure that they know their responsibilities and, in particular, delivery times'

6.8.4 Flexibility

CMCs decision to adopted lean production was predicated on the expectation that the full adoption of lean production would make the company more flexible and increase its ability to respond to market demands at very short notice. In retrospect, The plant manager viewed the company as 'having increased its overall flexiblity' through three key actions:

1) Outsourcing of small parts production in what is referred to as non-core activities (i.e. those that are not critical to the competitive advantage of the company).

2) Multiskilling of operators. The company opted for having a core multi-skilled, flexible workforce whose skill made it possible to adopt new systems and do changes to the production process without worrying about the ability of the operators to handle these new changes. Having a knowledgeable workforce to have *'significantly reduced the learning curve of new systems and new production changes'*. In addition, it encouraged a closer relationship between the operators and the new technology vendors and maintenance companies thus increasing operator knowledge of the systems.

3) Flexible Manufacturing Systems: in addition to the skilled workforce, having the right technological tools to implement desired production changes and the ability to machine different jobs through simple reprogramming.

These three components were present at CMC and as a result, the production team was able to adopt the new compressor design without any major disruptions and CMC did not experience the traditional teething problems that were usually associated with manufacturing of a model.

6.9 Analysis and Discussion

CMC compressors provided an example of a relatively small sized company (180 employees) which also implemented lean production to its manufacturing functions including the flexible manufacturing systems environment. The results of this interaction led to perceived notable increases in productivity and reductions in lead times. Additionally, lean production was seen by both management and workers alike to have helped the company to become more flexible and responsive to market changes.

A situation where the planning department traditionally argues with the production over who does the programming was not present in this case. Traditional friction was eliminated and management truly, it seems, believed in the need to transfer power down to the shop floor through giving control and support to operators and developing a multi-skilled, autonomous work force. Because the size of the operation was relatively small, operators were skilled and FMS programming was not an issue. Even for the robot programming, the company opted to subcontract this job too. Lean production was viewed by the plant manager to be a success. Successes in increasing the plant productivity, introducing a new compressor to production, while keeping up with increased product demands, were all seen to be the result of the full-hearted adoption of the lean production philosophy. The CMC adoption of lean production was not trouble free. Tensions did arise as a result of inadequate training. While the operators working in teams were given increased autonomy and control over the process, they were not adequately trained to manage the sequencing problems that was discussed earlier. The production manager recentralised the operation thus reducing what he saw as 'has gone a step too far' i.e. team autonomy.

Two important qualifications are immediately visible when analysing this company:

1) Production volumes: a possible reason which contributed to the successful coupling of AMT and NWM and the resultant perceived success of CMC could be due to the relatively low volumes of production associated with the market for these types of large compressors.

2) Company size: the size of CMC was of manageable proportions and made it is easy to maintain a small company atmosphere and develop the necessary teamwork structures to a higher efficiency and advantage. At the same time its size made it possible to minimise the traditional demarcation antagonisms between departments such as those traditionally found between production and human resources as well as between programmers and shop floor operators.

6.10 Conclusions and Summary

The results from this company thus seem to indicate that the tensions predicted and found in the other larger manufacturing companies did not surface in this case. In the early stage of lean production implementation to the FMS area, some problems were encountered in the operation and the organisation of team production deliverables and scheduling of work. But as these problems were later addressed by the production manager to the satisfaction of both production staff and the teams, and the lean production system was seen to perform better. The general impression from the responses of managers and operators and production staff interviewed pointed to an apparent good fit in the application of the lean production to the flexible manufacturing systems environment where the lean production system was deployed.

CHAPTER SEVEN

CMN ENGINES MANUFACTURING COMPANY

7.1 Introduction

This is another case study in which the application of lean production to the FMS environment was investigated. CMN was chosen for three main reasons: firstly; this company claimed to be in tune with the 'the best practice' approaches and has implemented a 'customised' lean production system based on these perceived best practices. Secondly, this company has the reputation of being on the cutting edge of the technology in its field and has consistently adopted new production technologies including flexible manufacturing systems (FMS) making it an ideal candidate for this study having implemented the lean production system to the FMS environment. Thirdly, which we will discuss in more detail later, is that this company used a systematic and formalised approach to the implementation of the lean production system. The implementation of lean production followed a highly prescriptive model that was developed with the help of consultants and an organised bureaucracy using high levels of standardisation and regulation.

Based on these three factors and the added advantage of access to the company that extended over a period of four years, CMN was well suited for the detailed study and analysis of the relationship and interaction at the shop floor level between lean production and the FMS. In the first section of this chapter, a general description of the company and its internal environment will be provided with a description of the production system used as well as the lean production approaches incorporated within that system. The second part will describe the interaction between the two and will present the points of tension identified in the research and the changes that have occurred over the four year period which illustrated the complex nature of this interaction. Section three will provide a general analysis of the case as well as a detailed analysis of the stress points associated with the production system and the resultant managerial changes to the structure of the FMS and work organisation.

7.2 The Company and its Internal Environment

CMN Engines is a diesel engines manufacturing company. The company has formed a successful joint venture relationship with a Japanese engine manufacturer and another joint venture with a Scandinavian company giving CMN access to engine technology for the above 2200-cc engine range. In its three major plants in the United Kingdom, the company developed specially customised lean production system that introduced total quality management (TQM), Kaizen (continuous improvements), extensive training programs, and multiskilling to all areas of plant operations.

The second section will discuss the operation and organisational structure of the Delta plant, one of three CMN plants in the UK, and the interaction and use of the FMS within the new production system. The third section will focus on the main questions of this thesis and investigate the stress points as they relate to the key dimensions of complexity, integration, regulation, and flexibility.

7.2.1 The Delta Plant

The Delta plant is located on a 25000 square ft. site which houses high power engine manufacturing plant as well as a training centre and a CMN marketing group. The plant produces two main types of engines (K-series and B-series) with high horse power and heavy-duty engines in the 19, 30, 38, and 50 litre ranges. These engines are used for power generation, mining, and marine propulsion and locomotive. About eighty percent of the engines are used for standby power generation for hospitals, factories and so on. There are 570 employees in the plant 260 of which are direct workers working in three shifts. The factory produces 14 engines per day at an average $1 million per day.

The company had entered into a joint venture with a Finnish engine manufacturer of very large engines (traditionally engines above 6000 c.c. used in cruisers and ships) to manufacture jointly a medium range engine (between 2200 c. c to 6000 c. c) to be used in large heavy construction and mining vehicles. Additionally, the company had introduced a new version of the 12 cylinder and 16 cylinder engines as well as a totally new engine series design (Q-series) with better emission standards, better fuel economy, and more efficient lubrication (with less oil leakage and lower oil changes). This new engine required a significant restructuring of the existing production environment as well as phasing out of some FMS stations and the introduction of new machinery and all the supporting technical, physical, organisational changes, and problems traditionally associated of new introductions. By May 1999, the date of the last visit to the Delta factory, the new Q-series engine was still in its phased introduction phase with less than 75 Q type engines having been produced.

In the next sections, the focus will centre on the application of the lean production system to the FMS environment in the Delta plant.

7.3 The Plant Organisational Structure

The company has a divisional; highly functionalised organisational structure as can be seen in Figure 7.1. The Delta plant structure consists of nine departments each with its own manager reporting to the plant manager: Manufacturing Engineering, Shop Operations, Materials, Quality, Finance, New Projects, Production engineering, Personnel & Industrial Relations, and Customer Service.

The Engineering Manufacturing department is run by the Manager of Manufacturing Engineering who has three other managers reporting to him: The Advanced Manufacturing Manager, the Manufacturing Engineering Manager, and the Maintenance and Facilities Manager.

MANUFACTURING ENGINEERING & SUPPORT

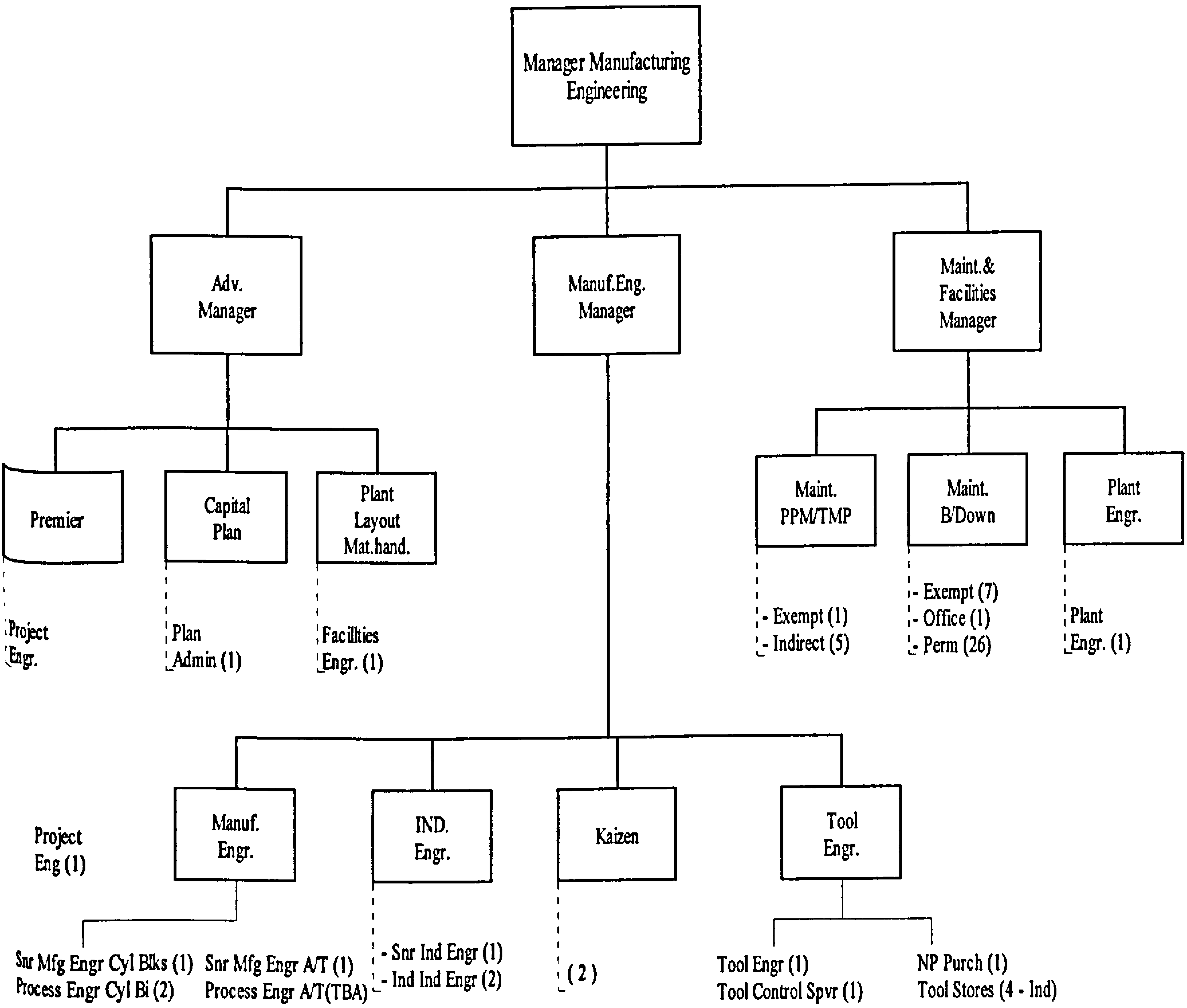


Figure 7.1: Organisational Structure

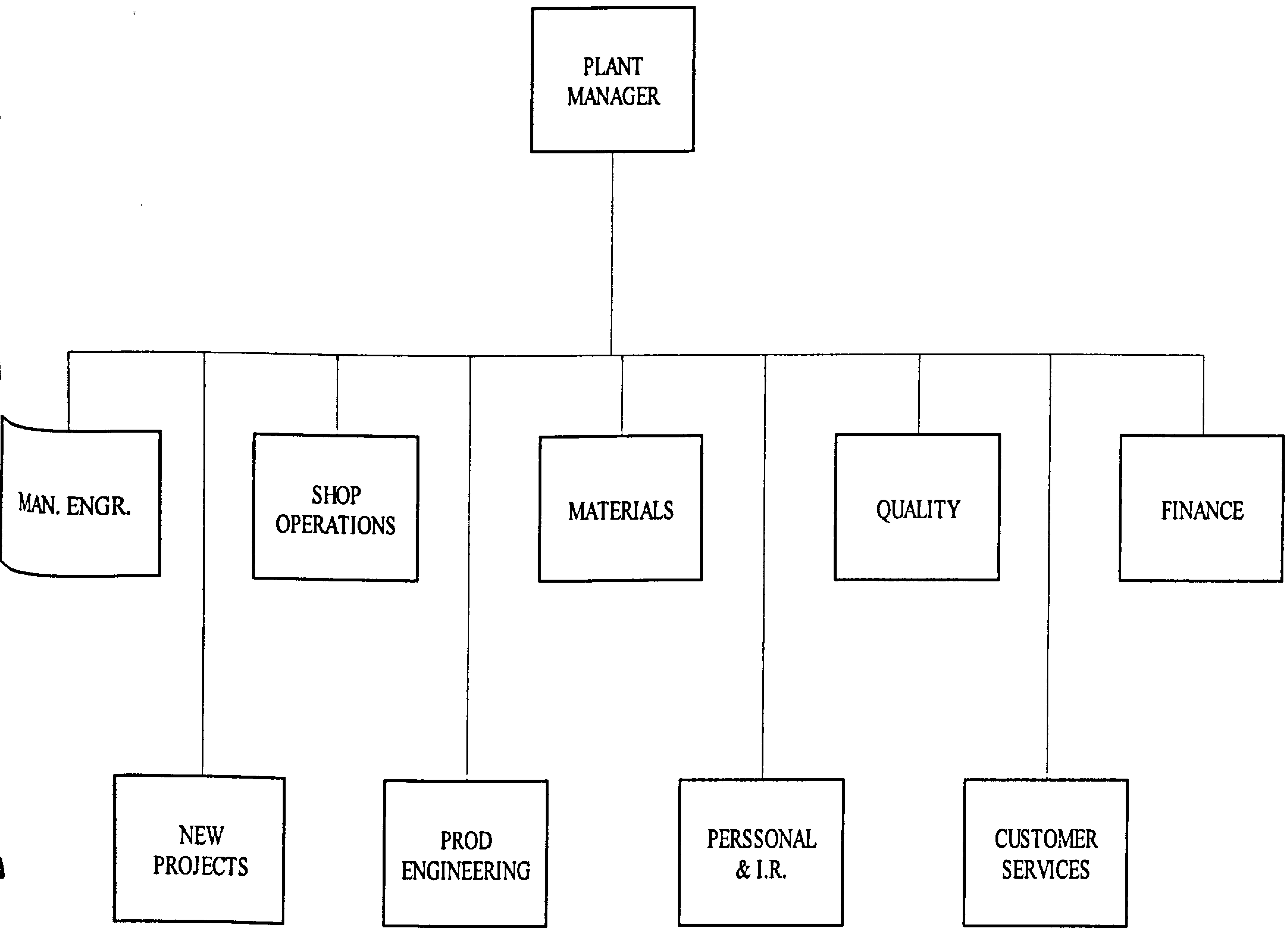


Figure 7.2 Management chart

In turn each of these managers has the responsibility for the following: the advanced manufacturing manager is in charge of new engine project development (project engineer), capital plan (plan admin. (1), and plant layout and material handling (a facilities engineer). The manufacturing manager is responsible for four departments: 1) Manufacturing engineering, which includes one senior manufacturing engineer and two process engineers. 2) Industrial engineering which includes one senior industrial engineer, two industrial engineers, one senior manufacturing engineer, assembly/test, and one process engineer. 3) Kaizen, or continuous improvement department, has two specialists, one responsible for the internal continuous improvement programs, and the other is external, responsible for developing such programs with suppliers. 4) Tool engineering, responsible for tool management and control of the tool library and all the tools and their maintenance on the shop floor. This department is made up of one tool engineer, one tool control supervisor, one purchasing and four workers in the tool stores. The third manager reporting to the manager of manufacturing engineering, is the maintenance and facilities manager who is responsible for three maintenance departments: 1) The plant predictive maintenance (PPM) / total productive maintenance (TPM) department which is made up of 5 core skilled indirect employees including diagnostic technicians; 2) The maintenance/ breakdown department which supports plant maintenance for the three shifts; 3) Plant engineering department made up of one plant engineer.

7.4 The New Production system

CMN introduced new organisational structures in all its plants and introduced a company wide customised program designed to take advantage of the lean production especially Total Quality Management (TQM) and Kaizen or 'Continuous Improvement'. The new lean production system was designed to establish clear functional structures and develop a common operational language and objectives for all the CMN plants and at every level in the organisation. The outline of this plan was based on what was referred to as the 'House of Quality' seen in figure 7.3 which focused on developing TQM and all the supporting systems and training necessary for its success. The system was customised to fit the objectives of each function and accordingly, was divided into a Marketing System (CMS), a Technical System (TMS), a (lean) Production System (CPS), and a Distribution System (CDS). Each of these individualised systems concentrated on developing the necessary skills and support mechanisms on the basis of 'customer focus' and 'Customer led Quality'.

7.4.1 The CMN Lean Production System (CPS)

The CMN lean production system (CPS) was introduced as the first step towards the development of '*a truly synchronous manufacturing system*' as the plant manger indicated. The fundamental approach for this system was stated in a company document to be the following:

'*Continuous improvement in our capability (people, equipment, facilities, systems, processes, supply base) to meet ever increasing customer expectations by eliminating waste and reducing variation.*'

In order to achieve these objectives the company focused on developing mechanisms for adopting common practices '*that bring the basic engine business principles alive*' using a common approach to problem- solving and establish a system where employees

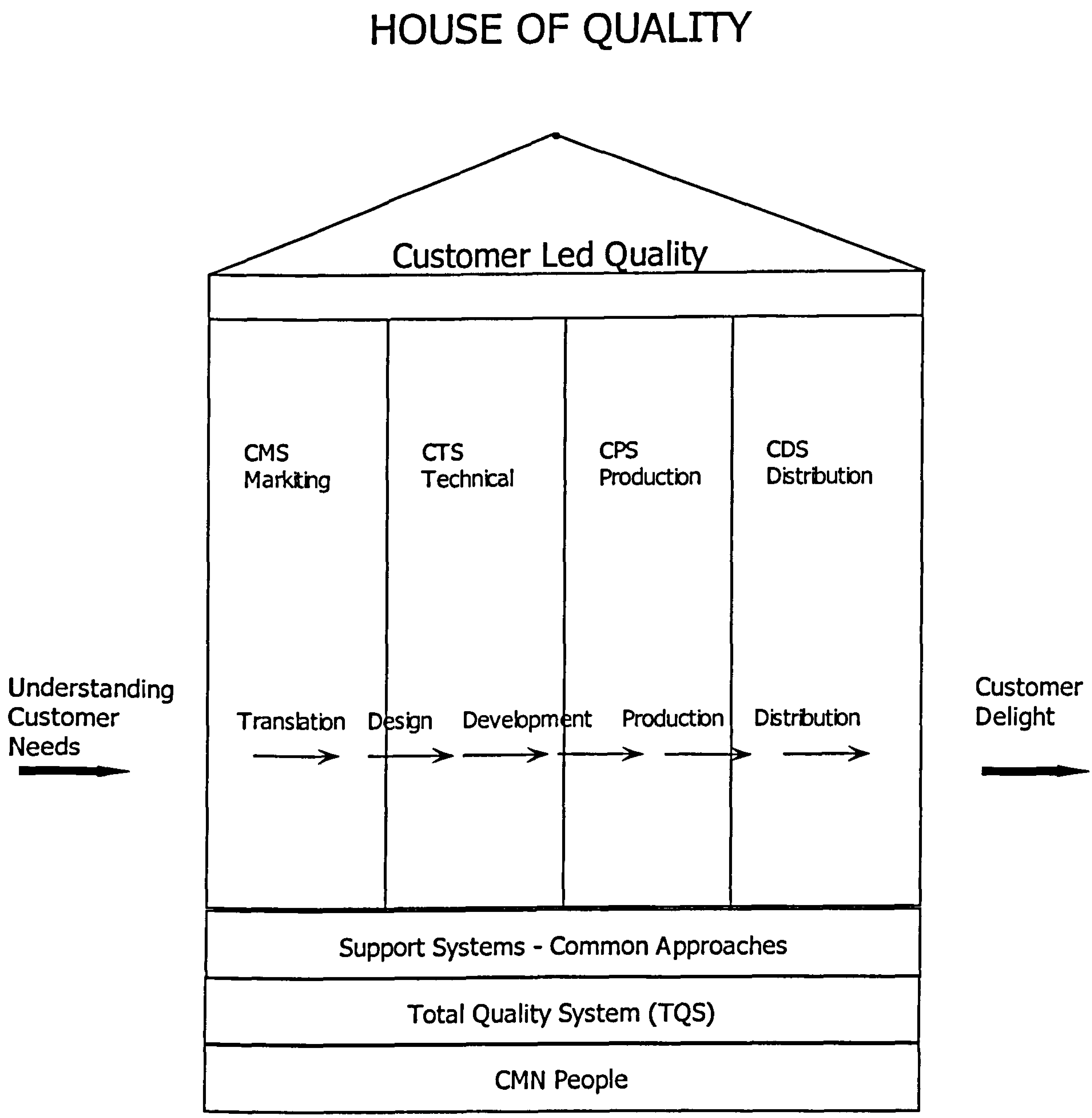


Figure 7.3 CMN new organisational concept (house of quality)

'consistently follow the same improvement process' as one internal company document indicated. CPS concentrated on applying TQM and developing a customer focus ethic in all aspects of shop floor operations. CPS was the first real large-scale program in which the management made clear its full commitment and support, financial and otherwise, to its full implementation and success. The thrust for this approach began in 1991 through a joint agreement with a Japanese partner who invested in CMN Engines and signed a joint agreement to share its 'emissions control' technology in return for help in the development of Kaizen in all CMN plants. With the total support of senior management and a *'no expense spared'* attitude, experts from this Japanese partner visited CMN UK plants and established the first Kaizen teams. An initial agreement was reached with the unions that they give their consent to the changes associated with Kaizen and work organisation changes during the introduction period. Later, a more comprehensive deal was signed with the unions in which management guaranteed that no workers would be made redundant due to any of the work changes associated with these improvements. The general premise of CPS was based on what was referred to as the *'CPS Model'* shown in Figure 7.4. This model encompassed general principles designed to facilitate achieving synchronised flows and shorter lead times. It focused on developing customer awareness, both internal and external; ensuring that *'quality is built in'* at every stage in the process; and promoting *'people involvement'* through trainirg, development of problem solving techniques, team building, continuous improvement, and an overall *'commitment to functional excellence'*. The translation of this model into the organisation began with the introduction of a top-down training program in which every employee in the organisation, including senior management, attended a training course. This training course was designed to introduce the new concepts and establish a springboard from which these principles could be adopted and further developed in the day to day operation of each function.

