Sequences in the Process of Adopting Lean Production

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AKADEMISK AVHANDLING
FÖR AVLÄGGANDE AV
EKONOMIE DOKTORSEXAMEN

Avhandlingen framläggs till offentlig granskning
onsdagen den 17 december 1997 kl 13.15
Sal 550, Handelshögskolan, Sveavägen 65

STOCKHOLM 1997

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A thesis for the doctor's degree
in Business Administration
Stockholm School of Economics 1997

ISBN 91-7258-456-4

Key words:
Operations management
Lean production
Implementation
Sequences
Clinical methodology

Cover design: Sheelagh Gaw

Printed by: Gotab, Stockholm 1997

Distributed by:
EFI, The Economic Research Institute
Stockholm School of Economics
Box 6501, S-113 83 Stockholm, Sweden

To Sheelagh

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I -
I took the one less travelled by,
And that has made all the difference.

Robert Frost

Preface

This report is submitted as a doctor's thesis at the Stockholm School of Economics. The research has been carried out as a part of the research programme at the Centre for Industrial Production at EFI, the Economic Research Institute at the Stockholm School of Economics.

The research project has been carried out within Institute for Management of Innovation and Technology (IMIT). The project has been generously funded by the case company Office Machines. This support is gratefully acknowledged and special thanks are given to the managing director and the production director for their helpful collaboration.

As usual, the author has been entirely free to conduct and present his research in his own ways as an expression of his own ideas.

Stockholm in November, 1997

Rune Castenäs	Christer Karlsson
Director EFI, The Economic Research Institute at the Stockholm School of Economics	Professor in Industrial Production Director Institute for Management of Innovation and Technology and Head of the Centre for Industrial Production at EFI

Acknowledgements

Researching and writing a doctoral thesis is like setting out on a journey; a rather long and solitary journey, which now has come to an end. I started my journey on a cold night in January 1993, by taking the train from Stockholm to a remote part of Sweden. This part of the country would prove to be my second home for the following two and a half years.

I have had the privilege to spend this time in Office Machines, where my doctoral research took place. To preserve the true identity of the company, I cannot unfortunately by name thank all those to whom I remain most grateful. My gratitude extends particularly to VD, who initiated the collaboration leading to the study, and to P, for his support during my work at the company. However, a warm thanks must go to all those who I came into contact with at Office Machines. To numerous to mention; you all contributed to my second home being enjoyable and educational.

Although I have undertaken the journey leading to this thesis alone, I have benefited from the support of others. The journey has throughout been made under the guidance of Professor Christer Karlsson, Stockholm School of Economics, my thesis supervisor and mentor. He took me on as a doctoral student and introduced me to the process of doing research. I have learnt much under his guidance and could not have wished for a better introduction to the land of research. I owe much of this thesis to him.

My colleagues and friends at Stockholm School of Economics have also contributed to my work and views on research. The stimulating coffee table discussions and (sometimes critical) comments on my work, have affected my thinking, though you may not think that is the case, from reading this thesis. I am particularly thankful to Professor Bengt Stymne, who has provided me with challenging and stimulating comments throughout my work. His questions always gave me a lot to think about. Partial financial support was given to me by a research programme at the department for Man and Organisation, for which I am grateful. The third member of my thesis committee, Professor Leif Melin, Jönköping International Business School, also deserves to be mentioned for his constructive comments.

The last two and a half years, the role of mentor has to some extent been played by Professor Christopher Voss, at the Centre for Operations Management, London Business School. Through the generous sponsorship of the Swedish Council for Work Life Research, I was able to spend a year at the Centre as a visitor. Later, Professor Voss gave me an opportunity to stay in London and conduct research. His knowledge of operations management has been a source of inspiration and support for me the past two and a half years.

I have learnt a great deal during my time in London and particularly from the research I have conducted here. I have also benefited from discussions with colleagues at London Business School, who have commented on earlier drafts of the thesis. Be certain that without my staying in London, this thesis would have been something completely different.

Finally, to someone who more than anyone has supported me in writing this thesis. Beyond the call of duty, you have read and commented on my drafts, improving both my language and the logic of my argument. The encouragement and love you have given me, throughout the final stages of my journey, has made it all worthwhile.

Sheelagh, this one is for you.

London in November, 1997

Pär Åhlström

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CHAPTER 1

Sequences of Improvement Initiatives in Manufacturing

A central debate in manufacturing strategy theory is whether or not trade-offs exist between different capabilities of a manufacturing system. Does a manufacturing company have to concentrate on a few competitive priorities or can it excel at everything it does? The notion of trade-offs was introduced by the manufacturing strategy field's founder (Skinner, 1969; 1974) and implies that improvement of one manufacturing capability is possible only at the expense of others (Wheelwright, 1984).

The success of Japanese manufacturing companies has led to the notion of trade-offs being questioned (Voss, 1995b). Compared with their competitors, Japanese companies seemed to simultaneously excel at several capabilities: quality, dependability, flexibility, variety, and cost (Clark, 1996). The success of Japanese companies has led to the emergence of a dominant design of manufacturing management practices (Hayes and Pisano, 1996).

Principal among those who question the notion of trade-offs are Ferdows and De Meyer (1990). Based on how Japanese manufacturing companies build their capabilities, Ferdows and De Meyer argue that manufacturing capabilities are not the result of compromises and trade-offs but are instead built cumulatively. In their sandcone model, Ferdows and De Meyer suggest the sequence in which capabilities should be built. The sequence they suggest:

> Puts the quality at the base; then - while the efforts on quality improvement continue and expand - focuses also on improving the dependability of the production process; next, again while the previous efforts are expanded, also pays attention to improving the reaction speed and flexibility of the production system. It is then, while all previous efforts continue to expand, that direct attention to cost efficiency is justified. (p. 170)

However, Ferdows and De Meyer say nothing about how the capabilities are built. On this issue, the authors state that companies can use a multitude of different initiatives. Neither do Ferdows and De Meyer say anything about the sequence of the initiatives with which manufacturing capabilities are built. The central problem examined in the present study is sequences of improvement initiatives in manufacturing.

1.1 Implementation of Japanese Manufacturing Management Practices

Research on sequences of improvement initiatives in manufacturing is concerned with how manufacturing capabilities are built. The research is therefore part of the literature on implementation of Japanese manufacturing management practices. Implementation has relatively recently begun to attract attention in literature (Storhagen, 1993). Early literature on Japanese manufacturing management practices described the content of the practices, not how the practices were implemented.

1.1.1 Early Literature Described the Content of Japanese Manufacturing Management Practices

The first article describing Japanese manufacturing management practices in English was written by Sugimori and colleagues (1977). The article familiarised Western researchers with the reasons behind the success of some Japanese companies such as Toyota Motor Corporation. It helped shift the explanation for the success away from contextual factors, such as institutional arrangements, wage structure, and culture, towards the manufacturing management practices (Hayes, 1981). Since then, the literature has been replete with research on topics related to the way Japanese companies manage manufacturing.

The initial literature contained descriptions of Japanese companies made both by Japanese and Western observers. An early contribution was made by Monden (1981a; 1981b; 1981c; 1981d) who, in a series of articles, described Toyota Motor Corporation's production system. The articles were the foundation for his influential book *Toyota Production System* (Monden, 1983), which contained a detailed account of how Toyota manages its production system. At about the same time Shingo (1981), one of the architects of the Toyota production system, published a book translated into English.

Slowly Western observers began to realise that a reason behind the success of some Japanese companies was their manufacturing management practices. An early indication was three articles in *Harvard Business Review*, which refuted the idea the Japanese success was attributable to factors such as institutional arrangements, wage structure, and culture:

- In the first article, the Japanese car-makers' success was attributed to 'superiority in the manufacturing plant, especially in their process systems and workforce management' (Abernathy et al., 1981, p. 68).
- The second article concluded that the Japanese success was attributable to the fact they have 'never stopped emphasizing the basics. To them, every stage of the manufacturing process - from product design to distribution - is equally important' (Hayes, 1981, p. 57).
- The third article concluded that the secret behind the Japanese achievements in manufacturing was 'not cultural ideals nor government policies nor industry structures but a very special understanding of what it means to manage a production system' (Wheelwright, 1981, p. 68).

The first Western author who systematically analysed Japanese manufacturing management practices was Schonberger (1982a) in his influential book *Japanese Manufacturing Techniques*. He was the person who most of all familiarised us with concepts such as "just-in-time" and "total quality control", which he claimed were the reasons behind the Japanese success. The issue of transferability of Japanese manufacturing management practices to the West, was another theme in the book. Here Schonberger was optimistic and did not see cultural differences between countries as an impediment to the transfer.

1.1.2 Descriptions of Western Applications of Japanese Manufacturing Management Practices

A second stream of literature contained descriptions of Japanese manufacturing management practices applied in Western industry. Schonberger (1982a) was an early contributor to this stream of literature with his description of Kawasaki in Nebraska, who were working with just-in-time and total quality control. In his second book, Schonberger (1986) described numerous U.S. companies working with Japanese manufacturing management practices.

The transfer of Japanese manufacturing management practices was not restricted to companies in the United States. Other early contributions to this stream of literature contained descriptions of British companies. Turnbull (1986; 1988) described the experiences of Lucas Electrical in working with just-in-time. A survey made by Voss and Robinson (1987) indicated a high level of awareness and understanding of just-in-time among British companies.

Findings on actual implementation, however, produced a less favourable picture. Few British companies were making a serious attempt to implement just-in-time (Voss and Robinson, 1987). One explanation for the lack of implementation is that although Japanese manufacturing management practices are transferable to the West, they are difficult to implement (Nakane and Hall, 1983). Indeed, not all companies in Japan have implemented the practices.

The difference in manufacturing management practices among Japanese companies was found in a survey of operational practice and performance of assembly plants in the world auto industry (Krafcik, 1988a). Two empirical findings were that:

- Quality and productivity performance differed among Japanese plants.
- Subsidiaries of Japanese companies had approximately the same performance as their parents.

The conclusions, therefore, were that some manufacturing systems produce better results than others and the myth of national performance could be debunked (Krafcik, 1988b). No longer was it appropriate to discuss Japanese manufacturing management practices. It was more appropriate to discuss the Toyota production system, which Krafcik termed "lean production".

1.1.3 Consistent Terminology Is Lacking

A note on the diversity and lack of consistent terminology is appropriate before we proceed to discuss the implementation literature. Several terms are used to characterise Japanese manufacturing management practices. Some examples are: just-in-time, world class manufacturing, time-based management, and lean production.

The term "lean production" has been chosen in the present study. The main reason for this choice is that the term has gained widespread attention, both in research and in practice. The term is probably also the best suited for the purpose of reflecting the full scope of Japanese manufacturing management practices (Voss, 1995a). The consequence of the diversity in terminology is that different studies may use different terms for describing Japanese manufacturing management practices. However, the difference is likely to be a minor problem, since the different terms often denote similar basic components.

A note on the difference between conceptual and empirical studies is also appropriate (Gomes and Mentzer, 1988). Conceptual studies contain descriptions and lack empirical tests. Most research on implementation is conceptual, suggesting how strategy should be implemented, without the empirical evidence to support the suggestions (Skivington and Daft, 1991). Attention is primarily devoted to studies with a basis in the empirical world.

1.1.4 Areas Presenting a Challenge During the Implementation of Lean Production

Turning our attention to literature on implementation of Japanese manufacturing management practices, or lean production, we are not interested in the content of lean production, but in how it is implemented. Implementing lean production is a significant managerial challenge (Zipkin, 1991). Implementing lean production is likely to be associated with a number of problems, issues, and obstacles (Arogyaswarmy and Simmons, 1991). Areas that present a challenge have been identified in the implementation literature (Young, 1992). A few examples of challenging areas are discussed below.

Employee Involvement and Support from Unions

A challenge highlighted by different authors, is the need for employee involvement in order to succeed with the implementation of lean production (Chen, 1991). Employee involvement is, for instance, stressed by Giles and Starkey (1988) in their account of the Japanisation of Rank Xerox. The need for employee involvement should be no surprise, considering the emphasis put on it in the literature on organisational change (see for instance Stjernberg, 1977).

The implementation of lean production can be seen as a threat by employees, due to its radical impact on the shop floor. There is, therefore, a need to involve unions in the implementation (Harber et al., 1990). Proper implementation also requires operators to perform several different jobs. In Western industry, this often requires support from unions to overcome limitations of too narrowly defined job specifications (Lee and Ebrahimpour, 1984; Inman and Mehra, 1989).

Top Management Support and the Changing Role of Supervisors

The effects of lean production are not restricted to the shop floor level. Changes need to take place at all levels of the organisation. Top management support during implementation is therefore crucial. The need for top management support is stressed by numerous authors (see for instance Lee and Ebrahimpour, 1984; Harber et al., 1990; Im and Lee, 1989).

The implementation of lean production has effects at the supervisory level (Oliver and Davies, 1990). Organisation hierarchies are often flattened, so if there is still a supervisory level in the organisation, its role will change. One empirical finding is that supervisors may find themselves faced with implementing decisions, but divorced from the status and authority associated with being a manager (Lowe, 1993). In an Australian car manufacturing plant, supervisors were more likely than operators to report stress in their work following the implementation of lean production (Shadur and Bamber, 1994). Lean production placed greater demands on supervisory staff to manage more indirect tasks than before, since the teams managed themselves.

Obsolete Management Accounting Systems

The management accounting system is a third area where difficulties are likely to arise during the implementation of lean production. Since the publication of the influential book with the challenging title *Relevance Lost* (Johnson and Kaplan, 1987), considerable attention has been directed towards management accounting systems' incompatibility with lean production. Two examples of the incompatibility are the importance of identifying cost drivers and the need to change performance measures. Due to its incompatibility with lean production, the management accounting system plays an important role when implementing lean production (Åhlström and Karlsson, 1996).

The implementation of lean production requires changes to the management accounting system. The need for making changes has been known since at least the early 1980s (see for instance Kaplan, 1983; 1984). The nature of the changes is not obvious and is the subject of a continuing debate among management accounting researchers. Several solutions have been suggested, for instance activity based costing (Cooper and Kaplan, 1988) and the balanced scorecard (Kaplan and Norton, 1992).

Performance Evaluation and Reward Systems

Related to the problem with management accounting are the performance evaluation and reward systems (Storhagen, 1993). A recurring difficulty during implementation is that organisations implement lean production while retaining the old performance evaluation system (Safayeni et al., 1991). The implicit and explicit reward systems in the organisation often encourage behaviour. To change such behaviour one needs to change the factors that feed them (Oliver, 1990). Performance evaluation and reward systems are such factors.

1.1.5 There Is a Need to Take a Systems View of Implementation

In view of the challenges associated with implementing lean production, a crucial starting point for successful implementation is that different elements of lean production can not be seen in isolation (Voss and Robinson, 1987; Storhagen, 1993; Hayes et al., 1988). The organisation structure and its appropriateness for lean production must also be considered for successful implementation (Safayeni and Purdy, 1991):

> Organisations cannot maintain the same structure, same habits, same performance evaluation systems and simply add JIT to the existing practices and events in the organisational system and expect it to work. (Safayeni et al., 1991, p. 36)

There is a need to take a systems view of implementation. Successful implementation of lean production requires first of all that the different elements of lean production are implemented together. Successful implementation also requires organisational changes. Most of these changes have long-term effects on the organisation and its surrounding environment. Implementing lean production can therefore not be done overnight; implementation may take several years (Lee and Ebrahimpour, 1984).

1.2 Sequences of Improvement Initiatives in Manufacturing

We now turn to the core problem researched in the present study - sequences of improvement initiatives in manufacturing. Improvement initiatives, to emphasise, refer to Japanese manufacturing management practices or lean production. The challenges facing a company implementing lean production implies that although it is important not to implement the different elements of lean production in isolation, the various problems that are likely to arise may necessitate sequencing the implementation. Different elements of lean production may therefore have to be implemented one after the other.

The empirical evidence suggests that companies address implementation sequentially. Regarding which sequence companies follow, the evidence is not conclusive. In a survey of the implementation schedules in eleven companies, it was difficult to identify a general implementation pattern (Im and Lee, 1989). The design of Im and Lee's study was unfortunately rather simplistic: implementation was researched through sending a four-page questionnaire to the companies. This makes the results difficult to interpret.

Criticising the use of short questionnaires for researching implementation sequences is a fair and serious criticism, if seen against the background of the need to take a systems view of implementation (Voss and Robinson, 1987). The problem is that collecting empirical data from the whole manufacturing system and the surrounding organisation is a major undertaking (Gomes and Mentzer, 1988). So far, there are only three studies that adequately research both the implementation of the different elements of lean production and their consequence for the organisation.

1.2.1 Reviewing Studies on Implementation Sequences

The first study taking a systems view of implementation was carried out by Roos (1990). Roos conducted case studies in twenty-one British companies working with Japanese manufacturing management practices. Based on the case studies, Roos presented a model of how the implementation of total quality management is carried out.

According to Roos, it is initially necessary to change employees' attitudes to quality, to achieve a material flow absent of non-value adding operations. Changing attitudes to quality requires changes in management profile and human resource practices. Managers need to be generalists instead of specialists. Human resource practices need to encompass for instance life time employment and equal status among different categories of employees.

Just-in-time can be implemented when the material flow consists only of value adding operations. Just-in-time denotes a material flow with deliveries in the right time, at the right place, and in the right quantities. Just-in-time is implemented by emphasising the group instead of the individual, through for instance reward systems and quality circles. Implementing just-in-time also requires activities and results to be simple and visible. Simplicity and visibility is accomplished by techniques such as kanban and flow layouts.

A second study taking a systems view of implementation was carried out by Storhagen (1993). He conducted fifty-two short case studies in Japan and three deeper case studies in Sweden. On the issue of implementation sequences, Storhagen suggested there is a need to start implementing what he termed "process factors". The main purpose of process factors is to support continuous improvement, change, and development. Examples of process factors are job rotation and teamwork.

After the process factors a company can implement what was termed "structural factors" and/or "interaction factors":

- Structural factors are techniques and methods that alter the structural features of the manufacturing system, such as layouts and set-up time reduction.
- Interaction factors increase the physical and organisational interaction along the material flow, for instance geographical proximity and quality certification of suppliers.

The implementation of structural and/or interaction factors does not mean the process factors are abandoned. The process factors are supplemented with the structural and interaction factors. The result of this implementation sequence will be a change in the performance of the manufacturing system.

A third and recent contribution to the literature on sequences of improvement initiatives in manufacturing is made by Filippini and colleagues (1998). The authors carried out a detailed survey of 125 companies in Italy, Japan, and the United States and analyse the sequence of the initiatives companies implemented to improve manufacturing. The study tries in particular to ascertain whether common sequences existed or whether each company had its own sequence, depending on its manufacturing process and context.

A number of conclusions are drawn regarding the relationship between manufacturing context and the sequence a company followed when improving manufacturing. The main conclusion is that there were relationships between the manufacturing context's complexity and improvement sequences:

- Companies operating in a context of high variety, low unitary volumes, and on international markets, implemented all initiatives the study considered.
- Companies with a high level of variety, but less exposed to international competition, concentrated mainly on technological initiatives, such as design computerisation and flexible manufacturing systems.
- Companies operating in stable conditions (little variety, high levels of product standardisation, and long product life cycles) only launched initiatives with the aim of changing the manufacturing organisation. Examples are employee involvement and reduction of the number of hierarchical levels.

Filippini and colleagues also found a difference between country of origin and the sequence of initiatives. The Japanese plants in the sample were mainly implementing all initiatives the study considered whereas the U.S. plants were more frequently discriminating between the initiatives. Furthermore, only ten percent of the Japanese plants implemented the more technologically-oriented initiatives prior to those oriented more towards organisation and management. Forty-three percent of the U.S. plants in the sample, on the other hand, implemented the more technologically-oriented initiatives first.

Taken together, the three studies add to our knowledge of sequences of improvement initiatives in manufacturing. Perhaps most importantly, the studies provide support for the notion that there are sequences of improvement initiatives in manufacturing. Regarding which sequences exist, the message seems to be that there are various sequences. From the studies we can also conclude that apart from being implemented one after the other, initiatives frequently seem to be implemented in parallel.

1.2.2 The Importance of Studying the Implementation Process

Although increasing our knowledge of sequences of improvement initiatives in manufacturing, the three studies of the subject share one weakness: they do not take a process view of implementation (Storhagen, 1993; Young, 1992). A process view implies studying implementation through longitudinal research, as opposed to cross-sectional research (Kimberly, 1976). A process view of implementation is particularly appropriate if we are to gain a better understanding of sequences of improvement initiatives in manufacturing. Against the need to take a process view, objections can be raised against the research design of the three studies reviewed above.

Roos (1990) conducted a series of case studies. The primary source of data was one visit to each company, containing interviews with between one and six managers per company. The interviews were in some cases supplemented by secondary data, such as annual reports and newspaper articles. My objection concerns the fact this research design led to a prescriptive model for the implementation process. I find it difficult to see how Roos could arrive at these conclusions using the type of data he collected at the companies.

Storhagen (1993) based his conclusions regarding sequences on a detailed description of the three Swedish companies, as organised at the time of the study. Based on the extensive Japanese case material, the descriptions of the Swedish companies were converted to an ideal picture of how the companies would (presumably) be organised if based in Japan. The hypothetical descriptions were presented to the managers of the Swedish companies. The managers' reactions on what was realistic, unrealistic, and difficult to implement were recorded. The reactions, combined with implementation literature, formed the basis for the conclusions. Although this is an innovative method, I maintain that managers' reactions prior to implementation do not accurately reflect the actual difficulties associated with implementation.

Filippini and colleagues (1998) used questionnaires to collect data, as a part of the World class manufacturing project (Flynn et al., 1989). In the questionnaire, managers were asked to indicate when the company had started a particular initiative on a pre-defined list. The strength of this research design is the possibility of analysing sequences of improvement initiatives in many companies with different contexts, to ascertain the influence of context on the sequences. The weakness of the research design is the lack of depth in the analysis. Based on a questionnaire, it is difficult to gain knowledge of how companies actually implement various initiatives.

On the basis of these criticisms, I conclude that although the three studies have taught us a great deal about sequences of improvement initiatives in manufacturing, more remains to be learnt. If we are to learn more about sequences of improvement initiatives in manufacturing, we need research which takes a process view of implementation.

1.3 Sequences in the Process of Adopting Lean Production

The present study has been designed to address this gap in knowledge. The discussion has so far been focused on positioning the present study on the map of existing knowledge. We now turn to a discussion and elaboration of the research problem. The focus is on how sequences of improvement initiatives in manufacturing is defined and researched in the present study.

1.3.1 Sequences of Lean Production Principles

Improvement initiatives first of all need definition. The present study is part of the literature on Japanese manufacturing management practices. Having noted the diversity in terms used to characterise Japanese manufacturing management practices, I have in the present study chosen the term "lean production". A reason for this choice, to emphasise, is that the term is probably the best suited for the purpose of reflecting the full scope of Japanese manufacturing management practices (Voss, 1995a).

With lean production being the operationalisation of improvement initiatives, the problem of sequences refer to the different elements of lean production. The elements are in the present study termed "principles" (Karlsson and Åhlström, 1996a). Lean production consists of several principles, each of which is concerned with a particular aspect of the manufacturing system. The principles are defined in Chapter Two.

The problem of sequences refers in the present study to the principles of lean production. Sequences are the order in which the principles are implemented, where the order underlines the relationships between the principles (Filippini et al., 1998). The central problem being researched in the present study, therefore, is whether there exist any sequences of lean production principles and what the sequences are.

1.3.2 Implementation as a Process of Adoption

Dealing with how manufacturing capabilities are built, the present study is part of the literature on implementation of Japanese manufacturing management practices. Using the term "implementation" to denote how manufacturing capabilities are built has, however, several drawbacks. Implementation is in the present study therefore seen as a process of adoption:

> The study of implementation might be called more precisely the study of the process of adoption. (Voss, 1988, p. 56)

Seeing implementation as a process of adoption has several benefits and consequences. The choice of adoption entails seeing the organisation as an organism accepting something new, in this case trying to change its way of working in accordance with lean production principles. Implementation, on the other hand, connotes a view of a ready-made solution being brought into the organisation, which will either resist it or accept it. Adoption should therefore not be seen as regarding how a particular change project can be foisted on a system with minimal resistance, as implied in the literature on resistance to change (see for instance Kotter and Schlesinger, 1979).

Seeing implementation as a process of adoption emphasises the necessity of adaptation, not just deployment or adherence to a plan (Leonard-Barton, 1991). The choice of adoption process as opposed to implementation also emphasises lean production's lack of a well-defined end point. Lean production points out the direction in which the organisation intends to move and is not an answer to a specific problem (Hayes and Pisano, 1994).

Most importantly, seeing implementation as a process of adoption entails taking a process view of the problem of sequences. By taking a process view, the present study seeks to make a contribution to existing knowledge. The term "process" has been used in many ways. Van de Ven (1993) makes a distinction between three different uses of the term "process" as:

1) A logic that explains a causal relationship between independent and dependent variables.
2) A category of concepts or variables that refer to action of individuals or organisations.
3) A sequence of events that describe how things change over time.

The term "process" has in the present study been used according to the third category and the definition of process is 'progressions (the order and sequence) of events' (Van de Ven and Poole, 1995, p. 512). The definition of the process of adopting lean production therefore reads: the order and sequence of events as an organisation adopts lean production.

1.3.3 Issues in the Process of Adopting Lean Production

Adopting lean production is a significant managerial challenge (Zipkin, 1991). Central to the management of the adoption process is the notion of issues:

> In any process of change a number of substantive issues arise which require decisions to be made by actors, either by conscious choice and negotiation or by omission (non-decision). (Clark et al., 1988, p. 31)

The rationale for emphasising issues is the challenge of adopting lean production (Nakane and Hall, 1983). Should we require further evidence for the challenge of the task, we have only to consult the extensive literature on organisational change. With the risk of sounding commonplace; organisational change is difficult (see for example Kanter et al., 1992). A number of issues are therefore likely to arise throughout the whole process of adopting lean production (Oliver, 1990; Arogyaswarmy and Simmons, 1991). We have already discussed a few areas where issues may arise.

Issues are a key construct in the present study. Three characteristics of issues, as conceived of here, need to be pointed out:

1) Issues refer to events and trends (Dutton and Dukerich, 1991).
2) Issues can emerge from the organisation's external or internal environment (Dutton and Ottensmeyer, 1987).
3) Issues are seen by managers as having a (potential) significant impact on the adoption process (Dutton et al., 1983).

Issues mostly concern problems and obstacles in the process of adopting lean production. However, issues are not equal to problems, but can relate both to threats and to opportunities (Ansoff, 1980). Managers are, on the other hand, likely to be more sensitive to issue characteristics associated with threats than to those associated with opportunities (Jackson and Dutton, 1988).

Issues reflect or indicate the effort and resources management need to devote to the adoption process. Central to managing an adoption process is to address the issues that arise (Clark et al., 1988). Addressing the issues is likely to require significant effort and resources from the managers responsible for the adoption of lean production, since 'not all obstacles can be anticipated at the outset, and problems must be worked out over time' (Brown and Mitchell, 1991, p. 915). Adopting lean production, with the purpose of achieving lasting improvements in manufacturing capability, therefore requires tolerance and patience (Ferdows and De Meyer, 1990).

1.3.4 Issues and Sequences of Lean Production Principles

Issues are a clue to sequences of lean production principles. The review of existing literature provided evidence for the existence of sequences of lean production principles in the adoption process. Depending on the role we acknowledge management, we obtain two reasons for the sequences:

1) Sequences of lean production principles are the outcome of the inherent logic of the adoption process. Compare this with the notion of a natural sequence in the building of manufacturing capabilities (Ferdows and De Meyer, 1990).
2) Sequences of lean production principles are the outcome of managerial action and decisions.

The two reasons for the existence of sequences can be seen as extreme positions on a continuum representing the possibility actors in the adoption process have to affect the sequences:

- Seeing the sequences as the outcome of the inherent logic of the adoption process minimises actors' possibility to affect the sequences.
- Seeing the sequences as the outcome of managerial action and decisions maximises actors' possibility to affect the sequences.

A third reason for the existence of sequences of lean production principles in the adoption process can be proposed. In the present study, sequences are seen as the outcome of a combination of the inherent logic of the adoption process and management action and decisions. Central to this view is Cyert and March's (1992) notion of problemistic search: 'search that is stimulated by a problem (usually a rather specific one) and is directed toward finding a solution to that problem' (p. 169). A second assumption is that management effort and resources are scarce. The resources have to be devoted to various tasks, of which the adoption of lean production is only one. Demands from other areas of the business affect the amount of effort and resources that can be devoted to the adoption process.

The issues that arise in the adoption process require management action (Clark et al., 1988). Management devotes effort and resources to the issues as they arise. Since management effort and resources are limited, there are only a certain number of issues that can be addressed simultaneously. There may therefore be a need to sequence the adoption of lean production. Thus, sequences are, if not caused by the issues that arise, at least reinforced by the issues. With this in mind, the purpose of the present study can be stated.