On the shop floor, the critical element of this training was the focus on applying concepts with a high practicable quotient, primarily the ABC of Continuous Improvement.

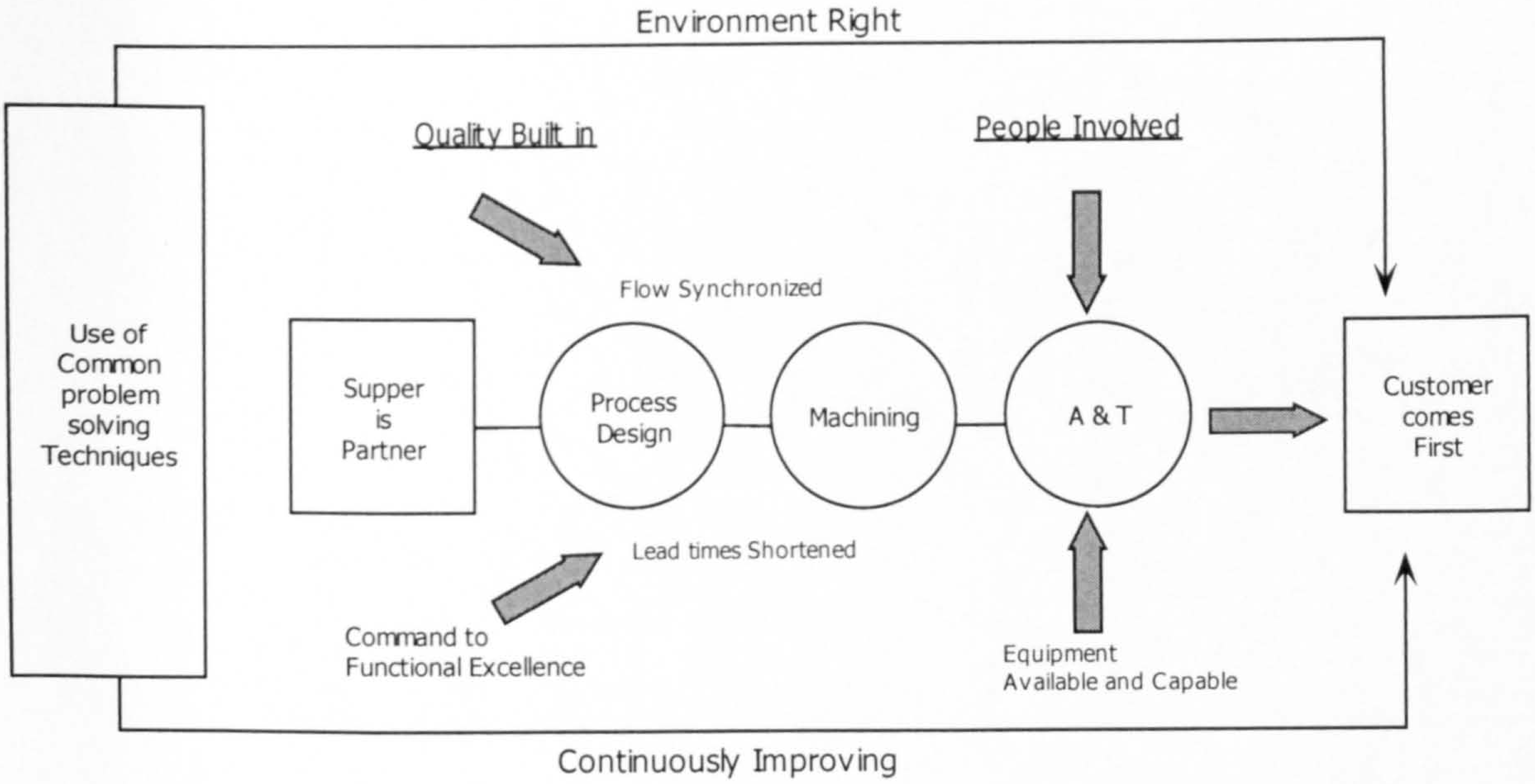


Figure 7.4: The CMN Production System model (CPS)

7.4.2 Continuous Improvement (Kaizen)

Kaizen is based on two Japanese words 'Kai' which means 'change' and 'Zen' which means 'good, for the better' and is commonly recognised as 'continuous improvement'. The adoption of Kaizen began with the creation of the first Kaizen team through a two-week project with the supervision of the Japanese partner experts. This was followed by a three-week trip to Japan for the team in which they worked in the Japanese partner's engine factory learning and implementing the mechanisms of the Kaizen system. Supervisors were also sent on a one- week training course to the U.S.A Kaizen Institute. Differences emerged between the Japanese style and the USA Kaizen Institute style where adjustments to the Japanese approach were made to fit with the American and European working practices. The Japanese partner approach differed in that it had a *'big picture focus'* and was *'more aggressive'* with its focus on business needs, while the American institute approach focused on developing *'small/ isolated'* improvements, establishing *'Islands of excellence'*, and making life easier for the operators. The two approaches were synthesised into the CMN lean production system (CPS) and the first Kaizen team project was started in January 1992. Three more teams were implemented in March and June of the same year with one of the teams focusing on standardising Kaizen changes. By 1993, a fifth team was added to focus on supporting supply base activities. Two supervisors from the original first Kaizen team were appointed as overall Kaizen supervisors reporting directly to the manufacturing manager (see Figure 7. 2).

The teams focused on achieving a synchronous flow on the block and assembly lines and used a 'TAKT TIME' (throughput time) concept to pace the flow, driven by customer demand and using levelled machining cycles, single piece flow, and minimum work in progress (WIP). The Kaizen process involved a four step approach: 1) Selecting the area which needs improvement and establishing improvement objectives; 2) Collecting and analysing data; 3) Implementing the improvement; and 4) Standardising the changes. Senior management selected areas for improvement and identified improvement objectives. The members of the Kaizen team then explained the objectives to operators

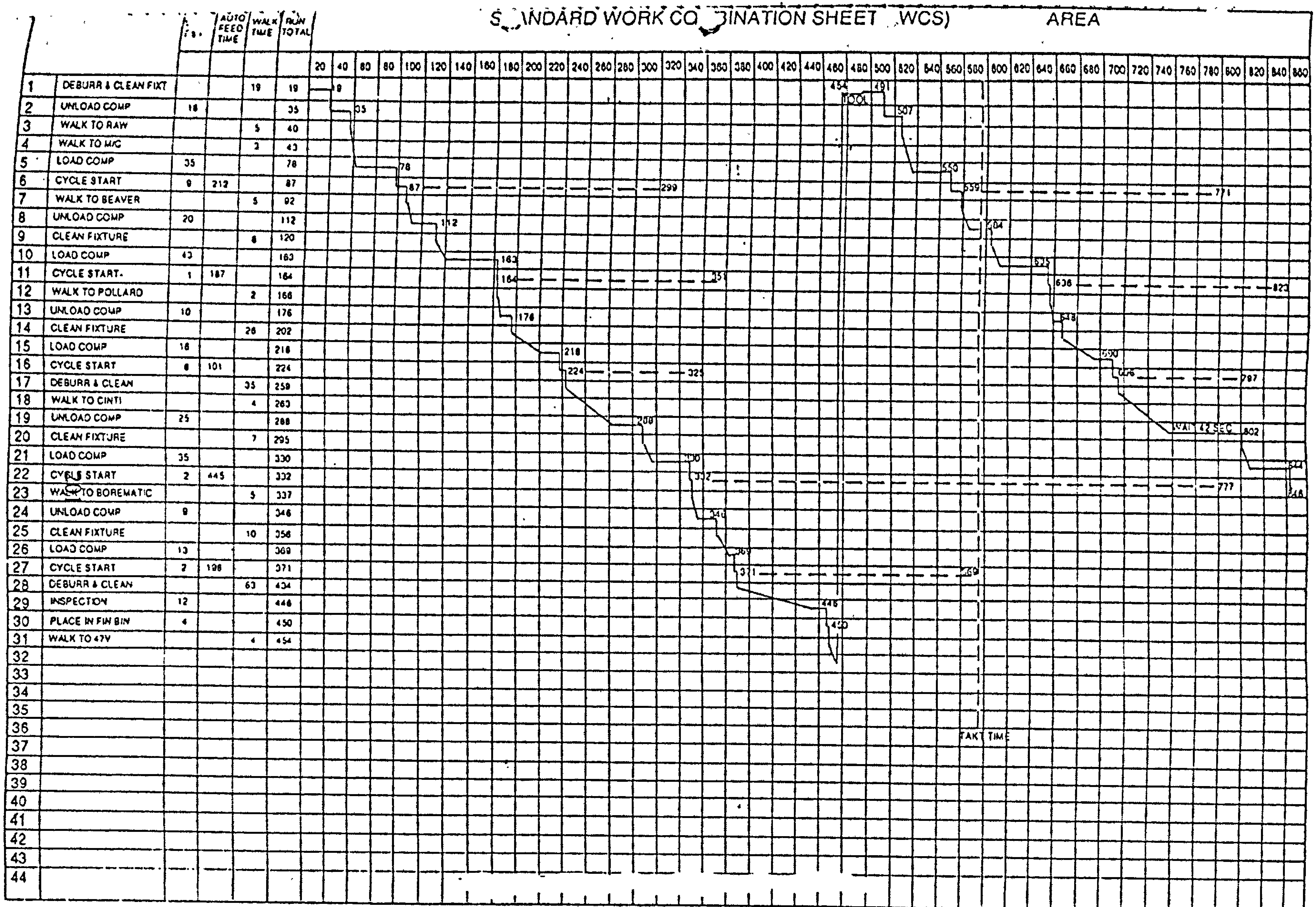


Figure 7.5: Sample of a Standard Work Combination sheet

and support groups, and agreement on the changes was reached by all the people involved.

As the Kaizen Engineer stated, data collection involves understanding the area *'warts and all'* and the use of videos to tape and document the process. A detailed activity chart is then developed based on the information from the video- tape. Afterwards, the data is analysed and waste is identified. An assessment of the options is then made and solutions are proposed. Once an agreement on the proposed changes is reached, an implementation plan is agreed upon and is then implemented. At the end of the process, the results of the improvements are compared with the original objectives and correctionsare made to any outstanding problems. The new method is then standardised and documented. A typical example of this Kaizen process can be seen near the FMS area in the Manifold line that consisted of a number of CNC machines. Poor utilisation in the Manifold line was recognised: Increased demand led to pressures on the batch production which had a two day minimum batch throughput dictated by long set-up times which created shortages during peak times. The Manufacturing manager directed the Kaizen team to address these problems. Using the four step approach mentioned earlier, one of the team members video taped (in real-time) the operation in the manifold line and through the review process all operations were broken down into individual steps and registered on a 'Standard Work Combination Sheet' (Manzoni chart) seen in Figure 7.5.

By tracing operator movements, the team was able to develop a layout diagram seen in Figure 7.6a, which describes the machine layout before the Kaizen changes. It was clear from the diagram that the machines' layout was inefficient and clearly needed adjustment.

From the analysis, it was determined that the machining time for the KV16 engine exhaust manifold was set at 207.3 minutes using three operators and a batch production of 9 per day. Waste was then identified in areas such as:

EXHAUST MANIFOLD LINE BEFORE IMPRONMENT
BATCH PRODUCTION MACHINE BY MACHINE
9/DAY 3 MEN
MACHINE TIME FOR KV 16 ENGINE SET = 207 MINUTES

OLD STYLE LAYOUT

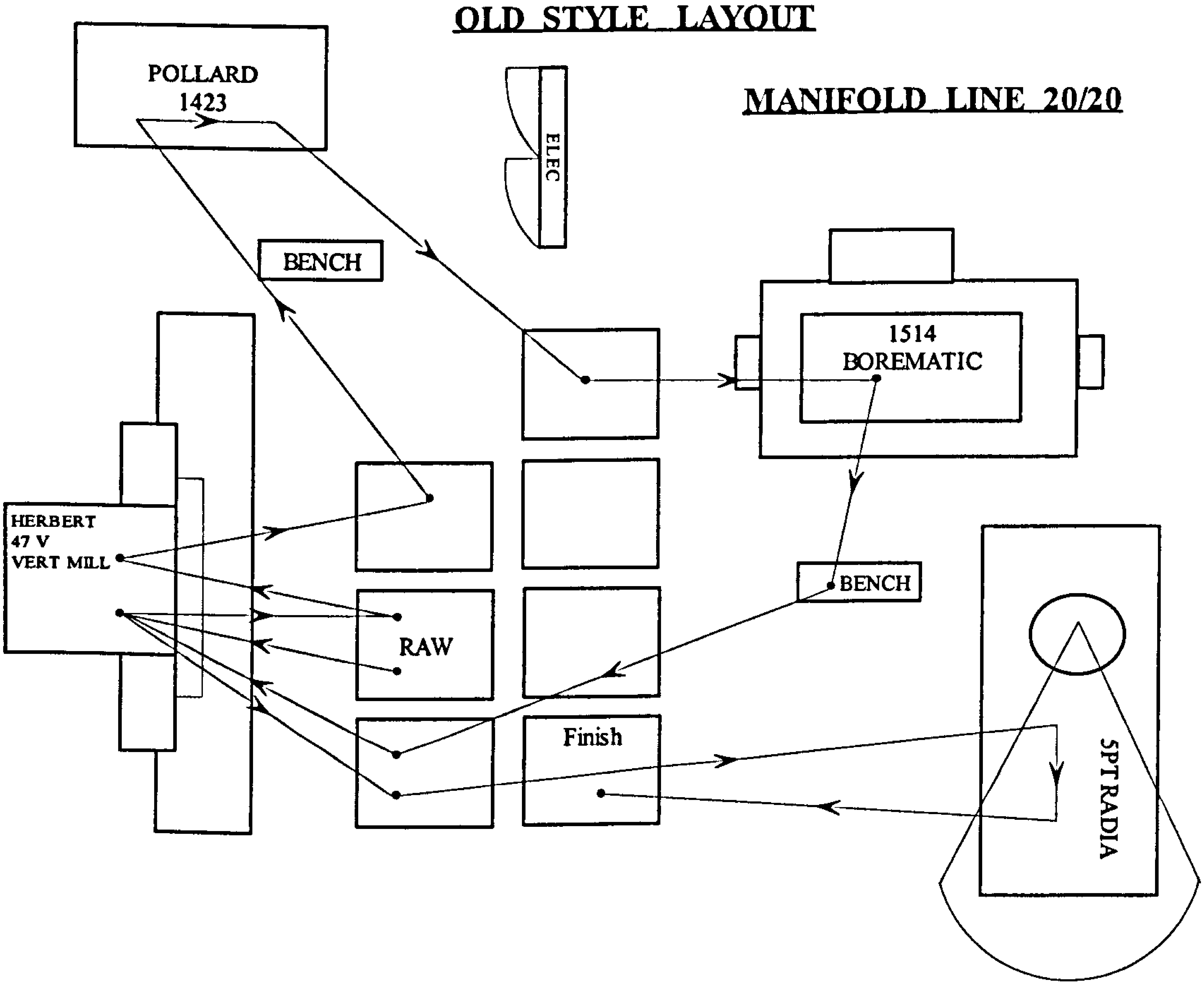


Figure 7.6: The old layout of the manifold line

Needing three set-ups on one machine causing batches;

1) Lengthy set-up on another machine;
2) Excessive operator waiting time;
3) Different floor heights for different machines;
4) Lack of flow in the machine layout;
5) Operators lifting parts in/out of bins;
6) Overall lack of control of the process.

Once the waste and inefficiency in the process were highlighted, the Kaizen team met with the operators and ideas for changes were discussed and agreed upon. In this case, it was agreed that the cell layout should be changed to a 'U' shape formation and moved to a new location smoothing component routing and reducing conveyance as can be seen in Figure 7.6b.

Other changes included requests for engineering changes such as moving the position of two bolt holes on one of the machines to eliminate lengthy change over time; raising the floor to one common height around the new section; constructing an automatic dip tank for oiling components; and a chute system for automatic removal of swarf (machining leftovers). With the implementation of these improvements, the team was able to reduce the machining time from 207.3 minutes to 67.5 minutes and transform the line into a one-piece flow line production of 12 per day instead of 9 per day. The team also reduced the manpower needed for the line from three operators to a single operator. Figure 7.6c shows the improvements in the 'Standard Times' before and after the implementation of Kaizen to the Manifold line.

These types of operational improvements played a significant role in changing the attitudes towards CPS. They helped influence the acceptance of the new changes and as one of the supervisors indicated: *'...We recognised after Kaizen that CPS is a serious new approach and that it is here to stay'*. Overall, the impact of Kaizen was felt in every aspect of the plant operations and was summarised by the operations manager:

NEW LAYOUT

MANIFOLD LINE 2020

EXHAUST MANIFOLD LINE AFTER IMPROVEMENT

ONE PIECE FLOW LINE PRODUCTION

12 / DAY 1 MAN

MACHINING TIME FOR KV16 ENGINE SET

67.5 MINUTES

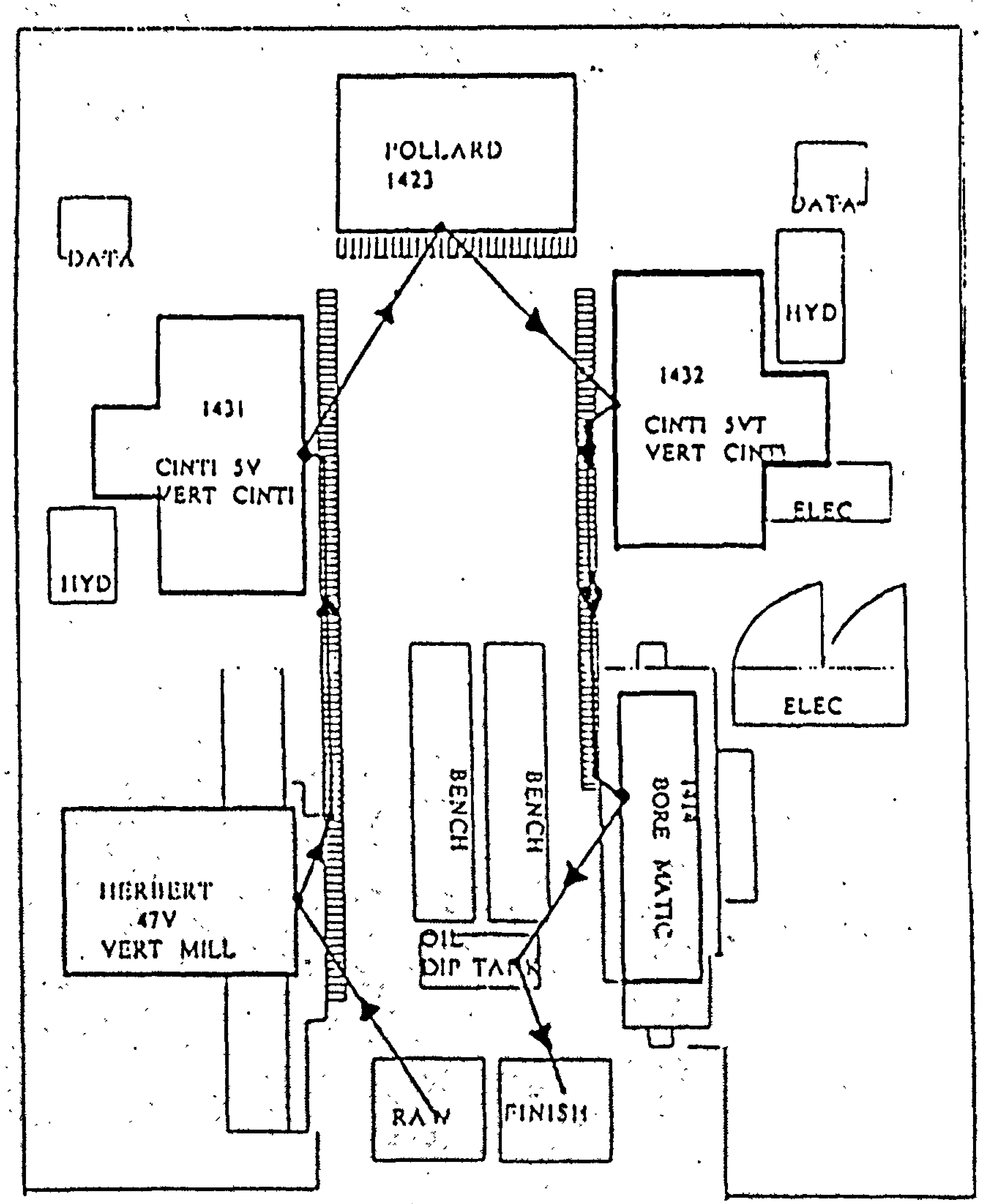


Figure 7.6b: The new Manifold layout as a result of NWM

' CPS and especially Kaizen played a major role in changing peoples attitudes. We took advantage of neglected process opportunities and it [Kaizen] played a role in attaining increases in demand and it freed up people to fund other activities and gave our teams confidence to tackle supply base opportunities'.

Training was a key element in ensuring that workers adopt the right attitude towards CPS. In the next section, we will look at the training process within CMN and its impact.

7.4.3 Training

The success of the new system depended primarily on developing the necessary skills and providing the right environment in which operators or team members could exercise these skills in a productive manner. A critical element for the success of CPS was the management's ability to establish a common framework for all employees where they could exercise these skills and use initiative to achieve desired results. At CMN, training played the key role in providing this much-needed common framework. All employees in the organisation attend training courses accounting for a minimum of four percent of the total man-hours (referred to as 'time served'). These courses, organised in cross-functional groups, focused mainly on the principles of CPS and TQM including Kaizen, problem solving techniques, and the development and understanding of the new performance measures and trend charts relevant to the production process. On the shop floor, this common induction of supervisors, and operators into the principles of CPS also established a common vocabulary between management and operators. A key aspect of the CPS model was the development of Kaizen. Yet, in developing the Kaizen training, management opted for a selective approach. Instead of applying Kaizen training to all operators on the production floor, the approach was to pull selected operators from the shop floor - for an extended period of time, to become part of a dedicated Kaizen team. The selected operators were then given extensive training on all Kaizen techniques and methods. During the operator's tenure with the Kaizen team, the operator also maintained close contact with the line through the implementation of the Kaizen process and discussions with the other operators.

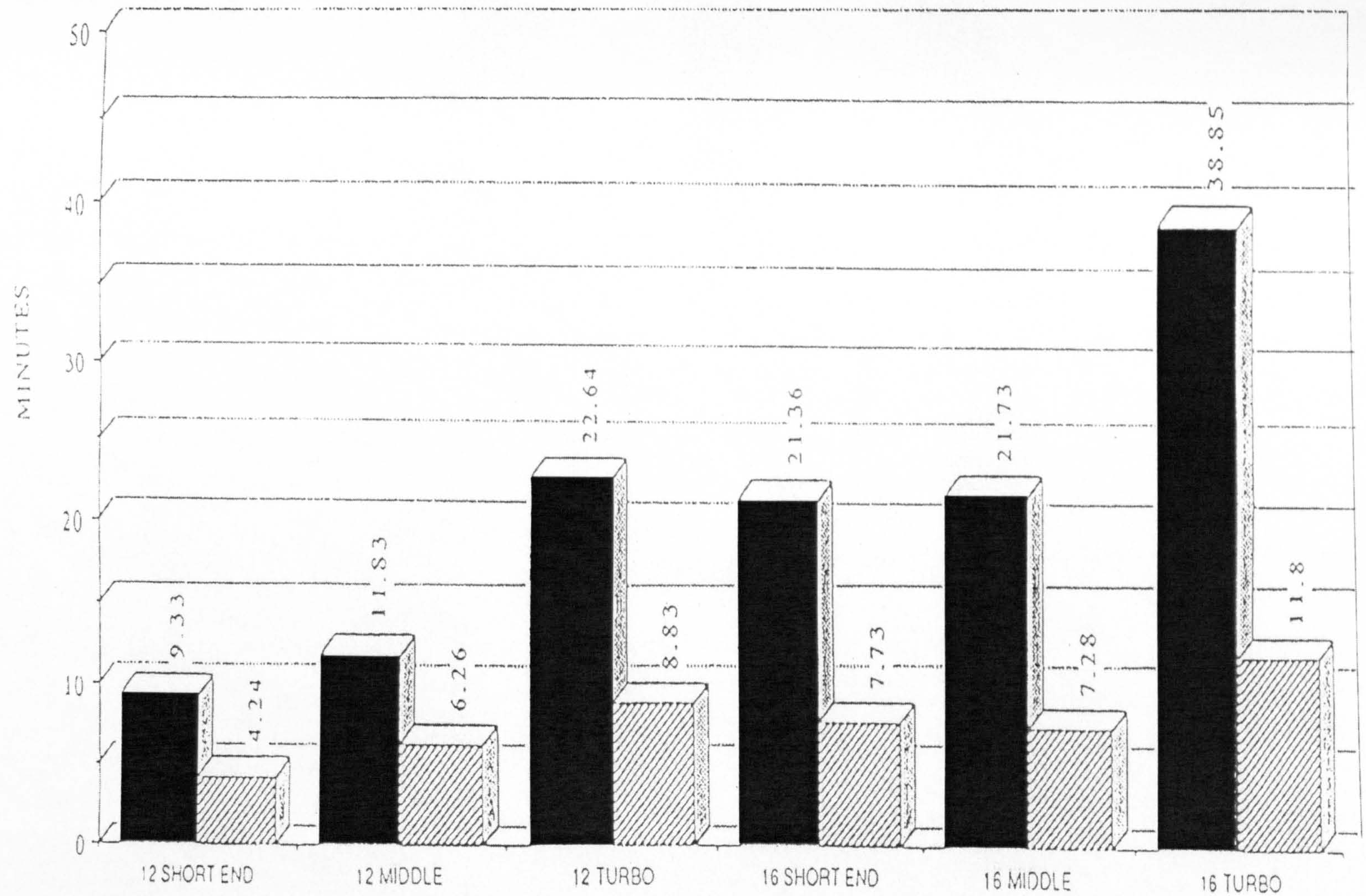


Figure 7.6c : Standard Times before and after Kaizen

7.4.4 Teamwork

Early in this study, CMN management was involved in discussions for the development of a company wide 'CPS Team Model'. The initiation of this project started with the circulation of a 'Team transition document' written by a senior corporate vice president and was distributed to all senior and middle managers in all CMN factories. This was followed by a number of meetings and discussions within each of the CMN plants designed to solicit suggestions and criticisms for the proposed transformation into a new team structure. On the basis of a 'team compliance to commitment' diagram given to the participants in these discussions, the current organisation of CMN production teams were assessed to be somewhere between the Involved and participative stages described in figure 7.7. Team members, through the CPS system implemented in the Delta plant were seen to have moved beyond the traditional structure as they had more responsibilities in such areas as quality, maintenance, and improvements on their specific job.

In 1995, efforts at further team development were well under way. The production manager indicated that following the guidelines of lean production, it was the intention of the plant manager to increase the span of control of the operators. To help the production manager in this effort, a 'Team Development Continuum' diagram was introduced by the human resources department to help in the evaluation of the teams and to point the production manager towards the necessary steps for increasing the span of control to operators.(figure 7.8). The CPS model and training offered the vehicle for the feasibility of this team improvement emphasis. Through CPS focus on five basic aspects: safety and housekeeping, quality, elimination of waste and cost improvements, Improving throughput, and the overall development of employees.

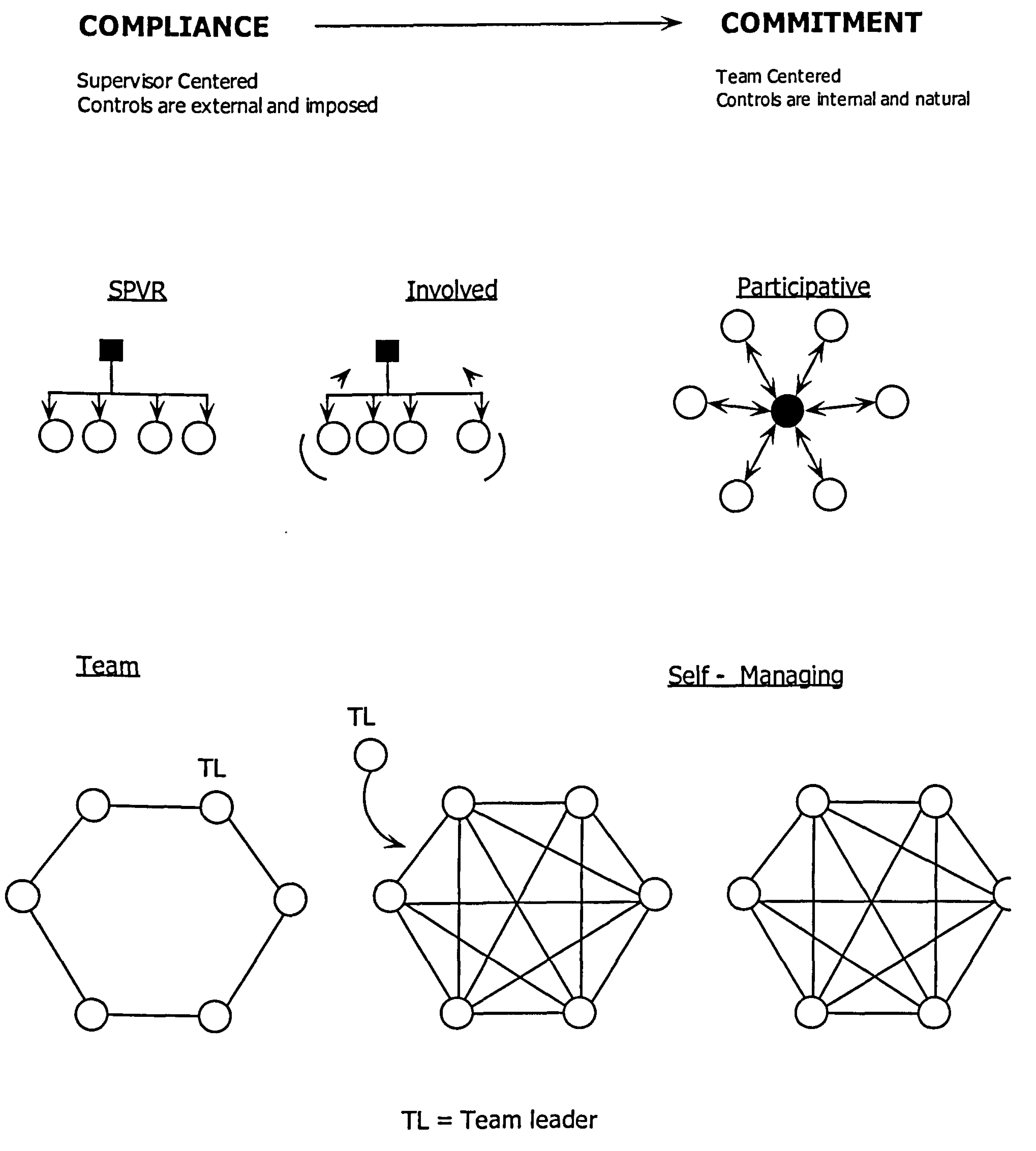


Figure 7.7: The Cps Team Model Compliance to Commitment

7.4.5 Total Quality System (TQS)

At the core of CMN lean production system (CPS) is the introduction of a 'Total Quality System (TQS)' based on the popular TQM approaches. TQS focused on continuously minimising waste and reducing variability in the production processes. New procedures were installed which formed the basis for a prevention oriented quality improvement effort. All CMN employees were expected to conduct their work in accordance with these new practices.

A CMN Quality Policy statement, seen in Figure 7.9, was introduced and circulated and posted throughout the organisation, and was explained to employees as a part of the CPS training program. Measurement systems were introduced to ensure high product and process quality in all stages of product development. A 'Right First Time' approach was a key part of this TQS philosophy. A 'Baldridge Criteria' based on the Baldridge Quality Award standard was used as a benchmark for monitoring quality standards and improvements. These measurement systems also formed the basis for the review of current practices and the development of the continuous improvement (Kaizen) approaches (figure 7.9b). The implementation of the TQS as a part of the CPS system has had a dramatic effect on improving product quality. Since the introduction of this system, the number of defects per 100 blocks of the K series have been reduced from 19.9 defects per 100 blocks to 5.0 defects per 100 blocks in less than four years. Similarly, a dramatic reduction in the number of warranty actions has also occurred.

7.4.6 Multiskilling

Historically, being a manufacturing company, CMN has concentrated on having skilled machinists capable of handling the various NC, CNC machinery which are at the heart of engine manufacturing. Machinist skill level or grade has followed the national UK standards for qualified machinists. A typical route for an operator starts through an apprentice system usually for four years. The introduction of CPS has helped focus attention on increasing the flexibility of these operators and directed attention on

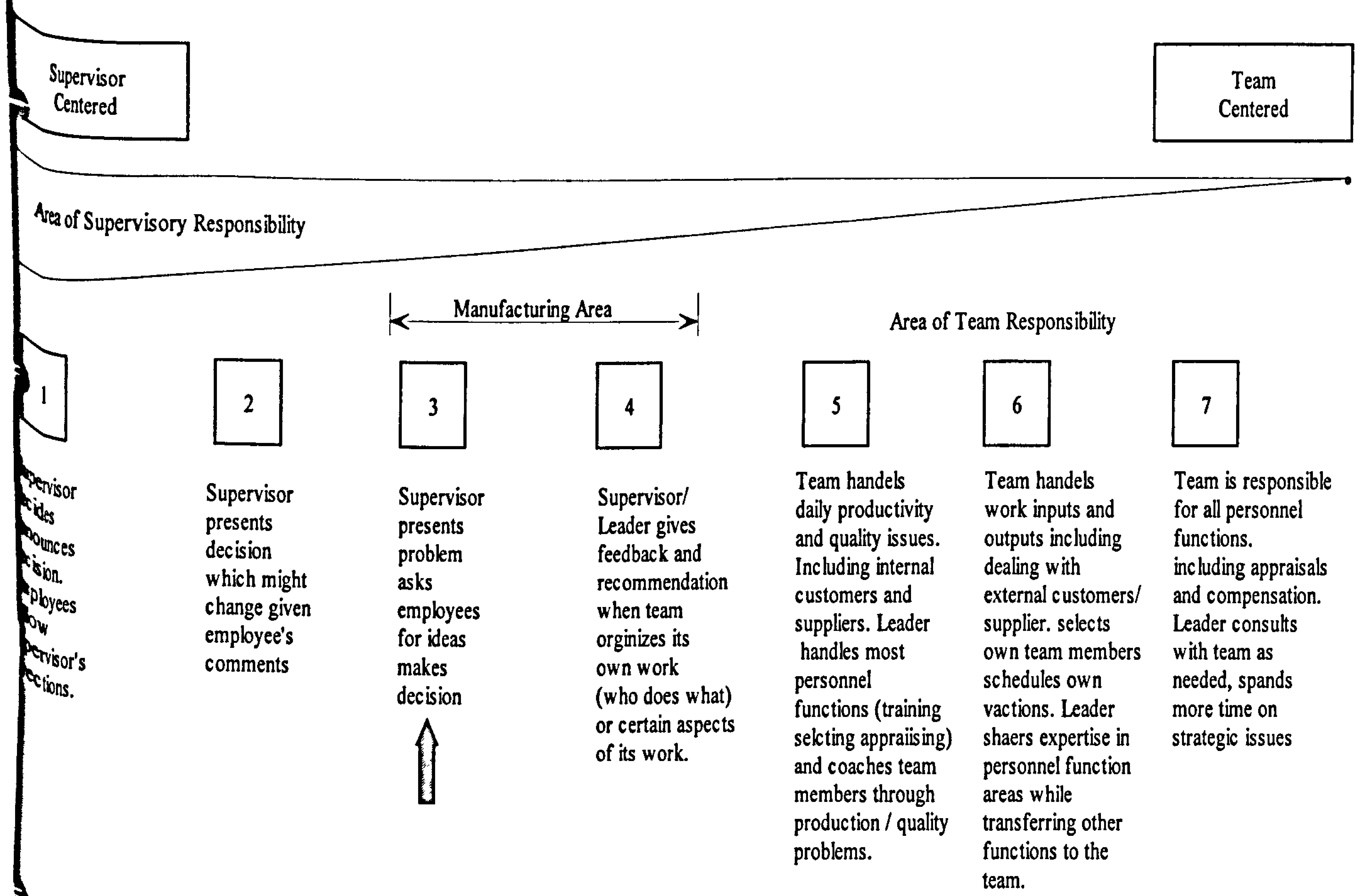


Figure 7.8: - Team development Continuum

Quality Policy

"THE QUALITY POLICY OF CMN ENGINE COMPANY IS TO PROVIDE PRODUCTS AND SERVICES WHICH CONSISTENTLY MEET OR EXCEED THE STANDARDS SET BY OUR CUSTOMERS, ON TIME AND AT THE LOWEST COST."

QUALITY IS A CUSTOMER DETERMINATION

We first must determine who our Customers are, and what their needs are. In order to serve our external customers well we must identify our internal customers and fully meet their expectation. Meeting customer needs in a quality way goes beyond shipping CMN products without defects. It includes all aspects of work. i.e. the way we answer the phone. The quality of a typed document, the correctness of a service publication and the accuracy of an engineering analysis.
As quality improves, customer expectations rise. We must identify and deal with these new expectations better than our competitors.

Each entity is responsible for establishing measurement systems which ensure that product and process quality is measured during development, manufacture, sale and customer use of the product.

The cost of attaining the necessary customer oriented quality levels will be measured in order to monitor progress toward improvement.

-TOTAL QUALITY- A WAY TO IMPROVE WORK-

Each individual employee is responsible for the quality of his/her work. The Total Quality System procedures form the basis of our Prevention oriented Quality Improvement effort and all people are expected to product their work in accordance with these practices.

Figure 7.9 – the Company Quality Policy

increasing not only the degree of skill of operators but also the variety of skills which are needed to facilitate the desired flexibility and effectiveness through CPS. An example of this increased focus can be seen in the skill progression of a typical Kaizen team leader: four years as a mechanical apprentice with first year in a training school and three years spent on CNC training as well as learning the operations in various areas of the plant. As part of the multiskilling training, he was initially assigned to the Assembly area where he learned all the basic fitting and fixturing techniques of engine assembly. Later, he was transferred to the machine shop area were he learned the practical skills of machining related functions, then he spent time in the maintenance department were he learned skills such as mechanical welding and machine maintenance. Then he was assigned to the tool room were he learned to set up and develop all needed fixtures and jigs. Afterwards, he became an operator on the FMS for a period of two and a half years where he learned all the necessary skills of the connecting rod FMS operation. Then he joined the Kaizen team and was given special Kaizen training and finally became a Kaizen team leader (three and a half years). This progression route involving multiskilling provided an example of CMNs' success in achieving desired operator flexibility were they are able to handle different tasks at different machines within the production system.

7.4.7 Communication

A key element of the corporate philosophy of CMN is establishing clear and direct communication lines both top-down as well as lateral communication between departments and groups. In any of the shop floor areas, one immediately noticed bulletin boards distributed almost in every working area as well as general meeting area across the plant. These boards were usually filled with various production and performance data and charts indicating the performance of the cell where the board was located. This performance information was regularly updated in addition to the posting of relevant company memos and notices. These bulletin boards were used mainly as a support for the more direct day-to-day communication. Concerning immediate as well as near term operational objectives, projects and production activities, group coordinator meetings were convened at 8 AM every day. On Fridays, manufacturing was halted between 8 and

9:30 AM where the time was used by the groups to concentrate on communication issues and any operator or team problems and /or needed improvement activities.

7.5 The Flexible Manufacturing System (FMS) Environment

The Delta plant specialises in the 12 and 16 cylinder water cooled, high speed, high horse power engines with an annual capacity of 8000 engines per annum. A number of engine sizes (K19, K38, and K50) based on the same engine type (K series) are manufactured with up to eighty per cent commonality between them minimising down time and reducing parts inventories. The plant also produces B-series engines in the 3.9 litre and 5.9 litre range. The use of the FMS plays an important role in the production of these high quality, fuel-efficient engines.

On the production floor there are fifty machine tools including: five spindle milling machine tools, five discrete machine relay/logic programmable controllers, CNC machines such as Giddings and Lewis 2500 four axis CNC machine tool, and in the cylinder block manufacturing area, a three station Flexible Manufacturing System. In addition, a number of specialised machines as well as an ALFING ($4 million) specialised machine tool used for special simultaneous line boring of seven to nine bores at a time (depending on the engine block size). Other tooling activities in addition to the milling/drilling include tapping and finishing operations. One or two operators as a part of production area teams operate the majority of these machines. For example, in the finishing area there are 10 machine tools operated by five operators (Some of the older machines still operate using a computer floppy disk containing the operation program written for specific tooling jobs).

The FMS's used are generally three station FMS with a rail guarding changer used for machining a variety of components such as gear housings, exhaust manifolds, and thermostat housings for the various diesel engine types.

The new FMS stations for the new engine design include seven new KOLB FMS machines, Varimat machines, and two engine washing machines. A total of 39 people work on these FMS stations working in 3 shifts, an average of one operator for every two machines (Operator starts the machining operation on one machine and begins engine setup and clamping on a second machine). Additionally, the production area contains 20 OKUMA LC40 CNC machines some of which are dual machines and are operated by a single operator.