1.3.5 Purpose and Research Design

The purpose of the present study is to determine sequences of lean production principles through an examination of the patterns of issues in the adoption process.

The purpose emphasises the role of issues. Issues indicate the amount of management effort and resources devoted to the adoption of lean production principles. Issues also indicate the sequence in which the principles of lean production are adopted. Sequences of lean production principles are, finally, reinforced by the issues that arise.

A premise in the design of the study was that the criteria for a good research design stem from the research problem, not an ideal of perfect knowledge (Diesing, 1991). The choice of research design is contingent both on the problems and questions being investigated and the state of knowledge development in the field (Pettigrew, 1990). The following considerations were the basis of the research design:

- The focus in the present study was the process of adopting lean production. The study of processes requires longitudinal research: 'techniques, methodologies and activities which permit the observation, description and/or classification of organizational phenomena in such a way that processes can be identified and empirically documented' (Kimberly, 1976, p. 329).
- It is best to study change processes as they unfold (Van de Ven, 1993). Process studies are best initiated before the outcomes are known (Van de Ven and Poole, 1990), since knowledge of outcomes can bias the findings of a study (Staw, 1975). The most significant limitation of retrospective research is the difficulty of determining cause and effect from reconstructed events (Leonard-Barton, 1990).
- A managerial perspective was chosen in studying the adoption process, since the purpose of the study in one respect regarded how to manage the adoption process: 'if the purpose of a study is to understand how to manage the formulation or implementation of an organizational strategy, it will be necessary for researchers to place themselves into the manager's temporal and contextual frames of reference' (Van de Ven, 1993, p. 319). Although placing oneself within a manager's frame of reference is likely to be difficult, and reconstruction is still likely to be made, taking a managerial perspective is to be differentiated from taking the perspective of other parties in the adoption process.

- Longitudinal studies of the types of changes the present study is concerned with are rare. The lack of studies is particularly pronounced if we consider studies carried out as the changes unfold. Since the current state of knowledge of the subject of interest is not well developed, the present study has an exploratory character.

These four considerations led to the choice of the clinical methodology, whose main characteristic is that researchers participate in and study organisational change from within the organisation (Stymne, 1970). The clinical methodology allows the researcher to follow an adoption process as it unfolds. This meets the criteria of studying the process longitudinally and in real-time. Being aligned with the management of an organisation, the researcher can easier assume a managerial perspective. The closeness to data achieved through spending a significant amount of time in an organisation, finally, facilitates theory building for exploratory purposes.

Given the considerable time needed to study the process of adopting lean production, I decided to use one deep case study. The study was carried out in Office Machines - the fictitious name of a company adopting lean production. The study spans a period of two and a half years, with 130 days in total of participation in the daily activities at various levels at the company. Data collection mainly took place through participant observation, which was supplemented by interviews and studies of documents.

1.3.6 A Road Map to the Study

Having introduced the background to and purpose of the present study, I now proceed to give a road map to the study, see Figure 1.1. The study contains four different parts, indicated at the top of Figure 1.1. The relationships between the chapters are indicated by the arrows.

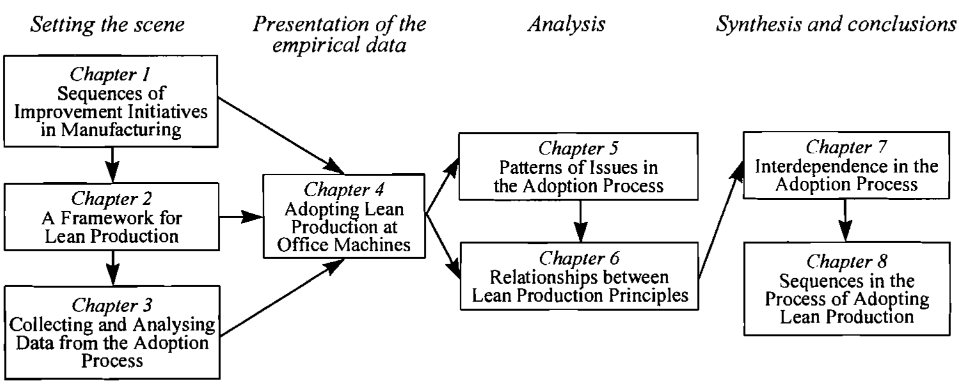

Figure 1.1 Road Map to the Study

The scene is set in the study's first part. Setting the scene is done through an introduction of the background to the research question and the tools used to carry out the research. Having defined the purpose of the study in the present chapter, the lean production framework is defined in Chapter Two. The lean production framework was crucial for the inquiry and was first of all used for data collection, which is the topic of Chapter Three. The chapter starts with a discussion of the nature, strengths, and weaknesses of the chosen research design and methods. It then proceeds to a discussion of how the analysis was conducted and the plausibility of the analysis.

The empirical data is introduced in the study's second part. Chapter Four starts with a general background to Office Machines, followed by an elaboration of why the company decided to adopt lean production. The main part of the chapter contains a presentation of the content of the adoption process: the actions taken to change the organisation according to lean production principles.

The analysis of the adoption process at Office Machines is the third part of the study. The analysis starts in Chapter Five, with an examination of the patterns of issues in the adoption process, with the aim of determining the major influences on the patterns. The relationships between the different lean production principles in the adoption process is the topic of Chapter Six. Determining the relationships between lean production principles is an important step in the pursuit of the final aim of the study - sequences of lean production principles.

The findings of the analysis are taken to a higher level of abstraction in the final part of the study. The findings are in Chapter Seven synthesised using operations management literature. The aim is to increase the generality of the findings by explaining why the sequences arose. The conclusions from the synthesis are, in Chapter Eight, compared with the existing studies of sequences of improvement initiatives in manufacturing. The comparison helps define the present study's contribution to existing knowledge. A summary of the conclusions and suggestions for future research ends the study.

CHAPTER 2

A Framework for Lean Production

With the purpose of studying the process of adopting lean production, a framework for the inquiry is needed. A framework 'explains, either graphically or in a narrative form, the main dimensions to be studied' (Miles and Huberman, 1984, p. 28). The framework of the present study contains the definition of lean production and was used to both collect and analyse data from the adoption process. This chapter makes a relatively detailed definition of lean production, which is necessary since lean production has been interpreted in many ways.

2.1 Lean Production

The term "lean production" was first introduced by Krafcik (1988b). However, it was through the bestseller *The Machine that Changed the World* (Womack et al., 1990), the lean production concept gained widespread attention. One consequence of the concept's popularity is that there exist several interpretations of what lean production encompasses.

The usage of the term "lean" has also been extended to other meanings. Womack and Jones (1994) use the term "the lean enterprise" to characterise a group of companies. Others use the term "lean management" to denote general aspects of management (Hinterhuber, 1994; Shadur and Bamber, 1994). Finally, the term "lean thinking" has been used to denote several aspects of organisational life (Womack and Jones, 1996).

As a consequence of this diversity in terminology, there is a need to make an explicit definition of lean production, see Figure 2.1. In making the definition, the starting point is the framework presented by Womack and colleagues (1990), which has been synthesised and further developed by Karlsson (1992).

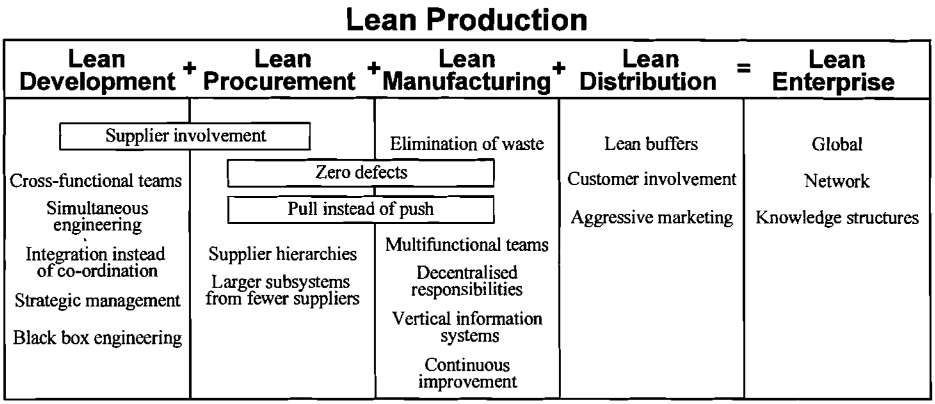

Figure 2.1 Lean Production

Although lean production spans several functional areas, as seen in Figure 2.1, the present study focuses on manufacturing. The study took place in a company working with the entire lean production framework, but longitudinal data were collected predominantly within manufacturing. Data from product development, procurement, and distribution were collected through snapshots at different points in time. Contributing to the decision to focus the present study on manufacturing is also that implementation issues in lean product development have been described separately (Karlsson and Åhlström, 1996b; 1997).

The decision to focus on manufacturing implies that changes within functions outside manufacturing were not dealt with in-depth in the present study. Functions outside manufacturing were, however, considered when they affected the adoption process within manufacturing. Recall that a prerequisite for successful adoption of lean production is to consider the required organisational changes. Functions outside manufacturing were, therefore, considered when they affected the adoption process within manufacturing.

Only the content of the manufacturing part of the lean production framework in Figure 2.1 will be developed. When developing the content of lean production, a distinction is made between principles and practices:

- *Lean production consists of a number of principles.* Each principle is concerned with a particular aspect of the manufacturing system. In Figure 2.1, the principles are Elimination of waste, Zero defects, Pull instead of push and so on. The principles are the lean production concept's building blocks. The question being researched in the present study is whether there exists any sequences of lean production principles in the adoption process and what the sequences are.

- *The principles consist of a set of practices.* Practices are the activities undertaken to change the organisation in order to achieve the desired performance (Dean and Bowen, 1994). The ultimate goal of adopting lean production is to enhance performance, for instance increase productivity, enhance quality, shorten lead times, and reduce costs. There is thus a distinction between the practice and the performance of a lean production system (Voss et al., 1995).

In developing the content of the lean production framework, it is the practices that need description. When describing lean production practices in more detail, Weick's (1979) characterisation of social theories has been kept in mind: it is impossible for a framework to simultaneously be general, accurate, and simple. The three dimensions are always in conflict with each other. I have chosen to make a definition of lean production that is general and simple. The accuracy of the definition has to some extent been sacrificed. This means I do not go into detail on the specific nature of the techniques associated with lean production practices (Dean and Bowen, 1994).

2.2 Elimination of Waste

Lean production's perhaps most distinguishing principle is the relentless pursuit of waste - everything that does not add value to the product (Monden, 1983). The customer is not willing to pay for waste and it should therefore be eliminated. Due to the lack of resources in Japan when Toyota Motor Corporation developed their production system, following the Second World War, eliminating waste was a necessary prerequisite of the production system (Schonberger, 1982b).

The principle of eliminating waste in the production system is not new. Taylor (1911), the founder of scientific management, paid attention to the importance of eliminating waste. However, for Taylor the greatest source of waste was the 'ill-directed movements of men' (p. 5). In lean production, waste is not limited to the movements of men. This difference has profound implications for how the production system is organised and managed.

2.2.1 Inventory Reduction

The most important source of waste is inventory. Holding parts and products in stock does not add value to them and inventory should therefore be eliminated. In the manufacturing process, inventory in the form of work-in-progress is especially wasteful (Hayes, 1981). Apart from representing committed funds, work-in-progress also hides problems and keeps them from getting solved. The effects of reducing work-in-progress, therefore, go beyond that of reducing capital employed (Hayes and Clark, 1986). However, since inventory exists for a reason, it is not advisable to eliminate inventory mindlessly. The causes behind the existence of inventory must be removed first (Zipkin, 1991). The practices detailed below reduce the need for inventory.

2.2.2 Set-up Time Reduction

One reason work-in-progress inventory exists is due to large batch sizes compensating for long set-up times (Shingo, 1981). The set-up time decides economically viable batch sizes, following the familiar formula for economic order quantities, since set-up times determine the set-up cost (Aquilano and Chase, 1991). The longer the set-up time is, the higher the set-up cost is, and the larger batch sizes need to be. The set-up cost is, however, not seen as constant within lean production (Schonberger, 1982a). If set-up cost is reduced, then cost per unit can be kept constant despite decreasing batch sizes. A reduction of set-up times is therefore essential.

Work to reduce set-up times was carried out at Toyota Motor Corporation following the Second World War (Shingo, 1985). Through an ingenious method, set-up times in large punch presses could be reduced from several hours to less than ten minutes (Shingo, 1981). Set-up times can often be reduced significantly at a surprisingly low cost (Johansen and McGuire, 1986). Set-up time reduction involves separating tasks which can be performed while the machine is still up and running (external set up) from tasks which requires the machine standing still (internal set up). As many tasks as possible are then converted to being performed while the machine is up and running. All tasks are finally performed more efficiently.

2.2.3 Preventive Maintenance for Reduced Machine Downtime

A second reason for the existence of inventory, is the use of work-in-progress as a buffer against shortages arising due to machine failures (Shingo, 1981). Preventive maintenance is a practice used to minimise downtime in machines (Nakajima, 1989). As a part of preventive maintenance, it is common for operators to check their machines daily (Schonberger, 1982a). Preventive maintenance techniques also include the use of careful records on each machine's usage as well as analysis to determine preventive maintenance needs and frequencies (Ainosuke, 1989).

Preventive maintenance is facilitated by avoiding overlapping shift-work (Schonberger, 1982a). Time between two shifts is instead kept free to perform preventive maintenance on the machines. Neither is equipment overloaded. Machines operate at slower rates than the maximum they were designed for, which increases the reliability of the machines (Hayes, 1981).

2.2.4 Layout Changes to Reduce Transportation of Parts

Transportation of parts is waste. Transporting parts from one location to another does not add any value to the product. A driving force of indirect costs are the transactions involved in ordering, executing, and confirming movement of parts from one location to another (Miller and Vollmann, 1985). Transportation of parts also adds to manufacturing lead time. It is therefore essential to reduce transportation in the manufacturing process.

When reducing transportation it is necessary to distinguish between rationalisation of transportation and an elimination of the need for transportation (Shingo, 1981). The use of automated carriers as a way of rationalising transportation is fine, but eliminating the need for transportation is far better. A practice used to eliminate the need for transportation is layout changes (Schonberger, 1982b).

A mutual theme for layout changes is that machines are grouped closer together, through the creation of manufacturing cells (Hyer and Wemmerlöv, 1984). A manufacturing cell is a collection of machines and material-handling equipment grouped together to manufacture one or several parts families. Parts are preferably completed within one cell. Within a manufacturing cell, further reduction of transportation can take place through physically connecting machines (Shingo, 1981). Transportation can also be reduced through organising machines in a U-shape (Monden, 1983). U-shaped layouts minimise transports since the entry and exit of a line are in the same position.

2.2.5 Reduction of Scrap and Rework

A final source of waste is lack of conformance quality. Manufacturing defective parts is wasteful, since they need to be scrapped or reworked. A lack of conformance quality is related to the existence of work-in-progress. One reason work-in-progress exists is to safeguard against the effects of unreliable manufacturing processes (Shingo, 1981). A driver of indirect costs are the transactions related to the manufacture of parts that do not conform to the specified quality requirements (Miller and Vollmann, 1985). The manufacture of fault-free parts takes place through the principle Zero defects.

2.3 Zero Defects

Quality is both a performance variable in and a prerequisite for a lean production system (Monden, 1983). The term "quality" is used here to mean conformance to specifications (Garvin, 1984). To attain high productivity, all parts and products need to be fault-free from the beginning (Hayes and Clark, 1986). The principle of Zero defects contains the practices used to attain quality products in lean production. The goal of the practices is to manufacture fault-free products.

2.3.1 Quality Is the Responsibility of Everyone

A salient feature of a lean production system is the lack of employees dedicated to quality control. Quality assurance is instead the responsibility of everyone. In manufacturing cells it is easy to trace a part to its origin and the responsibility for quality can therefore be assigned to the cell operators (Hyer and Wemmerlöv, 1984). Being held responsible for quality, operators in a lean production system demonstrate a clear concern for quality improvement even without explicit goals to reduce scrap and rework (Garvin, 1986). The operators' responsibility can be divided in two different areas:

- *Identification of defective parts.* Operators are allowed to stop the line if they find defective parts (Shingo, 1981).
- *Adjustment of defective parts.* The person who caused the defect is responsible for adjustment.

As a consequence of making operators responsible for quality, the size of the quality control department can be reduced (Schonberger, 1986). Ensuring quality from the beginning means the size of the adjustment and repair areas can be reduced (Krafcik, 1988b).

2.3.2 A Higher Degree of Process Control

One goal of the work with quality is to achieve a higher degree of process capability and control (Wheelwright and Bowen, 1996). Instead of inspecting the manufactured parts, the manufacturing process is kept under control. Keeping the process under control is achieved through knowledge of how process parameters and their interaction affect the characteristics of the product (Hayes et al., 1988). The aim is to use this knowledge to achieve consistency between products manufactured in repeated runs of the process. A tool in this work is statistical process control (Garvin, 1988), which facilitates both gaining new insights and communicating the insights (Hayes et al., 1988).

2.3.3 Autonomous Inspection

Devices for autonomous inspection or *poka yoke* are tools for the achievement of fault-free products (Monden, 1983). *Poka yoke* are inexpensive devices for ensuring defects and mistakes do not occur in the manufacturing process. The devices ensure the process stops, for instance if a part is wrongly assembled or if an operator forgets to pack a brochure in a box. *Poka yoke* can also be used to ensure the right part is fed to the operator assembling multiple products. The use of *poka yoke* is a means of conducting inspection of all units (Shingo, 1981). The power of *poka yoke* is their versatility; they can be used by anyone who understands the cause of a defect. However, the tools are most appropriate in situations involving repetitive work (Robinson and Schroeder, 1990).

The essence of both *poka yoke* and the achievement of a higher degree of process control, is that through discovering errors that can lead to defects, defects can be prevented from occurring (Oakland, 1993). Preventing defects from occurring contrasts with an inspection orientation, where the aim is to determine whether or not a batch of products is correct through sampling a percentage of products and testing them. An inspection orientation is reactive and does not assure quality (Robinson and Schroeder, 1990). An inspection orientation is more like writing out a death certificate after the patient has already died, instead of treating the illness while the patient is still alive.

2.4 Pull Instead of Push

In a lean production system, material is scheduled through pull instead of push. Scheduling in a push system starts with a forecast to determine an aggregate plan. The aggregate plan contains information on what to manufacture at different stages of the manufacturing process. A master schedule and more detailed schedules then control the manufacture of the forecasted number of parts at all stages of the manufacturing process (Aquilano and Chase, 1991). Parts are in a push system manufactured whether they are needed or not. In this sense, material and parts are "pushed" through the factory.

The pull principle of scheduling material stands in stark contrast to push scheduling. The starting point for manufacture in a pull system is not a forecast but a customer order (Karmarkar, 1989). The customer order goes to final assembly, who orders parts from the preceding manufacturing process. This manufacturing process orders parts from its preceding process, and so on. The customer order is in this manner passed backwards through the manufacturing process. Passing the order backwards means nothing is produced which has not been ordered.

A prerequisite for pull scheduling is to reduce batch sizes (Schonberger, 1982a). Through reducing batch sizes, flexibility to match production to demand is increased, since it is possible to switch between different parts more often without penalty in terms of cost or time. A second prerequisite for pull scheduling is fault-free parts. As batch sizes are reduced towards the ultimate goal of one, the effects of faulty parts become increasingly severe. If parts need to be reworked or scrapped, pull scheduling is not possible.

A pull scheduling system in its most extreme form will provide each operation in the manufacturing process with the right part, in the right quantity, at exactly the right point in time (Shingo, 1981). This is the just-in-time principle of material control. The ultimate goal of just-in-time is that every operation should be provided with one part at a time, exactly when needed. The ideal of piece-for-piece processing is seldom attained, but is an objective to be pursued (Schonberger, 1982b).

Push and pull scheduling are not mutually exclusive (Karmarkar, 1989). Since pull scheduling requires small batch sizes and short manufacturing lead times, it may take time for a company to move towards pull scheduling in the whole manufacturing process. During the adoption of lean production there will be an operation in the material flow where pull scheduling meets push scheduling. Prior to this operation, material is scheduled via a push system. After the operation, a pull system is used for scheduling material. The adoption of lean production means the point at which pull meets push is moved backwards in the material flow, until material is procured from suppliers on a pull basis.

2.5 Multifunctional Teams

The workforce makes an important contribution in a lean production system (Monden, 1983). The view of the workforce is different from the traditional view, rooted in scientific management. A basic tenet in scientific management is that management should assume responsibility for how the operator performs the job (Taylor, 1911). In lean production, investments are instead made in the problem-solving skills of the operators and their attention is focused on those problems they are in the best position to solve (Wheelwright, 1985). Releasing the operators' potential is done through multifunctional teams.

2.5.1 Increasing Use of Teamwork

The use of teamwork is widespread in lean production (Krafcik, 1988b). Teams are often organised around cell-based parts of the material flow. Each team is responsible for performing all tasks in this part of the material flow (Hyer and Wemmerlöv, 1984). However, it is not necessary to organise work in a manufacturing cell to have teamwork. It is possible to have teamwork along a driven production line. The layout dimension is not to be confused with the work organisation (Karlsson, 1996).

2.5.2 Developing the Flexibility of the Employees

The teams are manned by multifunctional operators (Monden, 1983). Instead of performing only a limited number of tasks, operators are able to perform several tasks in the team (Krafcik, 1988b). Operators are rotated between different tasks in the team several times per day (Monden, 1983). Achieving the goal of multifunctional operators has rather obvious demands on the amount of training operators require (Schonberger, 1986).

The development of multifunctional operators also calls for broad job specifications. Broad job specifications allow for the usage of fewer operators, since it is possible to shift operators to different jobs in line with the need of any given moment (Cusumano, 1988). Shifting operators to different jobs increases the flexibility and reduces the vulnerability of the manufacturing system.

Broader job specifications require appropriate payment forms (Symons and Jacobs, 1995). An individually oriented piece-rate system is likely to be inappropriate in a lean production environment (Karlsson and Åhlström, 1995). There is a need for a payment system congruent with lean production practices.

2.5.3 Increasing the Number of Tasks the Team Is Responsible For

Operators are made responsible for a number of indirect tasks. Job-related responsibilities are broad, going beyond the responsibility for a certain output and the cost of that output (Wheelwright, 1981). The teams are responsible for the regulation, organisation, and control of their jobs and the conditions immediately surrounding the jobs (Sexton, 1994).

Tasks such as machine maintenance and quality assurance are examples of tasks integrated in the multifunctional team's responsibilities. Other tasks that are candidates for integration are procurement and material handling and control. The practice of integrating indirect tasks changes the tasks of, for instance, production planners, schedulers, and manufacturing engineers (Hyer and Wemmerlöv, 1984). The number of indirect employees can also be reduced, since support functions are no longer necessary to the same extent (Schonberger, 1986).

2.6 Decentralised Responsibilities

The essence of decentralised responsibilities is that the multifunctional teams are held responsible for supervisory tasks. Depending on the size of the organisation, there may still be hierarchical levels between the team and the production manager. However, in a lean production system responsibility and authority are consistently pushed down to the lowest levels of the organisation (Hayes et al., 1988). The number of hierarchical levels in the organisation can as a consequence be reduced (Gunn, 1987).

One way in which supervisory tasks are transferred to the teams is through team leaders. Team leaders take on the supervisory roles of advisers, coaches, and providers of support, as opposed to the more traditional roles of bosses, disciplinarians, and givers of specific assignments (Hayes et al., 1988). Team leadership is in its most elaborate form rotated among employees especially trained for the task.

2.7 Vertical Information Systems

Vertical information systems are simple information systems relying on direct information flows to the relevant decision makers (Cole, 1985). A high amount of business information about performance and environment is distributed to all employees (Cole et al., 1993). Training is therefore necessary to ensure employees understand the information being provided.

One reason information is provided is for the multifunctional teams to perform according to the company's goals (Flynn et al., 1989). Independent problem solving also requires that each employee has an awareness of operating objectives. This awareness reduces the need for managers to micromanage the manufacturing process (Leonard-Barton, 1992). Making employees aware of operating objectives requires an information system that is real-time, problem identifying, and problem solving orientated (Wheelwright, 1985).

Providing operators with timely information allows for immediate feedback and rapid corrective action (Cole, 1985). Contrast this to a situation where decisions have to pass up through the organisation hierarchy and then down again, before corrective action can take place. Combined with systems taking top-level information down the organisation, there is also a need for systems taking information up through the organisation hierarchy (Hayes et al., 1988).

2.8 Continuous Improvement

The final lean production principle is Continuous improvement. The manufacturing system is constantly improved; perfection is the only goal (Hayes, 1981). After the Elimination of waste, Continuous improvement is the most fundamental principle of lean production. The constant striving for perfection has its own word in Japanese - *kaizen* - a term used as an overriding concept of Japanese manufacturing management (Imai, 1986). Continuous improvement is here applied in a more restricted sense and refers to the ongoing improvement involving operators (Wheelwright, 1985).

Involving operators in the improvement of the manufacturing process can be done in many forms (Hart et al., 1996). The most structured form of involvement is quality circles, where operators gather in groups to come up with suggestions on how to solve quality problems and make possible improvements to the manufacturing process (Cole, 1980b). Prior to participating in quality circles, operators need training in problem solving techniques and related matters (Cole, 1980a).

2.9 The Multiple Roles of the Lean Production Framework

Having defined the lean production framework, let me briefly describe the use of the framework in the present study. The lean production framework fulfils multiple roles. The framework first of all describes the content of the change Office Machines went through. When undertaking their efforts to improve manufacturing performance, managers at Office Machines used the framework as a guide to their actions and activities.

The lean production framework was also used as a conceptual guide during data collection. A conceptual guide was necessary to avoid getting overwhelmed by data (Miles, 1979). As a conceptual guide, the framework is not to be confused with pre-formulated theoretical propositions (Eisenhardt, 1989). The framework acted more like a telescope, pointed towards the organisation to direct my attention towards certain aspects of the organisation (Berg, 1974).

The framework was finally used during the analysis of data. The rationale for this choice being that the purpose of the study was to determine sequences of lean production principles. The framework thus served to focus the inquiry. Recall that a framework 'explains, either graphically or in a narrative form, the main dimensions to be studied' (Miles and Huberman, 1984, p. 28). Describing how the collection and analysis of data from the adoption process took place, is the task I turn to next.

CHAPTER 3

Collecting and Analysing Data from the Adoption Process

> People who write about methodology often forget that it is a matter of strategy, not of morals. There are neither good nor bad methods but only methods that are more or less effective under particular circumstances. (Homans, 1949, p. 330)

In describing the circumstances of and the way in which the present study was conducted, method and methodology are differentiated (Berg, 1981). Method is the way in which data are collected. Methodology is the set of basic principles of inquiry. There is an intimate link between method and methodology, since the choice of method implies a view of the studied situation (Morgan, 1983b). Methodology is also linked to the research design.

3.1 Research Design

The present study utilises the clinical methodology, whose principal characteristic is that the researcher participates in and studies organisational change from within the organisation. The aim is to contribute both to the advancement of knowledge and to the practical concerns of organisations:

> I use the term clinical organization research to denote research aimed at simultaneously solving organizational problems and acquiring increased knowledge about the way organizations function. (Stymne, 1970, p. 25)

The model for the clinical methodology is taken from clinical medicine. An active working relationship is sought with the organisation on its day-to-day problems. In this relationship, the researcher accepts a fully professional role with responsibility for helping in solving problems that arise (Jaques, 1951).

3.1.1 Reasons for Choosing the Clinical Methodology

The first rationale for the choice of the clinical methodology was the problem of access. Since organisations have a need to keep their inner functioning hidden from competitors, observers are often excluded. Observers may also get in the way or organisation members do not want to share personal conflicts, stress, and setbacks (Sofer, 1961).

Gaining access to an organisation is likely to be more of a problem the longer the study of the organisation is. The researcher who wishes to conduct a longitudinal field study faces a problem of access which is not to be underestimated (Van de Ven, 1993; Leonard-Barton, 1990). Clinical research offers a possibility to overcome the problem of access, since the organisation receives something in return for allowing the researcher access. Clinical research can therefore give access to situations from which researchers would otherwise have been barred (Sofer, 1961).

A second rationale for choosing the clinical methodology was the benefit of access to data not usually available for research (Stymne, 1970). One reason for the access to data is the psychological contract, the set of unspoken expectations operating between the researcher and members of the organisation (Schein, 1987). Since the members of the organisation have a reason for having the researcher present, they are less likely to conceal data. By participating in the organisation and interacting with people for an extended period of time, the researcher can get close to the organisation (Sofer, 1961). Being close to data enhances the possibility of discovering the forces most crucial to the inquiry, which provides a fertile basis for generating theory (Miller and Friesen, 1982).