7.5.2 Three Dimensional Measuring Machine

This type of CNC is closely associated with the FMS. It is located in the FMS area. Called the Co-ordinate Measuring Machine it is used to measure tolerances of machined engine blocks and components. The machine is a high resolution, three-dimensional system. Its use in the FMS environment was said by the production engineers to have added another element of complexity of operation and programming to the regular duties of the FMS operators. Such a machine required special training in addition to the need for proficient programming knowledge.

7.6 CMN Human Resources Policies

The implementation of CPS depended on the development of coherent human resources policies and practices. CMN management has clearly understood the need to develop programs that are designed to affect acceptance and cooperation from all CMN employees. In one of the documents used for CPS training courses, the Human Resource view was summarised in five points: people are our greatest asset 1) can appreciate in value; 2) source of all improvement ideas; 3) can/must be trusted; 4) best when people work together as teams; 5) need to be motivated and recognised. These general statements provided the guidelines for developing human resource policies that were meant to help facilitate the introduction and application of CPS to all levels of the organisation.

The technique used for implementing these human resource guidelines focused on encouraging the adoption of common practices that - as the human resources manager stated, would:

'bring the basic engine business principles alive through the development of operator skills based on a common approach to problem solving and consistently following the same improvement process.'

The effort to harmonise the thinking of the CMN employees to CPS started with a detailed employee survey which was conducted by an external consultant. This survey, inter alia, contained an employee attitude survey whose results were used to redesign some of the work aspects on the shop floor. This survey has also helped managers to have a clearer understanding of the needs and demands of employees.

Another human resources related input of CPS was the use of a performance benchmark system based on a percentage point system in which pay incentives (increment pay) are used on the basis of a special performance percentage point system. Also, a new CPE: recognition system for 'CPS Excellence' was also introduced to provide further incentive to maximise the potential of CPS.

A reduction in the number of job grades was another CPS related change. This reduction was possible only through extensive negotiations and finally an agreement with the unions. A change in the payment system to reflect reward for new skill acquisition was also introduced.

7.7 Analysis of the CMN lean production system

Through interviews with the various actors in the manufacturing organisation (manufacturing engineers, production managers, production staff, supervisors or team leaders, and shop floor operators) and review of the progress over time of the CPS system, it was possible to record first hand the transformations and changes in the production environment.

It is clear from the previous sections that this company has adopted the lean production system throughout the organisation including the FMS production areas. Accordingly, it is an ideal case to investigate the points of tension in the relationship between the CPS lean production system and its application to the FMS system.

In the rest of this chapter, I will focus on the Flexible Manufacturing Systems environment and will further analyse the interaction with the CPS production system.

7.7.1 The CMN lean production system (CPS): rhetoric versus reality

With the benefit of hindsight, the decision by CMN management to adopt CPS could be seen as a methodical departure from earlier organisational systems. This system was not a 'flavour of the month' approach that characterised many companies in the same situation. Four years after its introduction CPS remains the core organising concept of the company and its original language and buzzwords were still being used. Yet, over this four years period, CPS has undergone many changes and transformations. These changes were a result of the dynamic and complex interactions between management, production staff and shop floor personnel. These changes were also the result of tensions between the organisational arrangements being practised on the shop floor and the demands of the flexible manufacturing system.

Based on responses to interview questions by managers, production staff, supervisors, and operators, many of the original revolutionary ideas of CPS have been watered down and in some cases discarded completely. Early in this study, tensions on the shop floor were beginning to emerge fuelled by increased pressures on operators as a result of the new measures associated with CPS as well as the increases in production volumes. Points of stress were detected in the FMS environment which appeared to be caused in part by conflicting messages being sent to the operators through the application of CPS to the FMS.

7.7.2 Tensions and Stresses in the CPS System

As mentioned earlier, at the beginning of this study in 1995, managers were clearly excited by the positive impact CPS had on CMN in general and CPS success in increasing productivity on the shop floor. But, over time, as the impact of the initial improvements began to plateau, tensions began to emerge.

By the second year, judging from responses and statements from different levels in the organisation, the earlier bright picture of CPS seemed to dissipate and the attitudes of operators, supervisor and even mid level managers towards CPS had shifted to the negative.

Many of the operators felt a shift from what they were originally informed about the benefits of CPS. There were increased pressures, increased workloads as well as increased control by the production manager and production staff on the basis of the new CPS measures particularly Kaizen.

In the manufacturing engineering department, the concern revolved around the degree of control over production. The manufacturing engineers (or process engineers as they are sometimes called) felt that operator and operator autonomy particularly in the FMS could negatively impact production operations. Manufacturing engineering saw that these teams were 'wasting precious time in group meetings' that did not necessarily lead to concrete results. In interviews particularly with production engineers, there were strong feelings on the issue of operator FMS programming skills. These engineers clearly felt that the programming function should remain with the manufacturing/process engineers and that operators should not be allowed to tamper with FMS programming. Even though the operators or team members were recognised by the manufacturing engineers as skilled and certainly capable of operating the FMS, the view was that there was an increased risk of 'costly mistakes' that could jeopardise the FMS and the overall production schedule.

These tensions relating to the practice of CPS and the resultant transformations and pressures on the shop floor continued to grow. Dissatisfaction with the direction of CPS became more vocal from operators as well as supervisors. Eventually, management restructured the CPS and suspended many of the original progressive measures particularly the teamwork structures in the FMS areas.

What were the reasons for this change and to what extent were these tensions the cause of the suspension of the team structures and the return to the approaches traditionally practised by production and manufacturing engineering? In the next section, I will go over the early stages of the development of CPS and the tensions that emerged and will focus on the key dimensions of regulation, and complexity, as the key actors in this process.

7.7.3 Implementation of CPS and Increased Pressures on Operators

With the implementation of CPS pressures on the operators increased and although CPS subscribed to multiskilling of operators - typically increasing their span of control over the production process, operators felt less rather than more autonomous and saw tighter control by production management and manufacturing engineering over the production process in their areas.

Although operators subscribed to the management line on the advantages of CPS and Kaizen, they did feel that there was a significant increase in the number of procedures and rules associated with the operators individual work areas. Because of CPS, everything was measured, charted, and continuously examined. Any weaknesses in the production area were now clearly visible and as work increased, operators were constantly trying to solve these problems and follow up on the newer problems as they emerged.

Initially, operators felt that with the team changes with CPS that they have gained more independence and control over the production process particularly in the FMS areas. When the FMS operators were questioned about their independence at the beginning stage of the implementation of CPS, the immediate response by most of the operators was that 'yes they felt increased independence'. Yet, probed further by the questionnaire into their daily procedures and routines, they indicated that paper work had increased and that there were more charts, tables, performance measures, and reports to be written on the status of the FMS and production.

What emerged was a complex dynamic of interaction processes between management, staff, and operators which appear to be driven in part by the FMS technology and the lean production approaches. The responses to the interview questions did not give any clear cut answers or agreement by the parties to the question of increased control. Yes, the operators are operating under a new regime giving them more tasks and multiskilling as a team, but it is also true that the input of the production manager and manufacturing engineering staff on the FMS has also reduced the room for autonomy by the operators. Nevertheless, The responses of the operators themselves were mixed. Initial responses invariably followed the 'management line' of tremendous improvements and increased responsibility but probed further and as the interviewee got more comfortable with the discussion more independent views began to emerge and in a few cases resentments over the changes emerged particularly by older, more experienced operators.

Although the workers had more to do, many did not feel that they had increased their independence since the introduction of CPS. The perception was that management increased rather than decreased its control over the production process as managers kept a close watch over the process and the operation of teams through the various measures implemented within CPS. Consequently, operators felt the pressure to deliver as well as to keep up with these new changes incorporated through CPS and the performance analysis criteria. When the production manager was questioned about the improvements resulting from CPS he replied:

' ...plenty of improvements, with CPS there is more information available. I know what is happening at the floor every step of the way... which machines are performing and which are not, I know if a cell is having problems or not and through all the charts and statistics I have a continuously updated picture of the situation'

The use of CPS in the FMS area extended management control by providing faster and more precise knowledge of what is happening on the shop floor all the time. CPS also provided the mechanism for clarifying what was expected from every level at the shop floor by adding a strict measuring criterion for the performance of the various tasks.

A number of reasons were given by managers who corroborated this impression: They pointed that, among other reasons, that the complexity of the system and the large number of product and specification matrix of changes as possible causes for the strict criteria and rules imposed on the FMS team. But, the most noteworthy were comments by manufacturing engineering manger who cited fear of damaging expensive equipment as a reason for tighter control. This comment had been heard on the shop floor making operators feel less rather than more independent. When questioned about the meaning of 'mistakes', one manager's reply was:

'Take the 3D measuring machine, it is the most sophisticated technology available and we bought one. This is a very expensive machine and I can't afford to have the operators playing with it. That is why I have left the job to the process engineers. One mistake in the calibration would take a long time to fix and would cause costly delays.'

Thus, from the perspective of the operator on the shop floor, the new changes resulting from CPS led to misapprehensions. In certain instances, the interaction with CPS was exasperated by failed attempts to increase capacity by the FMS team. This was due to the presence of bottlenecks based on a limited tack-time of two hours (available hours/number of units).

In section 7.4.2, We have seen the high regard expressed by managers for the use of videotape in the Kaizen process. Although, on the surface, this seemed to be acceptable to the operators, in reality, many operators felt ill at ease with what they viewed as an 'intrusive' process. A number of operators in the FMS expressed their dissatisfaction with this part of the Kaizen procedures and the practice of 'choosing and withdrawing an operator ' from the FMS area for Kaizen training. Operators did not like the idea of pulling a fellow operator off the line to work at a comfortable desk job with the Kaizen team. This selection approach was viewed as 'elitist' giving the chosen operator an advantage over the others in the team in his new white-collar position.

In general, the attitude towards Kaizen remained timid and it did not flourish as the original CPS plan stipulated. The CPS approach of transforming all production operators into Kaizen implementers has not been successful. Kaizen trained operators did not follow up on what they have learned through the various Kaizen training initiatives. At the same time, management did not follow up and insist on full Kaizen implementation as originally planned. This, in my opinion, was a reflection of the tension in the relationship between operators and supervisors with production and manufacturing managers.

Kaizen was another structure that was not adopted wholeheartedly at CMN and its failure did not cause any major concerns for management. Instead, the role of the Kaizen team was transformed - and Kaizen team members became specialists in 'fire fighting' production line problems through the use of problem solving techniques. This process continued and led Kaizen to develop as a separate identity form on the shop floor.

7.7.4 Managerial Control versus Employee Empowerment

The response to CPS and its implementation on the shop floor followed the familiar managerial control / workers empowerment dichotomy. Although CPS intended to increase worker empowerment through the adoption of the team-based structures, at the same time, it introduced a new regimentation and discipline that scrutinised every aspect within the production process. At the FMS, the new production system added another layer of control to the existing extensive set of rules and regulations. This mix of a new production system, increased complexity, and increased regulation led to increased tensions on the shop floor between management and operators.

The new production system with its lean production principles led to a series of employee reactions over time. Reaction ranged from initial enthusiasm over the introduction of new work organisation measures with visible improvements to the production system, to passive acceptance of the new changes, to dissatisfaction with particular aspects of CPS. Once CPS was fully implemented, there were aspects within it that significantly affected the traditional roles of operators, supervisors, and even managers. In this case, operators on the shop floor went through an early period of independence through the implementation of team structures and multiskilling efforts. Yet, when it came to the manufacturing / process engineering staff, they viewed this increased independence as counterproductive. They consistently lobbied for stricter control and regulation over team operations.

One of the lean production ideas introduced through CPS was the development of participative team structures where operator teams assumed new responsibilities such as internal coordination, and some administrative responsibilities. A key CPS related effort was an attempt to transform the role of supervisors into Coordinators -which is one of the key roles of supervisors- through a job title change to 'Business Coordinator' (BC). This novel participative team format where the business coordinator (supervisor) co-ordinates operator activities which assumed specific individual responsibilities was short lived. Tensions emerged between operators and engineering staff relating to the role of these teams and their span of control. At the FMS, the skilled workers were now doing programming functions on the CNC machines as well as the FMS.

Many engineers viewed these changes as giving away too much control to the teams and that this type of structure would affect productivity. This attitude towards teams was prevalent between the manufacturing/ process engineers whose arguments were anchored in the traditional mass production view of the production system.

7.7.5 Corporate Transformations: macro level changes and CPS

While mid level managers continued to fine tune and deal with CPS related issues on the shop floor, corporate changes on the macro level had a dramatic impact on the manufacturing environment and work organisation within the company.

In the 1980s and early 1990s, most of the macro level corporate changes in manufacturing companies revolved around strategic, existential issues related to competition, mergers, market share, redundancies, and in extreme cases factory closures and bankruptcy. These macro level events tended to have severe consequences on the shop floor level. Issues such as, for example, incremental quality improvements and other production related concerns lost their significance when the company as a whole faced a crisis. As managers, supervisors, and operators worried about their livelihood, lean production system and any micro level compatibility or incompatibility issues relating to the use of FMS, drastically lost their importance as the organisation as a whole became entranced with the dramatic transformations that befell it.

In the case of CMN, these macro level transformations were of the positive kind. CMN had entered into a joint venture partnership with a northern European engine manufacturer with the objective of developing a new type of engine (Q Engine) for the medium to large engine market (2200 to 6000 cc range). This new partnership resulted in a $100 million investment in capital expenditure and manufacturing machinery for the new Q engine at the Delta plant.

The addition of a new manufacturing area for the Q engine while at the same time maintaining the production schedules of the k12 and k16 engines also significantly increased the complexity of the plant operation and led to increased demands on engineering staff as well as for employees on the shop floor, particularly operators in the CNC and FMS production areas. This new development had a dramatic effect on the overall work organisation of the factory and acted as a catalyst that brought the tensions concerning the implementation of CPS in the FMS area in particular to their climax.

In the flexible manufacturing systems (FMS) area under study, a decision was made by management to stream line production and 'outsource' the majority of the non core elements of the 4000 parts that were traditionally manufactured at CMN. Thus was done by subcontracting these parts to outside vendors at more competitive prices. CMN was able to focus the manufacturing process on its core block manufacturing. Many of the 4000 parts which were totally machined and made at Delta were available at a lower cost through external suppliers. This outsourcing helped management to take the dramatic decision to phase out the MAKINO FMS area and the powerful FMS team was disbanded and its members were placed on other CNC's and FMS machining centres.

7.7.6 Suspension of Production Teams

In 1998, CMN management, driven in part by the opinions of the manufacturing engineers, opted to limit team operations at the FMS. The company decided to change its policy on teams citing the following reasons: the complex nature of the new engine introduction process and the need to focus attention on the core issues of new engine production and the installation of new CNC and FMS machinery while at the same time dealing with increased production demands of the K series engines.

In effect, the team structure as the corner stone of CPS was practically reversed. Teams were practically suspended as their role was relegated to smaller tasks with very specific objectives and performance measures.

The production management as well as the manufacturing engineers viewed CPS teamwork operation at this stage of new product introduction as ineffective and Kaizen viewed improvements to be a luxury at this stage. Instead, they emphasised that the operators (still being referred to as teams) should focus on new systems and manufacturing machinery introductions.

Teams could no longer operate within the ' same environment ' of the FMS. Their micro level improvements were overshadowed by macro level changes to the production including layout, introduction of new machinery, the phase-out of old machines and finally the total dissolution of the FMS unit

The suspension of teams was presented to the operators as an interim measure to focus all efforts on the problems associated with new engine introduction and in order to handle the complex 'teething problems' associated with creating a new production and assembly structures for the new engine.

This suspension of teams reflected the managerial view that the team operation is mainly for Kaizen or continuous improvements in the team cell areas and not for the problems relating to new machinery introductions and the numerous problems associated with new vendors, new programming, new tolerances, and new, more complex machinery. As the manufacturing manager stated:

'In a very short time we have seen a significant increase in the number of engine types produced, from two engines to fourteen engines. Now we are dealing with the new Q engine manufacturing set ups and I need the operators to focus on these problems...when we solve these problems and everything gets back to normal, then we will restart the teams.'

The justification that teams will not be effective at this stage of new engine introduction was not very convincing to the operators. Nevertheless, it appears that the suspension of teams did not lead to dramatic outbursts or complaints for the team members. In fact, the operators simply accepted the return to the old formulas and worked accordingly. When questioned about this seeming lack of interest in the new changes and especially the disruption of the team operation, operators pointed to the increased workloads and increased pressures that were keeping them busy.

The production manager reflected on the apparent acceptance of team structure suspension as a result of a new mode in the organisation as a whole. The implication for job security was such that it tempered operator response to the suspension of teams. The new investment of $100 million and the purchase of new CNC and FMS equipment while phasing out older equipment gave operators an increased sense of employment security. As operators saw the massive new investment in machinery and new product development, it made them feel more secure about the future of their jobs.

Another reason that tempered the reaction to the suspension of teams was the phasing out of the old FMS and the introduction of new systems and machinery. This created an environment that was ripe for change. By creating this upheaval in the production system and moving people, machinery, and resources within the plant, operators accepted the suspension of teams and other changes were easier.

On a broader level, the general competitive environment, job security was no longer guaranteed. Unions no longer had the same clout and bargaining power as they used to have. In this environment, the disruption on the shop floor, even the dissolution of the teams was accepted and the management reverted to the traditional ways of management downsizing the lean production system to specific production related issues at the micro level of production.

7.7.7 Reversal of Operator Programming Privileges

The new developments and reorganisation of the shop floor was an opportunity for the manufacturing engineering department to reassert its control over the programming functions of the FMS. Initially, CPS extended management control over the production area through the set of performance measures that continually provided timely information on the status of production. The development of strict measuring criteria for the performance of the various tasks was a way to maintain control over the process and reduce the effects of operator autonomy particularly the programming functions of the FMS.

But even these strict performance criteria were not enough to alleviate manufacturing engineering apprehension and the fear that this programming autonomy of operators would lead to a major mistake that could disrupt the FMS and have significant consequence for the production schedule. They argued that the complexity of the system and the large number of product specification matrix changes were reasons why the management should have kept all the programming functions with the manufacturing engineers and maintenance engineers only and not with the operators.

The prediction of a potential mistake on the FMS eventually came true and a crash on one FMS, while machining an engine block did occur prior to the reorganisation of the production area. The exact cause of the crash could not be established. Was it an operation team member error? Or was it a machine error? The results were inconclusive, but the damage and disruption to production was enough to remove these programming 'privileges' from the system.

With the new reorganisation of production, manufacturing engineering was able to revert all the programming to its process engineers. An 'idiot proofing' mechanism was introduced with the computer program being locked from manufacturing engineering. Now operators could only program start and program set-up latch and unlatch functions of the engine blocks. With the program being locked from manufacturing (process) engineering, only maintenance engineers and process engineers could now program or reprogram the FMS.

What emerged in this interaction between the lean production approaches and the use of flexible manufacturing systems was that the old battle lines of worker autonomy versus managerial control were still being drawn. The traditional tension of control between management and workers were still present. Even though management had introduced a lean production system that embodied all the 'in' concepts of operator autonomy, multiskilling, and teamwork, on the ground, the success or failure of these measures was dependent on the actors in the process. In this case, the coupling of lean production with he FMS did lead to initial productivity gains and success stories. But, as time passed, the underlying tension between operator autonomy and managerial control led to the reversal of many of the lean production system components. In spite of the rhetoric of CPS, it seems that management re-consolidated its control over the production floor using the new work reorganisation and the complex restructuring process on the shop floor as the reason for arresting teamwork and operator programming privileges.

7.8 CPS on the Production Floor (Key Dimensions)

In the early stages of CPS adoption, its impact on the shop floor productivity was dramatic. Strong corporate commitment and support for CPS's full implementation were the key to its early success. Supported by an organised bureaucracy, management used extensive training on every aspect of CPS and at all levels in the organisation as a way to achieve the widest possible support for CPS. The introduction plan which followed clearly prescribed policies and initiatives designed to orient all elements and resources of the factory towards the execution of CPS's specified objectives.

The written objectives and methods for achieving these objectives were clear enough, what was a mystery during the early visits to this company was the degree of acceptance and commitment of operators to those objectives. Was management successful in ensuring acceptance and compliance? To what extent did these changes constitute a true transformation on the part of CMN management? (From traditional organisational structure to the lean production organisation). Was this a paradigm shift on the part of CMN management embracing lean production system and discarding the traditional work organisation that was in use prior to CPS?

In spite of the fact that CPS did usher in positive improvements in areas of quality and productivity, when it came to the issue of devolving power down to the lower echelons of the organisation, management was unwilling to let go. Faced with increased competitive challenges and increased production demands due to the introduction of a new engine class, the company reverted to its traditional ways of doing business and suspended many of the key elements of CPS that characterised the innovative content.

As a result of these tensions on the shop floor, the aspects of CPS which caused these tensions and were viewed by management as 'problematic' (in particular, those that devolved power to the shop floor) were suspended. Accordingly, the use of lean production system did not develop enough in this case to constitute a true paradigm shift. In fact, when the opportunity arose, it was management who reverted to the traditional work organisation structures sensing the tensions on the shop floor particularly in the FMS production areas. Even in the implementation process, the key drivers of CPS that called for increasing operators' autonomy as well developing teamwork, multiskilling, and Kaizen, were met with suspicion by operators due to increased pressures on operators and a tightening rather than a loosening of control over the production process,

Viewed at the shop floor level, stresses in the existing relationships as a result of CPS were revealed. CPS implementation in the FMS production areas contained conflicting elements. As time passed, these tensions were resolved in a variety of ways: many of the

CPS initiatives were diminished and relegated to implementation in specific functions rather than across the organisation. Other elements of CPS were completely discarded.

At the beginning of this study, I set out to investigate the existence of tensions in the application of lean production systems to the FMS environment. As I examined this company and followed the progress of the CPS system particularly in the flexible manufacturing systems area, inconsistencies were recognised.

The key dimensions that impacted the role of CPS and led to the resultant inconsistencies in the FMS area were: the complexity at the FMS stations, the rules and regulations that were introduced as part of CPS and the high degree of integration and in the system.

7.8.1 Complexity

In this case, The complexity in the system, particularly at the FMS, was seen as a key factor that led to incompatibilities and tensions. The complexity was, in part, seen by operators and production staff to be a result of the inter-relatedness of workstations, material handling systems, and control systems. It revolved around the different interrelated elements in the system such as the machining, loading and unloading, operations control, and cleaning, materials handling for work pieces, and control system hardware and software. The large number of product and specification matrix changes including fixtures, pallets, pallet-changers, tool storage, tool change devices and programs required to operate and maintain the FMS at optimum capacity was a critical factor in increasing the complexity of the system.

Over the four-year period of this study, of the twenty operators asked about the degree of complexity in the production system since the introduction of CPS. Fifteen operators responded that the system's complexity had 'increased'. Reasons provided for the increase were primarily related to the increased pressure to improve productivity. Perceived increases in the number of rules and regulations were considered by the operators as one of the factors that influenced the complexity of the system. A number of operators viewed the operation on the FMS as more complex because:

'now we are measured every step of the way ...there are forms and strict rules that we need to follow even if we know a short cut'.

Management seemed to be aware of this complaint and in an effort to reduce the complexity, a number of fail-safe systems were introduced such as a tool life and tool breakdown alarms which automatically alert the operator and temporarily halt the machining process.

CPS provided management with a system to maintain a watchful eye on the FMS and to keep the complexity in check. In doing so, management ushered in new regulations and rules designed to minimise any disruptions and problems that could affect overall production schedules. Yet, operators viewed this increase in regulations and rules as adding an extra load on their work and it increased the tension on the shop floor as it significantly reduced slack time for the operators. Kaizen in particular was seen by three FMS operators from different shifts as ' a way to constantly increase our work loads'. Although these responses do not constitute a statistical sample to prove or disprove the increase in complexity, it provides a sense of the general feelings on the shop floor that the introduction of the lean production system complicated rather than simplified the work of operators. In management's view, the introduction of lean production system exemplified in the CPS production system was supposed to simplify the operation on the shop floor and eliminate waste and variation. It is precisely this constant effort to eliminate variation that did not bode well with the operators. The variation that management sought to eliminate was not limited to the quality of the machined parts but it also extended to the work organisation on the shop floor. Although the original message called for team work, multiskilling and increasing the autonomy of operators or team members, what emerged was a new system of bureaucratic control particularly at the FMS with its complexity as the key driver for this new form of bureaucratic control.

Even with this new form of control, the complexity on the shop floor in the flexible manufacturing areas was the key element used by manufacturing engineering to justify its objections to other aspects of CPS that called for increasing employee autonomy. The net effect was an increase rather than a lessening of management control over the production process through increasing management knowledge of the production status at every step in the production process, using the CPS measures and indicators introduced at every step of production as a tool to reduce rather than enlarge operator autonomy.

7.8.2 Integration

Responses to interview questions indicated the degree of integration in the FMS area has increased since the introduction of the CPS system. The operation of the FMS in the machining of K12 and K16 was perceived as highly integrated and schedules of the k12 and k16 engines were complex. Increased demands on the production function in general and the FMS in particular also contributed to the engineering staff as well as shop floor operators feelings of an increased interdependence. In later visits Both operators and staff responded with 'significantly increased' in reference to the degree of interdependence of work stations and changes as a result of the CPS implementation. The high degree of integration was also seen as a factor by operators and production staff of the inter-relatedness of workstations, material handling systems, and control systems.

7.8.3 Regulation

Regulation by FMS is defined as the influence the system exerts on the work of the operators or, in other words, the extent to which the operators work is regulated by the system, through rules and procedures incorporated in the system. At the FMS, the close supervision of manufacturing engineering (process engineers) and the strict criteria and rule imposed on the FMS team including the CPS measures, made operators feel less rather than more independent. Initially, CPS increased the span of control on operators through teamwork and multiskilling to improve the work area and increase efficiency through Kaizen. But as tensions grew between the conflicting demands of operators and manufacturing engineers, the degree of discretion the operators had was decreased rather than enlarged as a result of CPS. By increasing the number of rules and regulations that govern the operation on the shop floor, manufacturing engineering was able to reassert its control over the FMS and eventually was successful in convincing management to do away with the team structure altogether.

There was agreement between operators and supervisors that the number of rules in the FMS had increased since the introduction of CPS. CPS added new rules concerning computer programming, tool setting, inspection, maintenance, production scheduling orders, material flow, quality control, time sheets, etc. In addition, the paper work for operators increased. With CPS there were more forms to fillin, books that included highly descriptive methodologies of FMS operation were introduced on the shop floor with the production manager and manufacturing engineers playing the key role in introducing these new formats, rules and regulations.

CPS introduced very perspective discrete practices with the view that these were 'predicated on functional excellence'. New 'standards for excellence' with mandatory measures and audits were introduced. For example, a time-based system which centrally established two change frequencies was introduced. The FMS prompted the operator for the next insert while the needed tools were delivered daily based on a set schedule. The FMS powers down for the tip to be changed. This was in contract to the original system were the team leader had the key to restart process.

In general, CPS improved material flow through the factory which aimed to reduce lead times by shortening production routes and to eliminating waste. The underlying objectives of this model were achieving synchronised flows and shorter lead times. Regulation was viewed as a critical factor to ensure that the synchronised flows were maintained.

The increase in regulation provided engineering management with a way to limit the autonomy of the FMS teams. As CPS called for increased operator autonomy and control over the process, manufacturing engineering viewed this aspect of CPS as detrimental to the production process and predicted that it would lead to crashes and disruptions in the production schedule. The increase in the number of rules, according to the manufacturing engineering, was necessary to ensure that the complexity of the FMS system did not hinder the operator's ability to keep up with the production schedule.

It was precisely this increase in the number of rules and regulations that contradicted the original view of CPS as giving operators or team members, as they were called increased responsibility and autonomy over their production area. This apparent contradiction in the original objectives of CPS and its actual application in the FMS area were not recognised by the Human Resources department. Instead, Human Resources continued to put forward the line of the productivity improvements and the lean production logic calling for increased autonomy and independence of operators. The results were an increase in the tensions on the shop floor where on the one hand where Human Resources focused on operator training and increased control for operators over the FMS. On the other hand, the production and manufacturing management were stressing the need for more and better rules for production in order to prevent crashes in the FMS as a result of the complexity associated with these systems.

The freedom of operators to plan their work on the FMS was curtailed. Manufacturing engineering continued to limit the role of the operators and to pressure the production manager to limit the interference of operators in what was traditionally the role of process (manufacturing) engineers.

As the demand for the R12 and K16 engines continued to grow and with the addition of a new engine family, the pressures on the production people increased significantly and manufacturing engineering was able to convince management to suspend the teamwork structures. The suspension of the teams was presented as a temporary measure which was necessary for the restructuring and the introduction of new FMS and CNC production machines used in the development of the new Q class of engine.

The surprising fact was that operators have accepted the new changes and the suspension of teamwork as a *fait accompli*. This easy acceptance points to two issues: 1) that the original team structure, which was in practice, was not viewed as effective by managers and was not thought of highly by the operators.

One reason for the lack of enthusiasm for the teamwork component of CPS was the degree of increased regulation that accompanied the implementation of CPS. More rules and regulations, less autonomy and control for team members meant that these teams were not true teams and accordingly the suspension did not constitute loss of an acquired privilege.

The second reason mentioned earlier, was the employees' worry about the future of their jobs. Realising the competitive external environment and the constant call by CPS to improve productivity and efficiency, operators worried about job security. Because of the change in circumstances, unions did not have the same leverage that they had had before. CMN management was able to convey to employees through CPS and various steps that management was serious about cost cutting and that top management was facing increased pressures from share holders to deliver on profitability. This fact was evident in the ability of operators to quote the price of CMN stock on the financial markets. The joint venture with another company and the infusion of $100 million investment in the company was a boost for CMN and it made workers feel more secure about the future of their jobs. This overriding fact seemed to have tempered operator objections to the new changes and made them accept a return to the bureaucratic, traditional control strategies that the company had exercised before CPS and, as it seems, also during CPS.
Regulations and rules were the key instruments of managerial control and through these rules and regulations, manufacturing management was able to limit the degree of operator autonomy and freedom over the flexible manufacturing systems and maintain its overall control of the production area.

7.8.4 Flexibility

The importance of flexibility in the system was underscored by the production manager. The company placed considerable importance to its customers and the market demands for quitter, more efficient, environmentally friendly diesel engines . The flexibility of the

FMS was instrumental in helping the company keep up with the competition in the market place. Additionally, operator skill was also seen as an essential element in the flexibility equation. CPS with its focus on training of operators to be multi-skilled contributed to the development of CMN production flexibility.

On the shop floor, Although the production manager and manufacturing view was that the company possessed both flexible technology and flexible operators, in the responses to interview questions concerning changes to flexibility as a result of the introduction of CPS, the general view was that it remained 'about the same'. Nevertheless,. the flexibility was seen by some operators in the FMS area to be constrained by the degree of regulation associated with the CPS system.

7.9 CPS Dilemma: Bureaucratic versus Organic Organisation

The introduction of CPS was in keeping with the trend for lean production system encompassed in the new philosophy for the reorganisation of work through teamwork, multiskilling, and increased worker autonomy in addition to TQM, JIT, Kaizen and other lean production practices.

Coupled with the FMS, the lean production system, although showed improvements in the initial investigation of the CPS practice in the FMS area, By the end of the four years period, it became obvious that CPS has not delivered on its initial promises. Differences emerged between the stated objectives and the actual practice on the shop floor.

CPS introduced a mixture of both the bureaucratic and the organic structures, but this mixed organisation led to tensions. These tensions were detected by the production manager and production and manufacturing engineering staff. Managerial response to these tensions was to deviate from the stated objectives of the CPS philosophy and revert to the older structure of close monitoring and control as well as the dismantling of the team structure. The three key dimensions of complexity, regulation, and Integration in the FMS were seen by the manufacturing engineering staff to be factors in forcing the issue of reversal of autonomy and operator control and eventually led to the suspension of the organic elements in CPS. By the end of the four years period of this study, teams were disbanded, management had asserted its control through the traditional structures and the bureaucratic culture that existed before CPS remained in place.

7.10 Human Resources Department (The other side of CPS)

The human resources department played the key role in creating the needed environment for the early success of CPS. Based on an overall corporate plan to introduce the new work organisation concepts to all the company's plants, the human resources department was given a strong mandate to develop the new work organisation structure on the shop floor in cooperation with production and other management staff.

In discussions with the human resources manager and the training staff, it was clear that they were aware of the trends within the human resources management arena, and 'buzz words' in the lean production system literature were often used by the human resources manager to describe the changes in the company. The fact that CMN is owned by an American company with better exposure to the popular management books on manufacturing excellence, quality, productivity and other lean production practices also contributed to this knowledge of lean production.

Yet, this familiarity with the key concepts of lean production did not necessarily imply that they were truly applied to the production environment and if they were, not necessarily in a manner that fits with the original definitions. A key question addressed early in the study was the degree fit between this rhetoric on lean production and the reality of implementation on the shop floor. Was lean production truly being implemented? And if it was, was it successful?

In the early stages, as the newly introduced CPS measures began to show appreciable improvements on the shop floor, the human resources department was able to get commitment from the production mangers, manufacturing engineers, and unions on the new changes. This, off course, was possible only through the strong initial corporate commitment to the success of these changes.

The early message from the HR department to the shop floor and the company in general was full of hope and great expectations of the revolutionary transformations to be ushered in by CPS. This message was relayed to the company at large and to the production area in particular through the 'CPS Model' (seen in figure 7.4). This model focused on developing customer awareness, both internal and external by ensuring that *'quality is built in'* at every stage in the process; and promoting *'people involvement'* through training, development of problem solving techniques, team building, continuous improvement, and an overall *'commitment to functional excellence'*. The human resources department introduced a top-down training program in which every employee in the organisation, including senior management, attended a training course. This training course was designed to familiarise employees with the new concepts and establish a springboard from which these principles could be adopted and further developed in the day to day operation of each function.

But, even as the CPS system was being implemented, inconsistencies in the messages relating to CPS began to appear. The human resources department pushing for more autonomy while the production and manufacturing engineers using the CPS system to exercise more control over the process. Although CPS introduced lean production approaches such as teamwork, multiskilling, and Kaizen, its role and its name clearly indicated that is the domain of production/ manufacturing. Accordingly it was the production manager and engineering managers who had the ultimate control over the process. The responsibility of the human resources department, as they saw it, was to coordinate training schedules, personnel policies, and relations with the unions.

What CPS introduced is a demarcation of the traditional relationship between the human resources and the production and engineering staff. The fact that employee training was developed through the human resources department gave it an opportunity to influence production workers' attitudes and attempt to develop the lean production concepts.

The human resources input into the training process was to introduce the new concepts and encourage the development of teamwork, multiskilling and the use of continuous improvement as the drivers of the CPS philosophy. Increasing the autonomy of operators and empowering the production workers to take charge of the production process was mentioned by the human resources manager and training staff as an *'essential ingredient for the true success of the CPS system'*.

The final objective is to transform the company into a 'team based organisation' and increase the independence of these teams. This view on team work was supported by senior management and gave impetus for the acquiescence of the production and manufacturing staff for the new changes and the development of 'CPS Team Model' which stated the objective of developing team independence. This focus on team development was to evaluate the necessary steps for increasing the span of operator control through what was termed ' A Team Development Continuum'.

Initially, the human resources department was able to develop the team work structures to be situated between the involved and participative stages. Team members were made to assume more responsibilities in such areas as quality, maintenance, and improvements on their specific job. An attempt was made to transform the role of the supervisor into a 'coordinator' coordinating the activities of team members. Additionally, to further expand the abilities of the teams, job rotation was also introduced:

The CPS model and training offered the vehicle for the feasibility of this team improvement emphasis, through CPS focus on five basic aspects: Safety and housekeeping, quality, elimination of waste and cost improvements, improving throughput, and the overall development of employees.

In the Flexible Manufacturing Systems area, the team work approaches began to show improvements in the operation of the FMS. The lean production structure put forward by CPS made the FMS operate smoothly with the multiskilled operators working as a team. Yet at the same time, there was an increase in the rules and regulations governing the operation of the FMS with complexity of the system being given by the manufacturing engineers as a reason for the need to increase the rules and regulations called for in CPS. Thus, the situation on the FMS was becoming a testing ground for two competing practices: on the one hand, the human resources department called for increased autonomy and independence of operators, while, on the other, the production / manufacturing engineers tightened their control of the FMS by increasing the number of rules and regulations. These two competing objectives could be seen as key element in the tensions that developed in the FMS area. The production manager and manufacturing engineers saw the need to increase control over the process and CPS was the ideal vehicle in that it developed the mechanisms for measuring and evaluating the progress at every step of the production system.

The coupling of these human resources objectives with the production and manufacturing engineering objectives led to tensions on the FMS, and it seemed that manufacturing engineers did not fully accept the team approaches and viewed them as inefficient leading operators wasting time and not taking the necessary decisions.

These differing objectives and messages left their mark on the operators of the FMS. In the early days of CPS implementation, the FMS team was able to develop into the most independent team in production. Manufacturing engineers viewed this independence as a risk and predicted that it would lead to damaging the FMS station as a result of faulty programming or interference from the operators in the tolerance settings of the blocks.

The human resources objective with the message of increased autonomy was counteracted by the production / manufacturing engineering staff with a call for increased control and centralisation over the FMS in particular and the production floor in general. Both sides used CPS as the basis for the desired changes and in spite of top management efforts at developing coordination and soliciting commitment to the new changes, each function acted in the traditional way of trying to maintain its control over the process and use the available tools within the new system to advance their objectives.

Based on the interviews, observation of the company these tensions were seen to have eventually hindered the improvements and productivity gains expected from CPS when it was introduced. Although improvements were seen as 'good', the perceived initial potential of CPS was far greater. Had it not been for the dissatisfaction in employee attitude towards these contradictory inputs from production and human resources, CPS might have achieved far more productivity gains.

Increased bureaucracy and regulations while trying to introduce teamwork and self governance eventually failed and the company opted to do away with the team structure all together.

7.11 Summary and Conclusions

The key point in this chapter has been that while the initial implementation of these lean production strategies led to recognisable achievements in productivity, further developments and application of certain parts of the lean production system such as increasing employee autonomy and control, faced acceptance problems particularly in the flexible manufacturing systems area where the interaction between the demands of the FMS and those of the lean production were seen to be in conflict.

The highly standardised and formalised modes of operation, as they are used concurrently with attempts to implement the lean production system in full, point to an incongruity in the interaction between lean production and its application to the FMS environment. High levels of regulation control coupled with the aspects of lean production that called for increasing employee autonomy and control over the production process, sent clashing messages to the operators on the shop floor. This, in turn, were perceived to have led to less than the optimal productivity and flexibility gains that were expected as a result of CPS. These apparently conflicting messages had an impact on the system.

The human resources department wholeheartedly adopted the lean production steps calling for devolving power to the shop floor. CPS was supposed to be the tool for this transformation in the structure of the company from a traditional to a progressive organisation in tune with all the modern and advanced practices of work organisation. Yet, manufacturing engineering still viewed the relationship on the shop floor on traditional mass production terms. CPS ushered a new form of work organisation but it also increased the potential for better control of the manufacturing process.

Initially, manufacturing engineering did object to the changes and viewed operators as 'they can be a party to the control process', However, on the FMS, manufacturing engineering saw the system as too complex to be left to operators and introduced 'fail systems' adding alarms to minimise problems at the FMS.

At the same time, they increased the rules and regulations governing the entire operation of the FMS in particular. These included a Kaizen team request for authorisation. While operators' freedom to do jobs on the FMS initially increased with CPS, the manufacturing department through extensive new rules and regulations reduced the degree of freedom of the operators to plan and execute their work.

The lean production components which are commonly associated with worker empowerment and devolution of responsibility to the shop floor through team based organisation have, in this case, simultaneously increased centralisation and managerial control through increased surveillance and discipline through rules and regulations.

Eventually, the human resources department was unable to continue with its strategy to devolve control to the operators and teams were suspended and the FMS team the most independent of the teams, were disbanded. With this suspension of teams, manufacturing engineering regained its control over the production process, although management professed that this suspension of teams was temporary pending the settling down of the production process due to the introduction of new production lines and manufacturing areas for the new engine design. Thus, the input to the company of a new engine line and the need restructure the factory gave management the excuse it needed to address the contradictions between CPS and FMS. The old FMS has been replaced, new engines were introduced, teams were abolished even though a manufacturing engineering manager claimed that they had been 'refocused' rather than eliminated.

The view of production management on the team experiment is that these teams lacked the necessary discipline for success and that the teams were driven by a culture that was less 'hard nosed' and is cost reduction bottom line conscious.

At the macro level, pressures from shareholders and the need to improve productivity, cut costs, and improve profit margins led CMN to become ' hard nosed'. Awareness of this new fact permeated through out the company – in 1995 when a side question was directed to shop floor workers if they knew what the stock price of the company was- they did not. In 1999 when they were asked the same question –they knew what the stock price was. Although the responses were not tabulated, it was clear that shop floor employees knew the stock price and followed it as a gauge of the company's performance and stability. The new bottom line of management was shareholders equity. This idea was then permeated to the company workers as well as operators.

This could be explained in part because of the rumours of take-overs when the stock price was down below the equity and asset level of the company which meant that the company could have been ripe for a take over. Although this has changed and the price level returned to its normal levels, the people in the company still followed the stock price.

CHAPTER EIGHT
CONCLUSIONS AND SUMMARY

8.1 Introduction

This thesis addressed the issue of the application of lean production systems to the flexible manufacturing systems environment. It explored the application of lean production to the FMS environment and investigated the existence of tensions between FMS and lean production in four manufacturing companies in Holland and the United Kingdom. As was indicated in the literature review, the original ideal vision of the combination of lean production and satisfied workers has been rejected by many researchers who examined changes in the quality of work life under lean production (Parker and Slaughter, 1988; Klien, 1989; Fucini and Fucini, 1990; Sewell and Wilkinson, 1992; Graham, 1993, 1995; Babson, 1995; Delbridge, 1995, Landsbergis et al., 1996; Nishiyama and Johnson, 1997; Lewchuck and Robertson, 1997). Other researchers questioned the claims that lean production practices necessarily lead to high manufacturing gains. Researchers like Bennett Harrison (1997, p.38) referred to this as the 'dark side of flexible production' while others like Turnbull (1988, p.18) observed the British experience in operating JIT and saw it as illustrating 'both the degree off work intensification involved and the added stress that is endemic to the system'. Klien (1991) questioned the motives of employers who promise 'autonomy' when what they really intend is for workers to deliver an unprecedented level of cooperation while Lowe et al.(1997) findings emphasised the importance of context, specific plant characteristics, and choice, for understanding the performance of manufacturing organisations. Lowe et al. rejected the notion that the work organisation and human resource policies associated with the lean production model represent a universal "best way" for achieving high manufacturing performance.