The choice of the clinical methodology was finally governed by the desire to study the adoption process as it unfolded. Analysing processes on the basis of retrospective research is problematic, since it is difficult to determine cause and effect from reconstructed events (Clark and Ford, 1970; Leonard-Barton, 1990). Reinterpreting things from a new perspective, an interviewee cannot always give an accurate account of the past (Becker and Geer, 1957). It is therefore best to study processes in real-time (Van de Ven, 1993).

3.1.2 Studying the Adoption Process at Office Machines

The present study is based on real-time observations of the adoption process at Office Machines. The observations span a period of two and a half years, with 130 days of participation in the daily activities of the company. Office Machines is not the company's real name, but is used for reasons of anonymity.

A necessary prerequisite for choosing Office Machines is that the company was adopting lean production. The collaboration leading to the study began with the company's commitment to adopting lean production. The lean production framework, as defined in Chapter Two, was presented by my thesis supervisor at a seminar attended by Office Machines's managing director. The managing director saw the similarities between the framework and the changes planned at the company and proposed a collaboration.

The collaboration meant that Office Machines would provide us with the opportunity to study the process of adopting lean production in real-time, in exchange for our support in the adoption process. As a result of the collaboration, Office Machines decided to adopt the lean production framework. The adoption decision concerned the entire framework, but the main focus in the present study is the manufacturing function.

There are several reasons why Office Machines was a suitable research object. Due to reasons of time constraints, only one case could be chosen for the study. It therefore made sense to choose a case where the adoption process was likely to be transparently observable (Eisenhardt, 1989). Office Machines's structure at the outset of the study provided an opportunity to study a radical reorganisation:

- Manufacturing was functionally organised, with assembly carried out on a production line.
- Transportation was frequent within and between the company's two sites.
- Manufacturing lead times were long and inventory high.
- Internal cost of quality was high.
- The work organisation contained supervisors and preparatory workers, with each employee performing only one job.
- Management style had historically been authoritarian. Employees were not expected to act on their own initiative.

It also deserves to be mentioned that researchers often face limited possibilities for strategic choice (Berg, 1981). Research opportunities are not abundant and if one is given the possibility to conduct a study of this type, one must seize the opportunity (Czarniawska-Joerges, 1992). The amount of advance planning and consideration on the appropriateness of the research object are often limited:

> The subjects of the investigation were there and I had to decide whether or not to take the opportunity. (Stymne, 1970, p. 11)

3.1.3 The Nature of the Collaboration Agreement With Office Machines

Under the agreement between the researchers and the company, we would be given access to the adoption process in return for providing input from research to the process. Our role as researchers would be twofold:

1) As the more junior researcher, I would participate in the daily activities of the projects that were part of the adoption of lean production. I was therefore appointed secretary for these projects.
2) My thesis supervisor would visit the company approximately one day per month, to give various forms of input to the adoption process, often in the form of seminars.

The collaboration with Office Machines commenced at the end of January 1993 and finished in August 1995. The initial agreement was for us to study the adoption process for one year. During that time, I would be at the company on a part-time basis. The contract was extended, although the intensity of the contacts with the company slowed down. The main reason for slowing down the intensity was that the pace of the adoption process was slowing down. During the second year, I spent every third week at the company. In the final six months of the study, I spent every fourth week there.

Apart from my spending time at the company, there were numerous contacts over the phone throughout the whole study period. I was also in contact with managers in other arenas. Although the collaboration came to an end during the summer of 1995, my contacts with the company continued until it was necessary to close off data collection for the purpose of writing this thesis. Since the summer of 1995, data collection has taken place on three occasions.

In an ideal world one would like to study an adoption process throughout its entire life, from beginning to end (Van de Ven and Poole, 1990). However, it needs to be remembered that lean production has no well-defined end point (Hayes and Pisano, 1994). I decided to end the study in August 1995, when all major physical and organisational changes had taken place.

3.2 Implications of the Research Design

As all methodologies, clinical research has strengths and weaknesses. This section discusses the weaknesses and their effects on the collected data. Perhaps the major implication of the research design, the feasibility of generalising from a single case, will be addressed at the end of the chapter.

3.2.1 The Effects of the Researcher

A clinical researcher will, by the nature of the methodology, affect the studied organisation. However, all forms of inquiry into organisations entail intervention. Just by asking people questions, we (hopefully) start to make them think, possibly about things they had not thought of before (Schein, 1987). Even within physics, there is Heisenberg's uncertainty principle, which means that scientific research involves an interaction between the scientist and the object of observation (Morgan, 1983a). The interaction between the observer and the observed is compounded in organisational inquiry: 'in the organizational context, the quest for objectivity, in the sense of freedom from influence by the research process, is probably hopeless' (Schön, 1983, p. 127).

A more appropriate kind of objectivity has to do with the researcher's awareness of his or her effect on others (Schön, 1983). As a clinical researcher, you need to be aware of what you do in the organisation and how this is received. Such an awareness is 'the best remedy against self-confirming hypotheses and irresponsible interventions' (Czarniawska-Joerges, 1992). The researcher must also attempt to assess the nature and extent of his or her effect on the studied phenomena (Sofer, 1961).

Assessing the effects of interventions is facilitated by the in-depth nature of the access achieved in clinical research. The familiarity I gained with Office Machines helped me assess the effects of our interventions and facilitated discussions with those at the company regarding our effects. The assessment of researcher influence was also facilitated through the use of two researchers, with slightly different roles in the adoption process. As the more passive researcher I had opportunities to assess the effects of the more active researcher's interventions. These effects were in the analysis treated as if generated by any person coming from within or outside the company.

The risk of affecting the studied phenomena should not be overestimated. Perhaps an equally valid risk is that the clinical researcher is affected by the intention to help the organisation. The intention to study the adoption of lean production may have prevented us from seeing that the company was doing something other than that. The framework can over-influence the interpretation of the facts. Chapter Four, therefore, contains a description of the actions taken in the adoption of lean production and the resultant performance changes. The description helps make clear for the reader that the change Office Machines went through was in line with lean production principles.

3.2.2 Balancing the Scientific and the Clinical Aspects

The clinical methodology entails a balancing act between the scientific and the practical aspects of the collaboration. The balancing act concerns our interest to study the adoption process and the company's interest to receive support in the adoption process. The following was done to help me in this balancing act:

- The dual expectations were made explicit in the contract between the researchers and the company (Rapoport, 1970).
- The research design gave me the possibility to assume a more scholarly role in between the periods I spent at the company.
- I used my leisure time to type up the field notes (Rapoport, 1970).
- Both the company and the researchers were interested in the adoption process. The company was interested in keeping the adoption process as smooth as possible and my interest was the issues that arose in the process.

3.2.3 A Managerial View on the Changes

A managerial perspective was taken in the study of the process of adopting lean production at Office Machines. A managerial perspective was relevant since the research question in one respect concerned how the process of adopting lean production could be managed (Van de Ven, 1993). A guiding principle for field work is that the researcher's account of the studied scene should build on information provided by the most knowledgeable members of that scene (Van Maanen, 1979). The potential problem of aligning oneself with the management of an organisation, with subsequent effects on data (Barley, 1990), is with the managerial perspective in mind not to be exaggerated.

Taking a managerial perspective is not to ignore the views of those on the receiving end of the changes. Data were collected at different levels of management, among shop floor employees, and through discussions with union officials. Access to the higher levels of the organisation gives the clinical researcher a chance to assess the impact of high-level decisions on a lower level (Schein, 1987). A researcher who only gains access to the lower levels of the organisation has to infer decisions taken higher up in the organisation.

3.3 Collecting Data from the Adoption Process

3.3.1 Three Different Ways of Collecting Data

Different ways of collecting data were utilised, to overcome the weakness of one method with the strength of another: participant observation, interviews, and documents. The bulk of the data was collected through participant observation, which is nicely captured in the following:

> The participant observer gathers data by participating in the daily life of the group or organization he studies. He watches people he is studying to see what situations they ordinarily meet and how they behave in them. He enters into conversations with some or all of the participants in these situations and discovers their interpretations of the events he has observed. (Becker, 1958, p. 652)

Benefits of and Roles in Participant Observation

Participant observation allows the researcher to record action as it occurs, without relying on the willingness or ability of respondents to describe their actions (Scott, 1965). Participant observation also gives the researcher a possibility to learn the language of the group under study (Becker and Geer, 1957), which is helpful in reading the cues that are an important part of communication (Czarniawska-Joerges, 1992).

To judge the value of the observations one needs to know one's status in the observed organisation (Becker, 1958). Having spent only a short time at Office Machines, I received the informal status of an employee and was no longer regarded as "the researcher from the big city". The rapport gained through being seen as an employee was valuable, since information was not withheld from me for being an outsider. The employee status is likely to have increased the quality of the observations I made.

The role a participant observer can take in the field can be seen as positions on a continuum (Schwartz and Schwartz, 1955). At one end of the continuum is the passive observer and at the other end the active observer. The passive participant observer attempts not to interact with organisation members. Passive participant observation may therefore exclude the researcher from some arenas, for being an outsider. Staying passive is also increasingly difficult the longer you stay in the field, even with the intention not to get actively involved (Schwartz and Schwartz, 1955).

The active participant observer uses himself or herself as the principal instrument of observation and interpretation (Sanday, 1979). Participating actively in the organisation, the researcher builds an ever-growing fund of impressions which give an extensive base for interpretation and analysis

(Becker and Geer, 1957). By sharing the perspectives of the subject group, the researcher can use his or her own feelings and attitudes as clues in interpreting the behaviour of those observed (Scott, 1965). The researcher's experiences of the situation can also be used in the analysis (Smircich, 1983).

The participant observation used in the present study lies towards the active end of the continuum, a consequence of the clinical methodology. However, my role as a participant observer shifted; being more or less active depending on the circumstances. As a secretary in the projects concerned with the adoption of lean production, I participated in meetings. I was passive in these meetings until I had learnt more about the company and its employees. When I did voice my views on different subjects, I meticulously noted what I said and any observable effects in my field notes. Part of the more active participation was thus to take notes of the nature of my participation and the effects it had on those at the company. These notes were considered in the analysis.

Participant Observation at Office Machines

Data were collected through participant observation in many locations and instances. Most important were the meetings I participated in, which were an economical way of gaining access to data. Just by spending time at the company I was also able to collect data that proved useful for the analysis. Conversations were overheard, non-verbal cues were read, and who spoke to whom, about what, could be observed.

The bulk of data was collected during interaction with managers in the manufacturing function. But my interaction was not restricted to manufacturing managers. I was involved in a broad range of activities:

- I participated in meetings in product development projects, procurement, and distribution.
- I was involved in strategic discussions at the top management level and had regular conversations with union officials and shop floor employees.

This range of activities gave me an opportunity to observe the process of adopting lean production in its organisational context, a premise of the study.

Participant observation requires diaries (Czarniawska-Joerges, 1992). The participant observer needs to, as accurately as possible, note what is observed (Van Maanen, 1979). Good notes provide full or complete explanations. Good notes describe and explain the context of a comment or event and identify all actors (Martin and Turner, 1986).

I used pen and paper to take field notes, which were transcribed using a word processor. The workload of transcribing the field notes must not be underestimated: it takes almost as much time for a researcher to type notes as the original contact (Miles, 1979). The need for transcribing notes as quickly as possible after the observation is perhaps self-evident. Despite this need, the transcription was at times not done immediately. There was always a fear of having overlooked 'important social dynamics' (Barley, 1990, p. 240). To overcome this fear, emphasis was put on data collection. As more data were collected, the easier it was to become late with transcription (Miles, 1979). However, the overwhelming part of the field notes were transcribed within two days of the initial contact. Most often transcription took place the same day.

The more covert observations could not be noted down using pen and paper. I could not jeopardise the rapport I had achieved by constantly taking notes of what people said. Instead, I tried to memorise the most important points of what the subject(s) said and write them down as quickly as I could. Writing down observations was facilitated by having my own office at the company, to which I could retreat when necessary. I also experienced my skill in memorising observations increased over time, as I was forced to practise the skill of observing without taking notes (Barley, 1990).

Interviews

Interviews were to some extent used as a data collection method. The interviews were informal, bordering on conversations, which were part of the process of observation (Zelditch, 1962). By engaging in conversations with organisation members it was possible to gain a deeper understanding of the adoption process. During interaction with people at various organisational levels, I probed for what they felt of their current situation and the changes that were taking place.

On some occasions, the conversations were more formalised and more like informant interviews. The interviews were primarily used to collect data from the periods I was not present at the company, including the time before the study began. The interviews were also valuable in finding explanations to observed behaviour. The informants used for interviews can be seen as "surrogate observers": persons who were in a situation which enabled them to observe significant events (Scott, 1965). Most often, I used managers which had knowledge of the areas I was interested in.

The major reason for not conducting more formalised interviews was that I felt it would interrupt the rapport I had achieved. Being seen as an employee, rather than as a researcher, was of importance for the quality of the data obtained. This rapport would have been threatened by more formalised interviews.

The rapport was also the reason I chose not to use a tape recorder during data collection. The risk of missing something had to be weighed against the advantage of not disturbing too much. There is also a more pragmatic side to the choice of pen and paper. Transcribing tape recordings of 130 days of interaction is an awesome task, which I would have had to do myself.

Documents

A final source of data was documents. The danger with documents is that they cannot always be taken at face value (Scott, 1965). Documents may not contain enough information to be of any real value or be biased in the sense they do not reflect what was said in a meeting. Documents are also subject to the dangers of selective survival (Pettigrew, 1990). Documents were used mostly to keep track of events taking place before the study began and during the periods I was not present at the company. The content of the documents was cross-checked with informant interviews whenever possible.

3.3.2 Focusing Data Collection on Critical Incidents in the Process of Adopting Lean Production

Collecting data requires the formulation of what to look for. Before going into the field a qualitative researcher needs a framework. Without a research focus it is easy to become overwhelmed by the volume of data (Eisenhardt, 1989). The lean production framework had an important role in data collection. With the framework in mind, I directed my attention towards the adoption process: the order and sequence of events as the organisation adopted lean production.

The research question was used to further focus data collection. Spending a significant amount of time in the field compounded the need for having limited the range of behaviour to observe (Turner, 1981). Observation needed to be systematic, selecting particular aspects of behaviour as a consequence of the research question (Scott, 1965).

My interest during data collection was the issues that arose in the process of adopting lean production. The lean production framework served as the basis for defining issues. Issues were, however, not directly observable. Issues are conceptual constructs, which are indicated by empirically observable incidents (Van de Ven and Poole, 1990). Data collection thus focused on incidents.

The starting point for data collection was the critical incident technique, where an incident is defined as: 'any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act' (Flanagan, 1954, p. 327). Three modifications of this definition were made:

- Speech acts were included in the definition of acts. Acts are not confined to something being done, acts also refer to something being said.
- Incidents included non-acts. This is in line with Leonard-Barton (1990) who found it necessary to inquire 'about critical individuals' lack of action as well as about their overt actions' (p. 258).
- Non-observable human activity was included in the definition of critical incidents. There may have been issues managers were aware of and therefore able to circumvent. There was a risk of missing these issues if I focused solely on observable incidents. Part of data collection was therefore to query managers for the issues facing them.

During the collection of data, incidents were considered critical when they indicated issues that either facilitated or impeded the process of adopting lean production. Recall that incidents indicate issues. With the process view of manufacturing improvement taken in the present study, the factors influencing the success and failure of the adoption process are of essence (Voss, 1988). Issues that facilitated or impeded the process of adopting lean production were therefore crucial for the inquiry.

To judge whether incidents indicated issues that facilitated or impeded the adoption process, I used the lean production framework as a starting point. Incidents that either facilitated or impeded the work of adopting lean production practices were of interest. These incidents were termed "critical incidents" and were 'effective or in-effective with respect to attaining the general aims of the activity' (Flanagan, 1954, p. 338). When looking for the critical incidents two major types of questions were used:

1) For the observable incidents, I asked myself: "does it affect the adoption of lean production? If it does, then how?" The observable incidents comprised both acts (something which was done) and remarks (something which was said).
2) When searching for the covert incidents I asked myself: "if something should be done, why isn't it?"

These two questions cover most of the decision rules used for observing critical incidents. To the decision rules were added some "subjective judgements" (Van de Ven and Poole, 1990). Some personal judgements were necessary to decide whether an incident was to be classified as critical or not. Thus, it is not possible to give an exact account of the types of incidents that were noted down.

Having observed a critical incident, I noted down the relevant information concerning the incident as quickly as possible. For most of the observations I noted down as much as I could of what the subject(s) said. Following the advice of Van de Ven and Poole (1990), I also made sure to note the following:

- The type of action or behaviour that occurred.
- Type of incident (did the incident affect the adoption process positively or negatively)?
- The names of the actors involved in the incident.
- Time and place for the incident.
- Circumstances surrounding the incident.

Although data collection focused on critical incidents in the adoption process, other types of data were collected. Two examples here are the context of the adoption process and the history of the company and particularly the lean production project. This information was necessary for gaining an understanding of the adoption process.

The lean production framework and the decision rules behind the observation of critical incidents served as conceptual guides during data collection. The guides are, to emphasise, not to be taken for pre-formulated theoretical propositions, which may bias and limit the findings (Eisenhardt, 1989). The conceptual guides were more like telescopes, pointed towards the organisation to direct my attention towards some aspects of the organisation (Berg, 1974).

3.3.3 Risks Associated With the Chosen Data Collection Methods

All methods have strengths and weaknesses. Given the purpose of the present study, the strengths of the chosen methods are considered to outweigh the weaknesses. The weaknesses still need to be taken seriously. Constantly looking for the weaknesses, exploring their ramifications, and trying to correct them was part of the research process (Schwartz and Schwartz, 1955).

Participant observation involves the danger of "going native". The participant observer who has gone native gets totally immersed in the studied organisation and loses the perspective necessary for a researcher. Losing the perspective means the researcher finds little that requires explanation (Scott, 1965). One way of dealing with this risk is to temporarily withdraw from the field.

To help me avoid going native, the study was designed to let me withdraw regularly from the field back to the academic environment. I came back to the academic environment every other week at the outset of the study, but as time progressed, the periods in the field were less frequent. During the periods in the academic environment I read literature, took courses, wrote up field notes, and discussed with colleagues. These activities raised the level of abstraction on what had been observed while in the field, which helped me avoid the risk of losing my perspective.

The risk of going native was also reduced by my remaining cognisant of being a researcher, which I believe prevented me from getting totally absorbed in Office Machines. I noticed a large difference between being in an organisation as a researcher, compared with working in an organisation, as I previously did. The difference between working in and studying an organisation is large enough for me to withhold that the risk of going native is not to be overstated.

Participant observation is also associated with emotional difficulties. These kinds of problems accompany all methods, but are especially salient when researchers use themselves as research tools in longitudinal participant observation (Barley, 1990). Meeting your respondents day after day is more difficult than making a few visits or using the telephone. Conducting a longitudinal field study is like moving into a new culture with accompanying feelings of alienation (Czarniawska-Joerges, 1993).

Apart from affecting the researcher, the emotional difficulties associated with participant observation may have effects on the data that are collected. If you work long enough in one place, you tend to become involved with the observed emotional life (Schwartz and Schwartz, 1955). One negative effect this involvement could have is that the researcher finds that his or her concern with protecting and developing good relations with people in the organisation interferes with the collection of data (Scott, 1965). As far as possible, I attempted to avoid letting a concern over protecting relations interfere with the collection of data. However, the clinical role meant my interaction focused on managers within the manufacturing function.

3.4 Analysing Data from the Adoption Process

Analysing qualitative data is a challenging task (Huberman and Miles, 1983). The challenge is to order and analyse an overwhelming amount of descriptive data (Barley, 1990). For some, the result is 'death by data asphyxiation - the slow and inexorable sinking into the swimming pool which started so cool, clear and inviting and now has become a clinging mass of maple syrup' (Pettigrew, 1990, p. 281).

The central difficulty in analysing qualitative data is that methods are not well formulated (Miles, 1979). Methods for analysis are particularly lacking for researchers interested in processes of change in organisations. Researchers undertaking process studies have therefore been forced to develop their own methods through trial and error (Van de Ven and Huber, 1990).

Part of the analysis is going on when data are still being collected (Becker, 1958; Barley, 1990). While collecting data, one needs to write down whatever impressions occur; to react to rather than to sift out what may seem important (Eisenhardt, 1989). When noting down my own impressions I was careful to let them stand out in the field notes, so impressions were not mixed with observations. The analysis process described below concerns the activities undertaken when the field work was completed.

3.4.1 Reading the Collected Material and Writing a Narrative of the Adoption Process

In the first stage of the analysis, I read through all the collected material to gain familiarity with it. I read the material with an open mind, trying not to single out different aspects of it for further elaboration. Having read the material several times, it was typed up as a narrative in one document. Having all the collected material as one document gave me a better grasp of the adoption process before starting the more detailed analysis: 'we first need a story that narrates the sequence of events' (Van de Ven and Huber, 1990, p. 214).

The narrative was basically a compilation of all field notes and documents, sorted in chronological order. The narrative included all events in the process of adopting lean production, transcribed as closely from the original sources as possible. The field notes were most often in computer format and were just copied. From documents were extracted the parts of relevance for understanding the process of adopting lean production. Whatever interpretation I made of the material was kept out of the narrative and was added as comments. The narrative contained in total 600 pages of dense text.

3.4.2 Dividing the Narrative in Incidents for Further Analysis

In the second stage of the analysis, the narrative exposing the process of adopting lean production was divided. The division was made to arrive at the basic element of information - the datum. The datum was used as a building block in the analysis. A datum was defined as (Van de Ven and Poole, 1990):

1) A bracketed string of words capturing the basic elements of information,
2) about a discrete incident in the process of adopting lean production,
3) that happened on a specific date, which was
4) entered as a unique record in a qualitative data file, and
5) was subsequently coded and classified as an indicator of an issue.

The datum will henceforth be termed “incident”. An incident is related to but not restricted to a critical incident. The reason being that data collection, to emphasise, was focused on critical incidents, but not restricted to these incidents. Incidents are not equal to critical incidents also since the narrative contained a compilation of field notes, which contained relevant background information on an observed critical incident.

When defining the incidents, the basic material I used was the experiences of the actors involved in the adoption process, expressed through their language:

> The social science researcher is interested in understanding, explaining and influencing social states, social events and social action. But none of these overt things can ever be understood or make sense unless they are related to the internal, subjective reality pictures of the people involved on the social scene. (Normann, 1980, p. 18)

When dividing the narrative in incidents, I read the narrative a number of times. Each time I experienced a transition in meaning in the narrative, I marked the place and continued to read until I experienced the next transition, and so on (Giorgi, 1994). An incident is therefore not necessarily equal to one sentence in the narrative. The number of sentences could vary and it was the basic meaning of the incident that was of interest.

The outcome of this stage of the analysis was a series of incidents still expressed as closely as possible to the way they had been observed. My intention was to capture the experience of the individuals involved in the adoption process. However, the incidents were still created by the attitude and activity of the researcher (Giorgi, 1994).

3.4.3 Coding and Entering Incidents in a Database

The incidents were coded and entered in a database. Using a database gave me an opportunity to keep track of all incidents in an efficient manner. The incidents were described fully enough to avoid the need for backtracking to the notes to recall details (Martin and Turner, 1986). Each incident was coded along at least two of three dimensions: lean production principle, activity, and issue.

The principles of lean production were used as a first coding device. The reason for coding incidents with lean production principles was my interest to study sequences of lean production principles in the adoption process. All incidents were coded as belonging to a lean production principle. To the principles were added a code for the overall level of the lean production project: "Whole project". Although affecting the adoption process, all incidents could not be referred to a lean production principle. For example, an important part of the adoption process was discussions on and changes made to the management accounting system. These discussions and changes affected the adoption process but were not related to a lean production principle.

Each incident was then coded with activity and issue. Before explaining the two terms, it is necessary to point to the nature of the codes:

> A code is an abbreviation or symbol applied to a segment of words [---] in order to classify the words. Codes are categories. [---] They are retrieval and organizing devices. (Miles and Huberman, 1984, p. 56)

Issues are the main interest in the present study. A code for activities was introduced to reduce the complexity of the analysis task. When the narrative had been divided in incidents, the database contained 3,200 incidents. A starting point for reducing this complexity was to construct data categories around the activities associated with the adoption of lean production (Dawson, 1994).

On Activities

Activities are here used in a sense similar to the terminology of traditional project planning literature. An activity is something that consumes time and resources (Aquilano and Chase, 1991). When building a house, for example, one activity is to lay a foundation. Activities are in one sense 'action in a setting of more major duration - days, weeks, months - constituting significant elements of people's involvements' (Miles and Huberman, 1984, p. 57).

A number of activities are necessary to adopt lean production. The nature of the activities is not possible to define beforehand: 'it is impossible to provide a definitive list of tasks, activities and decisions associated with the management of change' (Dawson, 1994, p. 36). Although the lean production framework points to the nature of the activities associated with the adoption, the empirical data was used to define activities. Note also the following:

- A managerial perspective was taken when defining activities. I only devised codes for activities consciously initiated by management.
- A relatively coarse-grained definition of activities was made. A more detailed definition would have counteracted the purpose of introducing a code for activities, which was to reduce complexity.

A total of twenty-four activities were defined. Two examples illustrate how activities were contrived of. The examples are citations from the database, where individuals' names have been disguised. The first incident refers to the activity of creating a new payment system. This activity was part of the creation of multifunctional teams. The activity was termed "payment system":

> *Roger said that not much had happened in the payment project, except that Andy and Bob had been in contact with a company which had a good payment system. They would contact this company.*

The second incident illustrates an activity termed "team leaders", which was part of the decentralisation of responsibilities. The activity refers to the development of team leaders for the multifunctional teams:

> *Robert will summon a meeting on team leaders as soon as possible. There is a growing need for team leaders. Questions which need to be addressed are the size of the teams, demands on the team leaders, and the kind of training they need.*

Note here that incidents indicate activities, which means that activities existed between the observations of incidents. An activity did not stop just because there were no observations on it.

On Issues

Incidents were also coded with codes for issues. Concerning the usage of the term "issues" during the analysis, it needs to be emphasised that issues can relate both to threats and opportunities (Ansoff, 1980). At the same time, managers are likely to be more sensitive to issue characteristics associated with threats, than to those associated with opportunities (Jackson and Dutton, 1988). Recall also the following three characteristics of issues:

1) Issues refer to events and trends (Dutton and Dukerich, 1991).
2) Issues can emerge from the organisation's external or internal environment (Dutton and Ottensmeyer, 1987).
3) Issues are seen by managers as having a (potential) significant impact on the adoption process (Dutton et al., 1983).

In devising codes for issues, the starting point was the experiences of the individuals - what actors perceived as being important - expressed through their language. The terms individuals used comprised the fundamental material and the coding task was that of meaningfully abstracting from this material (Normann, 1980). Note that issues were indicated by recurring incidents. The following citation illustrates how codes for issues were devised:

> *I feel in my whole body how cumbersome it is to work with quality. A production manager at Electrolux said that they also received a lot of paperwork from the quality department, which they had to deal with in manufacturing.*

This incident was labelled "paperwork". The incident indicates a recurring issue: the quality management system created a lot of paperwork, which affected the adoption of lean production negatively. Table 3.1 summarises the terminology that was used in the analysis.

Table 3.1 Summary of Analysis Terminology

Term	*Definition*
Critical incidents	Data collection focused on but was not restricted to critical incidents, defined as acts that either facilitated or impeded the process of adopting lean production
Incidents	The basic element of information used in the analysis, defined through a repeated reading and division of the field notes
Activities	Using the data as a starting point, codes for activities were assigned to each incident, referring to by management consciously initiated activities to adopt lean production
Issues	Codes for issues were devised by abstracting from the actors' language, thus reflecting the actors' experiences

The definition of the codes used for the coding process was kept in a separate database. Using the database facilitated going back to the codes' definition when necessary. The database also made it possible for me to modify the definition to take into account new information. The database finally enabled me to search for all incidents with a certain code, should I want to see how the code was used. In total, eighty-three different issues were defined. A brief explanation of the codes used for the issues is found in the Appendix.

3.4.4 Coding Incidents With Codes for Principles, Activities, and Issues

To include the full meaning of an incident, each incident could be coded on more than one dimension (Van de Ven and Poole, 1990), see Figure 3.1. To the left in Figure 3.1 are the three codes used for coding incidents. The black horizontal arrows indicate which codes were mandatory. The white horizontal arrows indicate where codes were optional.