This study aimed to explore the fit between lean production and its application to the flexible manufacturing systems areas in four manufacturing companies located in

Holland and the United Kingdom. The choice of the case study approach to study these four companies was in an attempt to further clarify the work organisation and human resources interactions and evaluate the context in which these interactions occur.

The literature review in chapter two noted that a number of researchers identified discrepancies between the theory and actual results on the shop floor suggesting that the combination of lean production and the FMSs may be problematical and pointed to potential tensions or mismatches in the emergent new paradigm. The objective of this study was to try and elaborate on these interactions particularly in the FMS environment and to advance beyond the traditional survey approach typically associated with the study of the FMS. The decision to choose a multiple case study methodology was based in part on the desire to add comparative value through in depth cases while simultaneously engaging both the technical and organisational (social) arrangements side of the literature (See Harrison and Storey, 1996).

Using the dimensions of complexity, integration, regulation and flexibility characteristically associated with the FMS (Boer, 1990, 1991; Krabbendam, 1988; Boer and Krabbendam , 1991), these same measures were used in each of the four case studies as guideline for the exploration of the lean production interaction relationships in the FMS environment.

The investigation of these four case companies revealed the existence of tension with consequences to the production system as a whole. The indication from the four major FMS user factories in Holland and the UK pointed to inconsistencies and tensions in the interaction between lean production and flexible manufacturing systems which resulted, in part, from one or more of the following conditions: 1) lack of true managerial commitment to the lean production philosophy; 2) the contradictory messages being sent to the FMS environment encouraging increased operator autonomy under lean production while at the same time increasing the degree of control and regulation over the environment; and 3) macro level pressures such as lack of job security or significantly increased production pressures. In the next section, I will analyse the results of the field research and will summarise and present the general conclusions of the study including the academic implications, and will set the stage for possible future research in this area.

8.2 Overview of the research

8.3 Tensions in the implementation of lean production to the FMS Environment

The marriage of advanced manufacturing technology and the new wave manufacturing including new human resource management strategies is certainly a new phenomenon and one which has followed a large body of research that pointed to the disappointing results of AMT implementation. While at any level of automation there was a striking differences between the least and most efficient plants (Womack et al., 1990) and that in many cases increasing automation lead to a decreases rather than an increases in plant flexibility (Upton, 1995), the high failure rate of technology implementation was mainly attributed to non technical, people related organisational causes (Rosenthal, 1984; Voss, 1985; Jaikumar, 1986; New, 1986; Tarnfield and Smith, 1989; Bessant et al, 1990, 1993).

This realisation led to increased focus on ways to develop appropriate structural, organisational, human resources and personnel policies to achieve better results from the new manufacturing technologies (Wall et al, 1987; Campbell and Warner, 1992; Clark, 1993; Storey, 1994; Harrison and Storey, 1996; McLoughlin and Clark 1994). The development and adoption of lean production seemed to offer companies a magic solution and the answer to their AMT problems.

Most of the manufacturing companies that opted to adopt these lean production techniques tended to 'mix and match' between the various systems and organisational approaches and many hybrid systems were developed. Although these programs, systems, and structures carried widely varying labels, their core concepts, i.e. the basic organisational innovations were all based on key approaches such as JIT, TQM, teamwork, multiskilling, continuous improvement, and increased operator autonomy and empowerment. These, together, are recognised as the core elements of the lean production and they were presented by the consultants as offering the magic pill for AMT success.

In this study I set out to examine the interaction between the use of the lean production and FMS in four manufacturing companies in the truck, aircraft, diesel engines, and refrigeration compressors manufacturing areas.

After the initial visit to these companies, criteria for inclusion or exclusion for each of these companies was developed. The choice of the companies was based on the adoption of lean production and FMSs and thus, restricts the generalisable nature of this research.

Primarily as a result of being allowed access to these four manufacturing companies in the United Kingdom and Holland, I was able to investigate the nature of interaction between the lean production and the FMS on the shop floor. These four companies had adopted or were in the process of adopting lean production to the production floor where Flexible Manufacturing Systems were being used.

All four companies had reported various degrees of productivity and flexibility gains as a result of the coupling between the two. Nevertheless, the productivity and flexibility gains derived through the implementation of lean production did not appear to be as extensive or far reaching as originally predicted by the implementers.

The stresses found in the interaction between lean production in the FMS environment in three of the four cases do not support the far reaching claims of the emergence of 'new technology paradigm' and the associated revolutionary change from the coupling of lean production and the FMS feature of advanced manufacturing technologies.

Combining flexible production technologies with flexible work (i.e. the lean production) promised to usher in improved operational control, increased flexibility, and drastically reduced lead times. Proponents of this paradigm argued that only through the coupling between AMT and lean production would the full potential of AMT be realised and translated into true productivity gains (see Bessant 1990; 1993, Clark, 1993, Adler and Cole 1993).

This coupling or linkage between the FMS form of advanced manufacturing technology and lean production maximised the potential gains resulting from the use of advanced manufacturing technologies. Only through, inter alia, employees multiskilling, giving jobholders greater span of control (i.e. autonomy and discretion over the production machinery), and operating in teams will the new technology be able to achieve the optimum level of performance.

The proponents of this new paradigm presented a rosy picture of the fit between lean production and the advanced manufacturing technology used. In this study, I looked at the practices that pointed to the 'emergent paradigm' in the four chosen manufacturing companies and asked the question: might these practices contain internal contradictions?

McLoughlin and Clark (1994) pointed to the potential failure of achieving the benefits of AMT because of managerial resistance to, inter alia, increasing employee autonomy. This study supports this observation and extends it to point to situations where managerial resistance is not visible and where lean production is implemented in a complex manufacturing environment. The coupling of lean production to the FMS did not achieve the desired productivity gains.

This study investigated the relationship and coupling between lean production systems and the use of FMS in the four manufacturing companies. The result, that can be best determined in the complex dynamic that each of these companies was going through, was that indeed there were stresses and tensions in the existing relationships and that such tensions indicate the importance of looking at the context in the application of lean production in every case of implementation thus further questioning the universality of the 'new paradigm'.

In all the cases, the underlying and forceful change factor was often more existential. Macro-level issues relating to employment, redundancy, and the future survival of the company were always at the forefront. Thus the traditional issues of power relationships and control over the process remained hostage to these Maslows' hierarchy of needs related issues.

In the theoretical formulation at the conceptual level. The failure to achieve the optimum productivity gains in EBG Truck and CMN Engine where tensions were detected was deemed to be the result of inadequate managerial commitment to the full implementation of the Lean production in particular those aspect that called for increased employee autonomy and control over the production process. The results from the third company (Fokker Aircraft) where inconsistencies were detected but, due to the closure of the company were, could not be followed through, and thus were inconclusive.

In the two cases of EBG Truck and CMN Engine, there was disappointment in the failure to achieve predicted productivity gains. The tensions detected were deemed to be the result of inadequate managerial commitment to the full implementation of the lean production in particular those aspects of lean production that called for increased employee autonomy and control over the production process. The results from the third company (Fokker Aircraft) where inconsistencies were detected, but, due to the closure of the company were, could not be followed through, and thus were inconclusive. The fourth company CMC compressors, appeared to have adopted lean production and achieved a better fit than the other three companies in this study.

In CMN, the application of lean production to the FMS environment led to initial improvements and productivity gains in the manufacturing process. But later, because of the opposing messages between the human resources and the manufacturing engineering, inconsistencies in the relationship between the lean production and the Flexible Manufacturing Systems began to appear. These inconsistencies eventually appear to have contributed if not lead to the suspension of the team structures in the organisation (helped by macro level changes which forced the change in the structure).

Although this company professed to implement the lean production, its approach to the implementation followed traditional mass production logic. The key actors in this process who exercised the greatest influence were the production and manufacturing departments with the production managers, supervisors, and manufacturing engineers still clinging to maintain their control over the production process.

8.4 The Key Dimensions

8.4.1 Complexity

The complexity dimension was seen to be a key factor in the interaction relationship between lean production and the flexible manufacturing area in two of the four manufacturing companies examined

In EBG truck manufacturing company, at least two levels of complexity associated with the FMS operation were manifested. The first level involved tool management and tool kitting needed for the operation of the six FMS stations. This process is typically complex in the FMS operation, is this case, the operation is further complicated by the fact that at least two types of engines (an 8 litre and an 11 litre engines) and four types of engine heads were being machined at these stations. Operators had to go through a series of steps and operations which involved tool set-up and tool kitting, using an extensive tool library database. The second level of complexity involved the inter-relatedness between the elements of the six stations of the FMS and the machining operations preceding it. Coming from two different areas: one type of engine block coming directly to the FMS (referred to as the 'block line'), and another type of engine block coming directly to the FMS from other areas.

The increased complexity was seen in organising the timing and planning of the capacity for the four types of engine blocks.

Another aspect of the complexity involved actual programming and operation of some of the machinery related to the FMS. An example can be seen in the operation of a newly introduced 'Three-Dimensional Measuring Machine'. This type of machine is a computer numerical controlled (CNC) machine used in conjunction with the FMS primarily for testing tool tolerances.

Based on the interview and questionnaire to the area manager and production and manufacturing engineers dealing with the FMS area, two different perceptions relating the complexity of the production technology emerged:

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While the both managers and operators viewed the technology as complex, a significant part of the complexity was seen by the operators in terms of the increase in the interrelatedness of the system and the increase in capacity of the FMS. The complexity was reflected as much as in the use of the technology as it is reflected in the increase in pressure on the operators. While characterised as complex by all the operators interviewed, the actual programming of the FMS did not appear to present a problem particularly to the multi-skilled operators. This view was manifested in terms of an apparent sense of pride in their programming abilities.

This operators' view of complexity contrasted with the views of the area manager as well as the views of the manufacturing, production, and logistics engineers who saw a higher degree of complexity in the FMS environment. Discussions with the area manager and production engineers pointed to a view by the managers which appeared to overstate the degree of complexity of the operation as opposed to the operators who saw the FMS operation as , although complex, but not unmanageable.

The difference in the perception of complexity was much more pronounced when the interview questions referred to the complexity of the 'ThreeDimensional Measuring' CNC. This new CNC measuring machine could be considered as a part of the FMS system as it is used to measure FMS tool tolerances insuring the proper operation and quality of the FMS machining operations. Two divergent perceptions of its complexity were detected: Production and logistics engineers saw the 3D measuring machine as '*too complex for the FMS operators to operate*' and accordingly its operation was left to a specialist quality control engineer. On the other hand, the Facilitator and a number of the operators did not see this machine as '*any thing special except for the controls and that* *its programming is similar to those of the FMS although it takes only tolerance measurements'.*

The results confirmed that the role of teams has been enlarged as a result of lean production. Yet, equally, control over the FMS process was still being exercised primarily by the area manager and production and logistics engineers through the vehicle of the 'objective matrix' and team meetings. Operators indicated that the operational objectives of the teams or cell groups are strictly specified in the team meetings, and that the 'what, when, where, and how' of operations are thus established. A key component of this 'Objective (productivity) Matrix' review is the assessment of productivity levels and the achievement of set objectives. Accordingly, two apparently contradictory circumstances appear to be in operation here and that the complexity of the FMS system is being presented as the justification for its existence.

Taking a closer look at the FMS environment, it was evident that, individually or collectively, the technology used was complex: Interviews with the supervisor and operators in area confirmed this initial view complexity. The complexity was evident from the fact that operators had to undergo extensive programming training by the vendors as well as through in house multiskilling technical training programs.

Responses to the question on general operational complexity pointed to mixed opinions with the majority of respondent indicating that it 'remained the same' and only one operator indicating that it has 'increased'. There was general agreement that complexity in the FMS area did not exhibit any appreciable change as a result of the introduction of the lean production approaches. Responses to the complexity questions in the questionnaire regarding the degree of interdependence between work stations, the need for increased coordination between the FMS and other stations and areas, did not point to any appreciable changes as a result of the introduction of new organisational changes.

Programmers on the other hand, having recently been moved to the production floor near the FMS, did agree that the complexity of the FMS played a role in justifying the need to increase supervision of the FMS and monitoring the use of the specialised CNCs and the DNC database.

From the human resources manager perspective, the complexity of the manufacturing process and by extension the FMS has been handled through increased training and multiskilling of the operators. By introducing lean production approaches, and giving operators more control over the production process, he expected the teams to handle the complexity depending on the instructions of the production manager and the group leaders. On the other hand, the responses by the production manager indicated that the degree of complexity in the FMS did not appear to increase appreciably. He indicated that he '*had and continues to exercise firm control over the production process*' and that with lean production, because set objectives are closely measured and are consistently evaluated, he expected any complexity problems to manifest themselves quickly and be taken care of very early. He also expressed the view that by transferring the production, programmers, and quality staff to the production area and by monitoring team actions, particularly in relation to cost cutting measures, he made it easier for the teams to seek help in any arising complexities.

In chapter six With the skilled machinists and the relatively simple machining tasks required for the compressor housings, complexity of the FMS did not seem to be a key issue. The use of tools and fixtures as well as the programming of the FMS was viewed as 'relatively standard' by the operators. In their view, once operators achieved familiarity with the system, the FMS operation became easier. Accordingly, no increases in complexity were detected in this case. Operation of the FMS by the skilled operators was 'not so difficult' and tools and fixtures were seen as universal. In addition, as mentioned earlier, the two programmers who were retained from the technical / planning department and had been moved closer to shop floor, provided support to the production teams on the shop floor by checking the FMS and CNC programs.

In early interviews with staff engineers in the Technical/planning department two of the respondent did agree that the complexity of the FMS was a factor in their decisions to keep a closer watch over the operation of the FMS. Yet in later interviews post the dismantling of the technical / planning department, responses to questions about the changes in the degree of complexity, there was general agreement that it remained relatively unchanged.

In chapter seven, the complexity in the system, particularly at the FMS, was seen as a key factor that led to 'incompatibilities' and tensions. The complexity was, in part, seen by operators and production staff to be a result of the inter-relatedness of workstations, material handling systems, and control systems. interrelated elements such as the machining, loading and unloading, operations control, and cleaning, materials handling for work pieces, and control system hardware and software. The large number of product and specification matrix changes including fixtures, pallets, pallet-changers, tool storage, tool change devices and programs required to operate and maintain the FMS at optimum capacity was a critical factor in increasing the complexity of the system.

The view of operators on t the system's complexity was that it had 'increased'. Reasons provided for the increase were primarily related to the increased pressure to improve productivity. Perceived increases in the number of rules and regulations were considered by the operators as one of the factors that influenced the complexity of the system.

CPS provided management with a system to maintain a watchful eye on the FMS and to keep the complexity in check. In doing so, management ushered in new regulations and rules designed to minimise any disruptions and problems that could affect overall production schedules. Yet, operators viewed this increase in regulations and rules as adding an extra load on their work and it increased the tension on the shop floor as it significantly reduced slack time for the operators. Kaizen in particular was seen by FMS operators as ' a way to constantly increase our work loads'. Although these responses do not constitute a statistical sample to prove or disprove the increase in complexity, it provided a sense of the general feelings on the shop floor that the introduction of the lean production system complicated rather than simplified the work of operators. In management's view, the introduction of lean production system exemplified in the CPS production system was supposed to simplify the operation on the shop floor and eliminate waste and variation. This constant effort to eliminate variation that did not bode well with the operators and was seen to be adding to the complexity. The variation that management sought to eliminate was not limited to the quality of the machined parts but it also extended to the work organisation on the shop floor. Although the original message called for team work, multiskilling and increasing the autonomy of operators or team members, what emerged was a new system of bureaucratic control particularly at the FMS with its complexity as the key driver for this new form of bureaucratic control.

Even with this increased control, the complexity on the shop floor in the flexible manufacturing areas was the key element used by manufacturing engineering to justify its objections to other aspects of CPS that called for increasing employee autonomy. The net effect was an increase rather than a lessening of management control over the production process as a whole through increasing management knowledge of the production status at every step in the production process, using the CPS measures and indicators introduced at every step of production as a tool to reduce rather than enlarge operator autonomy.

The different responses in the use of the same technology by these four companies clearly pointed that the view of the degree of FMS complexity was driven by control and demarcation issues rather than by the actual characteristics of the technology. This conclusion was clearly visible in the view of the complexity of the 3-Dimensional measuring machine used in the FMS area. The 3-D measuring machines in the EBG and Fokker Aircraft case studies, although they were not made by the same company, both CNC machines could be described as very similar in nature and complexity. Yet , at EBG it was viewed as too complex for the operators to use while at Fokker, the same equipment was used by the FMS operators. The difference between the approach of both companies related to training. At Fokker, the 3-D machine vendor developed a training program for the operators and in a relatively short period of time, Fokker operators became skilled in the use of the machine. At EBG, the 3-D machine was the domain of the production staff programmers. No training was given to the operators on the machines even though it was a central tenant of the lean enterprise system implemented at EBG.

8.4.2 Integration and Regulation

The integration dimension in the FMS production at EBG also operated on two levels: the first involved the degree of FMS integration within the overall production function, while the second involves its harmonisation within the total system including the organisational arrangements and its internal cooperation mechanisms (such as teamwork). In the FMS area, the CNCs were integrated into cell groups organised around teams. These teams were responsible for all the activities in their cells including engine block machining operations prior to their transfer to the FMS stations. Accordingly, there was a high degree of interdependence between the operation of the six stations of the FMS and when viewed in totality, a high level of integration between the operation of the CNC cells and the operation of the FMS was identified. The new organisational arrangements through their focus on eliminating the functionalism of the past and fostering lateral communication between teams and groups within the various work areas, helped to develop the internal cooperative mechanisms between groups and made it possible to manage the various interdependence relationships within these areas. An organisational factor which helped support this integration within the production area was the elimination of many well entrenched departments (such as planning, manufacturing engineering, maintenance, and materials / production control), and the transfer of key personnel in these functions closer to production under the control of the area managers.

At Fokker Aircraft, the levels of integration in the FMS were seen to have increased as a result of the lean production approaches. Production units were physically moved closer to each other. Group leaders and operators clearly perceived an increased interaction and coordination between functions and the production manager also pointed to the tighter coupling of the production process and considered it to be at the heart of the lean production philosophy. This increased integration was consistent with management efforts to capitalise on lean production and reduce lead times driven by a sense of urgency and the realisation of the need to show concrete results.

In the eight month period between Nov. 1994 and June 1995 the lean production approaches seemed to take route and gain increasing acceptance by the supervisors, operators, and even the programmers on the shop floor. The teams were showing increasing signs of cohesion and increased confidence. Operators clearly stated that they felt that they had more autonomy in spite of the high degree of regulation that typically existed on the shop floor.

One reasons put foreword by the group leader (supervisor) of the FMS group for the increase in autonomy was, in part, due to the reduction in the number of engineering and production staff 'dictates' as a result of the redundancies. Mid-level staff positions suffered the largest percentage of cuts and the ratio of salaried employees to the total number of employees was reduced to ratio of 1:3 from a ratio of 1:1. Although by the standards of lean production systems this 1:3 ratio was still high, the change was considered to be significant.

Nevertheless, by the last visit to the Papendrecht plant, apparent resistance to increases to operator autonomy by the production staff declined. The production managers' attitude in respect to the existing high degree of regulation and control over the shop floor was transformed into a recognition of the need to give operators and teams more freedom and control over their individual work areas. Group members also perceived an increase in the cohesiveness of the groups and saw themselves as better able to distribute tasks and increase their ability to control the process. Yet some functions such as maintenance remained separate and maintenance staff still followed a prescribed preventive maintenance program.

In CMC Compressor manufacturing company, responses by operators to questions on changes to the interdependence of work flows and degree of interdependence between work stations as a result of the introduction of lean production did not point to any discernable trends. Responses by operators indicated that it 'remained about the same'. Nevertheless, lean production was seen by most operators to have standardised the operation in the FMS area through a set of rules and measurements introduced in the reorganisation.

Lean production team development had given the teams the freedom to decide on sequencing and delivery schedule. This resulted in sequencing and time delivery problems and confusion between departments. The production manager indicated that these problems were encountered in the as a result of the independence of the teams and existence of this problem was also confirmed by the team leader and operators of the FMS.

This process *'was taken a step too far'* according to the production manager and the department teams became *'too independent and led to variances and confusion in the planning times'*. As a result from these perceptions of team over independence put foreword primarily by the production and logistics staff, It was later decided to re-centralise the planning function for all departments by deciding on an end time for each team. Accordingly, the planning for the departments was re-centralised under the direction of the production manager. Now, working in teams with the aid of transparencies, each team's 'end-time' is set for every department. The production manager looked at efficiencies 'of the total rather than the old method of measuring efficiency for each team'.

Again, this case points to the differences in attitudes towards the degree of integration within the system. Although it was possible to handle the problem by providing the operators within the team more training, the decision in CMC was to revert to the old method of control over the process. But this reversal of control issue appeared to work and the operators accepted the arrangement made by the production manager and the lean production approaches appeared to achieve the desired results expressed by management.

In the CMN Engine case, the degree of integration in the FMS area increased since the introduction of the CPS system. The operation of the FMS in the machining of two engines was perceived as highly integrated and the schedules for these engines were seen as complex. Increased demands on the production function in general and the FMS in particular appear to have contributed to the engineering staff as well as shop floor operators feelings of an increased interdependence. In later visits Both operators and staff responded with 'significantly increased' in reference to the degree of interdependence of work stations and changes as a result of the CPS implementation. The high degree of integration here was also seen as a factor by operators and production staff of the inter-relatedness of workstations, material handling systems, and control systems.