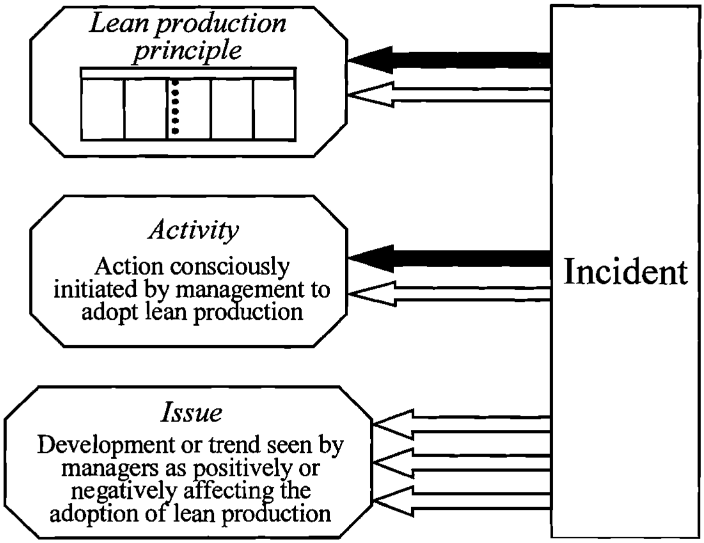

Figure 3.1 Relationship between Incidents and Codes for Lean Production Principles, Activities, and Issues

Figure 3.1 illustrates the following characteristics of how the codes were used:

- Each incident indicated at least one lean production principle and activity, but could be coded as indicating more than one of either.
- An incident could be coded as indicating up to three different issues, although an incident did not necessarily indicate an issue at all.

Not illustrated in the figure, but of relevance here, is that incidents indicating more than one principle, activity, or issue were, when possible, separated in several incidents. This separation was made to reduce complexity.

3.4.5 Searching for Incidents Indicating Recurring Issues

With all incidents properly coded, the next stage of the analysis was to systematically group the incidents together. This grouping was accomplished through sorting the incidents in various ways, reading, and re-coding them. This process meant that I switched between the whole and the parts; between a string of incidents and an individual incident. The rationale for switching between the whole and the parts was that coding an incident was easier when each incident was seen in relation to other incidents.

A tool in this stage of the analysis was print-outs of all the incidents appropriately sorted. Three different rounds were conducted to group incidents. In the first and second round, the primary sorting key was date, followed by lean production principle and activity. In the third round the primary sorting key was the lean production principle the incident indicated, followed by activity and date. Each round shared two characteristics: it involved a search for incidents indicating recurring issues and an elimination of those incidents that did not indicate recurring issues.

The assumption was that what may have seemed important during data collection, was not necessarily important in the retrospective analysis: 'time itself sets a frame of reference that directly affects our perceptions of change' (Van de Ven, 1993, p. 318). The retrospective analysis is to be trusted more than the initial assessment of an incident's importance. One needs the whole picture to be able to relate the details to it. Not all incidents had a significant effect, especially those related to individuals with only ephemeral roles in the adoption process (Leonard-Barton, 1990). However, the analysis did combine the retrospective assessment of an incident's importance with the judgement on criticality made during data collection.

It is also necessary to point out that all incidents kept in the analysis up to this stage were not indicating issues in the process of adopting lean production. Some incidents, for example, related to the history of the company, other incidents indicated attitudes and beliefs of managers. Incidents such as these did not relate directly to the adoption process, although useful in the analysis so far.

The outcome of the three rounds of sorting and re-coding incidents was that a number of incidents were excluded from further analysis, such as those indicating only activities and not issues. These incidents were excluded since the research interest was the issues that arose in the adoption process. Excluding incidents from analysis was done technically through a code in the database. The actual incidents were still kept for reference.

3.4.6 Using Incident Charts to Arrive at the Important Issues

Having exposed the incidents indicating recurring issues in the adoption process, the next stage of the analysis was to arrive at the important issues in the adoption process. As a help in this work, I used graphical techniques. The rationale for this way of working is indicated by the old adage: "a picture says more than a thousand words". After the three rounds of sorting and re-coding, there were nearly 2,000 incidents left. No matter how these were sorted, it was easy to get lost in detail if only text was used.

Lists of incidents were therefore converted to graphical displays. The displays consisted of a timeline with an "X" marking each incident. The timelines were produced for each lean production principle. The displays were useful as a starting point for assessing the importance of different issues. The graphical displays gave an overview of the adoption process. The displays were combined with print-outs of incidents and the database of incidents.

It was not only a matter of assessing the importance of an issue and excluding incidents based on simple counting. Both the graphical displays and print-outs of the incidents were used in arriving at important issues. This procedure was chosen to avoid a potential bias by only using the number of incidents as a measure of the importance of an issue. All tools were also complemented by the insights I gained during the field work.

As a result of this stage of the analysis, incidents were re-coded and issues were merged. Other issues proved to be unimportant relative to others. For instance, an issue indicated by two incidents, observed two years apart, was less important than an issue indicated by ten observations within a matter of months. Incidents were consequently excluded from further analysis and complexity could be reduced. The use of the graphical techniques for assessing important issues was carried out twice. The database contained as a result around 1,900 incidents. These incidents were used to graphically display the patterns of issues, which were the basis for the further analysis.

3.4.7 The Analysis Funnel

The analysis process described so far is summarised in the form of an analysis funnel, in Figure 3.2. The funnel illustrates the way in which I arrived at the important issues in the process of adopting lean production at Office Machines. The important issues were the base for displaying and analysing patterns of issues, a task to which I will return in Chapter Five. Recall from the purpose of the study that the patterns of issues are the basis for the inquiry into the sequences of lean production principles.

The main idea the analysis funnel conveys is the existence of a number of filters between the process of adopting lean production at Office Machines and the patterns of issues. Note in particular the following:

- The initial screening of potential observable phenomena was made by the *research question*. The research question helped focus my attention towards a limited range of activities and events.
- *Data collection* focused on critical incidents in the adoption process, limiting the range of observable behaviour further. The outcome here being critical incidents in the form of field notes.

- Data collection focused on but was not restricted to critical incidents. Documents were also used as a source of data. There was therefore a need to *select the activities and events from the adoption process*. These activities and events were typed up as a narrative.
- The fourth filter was my reading and *dividing the narrative in incidents*.
- The incidents were *coded and entered in a database*. The codes were assigned by abstracting the actors' language.
- Through using the database, the incidents were sorted and printed in various ways. This procedure helped me *sorting out incidents indicating important issues*. The patterns of issues were then displayed in graphical form for further analysis.

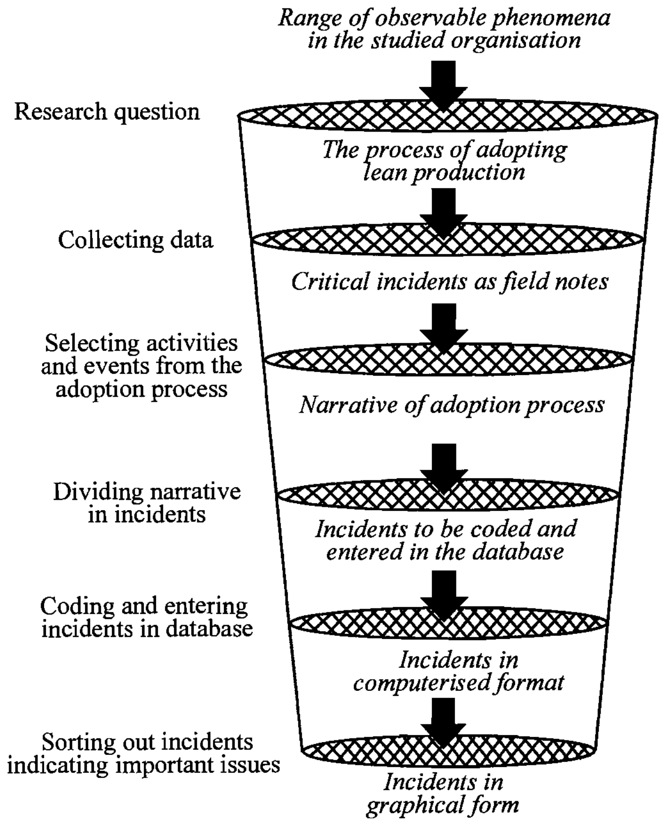

Figure 3.2 The Analysis Funnel

The filters add up to a funnelling effect, which means that at each stage in the analysis process, the original adoption process was condensed. The aim is that I, through this analysis process, would arrive at credible findings.

3.5 Judging the Credibility of the Analysis

The value of research findings must be seen in relation to the way in which they were derived (Berg, 1981). The researcher's task is to convince the reader the findings are reasonable, drawn from material which has been processed by methods which can be explicitly described. To judge the credibility of the analysis we first need to discuss the qualitative nature of the inquiry.

3.5.1 Qualitative Versus Quantitative Research: A Difference of Approach

Qualitative research is normally contrasted to quantitative research based on which techniques have been used for data collection and analysis. Proponents of quantitative research, in this technique-based view, stress the importance of reliability, validity, and accurate measurement before research outcomes can contribute to knowledge (Daft, 1983). Objectivity is another concept celebrated by quantitative researchers (Kirk and Miller, 1986).

However, distinguishing qualitative from quantitative research, based on which techniques are used for data collection and analysis, cannot absorb the diversity of uses to which the qualitative label applies (Van Maanen, 1983). Qualitative researchers are interested in the meaning, rather than the measurement, of organisational phenomena (Daft, 1983). Qualitative research is best seen as an approach rather than a set of techniques (Morgan and Smircich, 1980). Nothing excludes the qualitative researcher from using data collection and analysis techniques considered "quantitative", such as statistical techniques (Daft, 1983).

The standards used for judging quantitative studies are, on the other hand, inappropriate for qualitative studies (Agar, 1986). This does not mean that no standards are applicable to qualitative research; qualitative research is not less scientific than quantitative research (Silverman, 1993). The description of reliability and validity ordinarily provided by quantitative researchers needs to be modified to fit qualitative research (Kirk and Miller, 1986). A qualitative approach requires the reader to be able to make judgements about components of the research process leading to the final product (Strauss and Corbin, 1990). Qualitative research is scientific in that the collection and reporting of data are done systematically, with care and discipline (Smircich, 1983).

3.5.2 Reliability

Reliability for a quantitative researcher means that if another researcher replicates a study, the same results would be obtained (Yin, 1989). For a qualitative researcher, reliability translates to demands on the research process:

'reliability depends essentially on explicitly described observational procedures' (Kirk and Miller, 1986, p. 41). Two aspects of data collection are particularly relevant: making the observations and writing up field notes.

Making the Observations

While collecting data, one needs to pay continual and careful attention to the details of one's adventures in the field (Van Maanen, 1979). There is first of all a need to separate first and second-order concepts. First-order concepts are the facts of the investigation and second-order concepts are the theories the researcher uses to organise and explain the facts. During data collection, I was careful not to mix the observations with my own interpretation, through using different typefaces in the field notes. During the analysis, the interpretation of incidents was kept away from the actual observations through being entered in a separate field of the database.

During the field work there is also a need to pay constant attention to the distinction between observational and presentational data (Van Maanen, 1979). Observational data refer to observed activity. Presentational data concern those appearances informants strive to maintain or enhance. Making the separation between the two types of data is an analytic task, although the line separating the two types is not always distinct. Longitudinal observation facilitates the task of separating observational data from presentational data, since people will find it difficult to monitor their behaviour for a long period of time (Barley, 1990). Through spending a significant amount of time in the field, and participating in daily interaction, I also gained knowledge of how to read the cues that are part of communication (Czarniawska-Joerges, 1992). Reading these cues helped me separate observational from presentational data.

A final detail to pay attention while in the field, is whether informants speak the truth as they know it (Van Maanen, 1979). There may be different reasons why false information is given. Informants may want to mislead the researcher. A benefit of clinical research is that informants are less likely to conceal the truth since the researcher is there to help (Argyris, 1968). Informants may, on the other hand, themselves be misled or wrong about their own matters. The researcher therefore needs to rely on the information provided by the most knowledgeable members of the organisation (Van Maanen, 1979). These informants were in the present study judged to come from the managerial level.

Writing up Field Notes

The reliability of qualitative research is increased through proper field notes (Kirk and Miller, 1986). There is a need to 'conduct research as if someone were always looking over your shoulder' (Yin, 1989, p. 45). Information on how and in what contexts field notes were recorded is needed (Silverman, 1993). Apart from the observation, I added information on when the observation was made, in what forum, and which actors were present.

Field notes must conform to two requirements (Kirk and Miller, 1986). First, they must be legible and chronologically ordered. This requirement was met through typing up all field notes and dating them. Second, field notes must differentiate between what people said and the researcher's interpretation (although the field notes do intrinsically involve the observer). This differentiation, to repeat, was done using different typefaces in the field notes.

3.5.3 Validity

Validity for the quantitative researcher is whether the instrument measures what it is supposed to measure (Emory and Cooper, 1991). The choice of research design was in the present study a way of increasing the validity of the research. Through the research design, I was able to follow an adoption process in real-time. Making real-time observations increases the validity of a study compared with retrospective research (Leonard-Barton, 1990). Within the research design, one way of increasing validity is to transcribe the field notes as quickly as possible (Schwartz and Schwartz, 1955), which was my aim in the present study.

Qualitative research can be validated by triangulation: using multiple methods and sources of data (Silverman, 1993). Although the present study primarily rests on participant observation for the identification of issues, two other methods were used: informal interviews and documents. To achieve triangulation of data, quantitative measures of performance outcomes were used to verify that a lean production system was actually developed.

The choice of the lean production framework for data collection and analysis has implications for validity. For the qualitative observation, the issue of validity is to a certain degree a question of whether or not the researcher is calling what is measured by the right name (Kirk and Miller, 1986). My intention to study the adoption of lean production may have prevented me from seeing developments outside the areas specified by the framework. The framework can thus over-influence the interpretation of the facts.

Although being aware the framework could have limited my view, several measures were taken to avoid this risk. The familiarity I gained with the company helped me ascertain developments not part of the framework. My interaction with employees at different levels of the company, from managing director to operators and union officials, further enabled me to observe developments at the company. The developments were all considered if and when they affected the process of adopting lean production. This is why a code for the lean production project as a whole was necessary during the coding procedure.

The coding process has implications for validity. A premise of the present study was the importance of relating the coding procedure to the internal reality pictures of the actors in the adoption process (Normann, 1980). What the actors perceived as important, as expressed through their language, was used as a basis for devising codes for issues. The coding task was that of meaningfully abstracting from actors' language. Categories developed after data collection are less likely to be biased by the researcher's own fantasies, since the categories emerge from and remain closer to the data (Barley, 1990).

There is a relationship between participant observation and the coding procedure which helps increase validity. The participant observer has tested partial analyses for a period of time (Glaser and Strauss, 1967). During data collection, the researcher acts on tentative conclusions based on his or her current understanding of the situation. If this understanding is invalid, the researcher will sooner or later find out about it (Kirk and Miller, 1986).

Validity can be increased by feeding back the findings of the study to the subjects of the research and see whether it provides them with a meaningful explanation (Berg, 1981). The findings have been fed back to the relevant managers at Office Machines. The findings do, according to them, meaningfully portray the adoption process as they saw it.

Related to respondent validation is whether the research results can be communicated to and understood by other people (Normann, 1980). Are the findings understandable to individuals who have some familiarity with the phenomena under study (Turner, 1983)? Colleagues with an interest in and experience of the adoption of lean production have read the results of the study and found them understandable.

To complement these more traditional ways of validating qualitative research, simple counting procedures were used (Silverman, 1993). Counting enables researchers to remove nagging doubts about the accuracy of their impressions about the data. Counting took place at several stages of the analysis. Incidents were, for instance, counted to arrive at the important issues, to be retained for further analysis.

3.5.4 Generalisation

The methods of generalising to a larger population are a way of increasing the validity of a study's findings. The ability to generalise has widely been considered a barrier for case studies (Yin, 1989). The problem of generalisation is particularly difficult for single case studies (Berg, 1981). Single case studies can obviously not be generalised in the statistical sense. Statistical generalisation is, however, not the aim.

The ability to generalise is related to the way in which corroboration takes place (Spencer and Dale, 1979). Quantitative studies rely on multiplicative corroboration; a multiplication of evidence (Pepper, 1942). Qualitative studies, on the other hand, rely on a structure of evidence; structural corroboration (Spencer and Dale, 1979). The persuasive force in structural corroboration comes from assembling a mass of evidence converging on the same point (Pepper, 1942).

An example illustrates the difference between the two methods of corroboration. Suppose I want to find out if a chair is strong enough to hold my weight. I can ask several people of my approximate weight to sit on the chair, one at a time. If the chair holds these people, it should be strong enough to hold my weight. The problem has been solved through multiplicative corroboration.

Another way of solving the problem of the chair's strength, is by examining the relevant facts about the chair. What kind of material is it made of? Are the chair's legs thick enough? How is the chair joined together? Have the makers of the chair got a reputation for making solid chairs? Putting all this evidence together, it is possible to conclude whether the chair is strong enough to hold my weight. This process of giving evidence is structural corroboration.

Using structural corroboration to generalise from a single case can be done by comparing the findings with something outside the study (Berg, 1981). The general value of the findings will increase if they can be supported by observations from other organisations or from other theoretical frameworks. The findings on sequences of lean production principles in the empirical case will be compared with theory in two stages. First, operations management theory is, in Chapter Seven, used to seek explanations for the observed sequences. Second, the findings are in Chapter Eight compared with studies addressing the problem of sequences of improvement initiatives in manufacturing.

When discussing generalisation, one needs to bear in mind that generalisation from case studies takes place towards theory, not towards samples and universes (Yin, 1989). The value of in-depth single case studies lies in their capability to be used for developing and refining concepts and frameworks, which can be generalised (Pettigrew, 1985). Results of in-depth studies of single organisations can also be cumulative (Miller and Mintzberg, 1983). Therefore, I heartily agree with Simon (1991), a pioneer of research on organisations:

> If we are concerned about the imprecision of case studies as research data, we can console ourselves by noting that a man named Darwin was able to write a very persuasive (perhaps even correct) book on the origin of species on the basis of a study of the Galapagos Islands and a few other cases. (p. 128)

Apart from theoretical generalisation, there is a more practical side to the issue of generalisation. I am interested in arriving at conclusions with potential practical applicability. When generalising from single cases to the practical arena, it is the receivers of the information that must determine whether or not it applies to their own situation (Kennedy, 1979). Although one may be a bit unaccustomed to the notion of leaving generalisation up to the practitioner, it is not an uncommon occurrence in other fields, such as law and clinical medicine.

3.6 Presenting the Data

The final challenge for the qualitative researcher, is to present the huge amount of rich data that have been collected, so that the presentation provides evidence for the conclusions (Huberman and Miles, 1983). To facilitate the reader in understanding the conclusions, the patterns of issues are displayed graphically in Chapter Five. Graphs can offer a means to survey the whole corpus of data ordinarily lost in qualitative research. Instead of taking the researcher's word for it, the reader has a chance to gain a sense of the data (Silverman, 1993).

The graphs are, throughout the study, complemented with illustrations from the huge amount of rich qualitative data. The illustrations are given in the form of excerpts from the database of incidents. The main purpose of the excerpts is to introduce to the reader parts of my own learning process, in reaching the conclusions, to facilitate the reader's learning process (Normann, 1980). The use of shorter excerpts was chosen in favour of a lengthy narrative of the adoption process, since a narrative was judged not to add enough value to the reader's understanding.

My attempt to provide evidence for the conclusions rests finally on a description of the content of the adoption process. In the description I focus on the actions taken to adopt lean production at Office Machines. The description is intended to give the reader an understanding of the adoption process. The reader can therefore judge the nature of the change undertaken by Office Machines. It is to this description we now turn.

CHAPTER 4
Adopting Lean Production at Office Machines

This chapter introduces the empirical case in more detail. The content of the change Office Machines went through is described. By describing the actions taken to adopt lean production, the reader can gain an understanding of the adoption process. This understanding enables the reader to judge the similarity between Office Machines's change and the principles of lean production. First, however, a presentation of the company.

4.1 Office Machines - Market Changes

Office Machines is a medium-sized manufacturing company and is one of the larger in its industry, with an export share of ninety-three percent. Exports traditionally took place through distributors, who were granted exclusivity for one country. The exclusivity agreements changed and a couple of distributors per country were used. The distribution structure changed again, in the late 1980s, as sales subsidiaries were established in European markets.

The late 1980s and the beginning of the 1990s also saw changes in the way products were sold. Larger retail companies were being formed, who wanted to buy directly from the manufacturer and skip layers in the distribution chain. The retail companies were formed both in the United States and later in Europe, where companies formed across national boundaries.

The implication of the market changes for manufacturing was the need to deliver in small batches, on a short notice. Deliveries to distributors had traditionally taken place in large batches, with a minimum lead time of six to eight weeks. Starting in the early 1990s, customers were demanding shorter lead times, down to five days. Delivery reliability was also becoming emphasised.

4.2 Manufacturing Organisation Prior to the Adoption of Lean Production

Office Machines's manufacturing activities are based in Sweden and are split between two sites. The main site has a total of 300 employees. The second manufacturing site has about one hundred employees and is located sixty kilometres from the main site. The organisation of the manufacturing activities prior to the decision to adopt lean production was rather traditional.

4.2.1 Manufacturing Process

In the early 1990s, Office Machines's product range consisted of around seventy products selling in about 700 variants. Many products were manufactured in large volumes. The largest sellers sold up to 600,000 units per year, whereas the average volumes ranged between 20,000 and 40,000 units per year. Regardless of volume, the products were manufactured in the same process, see Figure 4.1.

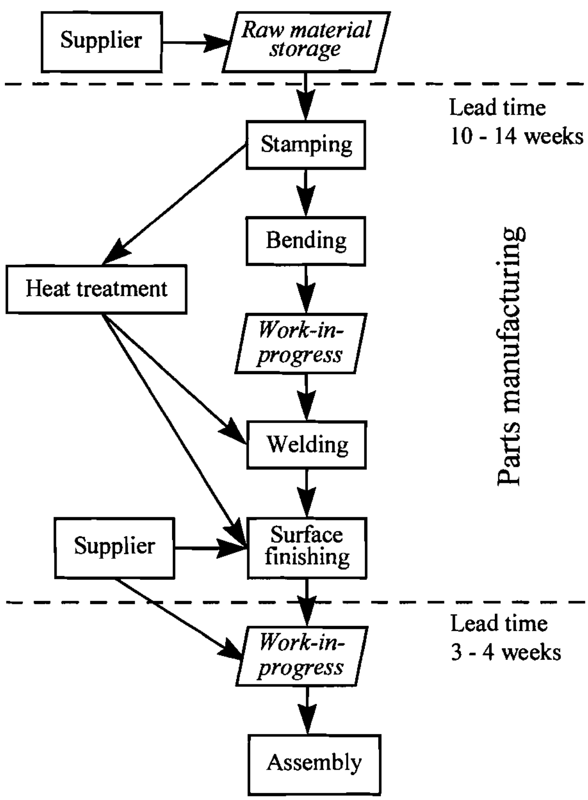

Figure 4.1 Material Flow and Stages in the Manufacturing Process

Figure 4.1 contains the main stages in the manufacturing process and the generic material flow between these stages. The following stages exist:

- *Stamping* - parts are stamped out from raw material.
- *Bending* - stamped parts are bent to different shapes in press machines using pick and place units to automatically pick the parts.
- *Heat treatment* - parts are heat treated, a sub-contracted operation.
- *Welding* - parts are welded together to form sub-assemblies.
- *Surface finishing* - parts are painted or coated in chrome and nickel.
- *Assembly* - parts manufactured in-house and externally procured parts are assembled. The bulk of assembly operations are manual, although a few products are assembled automatically.

Due to the long set-up times in the stamping and bending operations, manufacturing took place in large batches. A typical batch in stamping and bending consisted of enough parts for at least two months' consumption in final assembly. In other stages of the manufacturing process, batch sizes corresponded to between two weeks' and one month's consumption in final assembly. As a consequence of the large batch sizes, work-in-progress was kept at several places in the manufacturing process, indicated in Figure 4.1.

Parts manufacturing and procurement took place against a monthly forecast, made by the planning department in collaboration with sales. Assembly took place against a mixture of actual customer orders and the forecast. Manufacturing orders were issued every fortnight through the MRP system. All assembled products, whether assembled at the main site or at the sister site, were transported to the finished goods stock located at the main site. Typical lead times in the manufacturing process are indicated in Figure 4.1. Customers often ordered a mixture of different products and four days were allowed for packing and shipping. Sales lead times varied between six and eight weeks.

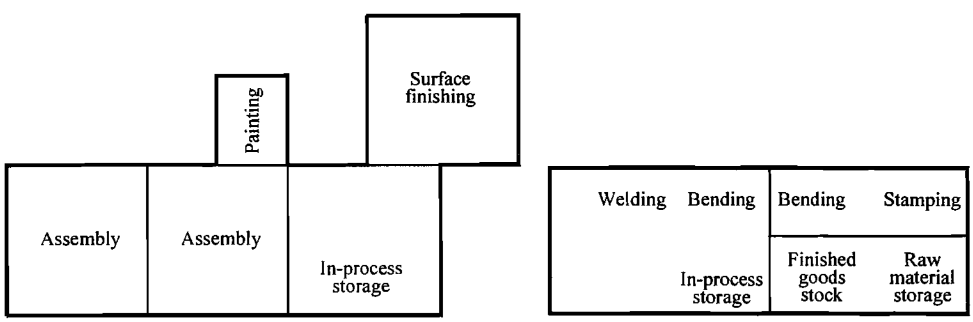

Figure 4.2 Main Site Factory Layout

The manufacturing process was functionally organised. Figure 4.2 schematically illustrates the layout of the main site, which consisted of two adjacent facilities. The functional organisation led to a number of internal transports. The number of transports was increased because the company had two sites. The company's second manufacturing site was also functionally organised and contained assembly and certain parts manufacturing operations. The site had for historical reasons come to specialise in certain operations in the manufacturing process. Parts could as a result be transported several times between the two sites before ending up in a product.

4.2.2 Quality Assurance

Office Machines enjoyed a good reputation in the market for the quality of their products. This standard of quality was costly to achieve, since much rework was done internally before the product was shipped. A certain percentage for rework had come to be included in the standard times for operations.

As a consequence of ISO 9002 certification in December 1991, quality awareness training was given to operators. A system of operator self-inspection had been started in the spring of 1991, but was complicated by blueprints that were not up-to-date. The measurements given on the blueprints were therefore not obeyed. Operators in parts manufacturing had experience and knowledge of the products which allowed them to adjust machines and tools for parts to fit with each other. Employees in final assembly were equipped with a rubber hammer to "fit" parts together.

Quality was inspected in the products. A system of final inspection was in place and one operation in assembly was to test the product. A sample of completed products were also reviewed once per month. The review corresponded to quality from the customer's point of view and fingerprints on a product were classified as a quality problem. The quality review did not function well as a tool for increasing product quality. If a large percentage of defects was found, operators only said: "now she has been fussy again" (referring to the person responsible for the quality review). Explicit action to find the cause of the defects was rarely undertaken.

4.2.3 Work Organisation

There was a maximum of three layers between the operators and the production director, as seen in Figure 4.3. Operators were not organised in teams, but sporadic rotation between different tasks took place in some parts of the organisation. Assembly activities were organised along production lines and each operator performed only a fraction of the work that was put in the product.

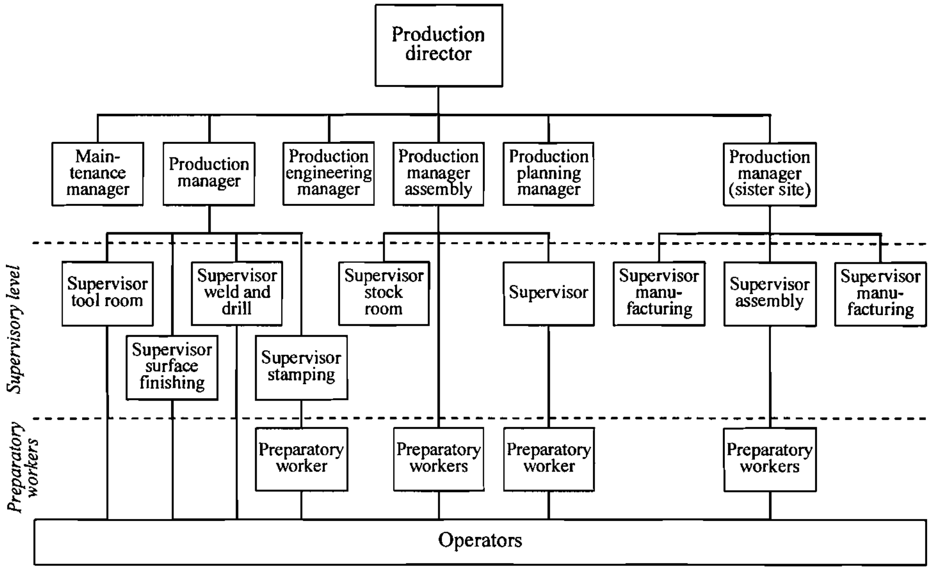

Figure 4.3 Previous Organisation Structure in Manufacturing

Operators were individually remunerated through a piece-rate system and formal training was minimal at shop floor level. A new employee was introduced to the job informally. It was more or less the task of the colleagues to train the new employee in the relevant jobs. A new employee was expected to perform his or her job after a few days, although not at full speed initially.

Operator suggestions were elicited on an individual basis through a suggestion scheme. There was little promotion of the scheme and the committee responsible for evaluating suggestions met once every six months. A total of around thirty suggestions came in per year. Up to three quarters of all suggestions received a monetary reward, but always with a delay.

4.3 Adopting Lean Production at Office Machines

The changes of concern in the present study have their roots in early 1990, when both the managing director and the production director were replaced. The change of directors was a consequence of the recession Office Machines had suffered through in the late 1980s. Part of the new directors' mandate upon arrival was therefore to achieve change.

4.3.1 The Project for Changing Manufacturing

When analysing the existing manufacturing organisation, the new production director concluded that improvements could be made. Particularly the following led the production director to the conclusion that change was needed:

- The structure and organisation of manufacturing led to problems of lengthy transports, high quality costs, high stock and work-in-progress, and long manufacturing and delivery lead times.
- Changes in the market led to an increase in the importance of delivering in small batches, on short notice.
- There was a need to increase cost efficiency, since the company had just suffered through a recession.
- It was envisioned that hiring would be a bottleneck in the future. Particularly the younger generation were not keen on working in industry. The work had to be made more appealing to employees.

The new production director had experience from changing manufacturing. In the late 1970s he had participated in the creation of manufacturing cells at a large defence contractor. Prior to his arrival at Office Machines, he had worked seven years at a manufacturing company, which had initiated changes similar to lean production. It was therefore natural for the production director to draw on his previous experiences, when changing manufacturing at Office Machines.

The attempts to change manufacturing started with informal discussions with manufacturing managers. The discussions were initially not that fruitful. Ideas on implementing manufacturing cells had been brought up by the previous production director. These ideas had been abandoned, since the resistance in the organisation was considered too great. The manufacturing organisation still consisted of the same managers. It therefore took a certain amount of selling his ideas for the new production director.

Gradually the ideas for change were accepted and in mid-1991 a tentative project plan for the change was written. The project to change manufacturing started in 1992 and was initially dominated by preparatory work. In February 1992, a project group was formed consisting of the production director, production managers, supervisors, operators, and union officials. One of the first tasks for the project group was to write an application to a government funding agency which sponsored changes within industry.

While waiting for the application to be accepted, information on the coming changes was given to all employees in March and August 1992. A just-in-time game was also conducted with all employees to give them a more hands-on experience of the benefits of reduced batch sizes. When the application to the funding agency was accepted in October 1992, planning of the changes was intensified. The plans were disturbed around Christmas 1992, by a large order the company received.

In November 1992, the managing director attended a seminar where the lean production framework of Chapter Two was presented. The managing director saw the similarities between the framework and the work the company had begun and proposed a collaboration with the researchers. The collaboration began in January 1993, with a seminar on lean production at the company. At this seminar, the lean production framework was presented to management representatives from all functions. The managing director and production director here officially stated the company's intention to work with the adoption of the lean production framework, as defined in Chapter Two.

Having adopted the lean production framework as a unifying guide for the coming changes at the company, managers at Office Machines used the framework to guide their actions. For the context of interest in the present study, the lean production framework was used as a guide to changing the manufacturing organisation. However, the framework only helped management postulate what should be done to change manufacturing. The framework did not postulate the order in which changes should be made.

4.3.2 Eliminating Waste in the Manufacturing Process

A main part of the adoption of lean production was to eliminate waste through cellular manufacturing. The manufacturing cells were created around families of similar products and contained both parts manufacturing and assembly. The only operations left outside the cells were stamping, surface finishing, and hardening. The creation of manufacturing cells took place through pilot projects.

Two manufacturing cells were created at the main site in April 1993. Due to the functional layout of the manufacturing process, the creation of manufacturing cells required physical relocation of tasks between and within the company's two sites. The relocation of tasks was also a preparation for the creation of manufacturing cells in the whole operation. Thus, even though only two manufacturing cells were created, more products were transferred between the two sites in April 1993.

The nature of the assembly task was also changed in April 1993, when assembly became organised in "rotation assembly". Each operator assembled a complete product. Operators stored the products on a cart when moving between assembly stations to perform different assembly operations. The operator and the products thus rotated between assembly operations, hence the term "rotation assembly". The change meant the assembly task was enlarged.

Both of the newly created manufacturing cells featured rotation assembly of the products. Rotation assembly was also introduced on other products as a preparation for the creation of manufacturing cells. The changes taking place in April 1993 resulted in a large share of operators being faced with new tasks overnight. In the sister site, for instance, forty operators were given new tasks.

The two manufacturing cells that were created as a pilot project were intended to point out the direction in which the whole manufacturing operation should move. The layout of the cells facilitated a smooth material flow between the different machines. The intention was to physically connect machines and have operators manning more than one machine. Storage of material took place within the cells to facilitate material movement and control.

In September 1993, a project to analyse the pilot cells was started. The aim was to use the experience gained to determine possible improvements of the cells. The analysis of the cells led to a split of the largest cell in two, to simplify material flow and to avoid clashes in machines. The physical separation of equipment to create the two cells took place in February 1994. The analysis of the cells also led to the installation of machines permanently set up to produce certain parts in one of the cells, starting in early 1994 and finishing in May.

A decision in the company's board was necessary to create manufacturing cells in the whole operation. Planning the manufacturing cells began in September 1993. One part of the plan was out-sourcing circuit boards, which the company manufactured from components. A decision to out-source the circuit boards was taken in October 1994 and the first delivery took place in April 1995.

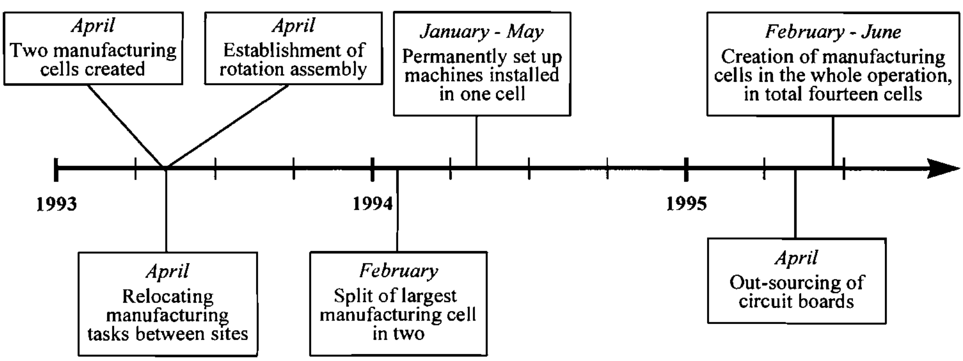

Figure 4.4 Major Actions to Eliminate Waste in the Manufacturing Process

Despite the early start of planning the second round of manufacturing cells, the relocation started in February 1995 and took place in stages. Fourteen cells were physically in place by June 1995. The major actions to eliminate waste in the manufacturing process are summarised in Figure 4.4.

4.3.3 Achieving Pull Instead of Push

When changing to pull scheduling, efforts were concentrated on the pilot manufacturing cells. In June 1993, the planning department noticed that the batch sizes in the MRP system were not obeyed. Operators used lower batch sizes than the planning department intended. The batch sizes were therefore lowered in the MRP system to fit reality better.

In August 1993, an alteration of product structure trees started being discussed, see Figure 4.5. Each product had two different product structure trees, with corresponding part numbers in the MRP system: one structure before and one after the welding operation. The same batch size was used within each section of the manufacturing process with the same product structure tree. Altering the product structure trees involved moving the point at which there was two different trees from the bending to the stamping operation.

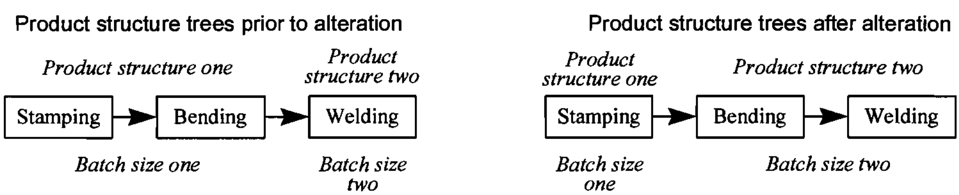

Figure 4.5 Alteration of Product Structure Trees

The alteration of product structure trees was initiated in September 1993 on products in the largest manufacturing cell. The primary consequence of the alteration was that batch sizes in stamping did no longer decide which batch sizes were used in the remainder of the parts manufacturing process. The batch sizes in the bending and welding operations could therefore be reduced.

In conjunction with altering the product structure trees, parts were divided in two different categories with their value as a guide:

1) The first category was the more valuable parts, to be controlled manually by operators.
2) The second category was the less valuable parts, to be controlled via a re-order point system, whether manufactured in-house or procured.

The second change to the MRP system was initiated in October 1993, as operations within the manufacturing cells were made to one planning point, for which capacity planning was performed and to which jobs were released. Operations in the manufacturing cells had previously been separate identities in the MRP system. Moving to one planning point simplified production planning and control.

The changes discussed so far meant that batch sizes could be reduced to stage one in Table 4.1. The table illustrates batch sizes in different operations for a high volume product (around 600,000 products sold per year). From May 1994, parts manufacturing within the cells took place against customer order and the move to stage two in Table 4.1 had been made. This effectively meant that pull scheduling took place on all manufacturing operations except stamping.

Table 4.1 Changes in Batch Sizes for a High Volume Product

	Stamping	*Bending 1*	*Bending 2*	*Welding*
Starting point	60,000	60,000	60,000	10,000
Stage one	60,000	10,000	10,000	10,000
Stage two	60,000	3,000	3,000	3,000

The next change to production control in the manufacturing cells started in March 1995, when a system simplifying material control was drafted. The new system was implemented in May. Visibility was increased through the use of kanban cards to control the movements of the more valuable parts. Re-order points utilising the MRP system were used for cheaper parts. This system was also used in the manufacturing cells created around the summer of 1995. The major actions to achieve pull instead of push are summarised in Figure 4.6.

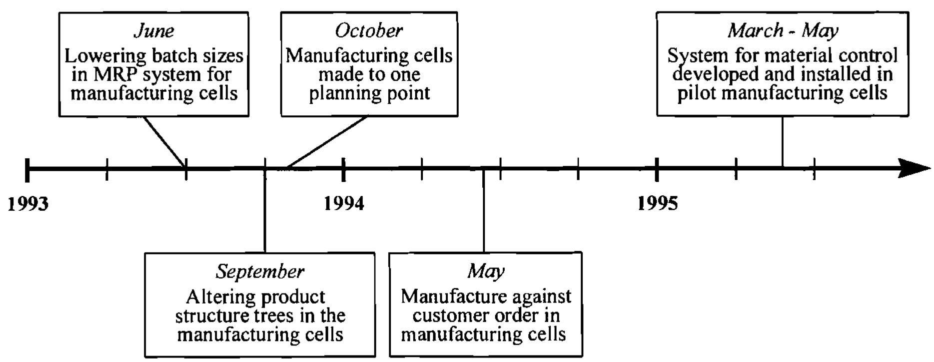

Figure 4.6 Major Actions to Achieve Pull Instead of Push

4.3.4 Installing a System for Zero Defects

An important motivation for the work with quality was an audit by a large customer in March 1992. The customer's interest in Office Machines's quality management system came through a new product that was being developed in collaboration between Office Machines and the customer. As a part of their supplier approval process, the customer audited Office Machines's quality management system and found it unsatisfactory. The customer therefore presented Office Machines with a list of systems and activities that had to be in place for Office Machines to become their supplier. The list was an extended version of ISO 9001, where the ISO standards made up about twenty-five percent of the customer's demands.

To meet the customer's demands, a team was put together to work with quality as a part of the lean production project. The work of implementing the items on the list presented by the customer began in March 1993. The work concerned the following main items:

- *Revision of blueprints* - updating blueprints to correspond with reality to restore operators' confidence in the blueprints.
- *Production engineering* - creating of work instructions to ensure the right methods and equipment were used in the manufacturing process.
- *Process improvements* - securing a manufacturing process that guaranteed all parts were conforming to specification. Accomplished through for instance statistical process control, capability studies, and systematic problem solving.
- *Training* - operator training was essential to succeed with the installation of a quality management system.

Office Machines started to implement the items on the action list in the pilot manufacturing cells. Quality training started in March 1993. The training totalled forty hours, divided in basic quality training, product knowledge, reading blueprints, measurement techniques, and statistical methods.

A particular item on the action list was the installation of a system for corrective action. The intention was to systematically follow up each departure from specifications. The system for corrective action was installed in the pilot manufacturing cells in April 1993. The customer audited Office Machines's progress on the action list in May 1993 and demanded that the system for corrective action was installed in the whole operation. The system was installed and started to be used in November 1993. Meanwhile the following major actions were taken as a part of the work with the quality management system:

- A system for tracing parts was installed in May 1993. Parts were clearly labelled to facilitate tracing them in the manufacturing process.
- A computerised system for statistical process control was installed in June 1993 and was used by sixty operators in August. Attribute charts were simultaneously introduced in the assembly operations.
- Revision of blueprints was initiated early in the quality project, but it was not until November 1993 the work was completed for the products within the pilot manufacturing cells.

Around eighty percent of the action list had been addressed by November 1993 and the new routines had become part of the daily operation. The quality project was therefore disbanded. This does not mean that efforts to improve quality were abandoned, only that management did not have to devote the same amount of effort and resources to the work with quality. The appropriate routines were also brought into the new manufacturing cells as they were created. The major actions to install a system for zero defects are summarised in Figure 4.7.

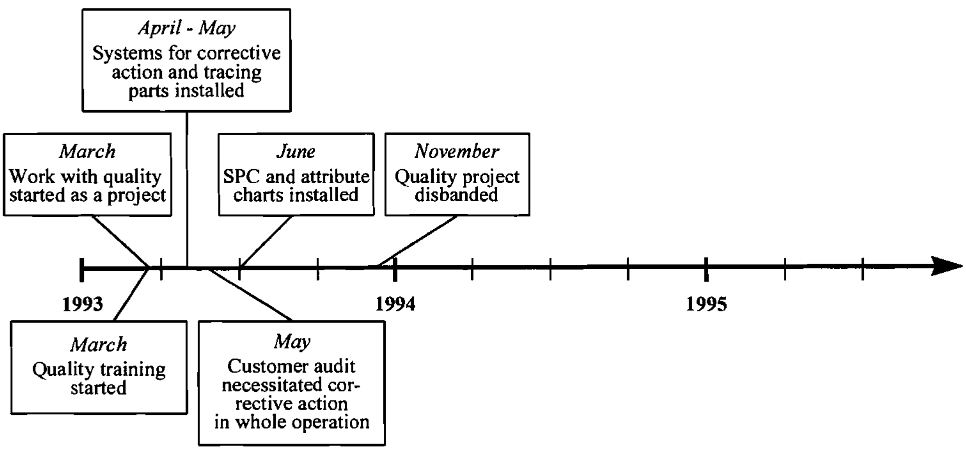

Figure 4.7 Major Actions to Install a System for Zero Defects

4.3.5 Creating Multifunctional Teams

An important part of Office Machines's change was the creation of multifunctional teams. Creating teams required a substantial investment in training, starting in late 1992, when all operators went through a one-day course in group dynamics. Further training was carried out, with emphasis on those part of the pilot manufacturing cells. Each operator received a total of sixty-eight hours of formal training in different areas, see Table 4.2. Thousands of hours had been spent on training by August 1993.

Table 4.2 Elements of Operator Training

• Group dynamics	• Product knowledge
• Basic quality	• Blueprint reading
• Statistical methods	• MRP system
• Measurement techniques	

The first multifunctional teams were created together with the pilot manufacturing cells, in April 1993. The teams were made responsible for the manufacture of complete products in the manufacturing cells. Two teams were created through a procedure where management and the union together decided which employees were to be part of the teams. This procedure was chosen to get teams made up of employees with different age, sex, and attitude towards the change. The largest team contained thirty people, with no more than fifteen present at any one time. The second team contained fifteen people.

Apart from the manufacture of products, the newly created multifunctional teams were also made responsible for a set of indirect tasks. The areas to which these tasks belonged are displayed in Table 4.3. With the creation of manufacturing cells and multifunctional teams, the number of job classifications was decreased from twenty-one to seven.

Table 4.3 Areas of Responsibility Integrated in the Multifunctional Teams

• Planning	• Human resources
• Quality	• Maintenance
• Purchasing	• Tool service and repair
• Production engineering	

Apart from the multifunctional teams in the manufacturing cells, teamwork was introduced in other areas of the manufacturing process as well. Organisational changes at one of the assembly areas in January 1993, meant that operators were made responsible for indirect tasks. Teamwork was introduced with the creation of rotation assembly in April 1993.

A multifunctional team was also created at the stamping department. A customer-supplier relationship was established between stamping and other areas of the manufacturing process. The stamping team was made responsible for tasks surrounding the stamping operation, such as material handling and maintenance. The creation of a multifunctional team started in January 1994, but was not finished until spring 1995. As the creation of manufacturing cells in the whole operation took place around the summer of 1995, multifunctional teams were created. Before this change, most operators had received both theoretical and practical training.

Early in the lean production project, it was clear the planned multifunctional teams needed a new payment system. The existing piece-rate system was no longer considered suitable. The work of creating a new payment system was an integral part of the creation of multifunctional teams. The task was to design a payment system promoting performance under the new manufacturing strategy.

The first change to the payment system took place in April 1993. Piece-rates were abandoned for operators working in the manufacturing cells and for operators working with rotation assembly. The operators instead received a salary and the work of finding a new payment system continued. An agreement between management and the union regarding the new payment system was reached in October 1993. The payment system consisted of two parts:

1) The size of the *fixed part* depended on the individual's achievements and was related to the employee's abilities.
2) The size of the *bonus* depended on the team's achievements in the areas of productivity, quality, and delivery precision.

The system was introduced in November 1993. The complete system was introduced only for the teams in the manufacturing cells. Teams working with rotation assembly were only assigned the payment system's bonus part. The intermediate stage was necessary since the organisation of the teams was not fully developed until manufacturing cells had been created. The major actions to create multifunctional teams are summarised in Figure 4.8.

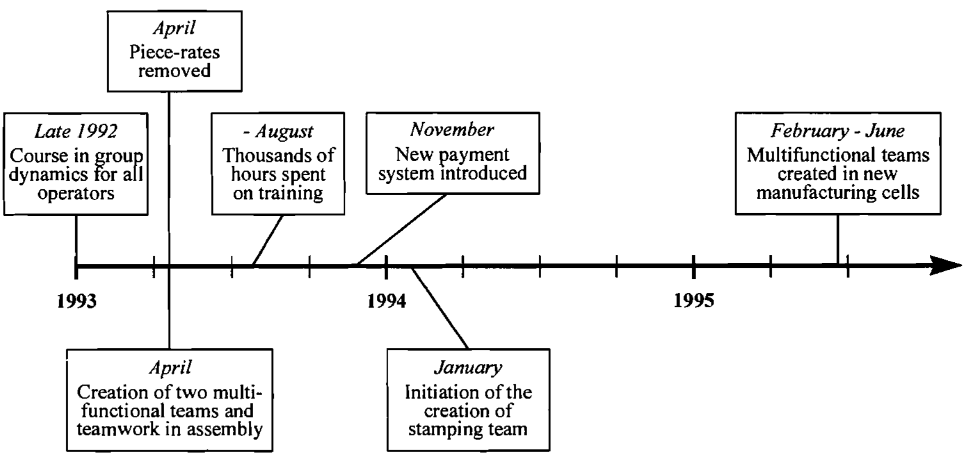

Figure 4.8 Major Actions to Create Multifunctional Teams

4.3.6 Decentralising Responsibilities

Supervisory tasks were integrated in the multifunctional teams. Changes to the work organisation started in January 1993, when one supervisor at the main site was transferred to a new job within the company. The preparatory worker in the same department was transferred to the operator level in January 1993. The remaining preparatory workers in the department were in April 1993 transferred to the newly created multifunctional teams.

The intention was to replace the supervisors with team leaders, a task to be rotated among suitably trained team members. However, until operators willing and able to take on the team leader task had been found and training started, contact persons were appointed in the multifunctional teams. The contact persons depended on the former supervisors and the production manager for support.

Team leader training was started in September 1993, for operators in the pilot manufacturing cells. Twelve operators went through the first round of training. Although not all of the operators receiving training were suitable as team leaders, training was carried out to increase competence. Team leaders assumed responsibility for managing the teams in the manufacturing cells from November 1993. Team leaders were responsible for a number of tasks, a selection of which are displayed in Table 4.4.

Table 4.4 Tasks to Be Incorporated in the Team Leader's Responsibility

Supervisory tasks • Capacity planning • Handling absence and presence • Manage the team and assign tasks *Planning* • Registration of production orders • Responsible for deliveries • Responsible for updating MRP system *Purchasing* • Registration of purchase orders • Contacts with suppliers *Production engineering* • Initiate problem solving • Continuous improvement	*Quality* • Responsible for ensuring quality routines are followed • Responsible for quality reports • Responsible for quality issues externally *Human resources* • Recruitment decisions • Creation of training plans • Rehabilitation issues *Indirect service tasks* • Participate in preventive tool and machine maintenance • Plan preventive tool and machine maintenance in the team

Until the team leaders had the appropriate competence to manage all tasks, they assumed responsibility gradually. The team leaders were responsible for all tasks in April 1994. During the transition period, responsibility for the tasks was split between the team leaders, the production manager, and the planning department. The following mechanisms were also used to support the team leaders during the transition:

- A weekly meeting between team leaders and the production manager responsible for the teams, to discuss the coming week's issues.
- Relocation of the production manager to an office close to the manufacturing cells in March 1994.

A second part of the team leader training started in February 1994 and continued until May. Since five team leaders left the company in the spring of 1994, a new round of team leader training was started in August 1994. To prepare for the creation of the new manufacturing cells, further batches of team leader training was started in October 1994 and February 1995.

In parallel to training team leaders and transferring responsibilities to them, a number of organisational changes were made. The supervisor at the stamping department was transferred from his position in January 1994, as were the three supervisors at the sister site. All four were given new jobs within the company.

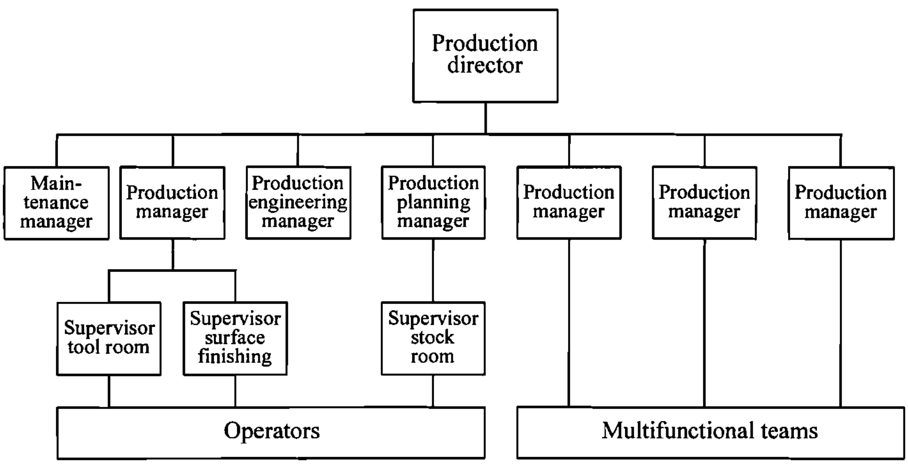

Figure 4.9 Resulting Manufacturing Organisation

With the organisational changes taking place as a consequence of the creation of manufacturing cells around the summer of 1995, the resulting manufacturing organisation had the structure shown in Figure 4.9. The major actions to decentralise responsibilities are summarised in Figure 4.10.

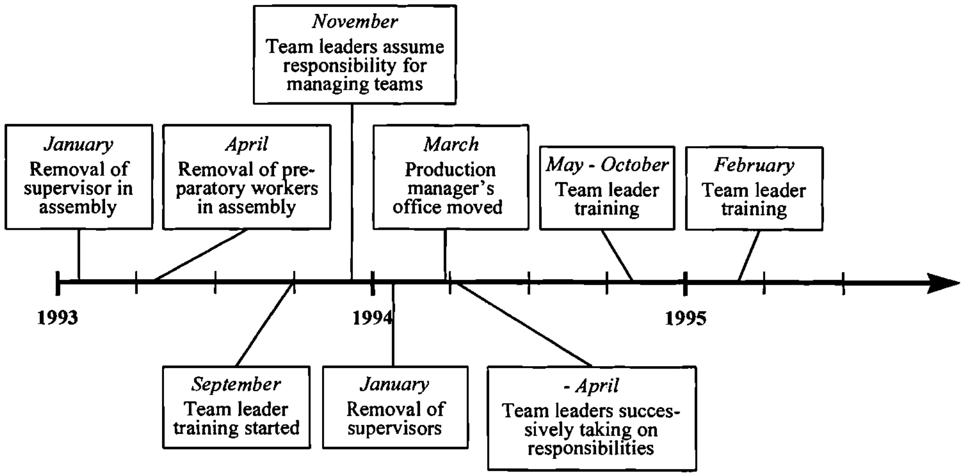

Figure 4.10 Major Actions to Decentralise Responsibilities

4.3.7 Creating Vertical Information Systems

As a support to the multifunctional teams in their work of manufacturing products, vertical information systems were installed. The systems primarily consisted of performance information relevant for the teams. Discussion on the systems started immediately prior to the relocation in April 1993. The discussion focused on the multifunctional teams created at that time.

Although the discussion on vertical information systems intensified after the creation of manufacturing cells in April 1993, no immediate action was taken to create the systems. It was not until October 1993, the relevant performance information was properly displayed on notice boards in the pilot manufacturing cells. The notice boards were copied as manufacturing cells were created in the whole operation around the summer of 1995.

4.3.8 Starting the Continuous Improvement Initiative

A continuous improvement initiative was launched in January 1995, with half a day of training for the three multifunctional teams in the pilot manufacturing cells. Each multifunctional team was divided in several continuous improvement teams. Each team consisted of between five and seven employees and had a team leader, a role which circulated among team members every two months. The teams met for a specified length of time once every fortnight. The ideas for improvements the teams came up with were owned by the teams. Each idea suggesting a solution to a problem was instantly rewarded with a lottery ticket. The further treatment of the suggestions is shown in Figure 4.11.

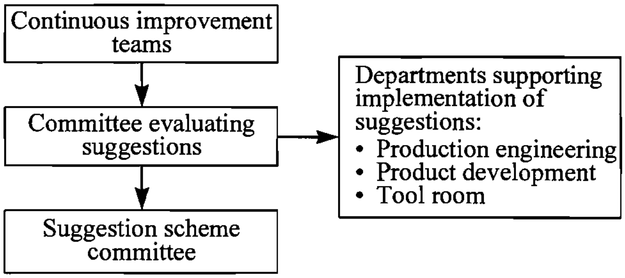

Figure 4.11 Organisation of the Continuous Improvement Initiative

All suggestions were sent to a committee, which met at least once per fortnight and contained the team leaders from the continuous improvement teams, the production director, a production manager, and representatives from production engineering and marketing. The committee's task was to decide what action was necessary as a consequence of a suggestion. Support from various departments may be needed to implement the suggested changes, but most often it was the operators who implemented the changes.

All suggestions of a certain quality were sent to the existing suggestion scheme committee to follow its reward procedure. The committee met once per fortnight, as opposed to once per six months. To further help improve response times, it was decided that as a general rule, teams should not have to wait more than two weeks before receiving feedback on a suggestion.

4.4 Changes in Operational Performance Measures

Important for any company adopting lean production are the resultant performance changes. This section illustrates changes in operational performance measures at Office Machines. When adopting lean production one needs to understand that improvements in performance measures require time to show up (Schroeder and Robinson, 1991). To take due account of these delays, the range of performance data extends beyond the scope of the study and goes from 1992 to 1996. The data are summarised per quarter and the first quarter of 1992 is chosen as a baseline comparison.

4.4.1 Delivery Precision

Delivery precision is measured as the percentage of orders delivered on time from manufacturing. As measured by Office Machines, "on time" refers to promised shipping date, not when the products actually arrived at the customer. Delivery precision in this form has, due to the availability of data, only been possible to measure from the second quarter of 1993, see Figure 4.12.

Figure 4.12 Delivery Precision

Figure 4.12 shows that delivery precision improved after the introduction of manufacturing cells in the second quarter of 1993, although there was a decline in performance during the third quarter of 1994. Note also that around half of the occasions when deliveries were delayed in 1996 were caused by one supplier. This indicates the bottleneck for achieving on-time deliveries had moved from internal operations towards suppliers.

4.4.2 Lead Times

The data on delivery precision need to be seen against the background of shrinking lead times. As a consequence of the changes, both manufacturing and sales lead times shrunk, see Table 4.5. The adoption of lean production had a dramatic effect on manufacturing lead times, which shrunk to around six percent of their value prior to the changes. Sales lead times were cut in half, but sales lead times are also subject to the way in which sales and distribution works.