In the case of EBG truck manufacturing company, a key aspect of the dimensions characterising the FMS were its influence on the work of operators and team members. This influence, owing to the high degree of complexity and integration in the FMS area, was seen through the rules and regulations incorporated by the system.Historically, EBG was highly functionalised with the planning department controlling every aspect of FMS operation. With the transformation of the company into new EBG, and the adoption of lean production (including the call for increasing employee autonomy), it seemed logical to expect that the degree of regulation associated with the FMS would also be positively affected by the new organisational transformations. However, responses of facilitaors and operators to interview questions about the increase or decrease in the number of procedures and rules indicated that the number of rules and regulations associated with the FMS has increased rather than decreased since the introduction of the lean production. This in spite of an overall, organisation wide move to devolve more power and control to the shop floor including the FMS area

These circumstances pointed to the inconsistencies and tensions which appear to be driven by contradictory internal messages sent to the FMS. A general feeling of an increase, rather than a decrease, in the number of rules and regulations associated with the FMS operation was detected. The interviews indicated that there was indeed a development in the role of FMS operators particularly within the new teamwork structures and an apparent expansion of operator roles to include quality control and maintenance functions. But coupled with this increase in operator responsibilities, there was also an increase in the operational rules and regulations governing the detailed execution of these new responsibilities. Added to this increase in rules, is the demands of team meetings and the establishment of the 'Objective Matrix' as the instrument for setting immediate goals and objectives for each of the cells.

From the operator's perspective, the objective matrix appeared to be acting as a measuring device to insure compliance to the specified goals and objectives as well as the adherence to the new rules. From the area manager and production engineers viewpoint, the justification for this increase in rules and regulations is the need for tighter control over the production process. Based on the interviews with the area manager, the production engineers and the logistics engineers, the need for tighter control of the system was internalised in the need limit any possible disruptions to the operation and flow of the production system. This was emphasised by the area manager as especially true at 'this critical juncture in the development of company', and the imperative need to increase production and maintain tighter control over the production process. This is reflected in statements such as *'...operators have freedom as long as they follow the block line'*, indicating the limit of operator control over the process. The high complexity and integration perceived to be associated with the six FMS stations and the production of 2 x 4 (two types of engine x four types of engine heads) was deemed enough to justify the need for the increase in regulation.

In the early interviews, both the area manager and the FMS facilitator were asked about the 'degree of operator freedom to do the job' in the FMS area. Both responded enthusiastically and positively indicating that 'operators have a greater freedom to do jobs now (with the introduction of the lean production) than they did before in the control culture of the old EBG. However, when the question is shifted to the 'degree of operator freedom to plan the work' both responded was less enthusiasm (although still indicating that in their view 'it was still high'). On the other hand, interviews with the FMS operators, both 'All Rounders' and 'Rounders', responding to the same question of 'degree of operator freedom to do the job' pointed to positive responses. Thus confirming the high degree of operator 'freedom to do the jobs' (owing to their high skill and training levels). The response to the planning aspect of their job indicated that it was about the same or slightly better than before. As one operator indicated: *'directives on what, where, and how, are still being dictated from above'*. The fact that operators indicated that in spite of the organisational changes and the efforts made towards increasing the level of operator control over their work, when it comes to the planning aspects of that work, the new organisational arrangements did not alter the existing relationships. In fact the general view of operators pointed to an increase in the degree of control.

At Fokker Aircraft, by virtue of the critical safety aspect of the aviation industry, the company had traditionally adopted a high degree of regulation in the manufacturing of aircraft parts and components. Over the years the company developed a highly functionalised bureaucracy that oversaw the establishment of rules, regulations and procedures. Prior to the introduction of lean production approaches, the company had a high ratio of one salaried employee (staff) for every worker on the shop floor. Although the number of salaried staff positions has been reduced under the lean production to a ratio of one staff for every three workers, as the Fabrication Unit manager stated 'the organisation had a long way to go and still suffered a high degree of red tape'.

The situation in the FMS area of production appeared to be similarly highly regulated. Every aspect of production had to follow a set of prescribed rules and be documented appropriately. According to the production manager, 'Fokker developed a bureaucracy with rules and regulations for every aspect of the production operation'. The extent of the 'red tape' as it was described by the group leader and operators at shop floor was so pervasive that it was estimated that for one '15 cent part the paperwork costs $150'.

The extensive degree of regulation in the production area was further increased following a joint Fokker-Boeing project. Both companies had extensive, well established, bureaucracies that added to the demands on documentation at the production floor. Of the 66 parts produced, 324 changes were made. The Boeing contract required, as per the conditions of the Boeing's company, extensive sets of rules and regulations governing the operation on the shop floor. Differences in part names and part numbers for the same manufactured items between the two companies led to complications and defaults in the paper work which caused the large percentage of parts changes.

Another shop floor problem revolved around the bureaucratic delays between engineering and the manufacturing cells concerning the new parts manufacturing. It took weeks to complete the manufacturing process for a single new part as a result of 'delays and excessive red tape' between engineering and production in finalising the manufacturing process. This problem was multiplied significantly considering the large number of parts required for each assigned job.

The high degree of regulation was reflected in the supervisors and operators responses to the interview questions concerning the number of procedures regarding operations, process planning, production planning, maintenance, and the degree of paperwork. There was a general agreement that the set work procedures and the number of rules and regulations relatively remained the same. Yet even with the increased operator autonomy and multiskilling, the regulation was still seen as very high.

Programmers responses to the same questions on regulation and the degree of control over the FMS operation indicated that they generally accepted the existence of high number of rules and procedures but that they viewed it as necessary for the efficient and proper function of production. The complexity of the FMS being used as one of the reasons for the need for the regulation. The Complexity of the three dimensional milling machine and the possibility of programming errors was one example put foreword by 4 of the programmers interviewed. The high degree of regulation and tight control over the production process was even confirmed by the production manager 'to be excessive'. Nevertheless, as testified by the group team leaders and operators, he continued to exercise control of the process through set team objectives that were closely measured and consistently evaluated.

At CMC compressor, With the full implementation of the lean production philosophy, the degree of autonomy of operators working through teams has been increased. This was reflected in operator responses to questions on the number of rules and procedures as 'decreased' and the degree of operator discretion as 'significantly increased'. Subsequent discussions with the operators and team leader in the FMS area informed the following:

Operators concurred that there has been a significant increase in their ability to do the work and their control over the production process as compared to the situation prior to the managerial change and the implementation of lean production. Similarly, with multiskilling and job rotation as well as the ability of the production teams to take corrective actions when necessary made it possible for CMC management to claim that the operators were 'partners' and not merely employees.

Operators were multi-skilled and were capable of doing the programming of the machines. This ability to program the machines including the FMS by the operators gave CMC an additional advantage in simplifying the steps it took from planning to programming to machining and corrections. Operators were given the freedom to do their own programming and accordingly increased their confidence in their skills. The programming was traditionally the role of the technical / planning department. However, with the dismantling of this department and the elimination of most its staff jobs, skilled operators were allowed to do the programming.

Nevertheless, as a result of this increased autonomy being granted to teams, some problems arose in the sequencing of jobs. However, the production manager reverted to the older system of direct control by the production manager over the sequencing and delivery times.

At CMN Engine company, the close supervision of manufacturing engineering (process engineers) and the strict criteria and rules imposed on the FMS team including the CPS measures, made operators feel less rather than more independent. Initially, CPS increased the span of control on operators through teamwork and multiskilling to improve the work area and increase efficiency through Kaizen. But as tensions grew between the conflicting demands of operators and manufacturing engineers, the degree of discretion the operators had was seen to decrease rather than increase as a result of CPS. By increasing the number of rules and regulations that govern the operation on the shop floor, manufacturing (production) engineers were able to reassert control over the FMS and eventually were successful in convincing management to do away with the team structure altogether.

There was agreement between operators and supervisors that the number of rules in the FMS had increased since the introduction of CPS. CPS added new rules concerning computer programming, tool setting, inspection, maintenance, production scheduling orders, material flow, quality control, time sheets, etc. In addition, the paper work for operators increased. With CPS there were more forms to fill-in, books that included highly descriptive methodologies of FMS operation were introduced on the shop floor with the production manager and manufacturing engineers playing the key role in introducing these new formats, rules and regulations.

CPS introduced very perspective discrete practices with the view that these were 'predicated on functional excellence'. New 'standards for excellence' with mandatory measures and audits were introduced.

In general, CPS improved material flow through the factory which aimed to reduce lead times by shortening production routes and to eliminating waste. The underlying objectives of this model were achieving synchronised flows and shorter lead times. Regulation was viewed as a critical factor to ensure that the synchronised flows were maintained.

The increase in regulation provided engineering management with a way to limit the autonomy of the FMS teams. As CPS called for increased operator autonomy and control over the process, manufacturing engineering viewed this aspect of CPS as detrimental to the production process and predicted that it would lead to crashes and disruptions in the production schedule. The increase in the number of rules, according to the manufacturing engineering, was necessary to ensure that the complexity of the FMS system did not hinder the operator's ability to keep up with the production schedule.

It was precisely this increase in the number of rules and regulations that contradicted the original view of CPS as giving operators or team members, as they were called increased responsibility and autonomy over their production area. This apparent contradiction in the original objectives of CPS and its actual application in the FMS area were not recognised by the human resources department. Instead, human resources continued to put forward the line of the productivity improvements and the lean production logic calling for increased autonomy and independence of operators. The results were an increase in the tensions on the shop floor where on the one hand where human resources focused on operator training and increased control for operators over the FMS. On the other hand, the production and manufacturing management were stressing the need for more and better rules for production in order to prevent crashes in the FMS as a result of the complexity associated with these systems.

The freedom of operators to plan their work on the FMS was curtailed. Manufacturing engineering continued to limit the role of the operators and to pressure the production manager to limit the interference of operators in what was traditionally the role of process (manufacturing) engineers.

As the demand for the two engine models continued to grow and with the addition of a new engine family, the pressures on the production people increased significantly and manufacturing engineering was able to convince management to suspend the teamwork structures. The suspension of the teams was presented as a temporary measure which was necessary for the restructuring and the introduction of new FMS and CNC production machines used in the development of a new class of engine.

The surprising fact was that operators have accepted the new changes and the suspension of teamwork as a *fait accompli*. This easy acceptance points to two issues: 1) that the original team structure, which was in practice, was not viewed as effective by managers and was not thought of highly by the operators.

One reason for the lack of enthusiasm for the teamwork component of CPS was the degree of increased regulation that accompanied the implementation of CPS. More rules and regulations, less autonomy and control for team members meant that these teams were not true teams and accordingly the suspension did not constitute loss of an acquired privilege.

The second reason mentioned earlier, was the employees' worry about the future of their jobs. Realising the competitive external environment and the constant call by CPS to improve productivity and efficiency, operators worried about job security. Because of the change in circumstances, unions did not have the same leverage that they had had before. CMN management was able to convey to employees through CPS and various steps that management was serious about cost cutting and that top management was facing increased pressures from share holders to deliver on profitability. The joint venture with another company and the infusion of new capital into the company was a boost for CMN and it made workers feel more secure about the future of their jobs. This overriding fact seemed to have tempered operator objections to the new changes and made them accept a return to the bureaucratic, traditional control strategies that the company had exercised before CPS and, as it seems, also during CPS.

Regulations and rules were the key instruments of managerial control and through these rules and regulations, manufacturing management was able to limit the degree of operator autonomy and freedom over the flexible manufacturing systems and maintain its overall control of the production area.

Inconsistencies and tensions in the interaction between lean production and FMS resulted in part from one or more of the following:

I. **Lack of true managerial commitment to full Lean Production philosophy implementation.**

II. **Contradictory messages sent to the FMS area were human resources encourages increasing operator autonomy through the LP system while production staff and supervisors increase the degree of regulation and control over the production process through a variety of means.**

III. **Macro level, existential pressures, such as redundancy, loss of job security, and significantly increased production pressures leading to a return to the pre Lean Production work methods.**

Figure 8.1: Key issues revealed in the case studies: Existence of tensions with consequences to the production system as a whole.

8.4.5 Flexibility

At EBG Truck manufacturing company, Under the new organisational arrangements, the company concentrated on increasing overall flexibility of the organisation with the intention of improving its competitiveness and maintaining production costs at competitive levels. The new focus was primarily on labour flexibility with flexible working hours and longer operating times. The company also adopted a 'buildto-order' philosophy and reorganised the manufacturing functions through the adoption of new wave manufacturing techniques such as 'lean enterprise' with the objective of increasing flexibility, reducing lead times, as well as coping with the changing environment and future demand. In the FMS area, the focus was on mix flexibility. Responses to the interview questionnaire by operators indicated that the overall flexibility of operations associated with the lean production in the FMS area appears to have remained at the same level. Because the FMS operators were Group 7 salary group, i.e. highly skilled and experienced workers, the ability of these workers to exercise judgement and make 'on the spot' operational changes remained the same. Probed further is subsequent interviews, it was noted that the implementation of operational teams and the Objective Matrix appears to have put certain constraints on the operators' discretion. On the other hand, by virtue of increased flow of information between production areas and increased knowledge of incoming production changes and targets, operators are better able to organise their work and alter their operational schedules to better advantage and hence increase their flexibility.

At Fokker Aircraft, the overall flexibility of the production system benefited from the lean production approaches. As the operators in the FMS were organised into teams of 10 –15 of multi-skilled operators and with the participation of staff programmers and quality personnel in addressing production problems, the flexibility of the system improved considerably. By its very nature, the flexibility of the FMS system and the CNCs in the area operated by multi-skilled operators, made possible for the company, in times of low manufacturing activity, to offer its production capacity to external clients. These FMS services were offered for other aviation companies as well as to the military. During the research, the two contracts in operation were for NATO as well as for the Boeing Aircraft company.

Production efficiencies and flexibility continued to be viewed by the group team leaders and operators as having been improved since the introduction of lean production. The responses to the questions on the degree of flexibility; the ability to adjust at any moment to changing market conditions; and the ability to change production parameters and make design changes scored positively by all respondents (ranging from increased to significantly increased).

In chapter six, CMCs decision to adopted lean production was predicated on the expectation that the full adoption of lean production would make the company more flexible and increase its ability to respond to market demands at very short notice. In retrospect, The plant manager viewed the company as 'having increased its overall flexibility' through Outsourcing of small parts production, multiskilling of operators, and the use of FMS in addition to the skilled workforce. These three components were present at CMC and as a result, the production team was able to adopt the new compressor design without any major disruptions and CMC did not experience the traditional teething problems that were usually associated with manufacturing of a model as we saw in the CMN case.

At CMN Engines, the importance of flexibility in the system was underscored by the production manager. The company placed considerable importance to its customers and the market demands for quitter, more efficient, environmentally friendly diesel engines . The flexibility of the FMS was instrumental in helping the company keep up with the competition in the market place. Additionally, operator skill was also seen as an essential element in the flexibility equation. CPS with its focus on training of operators to be multi-skilled contributed to the development of CMN production flexibility. In the FMS environment, Although the production manager and manufacturing view was that the company possessed both flexible technology and flexible operators, in the responses to interview questions concerning changes to flexibility as a result of the introduction of CPS, the general view was that it remained 'about the same'. Nevertheless,. the flexibility was seen by some operators in the FMS area to be constrained by the degree of regulation associated with the CPS system.

8.5 Thematic Analysis

There is an underlying assumption in most of the new 'Management of AMT' literature (Noori, 1990; Gerwin and Kolodny, 1992; Zairi, 1992; Karwowski and Salvendy, 1994) that the combination of AMT and NWM will lead to very high productivity and competitive gains. These gains are achieved through, inter alia, extensive increase in flexibility and significantly reduced lead times. In the four cases reported here interviewees reported a very different picture. The evidence from the four case studies indicated that there were indeed inconsistencies and tensions in the relationship between elements of the lean production and the adopted forms of AMT.

Accordingly, these tensions had an impact on the ability of three of the four manufacturers to realise the productivity and flexibility advantages managers sought. These tensions were primarily discovered in the type of procedures and rules associated with FMS use. The high degree of automation inherent in FMS embraced high levels of integration, as well as a high degree of regulation, and it included extensive sets of rules and procedures. These rules and procedures, when juxtaposed with the message of the new wave manufacturing approaches - which called for increased autonomy and employee empowerment and control-sent conflicting messages to the employeeson the shop floor.

A central aim was to explore whether these tensions and consistencies were due to an intrinsic incongruity in the application of lean production to the FMS environment.

In the CMC compressors case we saw that the coupling did lead to significant productivity and flexibility gains. Thus for this particular company no visible contradictions were discovered suggesting that these tensions and contradictions are not the result of an inherent flow in the concept.

Case study	Key issues	findings	Resulting Developments
EBG Truck Company	Increased complexity and demands on the FMS - LP coupling lead to increased regulation, inconsistencies and stresses on the system	Contradictory messages between Human Resources versus manufacturing production staff	Failure to achieve optimum productivity gains as a result of inadequate managerial commitment to full lean production implementation
CMN Engine	Initial implementation of LP lead to recognisable gains. Further development of LP system lead to inconsistencies and resistance	Contradictory messages: HR versus Manufacturing	Initial improvement and productivity gains but later tensions lead to suspension of teams
Fokker Aircraft	LP lead to improvements yet uncertainties over job security and high degree of regulation contributed to inconsistencies	Traditional high degree of regulation contrasted with move towards increasing autonomy	Job security pressure due to increased redundancies making LP and demarcation / power relationships less of an issue
CMC compressors	Adopted lean production and appeared to have achieved a better fit between LP and FMS	Combination of small size, autonomous multiskilled workers and simpler production process lead to gains	Operator autonomy was viewed excessive by management and lead to reverting to tighter control of job sequencing process

Table 8.1 Summary of case study results

Based on the investigation of these four manufacturing companies, it was found that when contradictions existed, these were more attributable to certain managerial, operational, or structural considerations and not due to a fault in the theory informing these concepts.

In the case of EBG Truck manufacturing company, inconsistencies were identified and the complexity of the FMS was presented as one of the reasons for the retreat from the earlier stated lean production and the return to more traditional manufacturing operations.

For EBG, as production increased, the complexity of the operation on the FMS increased. For example, while in 1994 the FMS area machined two types of timing cases, later they machined 10 different types of timing cases. Problems resulting from this increase in production also affected the MIS system of the company and led to reports of increased system breakdowns, problems in machinery breakdowns, as well as some quality problems associated with semi-skilled operators. The Management's response was to institute new rules and regulations particularly in the FMS.

The new team structure seen in Figure 4.15 was identified as a part of the EBG managements'increase in regulations at the FMS. It institutionalised the differences between the semi-skilled and multi-skilled operators and created an elite group of core multi-skilled operators who were flexible, moved from place to place on the production line depending on the need at the time, and gave directions and mentoring to the new semi-skilled operators. Yet, when it came to the specific production activities, management increased its control by focusing on 'departmental efficiencies' and a 'paper system' with 'performance indicators' detailing the set targets and the variability between them and what was actually being done on the shop floor. This 'paper system' related to all aspects of the operation including the man utilisation, maintenance, machine breakdowns, machine utilisation, training, and so on.

What was significant over the period of investigation of this company was that its general focus had shifted from the traditional issues of quality, delivery, and price that were the key terms in 1994 to 'man utilisation' as the key focus of EBG management. Targets were set top down based on managerial estimates and weekly controls are instituted through this 'paper system' to check on these targets.

The complexity of the FMS operation and the increase in the number of semi-skilled operators was given as one of the reasons why management opted for the new bureaucratic structure. Either way, the result was a definite move away from the original principles of the Lean Enterprise and a shift back to the more traditional manufacturing operation. These new arrangements led a reported decrease in the level of job satisfaction of the operators and even a decrease in the response to the set targets as well as to the production requests from other functions. This was directly attributed to the lean enterprise concept of continuous improvement where management was continuously optimising the process and setting new and more difficult targets once the old targets were reached without any recognition (in the view of workers) of the operators' efforts in achieving the set targets.

The return to traditional manufacturing operation was not limited to the advanced manufacturing areas (i.e. FMS and CNC production areas) but it also extended to the engine assembly. Driven by the decrease in multi-skilled assemblers/operators, a number of quality problems arose as a result of the inexperience of the new workers. Management moved to reorganise the assembly area and separate the work into simpler tasks within the cell so as to minimise the risk of quality defects.

Thus, at EGB, as pressure on the company increased, the interaction between the NWM strategies and the increased complexity and demands on the FMS led to increased regulation and inconsistencies that eventually led EBG management to revert to taking full charge of the production process.

The dramatic increase in demand for the EBG truck led its management to return to a functional, traditional form of work organisation. This, does not detract from the fact that while originally the NWM strategies implementation were very ambitious, the company often kept a significant number of these strategies intact even as it reverted to the traditional manufacturing operation.

In the second case, the Fokker aircraft manufacturing company, which adopted various forms of new production technologies in addition to lean production, the result of the interaction between the two did lead to reported improvements in productivity and efficiency. The human resources department played a key role in trying to increase the degree of autonomy and control of operators through the introduction of teamwork, multiskilling and problem solving techniques. Other managers, on the other hand, focused on reducing costs, eliminating waste, and improving lead times as key drivers for the company's survival, yet the company continued to be burdened with over-capacity and decreased demands for its products. In addition, the company carried the baggage of a complacent and inflexible bureaucracy that regulated every aspect of the production process. The restructuring of the company and the introduction of lean production played a major role in giving the company a second chance. Nevertheless, it still needed to be leaner and while the financial position worsened, the company continued to eliminate excess capacity and reduce the number of employees.