Table 4.5 Lead Times

	Prior to change	*After change*
Average manufacturing lead time	17 weeks	1 week
Average sales lead time	6 - 8 weeks	2 - 4 weeks

4.4.3 Quality

Two measures have been used to reflect quality performance. The first measure is quality scores from the product review, a measure which corresponds to quality from the customer's point of view. A sample of products is inspected each month and scored based on the frequency and type of defects found. The scores are then divided between the number of inspected products. A score of zero indicates the products are fault-free. The scores are found in Figure 4.13, where scores have been converted to a percentage, based on the score of the first quarter of 1992. Figure 4.13 reveals the quality scores declined following the adoption of lean production.

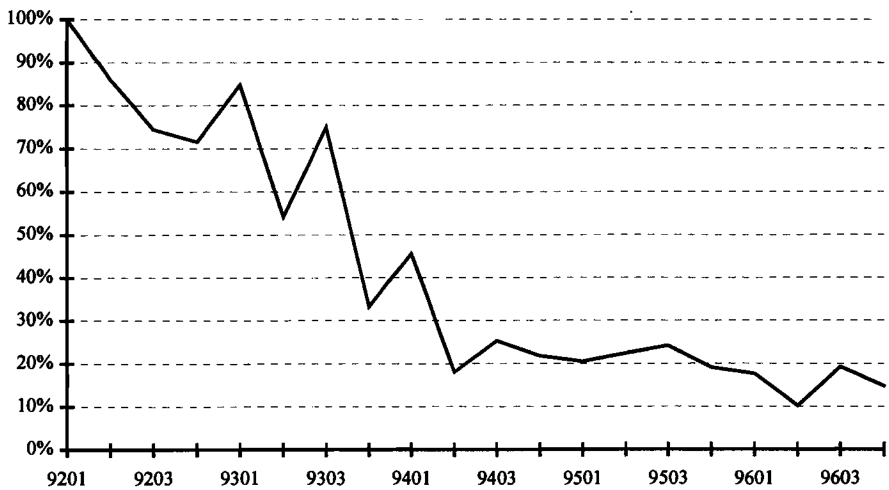

Figure 4.13 Quality Scores

The second measure used to reflect quality performance are statistics for scrap and rework. These statistics reflect the success of achieving conformance quality. Both scrap and rework are measured in terms of standard costs, see Figure 4.14, where values are given as a percentage of the first quarter of 1992.

Figure 4.14 is slightly puzzling, since it shows how scrap and rework increased over a period. According to managers at Office Machines, the major reason for the increase was that there were many newly hired employees around mid-1994 to late 1995. It took these employees a while to get accustomed to the quality management system, which resulted in higher than normal scrap and rework levels. As the employees got accustomed to the quality management system, scrap and rework decreased.

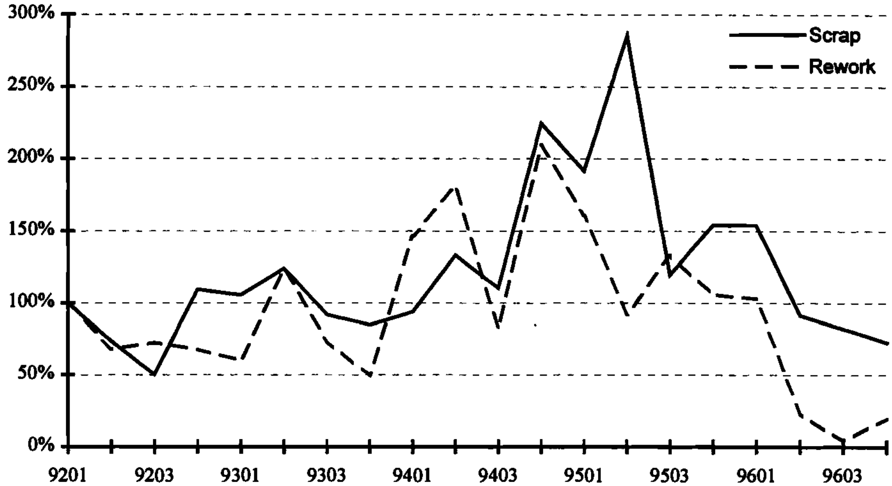

Figure 4.14 Scrap and Rework

4.4.4 Inventory

Two different measures of inventory have been used. First work-in-progress, measured as the average value of work-in-progress for each quarter. The values of work-in-progress are in Figure 4.15 given as a percentage of the first quarter of 1992. Figure 4.15 reveals that work-in-progress was cut to less than half of its original value by the end of 1996.

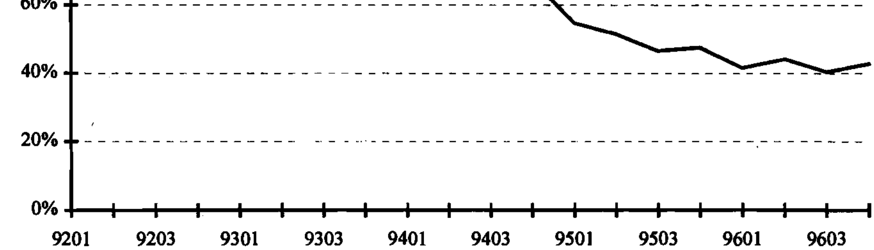

Figure 4.15 Work-in-Progress

The second measure of inventory, stock turns, is measured as cost of sales per quarter divided by total inventory value at the end of the quarter. Two separate calculations were made: stock turns including and excluding raw material. Newly developed products contained more externally procured parts than normal. The externally procured parts are procured from the Far East and are relatively expensive, compared with the raw material used for other products.

The values for stock turns, in Figure 4.16, have been given as a percentage of the first quarter of 1992. By the end of 1996, stock turns including raw material were 1.8 times that of the first quarter of 1992. One reason for the relatively small increase in total stock turns is the newly developed products. Stock turns excluding raw material show another picture: at the end of 1996, stock turns were almost 2.4 times of the value of the first quarter of 1992.

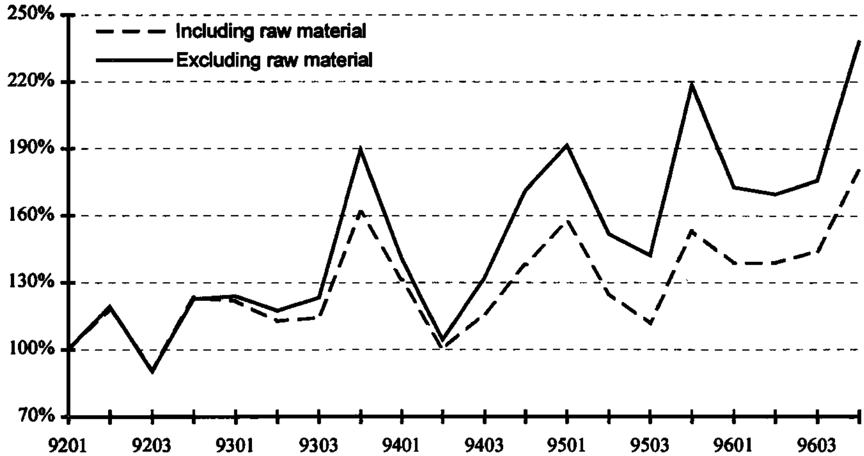

Figure 4.16 Stock Turns

4.4.5 Productivity

Productivity at Office Machines is measured as the number of direct hours spent in manufacturing relative to the standard number of hours. The outcome of this measure is displayed in Figure 4.17. There are no data available for the third and fourth quarter of 1995, since productivity was not measured during the physical changes to the manufacturing process around the summer of 1995. As seen in Figure 4.17, productivity declined as the organisation was changed in April 1993. Productivity only started to reach its previous level towards the end of 1996. There were several reasons behind the decline in productivity. One reason is the inappropriate way productivity is measured, considering the changes taking place within manufacturing.

Figure 4.17 Productivity

To compensate for the problem of measuring productivity, a second measure was calculated: value of produced goods per hour consumed in manufacturing (see also Roos, 1990). The basis of this measure is the standard cost of manufactured products. The cost of manufactured products is then divided by the total number of hours consumed in manufacturing, including both direct and indirect time. The distinction between direct and indirect time is blurred by the inclusion of indirect tasks in the multifunctional teams. The value of produced goods per hour consumed in manufacturing is found in Figure 4.18.

Figure 4.18 Value of Manufactured Products Per Hour Consumed in Manufacturing

Figure 4.18 reveals a different picture than the productivity measure and shows that the value of manufactured products increased over time. A contributing factor to the increase is that the adoption of lean production had by mid-1995 resulted in the transfer of twelve previously indirect employees to positions on the shop floor, where they participated in the adding of value to the products.

CHAPTER 5
Patterns of Issues in the Adoption Process

A number of issues arose in the process of adopting lean production at Office Machines. The patterns of issues are of interest in the present study, since they indicate the sequence in which management devoted effort and resources to the lean production principles. We have in Chapter Three seen how I arrived at the important issues, which are the basis for the analysis. As a first step in the analysis, the patterns of issues are in this chapter examined for major influences.

5.1 Analysing the Patterns of Issues in the Adoption Process

Before proceeding with the analysis of the patterns of issues, I need to remind the reader of a few points, to facilitate understanding the analysis. First, the purpose of the study was in Chapter One stated as: "determine sequences of lean production principles through an examination of the patterns of issues in the adoption process". Issues indicate the amount of management effort and resources that were devoted to the adoption of lean production. Issues also indicate the sequence in which principles were adopted.

Second, in Chapter Three it was stated that issues were indicated by incidents. The patterns of issues are made operational as, and can only be displayed as, patterns of incidents. Furthermore, only incidents indicating important issues were included for further analysis. Incidents that only indicated activities associated with the adoption of lean production were not included. Neither were incidents indicating insignificant issues included for further analysis.

Third, recall from Chapter Three the following details of how incidents that were kept for further analysis were coded:

- Each incident indicated at least one lean production principle, but could be coded as indicating more than one principle.
- An incident could be coded as indicating up to three different issues.

Finally, the content of the issues is not of interest at this stage of the analysis. It is the patterns in which the issues arose that is of interest.

The first tool used to analyse the patterns of issues was graphical displays of the number of issues as a function of time. The issues were displayed for each lean production principle, including the overall level of the lean production project (denoted "Whole project"). Although affecting the adoption process, all incidents could not be referred to a lean production principle.

The display of the number of issues as a function of time was made through sorting the coded incidents on each lean production principle. Incidents indicating more than one issue were separated and treated as more than one incident. Two considerations were made when displaying the patterns of issues:

1) *A monthly interval was chosen for the time dimension.* A monthly interval provided the most meaningful interpretation of the patterns. A monthly interval also corresponded to the average frequency of meetings and other activities at the company (see also Garud and Van de Ven, 1992). I did experiment with various intervals for the time dimension. Quarterly intervals aggregated away changes, whereas weekly intervals provided too much detail.
2) *I only included the study period in the analysis.* Documents indicated a few issues before the start of the study, in February 1993. These issues proved to be insignificant relative to observations made after the study had started. I also excluded July from further analysis. July is a holiday month in Sweden and most companies have little or no activity during July, as does Office Machines.

The patterns of issues can be found in Figure 5.1 to Figure 5.8. The figures display the number of issues as a function of time for each lean production principle, since the purpose of the study is to determine sequences of the principles. Figure 5.1 to Figure 5.8 reveal that the patterns of issues were episodic: periods of frequent observations of issues were followed by periods of less frequency and vice versa.

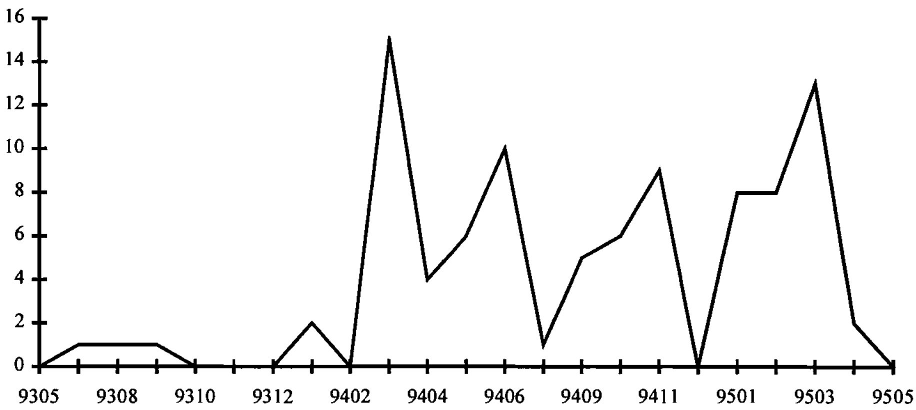

Figure 5.1 Pattern of Issues in Continuous Improvement

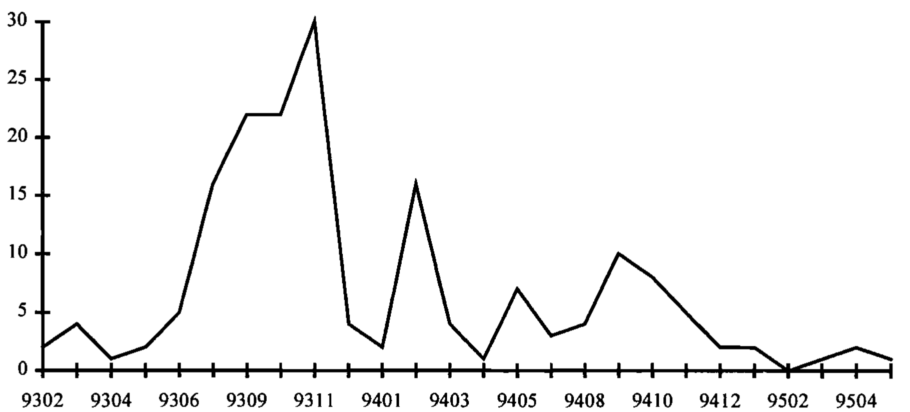

Figure 5.2 Pattern of Issues in Decentralised Responsibilities

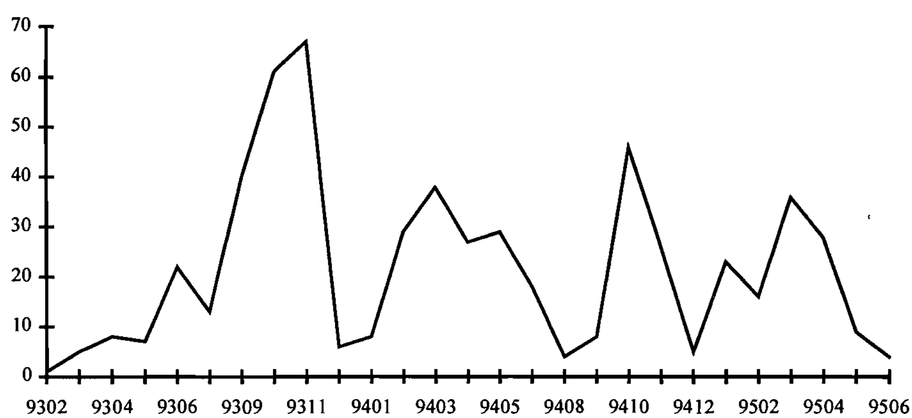

Figure 5.3 Pattern of Issues in Elimination of waste

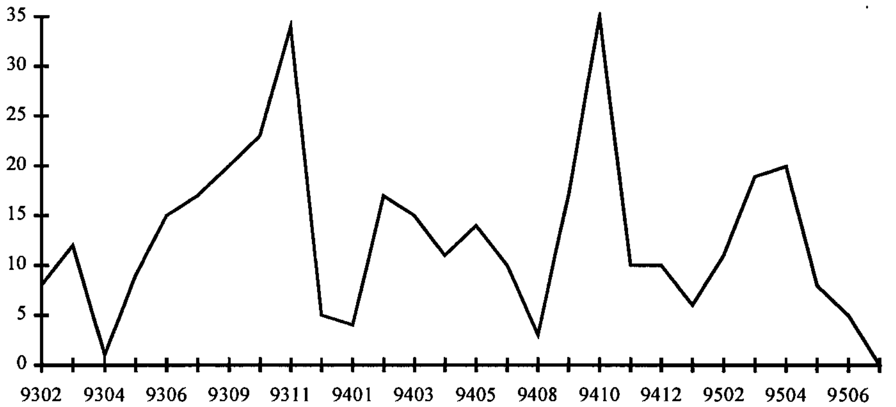

Figure 5.4 Pattern of Issues in Multifunctional Teams

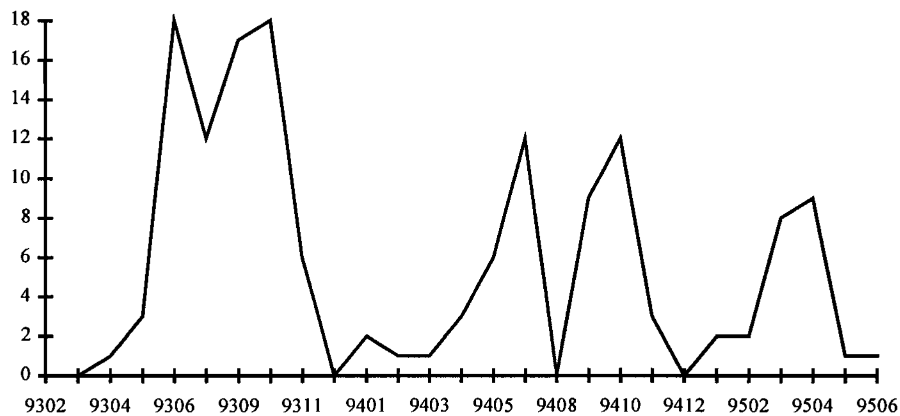

Figure 5.5 Pattern of Issues in Pull Instead of Push

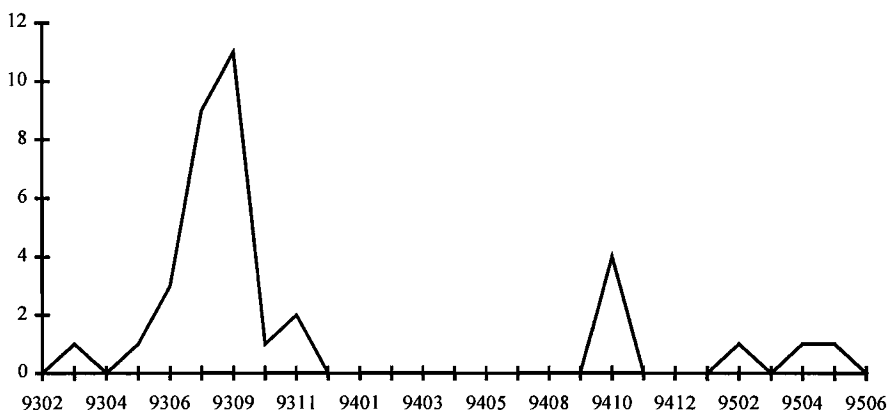

Figure 5.6 Pattern of Issues in Vertical Information Systems

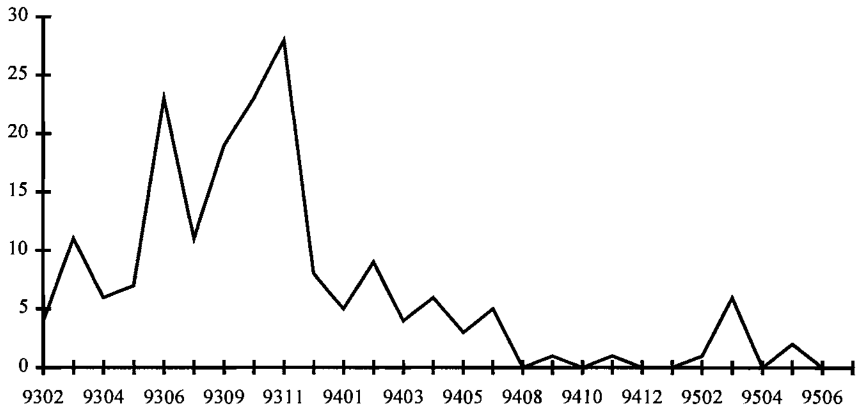

Figure 5.7 Pattern of Issues in Zero Defects

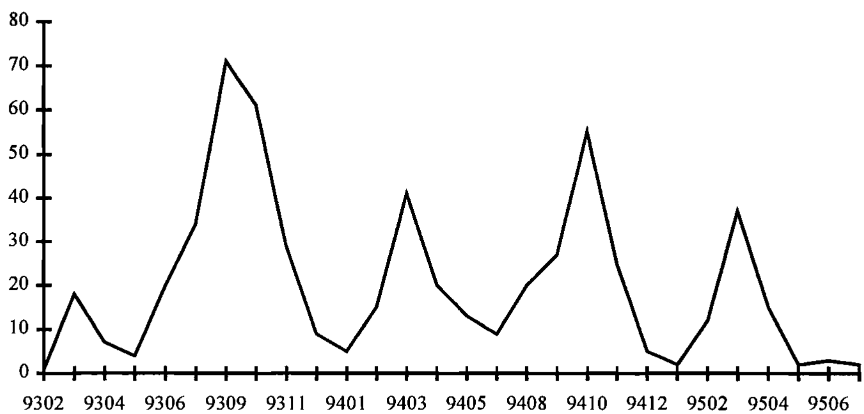

Figure 5.8 Pattern of Issues in Whole Project

Spearman's rank correlation coefficient, or Spearman's Rho, was the second tool used for analysing the patterns of issues. Contrary to a common dichotomy, taking a qualitative approach does not preclude the use of quantitative tools for the analysis (Silverman, 1993). Quantitative analytical tools can particularly be used to find regularities that may be hidden in the material (Berg, 1981). Spearman's Rho was thus a means of finding hidden information in the data, information which only made sense when related to the overall interpretation. Recall that by using a qualitative approach, I am interested in the meaning rather than the measurement of organisational phenomena (Daft, 1983).

Spearman's Rho involves calculating the correlation between two bi-variate populations. The underlying hypothesis being investigated is whether there is a relationship between two populations. A relationship would here imply that the patterns of issues in two principles were moving up and down at the same time.

The reason for choosing Spearman's Rho is that the method does not rely on the assumptions underlying traditional correlation coefficients (Daniel, 1990).

Spearman's Rho was in the main used to test whether two different patterns of issues were correlated. The underlying null hypothesis is that the two patterns were mutually independent. The tests were all single-sided, which means that the null hypothesis was tested against the alternatives that the patterns were either positively or negatively correlated. The single-sided test was used since it was possible beforehand to specify the direction of the expected relationship, either through the insights I gained during the field work or the graphs displaying patterns of issues. I chose at all times a cut-off point of $\alpha = 0.05$.

5.2 Influences on the Patterns of Issues

5.2.1 The Influence of Researcher Presence on the Patterns of Issues

When testing for major influences on the patterns of issues in Figure 5.1 to Figure 5.8, my presence at Office Machines may be one influence. My presence at Office Machines varied over the course of the study. Towards the end of the study, I did not spend as much time at the company as I initially did. The number of days per month I spent at the company are found in Figure 5.9.

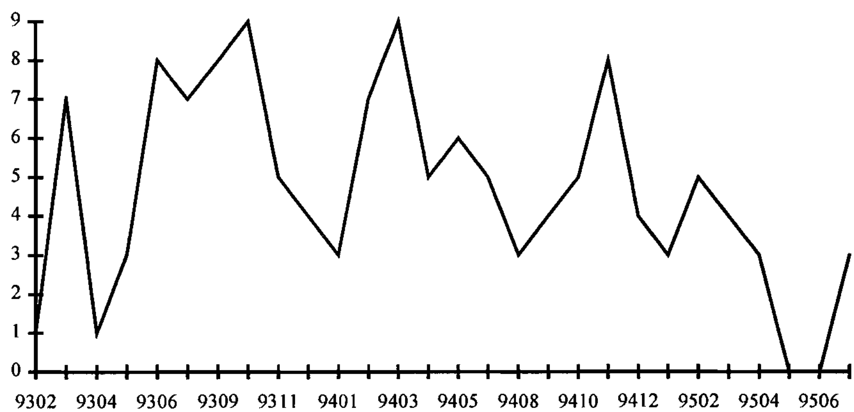

Figure 5.9 Days Per Month Present at Office Machines

It is plausible to expect that during the months I was at the company more often, I observed a high number of incidents, and vice versa. To test whether this expectation had any grounds, Spearman's Rho was used to test for the existence of correlation between the patterns of issues and the amount of time I spent at the company. The results of the tests are found in Table 5.1.

Table 5.1 Correlation between my Presence and Patterns of Issues

Principle	r_S	α (n=28)
Continuous improvement	0.316	
Decentralised responsibilities	0.683	0.0005
Elimination of waste	0.686	0.0005
Multifunctional teams	0.645	0.0005
Pull instead of push	0.535	0.0025
Vertical information systems	0.339	0.05
Zero defects	0.546	0.0025
Whole project	0.760	0.0005
Adoption process	0.797	0.0005

Table 5.1 contains the values of Spearman's Rho (r_s) and the equivalent critical values (α), when below the chosen cut-off point. Both Spearman's Rho and the critical values are given for each lean production principle, including Whole project. To the principles was added "Adoption process", which is the sum of issues in all lean production principles including Whole project. The table reveals that all but one principle (Continuous improvement) was significantly correlated to my presence. Adoption process was also significantly correlated to my presence. The results of the tests imply that we cannot rule out that my presence at the company was related to the patterns of issues.

Apart from the influence of my presence at Office Machines on the patterns of issues, the influence of the second researcher's presence needs to be discussed. My thesis supervisor visited Office Machines on average approximately one day per month. The purpose of his visits was to give various forms of input to the adoption process, in meetings and through seminars.

As a consequence of our clinical role, the input was dictated by the needs of the company. My supervisor's input also concerned a wider range of areas than the adoption process in manufacturing. One example of input is seminars on the lean production framework for managers, supervisors, and operators. A second example is facilitation of discussions at top management level to formulate manufacturing and product development strategies. However, most often the input took place in the form of meetings with top managers.

A series of tests were carried out to determine the correlation between the number of days per month my supervisor spent at Office Machines and patterns of issues. A total of seventeen days were spent at Office Machines in 1993 and 1994. In 1995, the visits concerned activities outside the lean production project and are not of interest here. The results of the tests are found in Table 5.2.

Table 5.2 Correlation between Second Researcher's Presence and Patterns of Issues

Principle	r_S	α *(n=28)*
Continuous improvement	0.239	
Decentralised responsibilities	0.484	0.005
Elimination of waste	0.257	
Multifunctional teams	0.260	
Pull instead of push	0.207	
Vertical information systems	0.031	
Zero defects	0.129	
Whole project	0.306	
Adoption process	0.327	0.05

The results in Table 5.2 reveal that the second researcher's presence was significantly related only to Decentralised responsibilities and Adoption process. The results are encouraging since they imply that the second researcher's presence was not related to the patterns of issues to any greater extent. The implications of the relationship between both researchers' presence and patterns of issues can now be considered.

Note first that based on the relative sizes of the correlation coefficients we cannot conclude that the presence of the researchers explains more or less of the patterns of issues than any other factor. It is difficult to interpret the exact measure of strength that Spearman's Rho is estimating (Daniel, 1990). The question then is whether the results of the tests present any major problems for interpreting the patterns of issues? I argue that they do not, although the results do caution me when interpreting certain aspects of the patterns. The premises of this argument are explored below.

The nature of the clinical methodology implies that the researchers' presence may be related to the patterns of issues. The clinical methodology meant that we as researchers were at the company to provide input to the adoption process. The input was provided through participation in discussions and theoretical contributions in seminar form. Effectively our clinical role at times meant we triggered discussions. As the production director put it in August 1993:

> *It is refreshing to have someone from outside of the company coming with a torch, urging us to take action; someone who says that it is a narrow path we are walking, but that there is a light at the end of the tunnel.*

Although our presence triggered discussions, it did not necessarily decide what issues were discussed and particularly not when they were discussed. As a clinical researcher, the importance does not lie in deciding what is discussed, but in providing support in solving the problems the organisation is experiencing (Jaques, 1951). In our clinical role, we had no preconceived notion of the sequence in which principles should be implemented, which we imposed on the company. It was the problems the company experienced in their adoption of lean production that stimulated our input. Thus, although we may have contributed to the content of the issues that were discussed, our effect on the timing of the issues was less evident.

The unclear effect of our presence on the timing of issues is particularly relevant since I am interested in sequences of lean production principles in the adoption process. This means that although my presence was related to the patterns of issues, my presence was not necessarily related to the sequences of principles. Such a statement is supported by the lack of a significant correlation between the pattern of issues in Continuous improvement and my presence at Office Machines.

The causality between my presence and patterns of issues is not straightforward: instead of causing issues, my presence may have been caused by issues. A contributing factor to my presence shifting over time was that there was less action in the adoption process and consequently less need for me to be present at the company. Conversely, when there was much activity in the lean production project, I spent more time at the company. Meetings were also scheduled for the periods I was at the company.

The reversal of the causal relationship between my presence and patterns of issues is supported by the few significant relationships between the second researcher's presence and patterns of issues. The second researcher took a more active role in the adoption process, but his presence was still only significantly correlated to the patterns of issues in one principle and the sum of all issues. My role in the adoption process, on the other hand, was to be more of an observer. The high number of significant relationships between my presence and patterns of issues can thus be caused by me recording issues, rather than affecting them.

The research design - the study of the adoption process in real-time - contributed to the relationship between my presence and patterns of issues. Had I investigated the adoption process in retrospect, the relationship between my presence and patterns of issues would not have occurred. I still believe the benefits gained from the chosen research design outweigh this disadvantage.

Finally, there is a lack of methods for studying processes (Van de Ven and Huber, 1990). The lack of methods means that invention was necessary, which means that pitfalls were inevitable. In another case it may be possible to control for the correlation between presence and patterns of issues.

I did experiment with adjusting the patterns of issues with my presence at the company, but this adjustment had a number of drawbacks. The adjustment made it more difficult to relate the patterns of issues to the field notes and the insights I gained during the field work. Tests also indicated that the relationships between my presence and patterns of issues remained, despite the adjustment. The relationships also remained if incidents were aggregated quarterly, instead of monthly. The aggregation also compounded the difficulties of interpretation.

5.2.2 The Influence of Season on the Patterns of Issues

The patterns of issues in Figure 5.1 to Figure 5.8 seem at first glance consistent in that they go up and down at approximately the same time of the year. This may indicate a seasonal effect on the patterns of issues. Through the design of the study, I had access to two full years of observations. Each principle was therefore divided in two periods to test for the influence of season: (a) February 1993 to January 1994, and (b) February 1994 to January 1995.

Spearman's Rho was used to perform a series of tests to investigate the patterns of issues for any seasonal effects. The patterns of issues in the two periods would be correlated for each principle if there was a seasonal effect. The results of the tests are found in Table 5.3, which contains values of Spearman's Rho and the equivalent critical value.

Table 5.3 The Influence of Season on the Patterns of Issues

Principle	r_S	α *(n=11)*
Continuous improvement	0.268	
Decentralised responsibilities	0.411	
Elimination of waste	-0.0568	
Multifunctional teams	0.207	
Pull instead of push	0.684	0.025
Vertical information systems	0.407	
Zero defects	-0.257	
Whole project	0.625	0.025
Adoption process	0.291	

Table 5.3 illustrates there are two principles where we cannot rule out the possibility there were seasonal effects on the patterns of issues: Pull instead of push and Whole project. The sum of the issues for all principles, that is Adoption process, did not exhibit a season-dependent pattern. The results are encouraging, since they imply that taken as a whole there must be other things besides a seasonal effect that influenced the patterns of issues.

5.3 Three Periods in the Adoption Process

The major drivers of the adoption process were arrived at using the insights I gained during the field work as a starting point. The adoption process was dominated by different themes at different points in time. Often there was one issue or set of issues that dominated what was taking place within the company and affected the activities in the process of adopting lean production. The issues that dominated the adoption process at different times led to the division of the adoption process in three periods, all with quite different character.

5.3.1 Period One: February 1993 to January 1994 - First Phase of Project Execution and Focus on Productivity

The issue that received most attention in the initial phase of the adoption process was productivity. Productivity is measured as the number of direct hours spent in manufacturing relative to the standard number of hours. Although this measure may in itself be inappropriate, to emphasise, it was widely used within the company. Figure 5.10 shows the monthly outcome on the productivity measure, from February 1993 to January 1994.

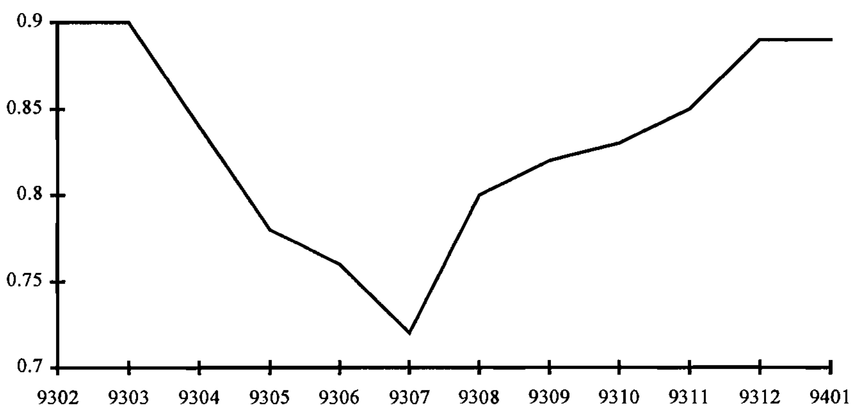

Figure 5.10 Productivity Outcome, February 1993 to January 1994

Productivity declined quite drastically after the organisational changes in April 1993. The productivity decline had major consequences for the lean production project and led to a number of initiatives to rectify the situation. The productivity decline was on the agenda of most meetings and also led to discussions on the appropriateness of the changes in the company's board. The productivity decline jeopardised the adoption of lean production and was even given its own name within the company: "the managing director's anguish".

As time progressed and productivity started to increase, attention to the productivity outcome faded. Attention instead shifted to other performance measures, such as work-in-progress, quality, and lead times. Productivity was no longer at the top of meeting agendas and the situation stabilised, as expressed by the managing director in January 1994:

> *There is no reason to have regular meetings in the top management team on the lean production project. The situation has stabilised and productivity increased.*

As an indication of the amount of effort and resources management devoted to productivity, Figure 5.11 shows the number of incidents indicating the productivity issue, from February 1993 to January 1994. Incidents were coded with "productivity" when productivity caused turbulence in the lean production project and when there were discussions concerning how to measure it.

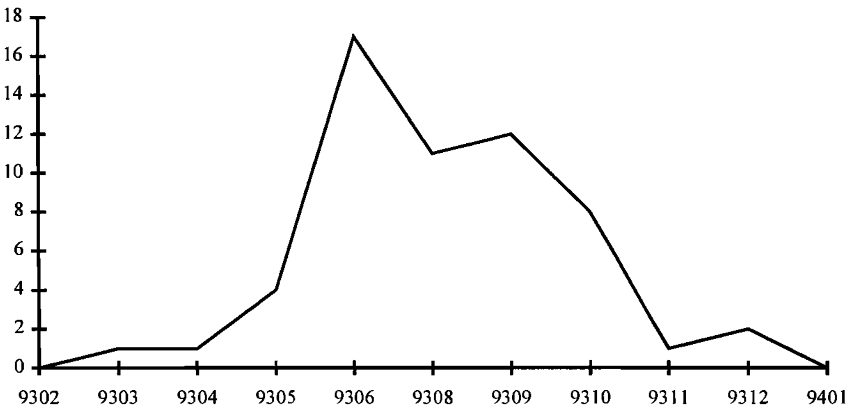

Figure 5.11 Productivity Issue, February 1993 to January 1994

Figure 5.11 reveals that most of the incidents indicating the productivity issue were observed in the period up to November 1993. The figure supports the notion that productivity was important in the early phase of the adoption process. From February 1994, discussions on productivity had nowhere near the same impact as up to January 1994. The discussions seldom led to any particular actions. It was more the nature of the productivity measure that was questioned.

Spearman's Rho was used to test the insights gained during the field work. The test was whether the productivity outcome was correlated with the patterns of issues. Productivity was first adjusted, since for a given month it was the productivity outcome of the previous month that was discussed. The performance measurement system at Office Machines did not permit calculation of productivity until halfway through the following month.

Table 5.4 Productivity Outcome and Patterns of Issues, February 1993 to January 1994

Principle	r_S	α *(n=11)*
Continuous improvement	-0.280	
Decentralised responsibilities	-0.717	0.01
Elimination of waste	-0.716	0.01
Multifunctional teams	-0.675	0.025
Pull instead of push	-0.866	0.001
Vertical information systems	-0.840	0.0025
Zero defects	-0.659	0.025
Whole project	-0.756	0.005
Adoption process	-0.766	0.005

The first series of tests concerned the period February 1993 to January 1994, when productivity mattered most. The results of the tests, in Table 5.4, reveal that the patterns of issues in seven lean production principles were significantly correlated with the productivity outcome. The direction of the relationships indicate that when productivity was low, activity in the lean production project was high. The results support the insights gained during the field work: productivity dominated the actions taken within the lean production project in the first period of the adoption process.

The insights gained during the field work also indicated that productivity did from February 1994 no longer have a major impact on the adoption process. A second series of tests were carried out to test whether productivity was correlated with the patterns of issues for the period February 1994 to June 1995. If the insights were correct, productivity should not be related to the patterns of issues during this period. The results of the tests are exhibited in Table 5.5.

Table 5.5 Productivity Outcome and Patterns of Issues, February 1994 to June 1995

Principle	r_S	α *(n=16)*
Continuous improvement	0.0897	
Decentralised responsibilities	0.240	
Elimination of waste	0.599	0.01
Multifunctional teams	0.266	
Pull instead of push	-0.111	
Vertical information systems	0.0897	
Zero defects	0.419	
Whole project	0.159	
Adoption process	0.379	

The results reveal that only one principle - Elimination of waste - was significantly correlated with the productivity outcome. The positive sign of the correlation coefficient implies that when productivity went up so did the number of incidents in the principle. This result is contrary to what was expected.

The results of the two tests taken together support the insights gained during the field work. Up to January 1994, the productivity outcome influenced what was taking place in the lean production project. After January 1994, productivity was no longer a major influence on the adoption of lean production.

5.3.2 Period Two: February 1994 to September 1994 - Halt in the Adoption of Lean Production

With productivity having lost its influence, the second period of the adoption process was influenced by the work a large customer imposed on Office Machines. The workload effectively halted the adoption of lean production. A project team was formed in February 1994 for the work of meeting the customer's demands. Due to the importance of the customer to Office Machines, the project was led by the managing director. In February 1994, the company's board postponed a decision to continue the lean production project, since all resources were needed to meet the large customer's demands.

The customer exerted a high degree of pressure on both manufacturing and product development. The activities associated with meeting the pressures influenced the lean production project. There was no time left for working with the adoption of lean production. This is illustrated by the following citation, taken from a conversation with the production director in August 1994:

> *Key at the moment is the [project involving the large customer]. We have no time for anything else. The project is tough, but we are subjected to tough demands.*

In October 1994, the production director made a number of statements which indicated the worst pressures were over for him. Between February and September 1994, the adoption process was thus influenced by the project involving the large customer.

The insight gained during the field work was tested using Spearman's Rho. As an approximation of the pressure exerted by the project involving the large customer, I used the number of hours spent on manufacturing the product the project concerned, see Figure 5.12. The reason for this choice is that the number of hours spent in manufacturing reflected the need for management effort and resources, since the manufacture concerned pilot runs.

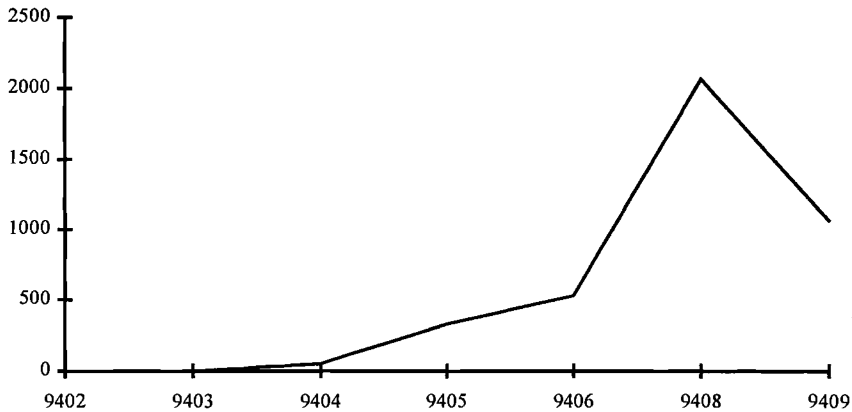

Figure 5.12 Hours Spent in Manufacturing between February and September 1994

The results of the tests are found in Table 5.6. The following patterns of issues were significantly related to the number of hours spent in manufacturing: Elimination of waste, Zero defects, and Adoption process (the sum of all issues). The relationships were all negative, implying that when the number of hours spent in manufacturing was high, the number of issues in the lean production project was low. The results support the existence of period two.

Table 5.6 Correlation between Hours Spent in Manufacturing and Patterns of Issues

Principle	r_S	$\alpha\ (n=7)$
Continuous improvement	-0.0982	
Decentralised responsibilities	-0.100	
Elimination of waste	-0.918	0.01
Multifunctional teams	-0.500	
Pull instead of push	0.214	
Vertical information systems	0.509	
Zero defects	-0.759	0.05
Whole project	-0.0893	
Adoption process	-0.795	0.025

The significant correlation between Adoption process and the number of hours is particularly important. This indicates there was a relationship between the project involving the large customer and the lean production project. The significant correlation between Elimination of waste and the number of hours is also important. Elimination of waste is a key lean production principle, which required attention, since manufacturing cells were to be created in the whole operation. The negative correlation indicates that no action was taken in the principle Elimination of waste, due to the pressures of the project involving the large customer. The correlation between Zero defects and the number of hours spent is less important, since the quality project was not a major concern during the second period of the adoption process.

5.3.3 Period Three: October 1994 to August 1995 - Second Phase of Project Execution and System Changes

Unlike period one and two, the third period of the adoption process had no major issue that dominated the adoption process. The third period was characterised by three action-triggering events, which were not possible to quantify in the same manner as were the causes of the first two periods.

The main reason for the break between period two and three was that the project involving the large customer was no longer a major concern for the production director. In October 1994, he re-started the lean production project on a larger scale with a memo to all concerned. The memo's opening sentence was:

> *The [lean production] project has now been at a standstill for eight months and needs a re-start, since [the project involving the large customer] has stabilised.*

A second driver of the adoption process in period three was the relocation and creation of manufacturing cells in the whole operation. Since the pressure from the large customer was less intense, planning of the second relocation was started on a large scale in the third period. The relocation meant a creation of manufacturing cells in the whole operation.

A third driver of the adoption process was a meeting between representatives from manufacturing and administration in March 1995. The meeting was called to discuss a new way of controlling material and measuring the performance of the manufacturing cells. The meeting was one of the first occasions manufacturing and administration sat down on a mutual basis to discuss the actions needed to drive the change. Said the production director in April 1995:

> *We have been active in the [lean production] project during the last month. Lately myself and the administrative director have been driving the changes.*

The outcome of the meeting in March 1995 was a series of actions to install a new system for material control in the manufacturing cells and change the management accounting system.

From this short summary of major events in period three, it follows there was no issue that dominated the adoption process. It was the need to take action in itself that was important in period three. The lean production project needed to be continued and so it was. Thus, the three periods in the adoption process were rather different in character and are distinguished in the further analysis.

CHAPTER 6

Relationships between Lean Production Principles

Although the aim of the present study is to determine sequences of lean production principles in the adoption process, determining relationships between the principles is a crucial step to reach the aim. Sequences are the order in which the various principles were adopted, where the order underlines the relationships between principles (Filippini et al., 1998). We can expect relationships between the lean production principles, since manufacturing capabilities are built cumulatively (Ferdows and De Meyer, 1990).

6.1 Relationships between Principles in the Three Periods

The inquiry into the relationships between lean production principles took place through an examination of the patterns of issues in the adoption process. The examination took place for the three periods of the adoption process, since they were all different in character. When using Spearman's Rho to examine the patterns of issues for relationships between principles, the content of the issues was not important. It is the patterns in which the issues arose that was important. When seeking explanations for why relationships occurred, on the other hand, the content of the issues was important. The results from the tests were interpreted using the insights gained during the field work. Inferences were drawn on the reasons why there was a relationship between principles. The inferences are illustrated by excerpts from the database of incidents.

6.1.1 Period One: Productivity Centred Relationships

Period one was first examined for the existence of relationships between lean production principles, using Spearman's Rho. The results of the tests are displayed in Table 6.1, which contains values of Spearman's Rho (above the diagonal) and the corresponding critical values (below the diagonal), when equivalent to or less than the chosen cut-off point of $\alpha = 0.05$. Such a value indicates the patterns of issues in two principles were correlated.

Table 6.1 Relationships between Lean Production Principles in Period One

	r_S							
	CI	DR	EW	MF	PP	VI	ZD	WP
CI		0.275	0.345	0.155	0.516	0.491	0.198	0.355
DR			0.906	0.934	0.716	0.772	0.912	0.878
EW		0.0005		0.900	0.848	0.764	0.930	0.845
MF		0.0005	0.0005		0.780	0.799	0.898	0.791
PP		0.01	0.001	0.005		0.807	0.773	0.743
VI		0.005	0.005	0.005	0.0025		0.725	0.782
ZD		0.0005	0.0005	0.0005	0.005	0.005		0.780
WP		0.001	0.001	0.005	0.01	0.005	0.005	
	α (n=11)							

Table 6.1 reveals a number of principles were related in period one: twenty-one of the twenty-eight possible correlation coefficients were significant. Most often, the critical values were much less than the chosen cut-off point.

The insights gained during the field work indicated that the relationships arose due to the productivity decline, which governed much of the action in the period. The causes of the decline were frequently discussed and a number of actions were taken to improve productivity. Both the causes of the productivity decline and the actions taken as a consequence of the decline are seen from the point of view of managers at the company, whether the causes were real or not. Part of the productivity decline was probably not real, to emphasise, but instead arose due to the way productivity was measured.

Causes of the Productivity Decline

Whatever caused the productivity decline was frequently discussed. Management attributed the decline to several causes, related to different lean production principles. The most important causes are summarised for the relevant lean production principles in Table 6.2.

Table 6.2 Causes of the Productivity Decline

• *Elimination of waste* - relocation and creation of manufacturing cells	• *Decentralised responsibilities* - removal of supervisors
• *Pull instead of push* - material control problems	• *Zero defects* - installation of a quality management system
• *Multifunctional teams* - integration of tasks and removal of piece-rates	

The first cause of the productivity decline was the changes in April 1993, as a consequence of the elimination of waste. Products were relocated between the company's two sites and two manufacturing cells were created. The changes meant that many employees were given new products to work with. Due to the learning curve effect, the tasks took longer to complete than previously.

The operators in the manufacturing cells were also struggling with material control, which contributed to the productivity decline. The aim was to move towards pull scheduling with the creation of manufacturing cells. Moving towards pull scheduling was difficult for two reasons. One difficulty was the large batches the stamping department continued to supply to the manufacturing cells. The second difficulty was that a lot of time was spent looking for material, since all parts affiliated with the manufacturing cells could not be stored in the vicinity of the cells. There was not enough room for storage, since too much material was left from before the relocation.

The multifunctional teams, created in April 1993, were another cause of the productivity decline. Both direct and indirect tasks were included in the teams. Although the rotation of operators between direct tasks was slow, the number of new tasks the operators were faced with created problems. Theoretical training had been given on the indirect tasks, but it was necessary to practice the skills. The indirect tasks therefore initially took more time to carry out. Said the managing director in a conversation in June 1993:

> *A lot of the lower productivity is because there are many new routines in the multifunctional teams.*

Another cause of the productivity decline, according the analysis made by managers, was the change in payment. Piece-rates were removed for all operators and replaced by a salary in April 1993. Productivity was seen as suffering, since operators did not feel the same urge to work at a fast pace as prior to the change in payment. Neither were lower level managers accustomed to the situation of not having piece-rates to motivate their subordinates. The managing director considered the payment system particularly important, as expressed at a meeting in August 1993:

I have personally asked twenty-five to thirty persons and almost all were convinced the lower productivity was because we have abandoned piece-rates. Even the former human resource manager was of that opinion.

The removal of supervisors further aggravated the productivity decline. Commented the production director in August 1993:

In the assembly department we lack a payment system to motivate the operators. The supervisors have also been removed. Taken together this means it is tempting for the operators to take the easy way out.

The final cause of the productivity decline was the installation of a quality management system. The new routines imposed by the quality management system necessitated extensive training of operators. The novelty of the tasks meant they were not carried out at full speed initially. An internal survey among operators on the causes of the productivity decline had "quality problems" on top. There were also several accounts of how much time was added since operators had to measure and keep track of data. The operators were concerned over whether to "produce or measure". Commented an operator from one of the manufacturing cells in June 1993:

The work with quality can take up to one or two hours at the moment, which affects productivity.

An estimate made in the stamping department was that fifteen percent could be added to the standard times for the work with quality. No formal estimates were, however, made as to how much time was really added due to the demands of the quality management system.

Actions Taken As a Consequence of the Productivity Decline

A large part of the actions taken in period one were, directly or indirectly, a consequence of the need to raise productivity. The more important actions are summarised for the relevant lean production principles in Table 6.3.

Table 6.3 Actions Taken As a Consequence of the Productivity Decline

• *Elimination of waste* - project to analyse manufacturing cells • *Pull instead of push* - alteration of product structure trees • *Whole project* - top management meetings and board postpones decision to continue the lean production project	• *Decentralised responsibilities* - development of team leaders • *Multifunctional teams* - new payment system and change in productivity measure • *Vertical information systems* - performance information and workplace meetings in cells

To continue the elimination of waste, a small project team was inaugurated in September 1993 to analyse the manufacturing cells. The team's task was to find solutions to problems that prevented those working in the manufacturing cells from performing their tasks efficiently. As a part of the analysis of the manufacturing cells, the product structure trees were altered to facilitate material control and to allow the reduction of batch sizes.

A second series of meetings was started at the top management level. Participants at the meeting were the managing director, production director, administrative director, product development director, and quality manager. The managing director explained the purpose of the meeting in August 1993:

> *The reason for this meeting is the consequences of the large changes that have taken place within manufacturing. This is not a decision meeting, but a way for the top management team to be informed and support the project in its progress. Perhaps we can also add some ideas on how to proceed in certain areas. It is still the project management who are responsible for the operative work.*

The top management meeting discussed a number of issues. An important issue was the decision in the company's board on whether or not to continue the lean production project. At the end of September 1993, the board decided to postpone the decision until the beginning of 1994. A major contributing factor to postponing the decision was the productivity decline.

A frequently discussed issue during the top management meeting was the decentralisation of responsibilities to the multifunctional teams in the manufacturing cells. A particularly controversial issue was the pace at which responsibility should be decentralised to the team leaders. Team leaders were trained in September 1993 and were from November 1993 made responsible for managing the multifunctional teams in the manufacturing cells.

The multifunctional teams were themselves subject to actions as a consequence of the productivity decline. The payment system was changed to incorporate a bonus based on the team's performance. The productivity measure was also changed, to account for the indirect tasks that had been transferred to the multifunctional teams. To the standard time was added a percentage to reflect the indirect tasks.

Vertical information systems for the multifunctional teams were finally created. First, notice boards with performance information. The aim of the boards was to raise productivity. The rationale being the belief that if operators found out their performance, it would be easier for them to take action to improve the performance. Said the production director in June 1993:

> *It is important that we post the productivity figures in the teams, since no one wants to see a curve that is pointing downwards.*

Second, the vertical information systems included workplace meetings. The meetings started in the pilot manufacturing cells in August 1993. The meetings sometimes gave rise to ambivalent feelings among operators, since having meetings was not considered logical if productivity was low.

6.1.2 Period Two: Halt in the Adoption of Lean Production

A second series of tests were conducted to examine the patterns of issues in period two for relationships between principles. The results of the tests are displayed in Table 6.4, which contains values of both Spearman's Rho (above the diagonal) and the corresponding critical values (below the diagonal). The results in Table 6.4 indicate only one significant relationship: Multifunctional teams was related to Decentralised responsibilities.

Table 6.4 Relationships between Lean Production Principles in Period Two

				r_s				
	CI	DR	EW	MF	PP	VI	ZD	WP
CI		-0.342	0.366	-0.054	0.473	n/a	-0.143	0.098
DR			0.145	0.745	-0.118	n/a	-0.090	0.064
EW				0.464	-0.118	n/a	0.541	0.073
MF		0.05			0.100	n/a	0.134	0.196
PP						n/a	0.098	-0.393
VI							n/a	n/a
ZD								-0.295
WP								
				α *(n=7)*				

Note: n/a = test cannot be performed, due to an excessive number of ties.

The insights gained during the field work revealed that the major reason for the relative lack of relationships was the halt in the execution of the lean production project. Due to the work with the large customer, there were hardly any resources left for working with the lean production project. The company's board had also put a lid on the execution of the lean production project, until the project regarding the large customer had been secured. What issues did arise in period two were more a result of previous actions to adopt lean production, than a conscious and concerted effort in period two. The lack of concerted effort is illustrated by the activities in the lean production project and the issues that arose, summarised for the relevant lean production principles in Table 6.5.

Table 6.5 Activities and Issues in Period Two

• *Whole project* - lack of action • *Elimination of waste* - no actions to create cells in whole operation • *Pull instead of push* - product structure trees altered, manufacture against customer order • *Decentralised responsibilities* - people lost their position and loss of team leaders a problem	• *Multifunctional teams* - problem make operators rotate between tasks and to move between payment systems • *Vertical information systems* - worked well and no issues arose • *Continuous improvement* - delayed • *Zero defects* - quality management system accepted by key actors and issues almost ceased

At an overall level of the lean production project, a major issue was the lack of action. Contributing to the lack of action in period two was a lack of production engineers to work with the necessary changes. Another frequently discussed issue was that the managing director did not trust the data from the management accounting system. Discussions on possible ways of changing the management accounting system started, but no changes were made in period two.

Neither was any action taken to create manufacturing cells in the whole operation. The company's board did not allow the lean production project to continue until the project involving the large customer had been secured. Planning the creation of manufacturing cells did, however, take place on a small scale. In the pilot manufacturing cells, permanently set up machines were installed in one cell, an outcome of the analysis of the cells made in period one.

To achieve pull scheduling, product structure trees were altered, also a consequence of the analysis of the cells made in period one. Following the introduction of permanently set up machines, manufacture against customer order commenced in the manufacturing cells. Manufacturing against customer order, instead of a plan, led to issues of material control being discussed. Since the inventory buffers that used to exist had been lowered, the multifunctional teams needed a system to help them control material.

Concerning the organisational changes, the emphasis at the start of period two was on removing supervisors as a consequence of the changes in period one. Several persons were demoted to other jobs within the company. The organisational changes demanded management effort and resources, since certain changes meant a loss of status for the people concerned. Further problems were caused by a loss of team leaders, as those initially trained for the task for personal reasons left the company.

The creation of multifunctional teams met with difficulties in period two. It was difficult to make operators rotate between different tasks in the manufacturing cells. Actions to promote rotation were discussed, but no progress was made. A second difficulty was the payment system, introduced in period one, which caused turbulence in the beginning of period two. The transition from the old to the new system was particularly discussed. A large spread in wages arose in the piece-rate system. The average salary in the new payment system ended up between the two extremes. Some employees therefore saw a gradual decrease of their salary in the new payment system, which caused heated discussions.

The vertical information systems created in period one were, however, working well, and discussions on the systems ceased in period two. Action was, on the other hand, taken in March 1994 to plan a continuous improvement initiative. The planned start was, however, postponed due to the work with the project involving the large customer.

The work with and discussions on the quality management system almost ceased in period two. The quality project was no longer perceived as a necessary part of the lean production project, since the quality management system was working in the day-to-day operation and was also starting to be accepted by key actors.

The short presentation of the major activities and issues in period two illustrates that few attempts were made to take the adoption of lean production forward. The issues that arose in period two were more a result of actions to adopt lean production in period one, rather than a conscious and concerted effort in period two. Consider in particular the following:

- Actions to eliminate waste and to achieve pull scheduling were minor changes. The changes related to the permanently set up machines, which were part of the agenda of period one, although their installation was delayed to period two.
- Planning the second phase of the lean production project was started, but no actions were taken.
- The significant relationship in period two, between Multifunctional teams and Decentralised responsibilities, was due to issues resulting from actions taken to adopt lean production in period one.

Despite the lack of action in period two, there were positive indications that the changes were starting to be accepted in the company. In April 1994, the managing director conducted information rounds with all employees. The reason formally stated as celebrating the best monthly turnover ever plus the end of "the managing director's anguish" (productivity was on the increase). In

June 1994, the union commented that the change was being accepted among a majority of employees. The managing director similarly commented on the production director's increased confidence:

> *What I notice is that when we have external visitors, the production director is much more confident on what we are doing. People often leave us thinking about doing the same thing as we are. This was not the feeling they had one year ago.*

6.1.3 Period Three: Management Driven Relationships

A final series of tests were conducted to examine the patterns of issues in period three for relationships between lean production principles. The results of the tests are found in Table 6.6, which contains values of both Spearman's Rho (above the diagonal) and the corresponding critical values (below the diagonal). Table 6.6 reveals that a number of principles were related to each other, with twelve of the twenty-eight possible correlation coefficients being significant.

Table 6.6 Relationships between Lean Production Principles in Period Three

	r_S							
	CI	DR	EW	MF	PP	VI	ZD	WP
CI		0.319	0.728	0.481	0.671	-0.050	0.493	0.597
DR			0.673	0.544	0.569	0.225	-0.169	0.517
EW	0.025	0.025		0.857	0.954	0.437	0.254	0.804
MF			0.0025		0.819	0.626	0.193	0.862
PP	0.025	0.05	0.0005	0.005		0.504	0.156	0.793
VI				0.05			0.043	0.316
ZD								0.215
WP	0.05		0.005	0.001	0.01			
	α (n=10)							

The insights gained during the field work indicated that there was no single reason for the relationships in period three of the adoption process. The third period was instead characterised by three action-triggering events, initiated by management, which were the reasons behind the relationships in Table 6.6:

1) The re-start of the lean production project in October 1994.
2) The meeting in March 1995 between manufacturing and administration to discuss a new way of controlling material and measuring the performance of the manufacturing cells.
3) The planning of the second relocation and creation of manufacturing cells in the whole operation.