Given this state of flux, it was difficult to reach a conclusion on the degree of compatibility or incompatibility between the advanced manufacturing technologies and the lean production approaches. The central issue reported by all employees in the company was 'job security' and the uncertain future of the company. Given this pessimistic outlook and the continued stream of layoffs, it was almost impossible to instil the desired new culture in the company and the ability to solicit cooperation in all areas of operation was diminished.

What was different in this case was the fact that on the production floor and particularly in the AMT areas, there was already a high degree of regulation. Even managers realised this fact and attempted to decrease the regulation through lean production. Again, looking at the interaction between the lean production approaches and the utilisation of AMT, although this company had utilised lean production, it was possible to identify inconsistencies and contradictions in the relationship between the approaches of the human resources and that of the production department and manufacturing staff. This was because the company was still operating on traditional terms and its adoption of lean production was not accompanied by an evident change in philosophy but rather sprang out of the need to drastically reduce costs.

Looking at the production floor and the FMS areas in particular, the dramatic impact of all the layoffs on the company had a severe negative impact on the atmosphere and the attitudes of operators and staff alike. The issue of compatibility or incompatibility between FMS use and lean production was not a major concern for employees. As mentioned earlier, there were tensions on the shop floor but these tensions were also a result of the uncertainty and fear of job loss. There were conflicting messages between the human resources department (with its call for increased operator autonomy and control) and the production staff (calling for increased managerial control). It was due, in part, to the complexity of the technology, that these messages were overshadowed by overriding tension between management and operators about the future of their jobs and distaste for the lean production approach. Lean production was viewed as the instrument for eliminating jobs, as well as a pervasive bureaucracy and high degree of regulation already being practised on the production floor and in the FMS area.

At CMN, the diesel engine manufacturing company, the key conclusions were that while the initial implementation of these lean approaches led to recognisable productivity and flexibility gains (through the coupling of LP and FMS), further developments of the more progressive stages of the lean production concepts faced acceptance problems. This was particularly true in the flexible manufacturing systems areas were the interaction between the demands of the FMS and those of the lean production where seen to be in conflict.

Over the years, the company developed standardised and formalised modes of operation which still affected the attitudes and behaviours of employees in the areas. With the attempts to implement the more progressive forms of new wave manufacturing (i.e. those that endeavour to increase employee level of autonomy and control), two contrasting messages were being sent to the shop floor. Here too, high levels of regulation and control coupled with these new wave manufacturing approaches confused the operators on the shop floor.

The human resources department wholeheartedly adopted the lean production particularly those calling for devolving power down on to the shop floor. CPS, the company's new production system, was the tool used to transform this company from a traditional organisation to a progressive organisation that is synchronised with all the modern and advanced practices of work organisation. Yet, on the opposite side, manufacturing engineering still viewed the relationship on the shop floor in traditional terms. CPS ushered in a new form of work organisation but it also increased the potential for improved control of the manufacturing process.

Initially, manufacturing engineers did object to the changes and viewed operators as; 'they can be a party to the control process'. But, at the FMS, manufacturing engineers saw the system as too complex to be left to operators and introduced 'fail systems' adding alarms to minimise problems at the FMS.

At the same time, management increased the rules and regulations governing the entire operation of the FMS. These included kaizen team requests for authorisation. While operators' span of control on the FMS initially increased with CPS, the manufacturing department through extensive new rules and regulations reduced the degree of freedom of the operators to plan and execute their work.

In this case, the adopted lean production approaches which also called for worker empowerment and devolution of responsibility to the shop floor through team based organisation have simultaneously increased centralisation and managerial control through increased surveillance and discipline through rules and regulations.

The company's new production system (CPS) improved the productivity of the company and reduced lead times. Yet with the contradictory messages and increased formalisation and regulation at the shop floor, it was not possible to sustain this same lead time level. By the last visit to the company in 1999, charts showed the lead-time for the engines to be around 23 days per engine a slight increase from before. Other factors could have contributed to this lead time change. It was clear that a contributing factor was the conflicting messages between human resources and manufacturing engineering and the dissatisfaction on the shop floor over the increased pressures and control from manufacturing engineering.

Eventually, the human resources department was unable to continue with its strategy to devolve control to the operators and teams were suspended and the FMS, the most independent of the teams was disbanded. With this suspension of teams, manufacturing engineering regained control of the production process. Although management professed that this suspension of teams was temporary pending the 'settling down' of the production process due to the introduction of new production lines and manufacturing areas for the new engine design, it is doubtful that the experiment will be repeated in the same way. Thus, the input to the company of a new engine line and the need to restructure the factory gave management the excuse it needed to address the contradictions between CPS and FMS. The old FMS has been replaced, new engines have been introduced, teams have been abolished even though manufacturing engineering manager claimed that they were 'refocused' rather than eliminated.

The view of management of the team experiment was that these teams lacked the necessary discipline for success and that teams were driven by a culture that was less 'hard nosed' and less 'cost reducing /bottom line' conscious.

In CNM, the coupling of the lean production and FMS lead to productivity gains in the manufacturing process. But later, because of the contradictory messages between the human resources and the manufacturing engineering, inconsistencies in the relationship between the lean production and the Flexible Manufacturing Systems began to appear. These inconsistencies eventually led to the suspension of the team structures in the organisation helped by macro level changes that forced the change in the structure.

Although this company professed to implement the lean production, its approach to the implementation followed a traditional manufacturing logic. The key actors in this process who exercised the greatest influence were the production and manufacturing departments with production managers, supervisors, and manufacturing engineers still clinging to maintain their control over the production process.

In the third company CMC Compressors, which provided an example of a relatively small size company (180 employees) which adopted lean production to its FMS environment, This coupling was exemplified in its adoption, in full, of the lean production philosophy as well as its use of flexible manufacturing systems (FMS). The results of this interaction appear to have led to increases in productivity and reductions in lead times as well as helped in making the company become more flexible and responsive to market changes. The success of the company in increasing its productivity, introducing a new compressor design for production and keeping up with increased product demands can be seen to be the result of its full-hearted adoption of the lean production philosophy. Management perceived CMC to be totally transformed from the its older traditional ways of operation using multi-skilled workers who apply new technology as well as utilise teamwork to achieve the company's desired objectives. All this is done quietly, and efficiently. Two important qualifications from the analysis of this company relate to production volume to be the contributor to the successful coupling of FMS and LP. CMC's relatively low volumes eased the pressure on the production function. Secondly, CMC's relatively small size made it is easy to maintain a small company atmosphere and develop the necessary teamwork structures to maximum efficiency and advantage. In contrast, the companies that had the apparent incongruity in the coupling of lean production to the FMS (EBG Trucks and CMN Engines) were relatively large in size and the pressures on the production function were much more acute.

In all the cases, the underlying and forceful change factor is often more existential. Macro-level issues relating to employment, redundancy, and the future survival of the company are always at the forefront. Thus the traditional issues of power relationships and control over the production process become secondary and lose their effect when the survival of all actors, managers and employees, is at stake.

The application of lean production systems to the flexible manufacturing systems environment will not mean an automatic improvement in productivity, reduction in lead times, or guarantee improvements in the desired type of flexibility. This study addressed some of the dimensions related to the interaction between lean production and FMS and pointed to areas that revealed the points of tension and addressed their consequences.

To date, the issue of AMT and NWM still occupies a significant portion of the interest of researchers and practitioners alike. Manufacturing companies are continually facing new challenges that call for an ongoing process of analysis and examination of the core competencies and contingencies necessary for their survival. Choices are being made about advanced manufacturing technology and these new organisational arrangements, structures and systems are being adopted and adapted in an effort to maximise these competencies and achieve and maintain competitive advantage.

Lowe et al.(1997) emphasised the importance of context, specific plant characteristics, and choice for understanding the performance of manufacturing organisations. They rejected the notion that the work organisation and human resource policies associated with the lean production model represent a universal "best way" for achieving high manufacturing performance. The evidence from the four manufacturing companies who adopted lean production to the FMS similarly points in the same direction.

8.5 Limitation of the Study

As is the case with all case study research, it is difficult to make a valid generalisation beyond the specifics of each case. By choosing four case studies with relatively similar flexible manufacturing and lean production systems, an attempt was made to find common themes and provide some insights on the dynamics of the interaction between the lean production system and the FMS. Nevertheless, each of the companies investigated had its own unique characteristics that made a true comparison between them suspect to methodological errors.

1. There any tensions in the interaction relationship between lean production concepts and systems and its coupling with Flexible Manufacturing Systems.

2. Some of the constraints to the overall flexibility seem to be associated with the application of lean production to the FMS.

3. Upon closer examination of the dimensions of these lean production formulas, when set along side the realities of FMS use in Western manufacturing, a more complex, even problematic relationship emerges. The reality of the actual coupling of lean production to the FMS environment points to a different picture.

The emphasis of production managers on tighter control and the regulation work process codification seems to contradict the human resources stated focus on increasing employee discretion, a contradiction similar to that between the "lean" and "team" approaches described by Applebaum and Bart (1994). The apparent increase in tensions between these approaches was particularly visible in the EBG and CMN cases.

8.6 Directions for future research

These tensions are affecting the ability of manufacturers to truly realise the claimed productivity and flexibility advantages. These tensions can be seen in the type of procedures and rules associated with FMS use. The high degree of automation inherent in the FMS embraces high levels of complexity, integration, as well as a high degree of regulation, which include extensive sets of rules and procedures. These rules and procedures, when juxtaposed with the message in lean production -which call for increased autonomy and employee empowerment and control- are sending opposing signals. compatible but due to certain managerial, operational, structural, environmental, or other similar considerations, the tensions exist - or are being allowed to exist. These tensions were an issue in the literature on job design particularly in repetitive operations such as auto assembly (e.g., Womack, Jones, and Roos, 1990; Berggren, 1992; Adler and Cole, 1993). Similar concern were expressed in companies were work is far less repetitive such as software development (Cusumano, 1991; Lecht, 1991; Scat, 1991). The varied nature of these debates reflect the conflicting assessments of the core features of regulation dimension discussed in this thesis. These are the outstanding issues which require further elaboration.

The application of lean production systems to the FMS environment will not necessarily mean an automatic improvement in productivity, reduction in lead times, or guarantee improvements in the desired type of flexibility. Future research on the interaction between lean production and the AMT could explore more closely how firm size affect might affect the interaction between the two.

APPENDIX I

3.2.5.6 List of Questions

Interviewee job title

Interviewee, background

Interviewee Duties, job description

Nature of the factory studied

Number of employees

Ratio of total number of employees to salaried employees

Business strategy

Key components of strategy

Main customers

Market changes?

Company performance

Major competitors

Types of products produced

Product range

Major kinds of manufacturing activities

Recent History?

Any major changes or developments on the manufacturing technology side

How many organisational levels are at the plant?

Organizational form?

Detailed description of the technology, nature of the production technologies used

Type of AMT (FMS)

Identify major kinds of equipment

The functions performed

How many of each kind

Characterise the production process type

(one of a kind? small batch? medium? large? mass?)

Date of introduction of equipment (FMS)?

Capacity of the equipment?

Types of employees and their numbers in the FMS?

Nature of the components produced?

How many different components typically use the equipment?

Identify the most important components typically produced?

What final product of the factory is each a component of?

Manufacturing Operations?

How? Number of shifts?

Amount of direct versus indirect labour performed?

Detailed description of the organisational arrangements

Lean production: JIT, TQM, SPC, Training, Zero defects, Teamwork, Multiskilling, Kaizen

Teams? history, details?

Self-regulating?

Does group make its own internal distribution of work tasks?

Monitoring of own performance: lead time, quality costs, suggestions for improvement

Monitoring of team performance? Haw? By whom?

Understanding key variances in the product and process?

Inspection?

Maintenance?

Programming?

Tool Setting?

Other? Specify

Interaction and coordination with others?

Lean Production

What effects did the use of lean production have on the organisation of work?

What is your view of the lean production components?

Lean production focus: approach to production?

What do you think is your primary focus? And how does the technology affect that focus

Haw are the lean production measures defined by the company: by managers? Staff? Supervisors? Operators? (at each level of the organisation.)

Questions on Key dimensions

Complexity

Has the production process become more or less complicated?

Do you do more or less jobs than you did before the FMS?

To what extent do you have different products following different process routings?

Control complexity (Resource complexity + product complexity)?

Number and Variety of machines are needed to transform or produce a part?

What are the skills needed to run the FMS?

Integration

Interdependence of workflows

Interdependence between work stations

Since the introduction of the FMS:

What Changes?

The level of responsibility of operators?

Regulation

Number of procedures?

Degree of adherence to these procedures and rules?

(Managerial perspective versus operator perspective?)

The degree to which operators' tasks are well defined and structured?

Has the actual duties associated with the machines/operation increased? Decreased?

Lets talk about:

The Rules, Procedures

Rules Type? Documentation? Supervision? Explain

Has pressure on you to perform work increased or decreased or remained the same?

Do you consider the technology (equipment) your using as highly regulating?

(Does it require uniform behaviour as regards to data inputs)? On the FMS Do you use the thing every time?

Parts fixturing? Change of worn-out tools?

(Predictable reaction to disturbances)

do you think this increase in rules and regulations had an impact on your work (autonomy)?

Are there any obstacles that you see due to rules and regulations and the nature of FMS work?

What changes have occurred in the policies, procedures relating to your area?

What changes have occurred on how you record and report your work (operating information)?

The following are questions relating to degree of control (autonomy)

Degree of discretion operators have over execution and planning of work:

Decision on where to work?

Decision on when to work?

Decisions on the pace of work?

Decision on activities?

Decisions on the use-age? (FMS)

Decisions on maintenance

The scope of initiatives for operators since introduction of lean production? Increased? Decreased?

Changes to operator's ability to reorganise individual jobs since the introduction of lean production?

The number of rules associated with work since the introduction of the lean production systems?

Flexibility

Type of flexibility?

Degree of flexibility for component

Production capacity

Material inputs

Organisation of work

Importance of flexibility?

Views of the extent of flexibility of the production process as understood by the users?

Ease in changing volume, lot sizes, number of different components, work organisation allocation of tasks, ease in changing output rate?

Has flexibility in your area increased, decreased, or remained the same as a result of the new technology?

Has flexibility in your area increased, decreased, or remained the same as a result of the organisational change?

Impact of FMS on flexibility?

What type of flexibility is the key actor here?

Work organisation:

Use of the technology

Automation levels in FMS area

How is work organised?

Describe your work

What changes have occurred since the introduction of the new technology?

Were these changes coupled (introduced together with organizational changes?

How do you view these changes?

Doing the job? Control? New skills learning?

Job rotation

Skill type

The range of skills used by an operator

The qualification level of the operators

Haw many shifts?

Haw many operators are under the responsibility of a supervisor (foreman) in Assembly and in Manufacturing.

How much change has occurred?

TQM programs used? Details?

When were these techniques (Org. changes, TQM) introduced

What effects?

Changes since implementation?

What type of adjustments did you make to these programs?

How extensive was the training?

What about multiskilling?

Job definitions? Employee roles?

What are your views about the organizational arrangements: lean production

Role of individual in FMS environment

Role of equipment/machine operators before/after/currently?

What changes have occurred in the activities, skills, and training of supervisors

What changes have occurred in the activities, skills, and training of operators

What changes have occurred in the policies and procedures of the following:

Production scheduling? Maintenance? Quality control? Inventory control?

What changes have occurred in the reporting of operation information?

What are your biggest problems with the organisation of your work on the FMS?

Criteria of effectiveness?

Productivity:

Labour productivity (output/man-hour)?

Machine utilisation?

Quality and reliability of produced components?

Length of time it takes to manufacture a component?

Cost of manufacturing equipment?

Human resources policies:

Personnel management policies

Selection

Reward systems

Pay scales

Training

Degree? Extent.

Do you think that the training was enough?

Or did you have to learn on the job from others

Empowerment?

Skilling

Multiskilling

Job reduction

Management Delayering

Team working

Human Resource Policies;

Personnel management policies?

Effectiveness and impact?

Haw many different job classifications in the manufacturing plant?

Suggestions for process and product improvements?

The control activities needed to perform the tasks:

Need to maintain control over the shop floor activities?

Degree of integration?

Inter-relatedness to other functions?

Degree of complexity?

The most important focus of manufacturing/production department at this time?

Improving lead times? Improving flexibility? Other?

The scope of initiative for operators since introduction of the FMS?

Since the introduction of the (FMS), your views on operators ability to reorganise individual jobs?

Questions for operators: Do you feel that supervisors listen to your inputs?

Your views on the Role of operator in the [FMS] environment

Before/ after introduction of FMS

What changes have occurred in the activities, skills, training of supervisors, team members, operators.

Questionnaire

These questions were developed to prepare the interviewees for the nature and scope of the questions and to gain insights on the key dimensions under study. These dimensions were used as the research tool for evaluating the consistency or tensions between 'Lean Enterprise' concepts and its application to the FMS environment. While the answers were collected and reviewed in terms of their differences, they were not further analysed.

Most of the interview started at question 5

Loughborough University Business School

Human Resources and Change Management Unit

Questionnaire:

This questionnaire is part of a Ph.D study investigating the compatibility between advanced manufacturing technologies (AMT) and the use of new organisational innovations and structures in manufacturing firms (recently termed New Wave Manufacturing).

NOTE: The Answers will be treated with full confidentiality and the names of the company, business unit, products, and individuals will not be released

Name

Company

Job title

Industry Sector

Nature of the factory studied

Number of employees

Types of products produced

Major kinds of manufacturing activties

Organisational form

Please answer all questions that apply to your plant

Greenfield site? Yes/No

1.Type of production in the Plant: Assembly ? Manufacturing ? Both ?

2. type of process used in the plant (tick all appropriate types)

One-off?

(Frequently used, sometimes used, Rarely used, Never used?)

Batch?

(Frequently used, sometimes used, Rarely used, Never used?)

Line?

(Frequently used, sometimes used, Rarely used, Never used?)

New work arrangements and organisation:

3. Please tick if your company is using any of the following work organisation methods and concepts. (Use a '?' if you are not sure about usage or unfamiliar with the term)

1= extensively implemented; 2= partially implemented, 3= beginning to implement; 4= Do not have

ISO9000 / BS5750

Just-in-time delivery (JIT)

Total Quality Control (TQC)

Total Quality Management (TQM)

Pull schedulling (e.g.Kanban)

Statistical Process control (SPC)

Zero defect programs

Continous Improvements (Kaizen)

Manufacturing organised into "plant-with-in-plant"

Machines organised into cells (Cellular layout)

Total Productive Maintenance (TPM)

Design for Assembly (DFA)

Design for Manufacturability (DFM)
Activity Based Accounting (ABC)
Master Production Schedule (MPS)
Lean Production system (LP)
Simultaneous Engineering
Benchmarking
Business Process Reengineering
Employees organised into teams
In-house training programs
Cross training of operators on different equipment
Job rotation

NEW TECHNOLOGIES

4. Please tick if your company is using any of the following manufacturing technologies (Use '?' if you are not sure about usage or unfamiliar with the term)

Numerical control machines (NC) _____
Computer Numerical Control (CNC) _____
Direct numerical control (DNC) _____
(Multiple machine controlled by
central computer)
Group Technology (GT) _____
Industrial Robots (IR) _____
Flexible Manufacturing Cells (FMC) _____
Flexible Manufacturing Systems (FMS) _____
Computer Integrated Manufacturing (CIM) _____
Automated Storage and Retreival (AS/AR) _____
Automated materials handling (MH) _____
Computer Aided Design (CAD) _____
Computer Aided Engineering (CAE) _____
Material Requirement Planning (MRP) _____

Manufacturing Resources Planning (MRPII)_____

5. Consider the degree of importance of the following goals to your company in your opinion

(please indicate by numbering from 1 to 5 your opinion on the order of importance where:

1= most important and 5= least important

Having lower manufacturing costs than our competitors ______

Offering faster deliveries than our competitors ______

Offering superior product design and manufacturing ______

Quality as compared to our competitors ______

Offering wider product range than our competitors ______

Having superior customer service ______

6a. Please indicate the extent of increase (or decrease) in each of the following activities since the introduction of the new (or advanced) manufacturing technology (FMS) to your plant.

1= Significantly decreased; 2= Deceased;3= About the same; 4= Increased; 5= Significantly increased

Interdependence between work stations

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Need for coordination between manufacturing and other areas

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Number of rules and procedures associated with work

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

The complexity of operations

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

The need for increased supervision and tighter management control

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Degree of freedom of operators to do the jobs

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Operators span of control over work assignments

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Operators freedom to plan the work

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

6b. Please indicate the extent of increase (or decrease) in each of the following activities since the introduction of the new manufacturing technology to your plant or area

7. The degree of flexibility:

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

The ability to adjust at any moment to changing market conditions

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Ability to change quickly between products

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Ability to easily change each of the following:

Production volume

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Lot size of a given component

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Ease of allocating tasks among operators

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Ease of rerouting components

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Ease in making design changes

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Ease in changing output rates

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

The extent to which managers communicate the importance of the various performance dimensions to you has?

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

8. For each of the following measures and activities, the use of the Flexible manufacturing technology has led :

Capacity

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Machine Utilisation

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

cost of manufacturing a component

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Productivity of labour (output/man-hour)

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

Quality and reliability of components produced

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

The time it takes to manufacture a component

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

The level of in-process inventories

1= Significantly decreased

2= Deceased

3= About the same

4= Increased

5= Significantly increased

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