The three events that drove the adoption process occurred at the overall level of the lean production project. The three events led to a number of activities and issues in the adoption process. The re-start of the lean production project, first of all, led to management devoting effort and resources on the following:

- Creating a multifunctional team at the stamping department, including training operators in the MRP and quality management systems.
- Finding payment systems for the planned multifunctional teams.
- Measuring and displaying productivity in the multifunctional teams.

The second driver of the adoption process, the meeting between manufacturing and administration, led to management devoting effort and resources on the management accounting system. A new system for material control was also drafted and subsequently implemented. The meeting finally led to issues in the principle Zero defects. The quality management system was seen as a potential impediment to the new material control system.

The third driver of the adoption process, the work of planning the second relocation, particularly affected the principles Elimination of waste and Multifunctional teams. One issue in the creation of manufacturing cells was layouts. Layouts were particularly acute at the sister site, since the original plan was flawed, due to the strength of the floor not permitting heavy machines to stand on it. Relocation of machines and equipment started in February 1995. The relocation was finalised around the summer of 1995. Much advance planning had been made and the relocation did not cause any major disturbances, despite being larger than the relocation in April 1993.

The work of planning the second phase of the lean production project also led to a number of issues concerning the multifunctional teams. The selection of operators to the new teams was discussed and various solutions to the problem of selection were sought. The task of encouraging employees to rotate among tasks within the teams was addressed through training. The work of planning the second relocation, finally, led to discussions on the vertical information systems to be used in the manufacturing cells.

Parallel to the three major action drivers in period three, other actions took place to adopt lean production. The cause of the issues in the principle Continuous improvement was the launch of the initiative, in January 1995. A second training round was carried out in March 1995. On both of these occasions, a number of issues arose.

The major concern in decentralising responsibilities was the development of team leaders. A loss of team leaders in period two created problems and there was a need to train team leaders. There was also a need to train team leaders for the new multifunctional teams. Training was as a consequence started in October 1994 and February 1995. The different activities and issues in period three are summarised in Table 6.7 for the relevant lean production principles.

Table 6.7 Activities and Issues in Period Three

• *Continuous improvement* - initiative launched • *Decentralised responsibilities* - training and appointment of team leaders for new multifunctional teams • *Elimination of waste* - second relocation and creation of manufacturing cells in whole operation • *Multifunctional teams* - teams created in the whole operation	• *Pull instead of push* - material control system • *Vertical information systems* - installed in manufacturing cells • *Whole project* - action taken to drive lean production project forward • *Zero defects* - quality management system impeding material control system

6.2 Relationships in the Adoption Process

From the above analysis emerges the conclusion that it was in period one and three the adoption of lean production was carried forward in a conscious and concerted manner. Only period one and three are therefore of interest in the further analysis. The analysis presented so far also indicates that when lean production was adopted, the number of relationships between different principles increased. It is now possible to draw conclusions on sequences of lean production principles in the adoption process. First, however, a more in-depth discussion on the nature of the relationships is necessary. Why were the principles related to each other? Spearman's Rho only indicates the existence of relationships, not why they occurred.

6.2.1 Interpreting the Nature of Relationships between Principles

The proposition here is that the relationships occurred since the nature of the adoption process necessitated different principles being discussed simultaneously. An alternative explanation may be that the relationships occurred due to the researchers' presence at the company, as discussed in Chapter Five. An objection against this explanation is that the nature of the relationships shifts between the three periods. This would not occur if our presence influenced the relationships.

The necessity to discuss different lean production principles simultaneously does not imply that different principles were affecting each other directly at all times. Actions in one principle did not necessarily have a direct effect on another principle.

There were, however, a number of incidents where two principles were mentioned in conjunction, as part of the same issue. This is illustrated by a discussion in April 1993, concerning the system for corrective action, part of the new quality management system:

> *Jeff thought that Victor had problems with the system for corrective action and he also wondered who would be responsible for corrective action after the organisational change. Rodney meant there must be a hierarchy and a routine for decisions in quality issues. Since there are no team leaders there is a risk issues will end up between chairs.*

The citation illustrates how activities in the principle Decentralised responsibilities were seen to affect the work in the principle Zero defects. The quality management system may not work properly since the supervisors had been removed, but not yet been replaced by team leaders.

Relationships between principles were, to emphasise, in most cases not a result of the principles being directly dependent on each other. The relationships were instead a result of the principles being necessary to discuss simultaneously, due to the nature of the adoption process. A few examples illustrate:

- Factors contributing to the productivity decline in period one were discussed simultaneously. The relocation in April 1993 was comprised of actions in a number of principles. The actions were all perceived as contributing to the productivity decline and no single cause of the decline could be singled out.
- Actions to raise productivity were taken in several principles simultaneously. Since the productivity decline threatened the lean production project, all available resources were devoted to improving the situation.
- To continue the creation of manufacturing cells in the whole operation, it was necessary to simultaneously discuss the creation of multifunctional teams. The plan for creating manufacturing cells also led to the installation of vertical information systems and training of team leaders.
- The creation of a new system to control material and measure the performance of the manufacturing cells (Whole project) had consequences for the work with material control (Pull instead of push).

6.2.2 Comparing Relationships in Period One and Three

The relationships in period one and three can now be compared with each other, to serve as the foundation for the further analysis, see Table 6.8.

- When two principles were significantly related to each other in period one, there is an "X" to the left in the cell where the two principles meet in Table 6.8. Vertical information systems was, for instance, significantly related to Zero defects in period one.
- Conversely, when two principles were related to each other in period three, there is an "X" to the right in the cell where the two principles meet in Table 6.8. Continuous improvement was, for instance, significantly related to Elimination of waste in period three.

Table 6.8 Comparing Relationships in Period One and Three

	CI		DR		EW		MF		PP		VI		ZD		WP	
CI	■	■														
DR			■	■												
EW		X	**X**	**X**	■	■										
MF			X		**X**	**X**	■	■								
PP		X	**X**	**X**	**X**	**X**	**X**	**X**	■	■						
VI			X		X		**X**	**X**	X		■	■				
ZD			X		X		X		X		X		■	■		
WP		X	X		**X**	**X**	**X**	**X**	**X**	**X**	X		X		■	■

Table 6.8 can be used to make observations on the sequence of principles in the adoption process. The observations serve as the basis for the remainder of the analysis. The observations will therefore be explained briefly here and expanded upon in the remainder of the chapter.

- Table 6.8 can first of all be examined for instances where two principles were correlated in both period one and three. Nine of these instances are found and have been highlighted in the table. A closer examination reveals that only three principles were mutually related to each other in both periods: Elimination of waste, Multifunctional teams, and Pull instead of Push. These three form a set of core principles that were related to each other throughout the whole adoption process.
- The only principles related to Whole project in both periods were the core principles. This further indicates the importance of the core principles in the adoption process, since the label "Whole project" was used for issues at the overall level of the lean production project.

- Decentralised responsibilities was related to the three core principles and Whole project in period one. In period three, Decentralised responsibilities was only related to Elimination of waste and Pull instead of push.
- Zero defects was related to other lean production principles only in period one.
- Continuous improvement was not related to any other lean production principle in period one, but to Elimination of waste, Pull instead of push, and Whole Project in period three.
- Vertical information systems was related to most other lean production principles in period one, but only to Multifunctional teams in period three.

The reasons behind the observations on sequences will be examined in more detail in the remainder of the chapter. The focus in this examination is on *why* the observations on sequences were made. The content of the issues that arose in the adoption process is here important and the insights gained during the field work are used to seek explanations for the observations on sequences of lean production principles in Table 6.8.

6.3 A Core of Mutually Related Principles

Three lean production principles were related to each other throughout the whole adoption process: Elimination of waste, Multifunctional teams, and Pull instead of push. The three principles formed a set of core principles. The importance of the core principles was indicated by their relationship to issues at the overall level of the lean production project throughout the adoption process. Why did these relationships occur?

6.3.1 Simultaneous Peaks for the Core Principles and Whole Project

If we examine the patterns of issues for the three core principles and Whole project in Chapter Five, we find that all four patterns peak simultaneously three times. The three peaks hold a key to why there was a core of principles requiring management effort and resources throughout the adoption process. The content of the issues that arose during the three peaks facilitates the interpretation of why the relationships between the core principles and Whole project occurred.

First Simultaneous Peak - October and November 1993

The patterns of issues in the core principles and Whole project peaked simultaneously for the first time in October and November 1993. The major reason for the first peak was the productivity decline. The productivity decline was indeed an issue of importance at the overall level of the lean production project: one fifth of all the observed incidents during period one concerned productivity. The productivity decline led to a number of activities.

One activity as a consequence of the productivity decline, was the analysis of the manufacturing cells. The analysis led to a number of issues in the principle Elimination of waste. Around one fifth of all incidents in Elimination of waste were, in fact, observed during the first peak.

The productivity decline and the analysis of the manufacturing cells were also related to the principle Pull instead of push. Too much material was left over from before the cells were created and the multifunctional teams spent time searching for material, which contributed to the productivity decline. The need to structure the material flow was urgent during the first peak and was the task of the project team responsible for analysing the manufacturing cells.

An activity at the overall level of the lean production project following the productivity decline, was the start of meetings in the top management team to discuss the lean production project. The discussions peaked in October and November 1993. One issue that recurred during the meetings was the need to create a multifunctional team at the stamping department. A contributing factor to the problems with material control in the manufacturing cells was that the stamping department produced large batches. The creation of a multifunctional team was suggested as a way of influencing operators at the stamping department to reduce set-up times and produce in smaller batches.

The need to raise productivity, dominant among issues in Whole project, was also related to the payment system. The analysis made by managers indicated the removal of piece-rates affected productivity. Work of finding a new payment system was therefore prioritised and this work culminated during the first peak in patterns of issues in the principle Multifunctional teams. A new payment system was also introduced in November 1993.

Second Simultaneous Peak - October 1994

The major reason for the second simultaneous peak in patterns of issues in the core principles and Whole project, was the re-start of the lean production project. The reason the production director took action was that the lean production project had come to a halt and needed a revitalisation. The re-start of the lean production project led to a number of activities and issues:

- The re-start led to management devoting effort and resources on the second relocation and creation of manufacturing cells and multifunctional teams in the whole operation.
- The re-start brought attention to the creation of a multifunctional team at the stamping department, an issue which had been dormant for some time.
- The re-start resulted in a need to find new payment systems for the new multifunctional teams. In discussions concerning the payment systems, the appropriateness of the way productivity was measured was questioned.

The problem of measuring productivity was also an issue at the overall level of the lean production project. The uncertainty surrounding the management accounting system was a dominant issue during the second peak in Whole project, illustrated by the following conversation with the managing director:

> *If the figures are compared, one finds that payment costs are 2.6 percent above budget, when we have produced much more than that. We have at the same time produced to stock. We have not been given the figures for productivity yet, but sometimes I wonder how productivity is measured.*

The second peak finally contained frequent discussions on material control in the manufacturing cells, as part of the work in the principle Pull instead of push. Following the introduction of manufacture and assembly of products against customer order, the need to structure the material flow became crucial. Several ideas on a system for material control were discussed, among others a kanban-based system, but no action was taken.

Third Simultaneous Peak - March 1995

The third and final simultaneous peak in the patterns of issues in the core principles and Whole project, was first of all due to the work of planning the second relocation and creating manufacturing cells in the whole operation. The planning activities were driven by the need to progress the adoption of lean production. The activities particularly affected the principles Elimination of waste and Multifunctional teams:

- The creation of layouts for the manufacturing cells was a recurring issue during the third peak in the principle Elimination of waste.
- The selection and training of employees for the new multifunctional teams was often discussed during the third peak in the principle Multifunctional teams. A new payment system for the teams was another recurring issue.

The third simultaneous peak was also driven by the meeting where representatives from manufacturing and administration sat down to discuss a new way of controlling material and measuring the performance of the manufacturing cells. A number of issues arose during this meeting, particularly in the principle Pull instead of push. The meeting triggered the activity of finding a new system for material control in the manufacturing cells.

The examination of the three peaks, to summarise, reveals reasons why the core principles were related to each other and to the overall level of the lean production project. Further support for the relationships is found in Figure 6.1. The figure contains the cumulative percentage of issues as a function of time for each principle. The values for the three core principles and Whole project have been highlighted.

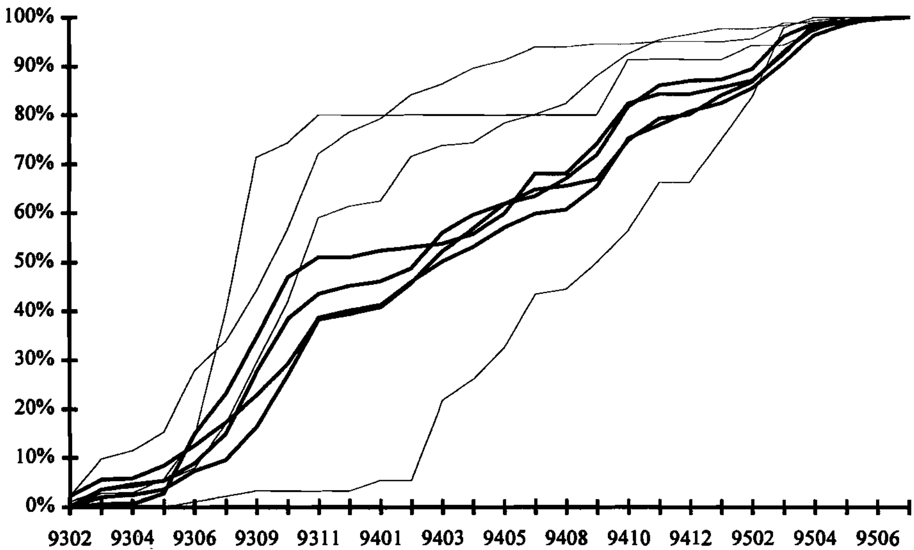

Figure 6.1 A Core of Lean Production Principles Related to Whole Project

Figure 6.1 reveals that the movements of the core principles and Whole project were closely related throughout the adoption process. Particularly revealing are the four highlighted graphs considered in relation to the other four. The figure further illustrates the notion that there existed a set of core principles, related to each other throughout the whole process of adopting lean production.

6.3.2 Direct Relationships between the Core Principles

Further support for the existence of a set of core principles can be found if we examine the distribution of incidents indicating a direct relationship between principles. There were a number of incidents where two principles were mentioned in conjunction, as part of the same issue. The incidents indicated that two principles were affecting each other directly. A total of sixty-one such incidents were observed in the first and third period of the adoption process. The distribution of these incidents is found in Table 6.9.

Table 6.9 illustrates that there are in total twenty-eight possible relationships between lean production principles. These relationships are represented by the cells where two principles meet. The total number of observed incidents indicating a direct relationship between principles are given in the appropriate cell. Since the examination here concerns the core principles and their relationship to Whole project, only six relationships in Table 6.9 are of interest. These relationships have been highlighted: (a) the three relationships between the core principles, and (b) the three relationships between the core principles and Whole project.

Table 6.9 Distribution of Incidents Indicating a Direct Relationship between Principles

	CI	DR	EW	MF	PP	VI	WP	ZD
CI								
DR								
EW		5						
MF		3	**8**					
PP		1	**6**	**6**				
VI			1					
ZD		3	4		2	1		
WP		1	**2**	**8**	**4**	4	2	

The six relationships of interest illustrate the existence of the core principles. If a set of core principles did not exist, we would expect that each of the twenty-eight possible relationships had the same likelihood of being represented by an incident. That is, we would expect the number of incidents being equally divided between the different cells in Table 6.9. The likelihood is, however, higher that an incident indicating a direct relationship between principles refers to the core principles, see Table 6.10.

Table 6.10 Likelihood of Observing an Incident Indicating a Set of Core Principles

Total number of incidents	61
Expected share based on three relationships (3 out of 28 possible)	11%
Number of incidents part of the core (percent)	20 (33%)
Expected share based on six relationships (6 out of 28 possible)	21%
Number of incidents part of the core and Whole project (percent)	34 (56%)

The existence of the core can be deduced using Table 6.10. If we did not expect to find a set of core principles, a total of eleven percent of the incidents would be observed in the cells in Table 6.9 containing the relationships between the three core principles. Since the share of observed incidents in the three cells is thirty-three percent, the existence of a set of core principles is supported.

We find further support for the existence of a set of core principles if we take into consideration the three cells in Table 6.9 indicating a relationship between the core principles and Whole project. If we did not expect a set of core principles, a total of twenty-one percent of the incidents would be observed in the six cells in Table 6.9. Since the share of observed incidents in the six cells is fifty-six percent, the existence of a set of core principles is supported.

6.4 Two Components in Decentralised Responsibilities

The principle Decentralised responsibilities was related to the core principles and Whole project in period one. In period three, Decentralised responsibilities was only related to Elimination of waste and Pull instead of push. These observations can best be understood if Decentralised responsibilities is divided in two separate principles: Delayering and Team leaders.

6.4.1 Dividing Decentralised Responsibilities in Two Components

Recall from Chapter Three that incidents were coded for activities, using the data as a starting point. Four different activities were defined within the principle Decentralised responsibilities:

1) *Organisation hierarchy* - removal of layers in the organisation.
2) *Relocation* - the relocation of a production manager's office to the shop floor, to support the multifunctional teams in assuming responsibilities.
3) *Responsibilities* - the actual transfer of responsibilities to the teams.
4) *Team leaders* - the development of team leaders for the teams.

The first three activities were related to the delayering of the organisation. Delayering refers to the removal of organisational layers and the consequences of transferring responsibilities to the teams. The patterns of issues for the two components of Decentralised responsibilities are displayed in Figure 6.2.

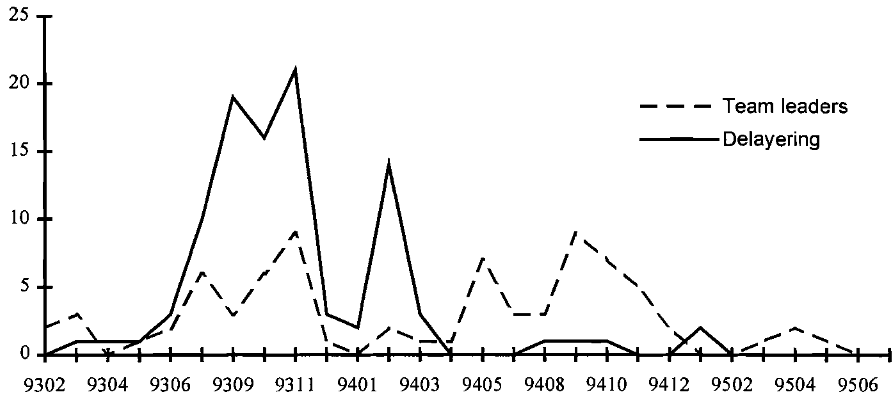

Figure 6.2 Two Components of the Principle Decentralised Responsibilities

Figure 6.2 reveals a difference in timing between Delayering and Team leaders. Issues in Delayering arose mostly in the beginning of the adoption process, whereas issues in Team leaders arose throughout the whole adoption process.

6.4.2 Delayering the Organisation in the Beginning of the Adoption Process

Spearman's Rho was used to examine the timing of issues in Delayering. Tests were conducted regarding the relationships between Delayering and the other lean production principles in period one and three, see Table 6.11, which contains values of Spearman's Rho and the corresponding critical values.

Table 6.11 Relationships between Delayering and Other Lean Production Principles

	Period One		*Period Three*	
Principle	r_S	α *(n=11)*	r_S	α *(n=10)*
Continuous improvement	0.380		0.237	
Elimination of waste	0.870	0.001	0.398	
Multifunctional teams	0.775	0.005	0.113	
Pull instead of push	0.693	0.025	0.354	
Vertical information systems	0.673	0.025	0.183	
Zero defects	0.793	0.005	-0.391	
Whole project	0.866	0.001	0.018	

The results in Table 6.11 support the notion that Delayering required management effort and resources in the beginning of the adoption process. In period one, all principles but Continuous improvement were significantly related to Delayering. In period three, none of the other principles were significantly related to Delayering.

Delayering was related to the three core principles and Whole project in period one. As with the core principles and Whole project, the pattern of issues in Delayering also peaked in October and November 1993, see Figure 6.2. The most important issues in October and November 1993 were consequences of the removal of supervisors and the transfer of their responsibilities to the multifunctional teams. Both managers and team members expressed a need for management to support the transfer of responsibilities. After a conversation with representatives from the multifunctional teams in the manufacturing cells, in October 1993, the production director said:

> *I had a two hour long discussion with the representatives and the conclusion was that the teams felt they needed someone who managed the operation, since they were used to having someone who managed them.*

The uncertainty the multifunctional teams experienced, and the resulting difficulty in transferring responsibilities to the teams, triggered several discussions at top management level. A controversial issue was the pace with which responsibility should be transferred to the teams. The administrative director emphasised a relatively quick pace, for example in November 1993:

> *I think it is important to define what we mean by transferring responsibility to the teams. When is the production manager to be relocated to the shop floor? When is the responsibility for quality control to be transferred? All this needs to be communicated and carried out as soon as possible.*

The production director and other managers emphasised the need for a gradual transfer of responsibilities to the teams. One type of support added during the transition was the relocation of the manager responsible for the manufacturing cells, from his office two floors and one hundred metres away from the manufacturing cells, to an office adjacent to the cells.

6.4.3 Developing Team Leaders throughout the Adoption Process

Figure 6.2 suggested that issues in Team leaders arose throughout the whole adoption process. Spearman's Rho was used to test for relationships between Team leaders and the other lean production principles in period one and three. The results of the tests are found in Table 6.12.

Table 6.12 Relationships between Team Leaders and Other Lean Production Principles

	Period One		*Period Three*	
Principle	r_S	α *(n=11)*	r_S	α *(n=10)*
Continuous improvement	0.066		0.176	
Elimination of waste	0.770	0.005	0.623	0.05
Multifunctional teams	0.934	0.0005	0.685	0.025
Pull instead of push	0.582	0.05	0.540	
Vertical information systems	0.698	0.025	0.357	
Zero defects	0.791	0.005	0.028	
Whole project	0.730	0.01	0.701	0.025

Table 6.12 supports the notion that management devoted effort and resources to Team leaders throughout the whole adoption process. In period one, all principles but Continuous improvement were significantly related to Team leaders. In period three, Team leaders was significantly related to Elimination of waste, Multifunctional teams, and Whole project.

Team leaders was related to the core principles and Whole project in period one. The pattern of issues in Team leaders also peaked in October and November 1993, see Figure 6.2. The issues that arose during the peak were in particular related to the start of the second phase of the team leader training, but also to the transfer of responsibilities to the multifunctional teams. The transfer of responsibilities had to take place gradually, since the team leaders did not have the proper competence. Said the production director in November 1993:

> *The team leaders are in place in the manufacturing cells, but do not yet have the competence needed to work fully within all areas. Quite a lot remains on the training of team leaders, a number of days per person.*

Team leaders was, on the other hand, not quite related to the core principles in period three: the relationship with Pull instead of push was not significant. An examination of Figure 6.2 reveals that the pattern of issues in Team leaders had a first peak in October 1994 and a second in April 1995, although the latter only contained a few incidents. Both peaks related to the planning of the second relocation and creation of manufacturing cells in the whole operation.

The most important issue in October 1994 concerned the positive feedback from the team leader training. Training raised competence and decreased scepticism towards the lean production project. The training was primarily for those who were to be team leaders in the new multifunctional teams. The peak in April 1995 also concerned the training of team leaders for coming teams, although the number of observed incidents were few. With this in mind, the relationships in period three can be interpreted:

- Planning the second relocation and creation of manufacturing cells was part of the re-start of the lean production project in October 1994. Team leaders was therefore related to the core principles and Whole project.
- The meeting between manufacturing and administration, in March 1995, did not affect Team leaders. Therefore, the relationship between Team leaders and Pull instead of push was not significant.

The conclusion regarding the split between Delayering and Team leaders, and their different emphasis in the adoption process, is supported by Figure 6.3. The figure contains the cumulative percentage of issues as a function of time for each principle. Decentralised responsibilities has been split in its two components, which have been highlighted. Figure 6.3 reveals that Delayering required management effort and resources in the beginning of the adoption process, whereas Team leaders required management effort and resources throughout the whole adoption process.

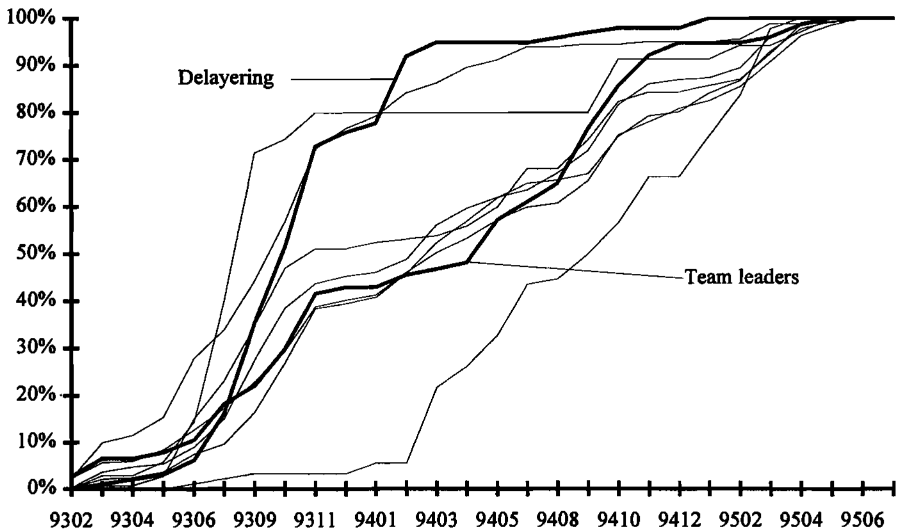

Figure 6.3 Delayering and Team leaders: Different Emphasis in the Adoption Process

6.5 Further Relationships in the Adoption Process

When the relationships between lean production principles in period one and three of the adoption process were examined in Table 6.8, observations were made on the principles Zero defects, Continuous improvement, and Vertical information systems. The three principles exhibited different relationships to other lean production principles. The task of this section is to examine why the observations were made.

6.5.1 Installing a System for Zero Defects in the Beginning of the Adoption Process

An insight gained during the field work was that issues in Zero defects arose relatively early in the adoption process. This is also the conclusion that can be drawn from Table 6.8. Zero defects was related to all other lean production principles in period one. In period three, Zero defects was not related to any of the other principles. These relationships support the notion that issues in Zero defects arose in the beginning of the adoption process.

Further support for the notion is found if we examine Figure 6.4, which contains the cumulative percentage of issues as a function of time for each principle. The values for Zero defects have been highlighted. Figure 6.4 illustrates how issues in Zero defects, almost throughout the whole adoption process, proceeded the other lean production principles.

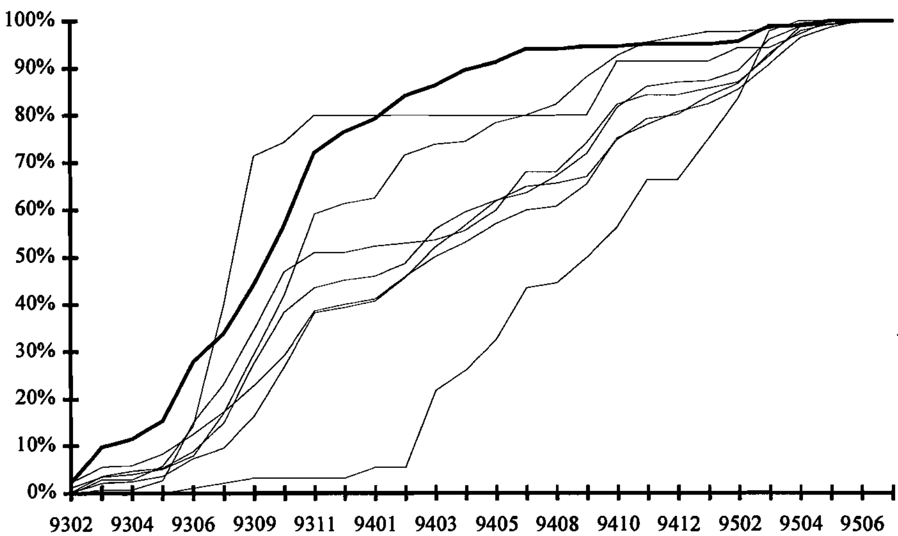

Figure 6.4 Issues in Zero Defects Arose in the Beginning of the Adoption Process

There are several reasons why issues in Zero defects arose in the beginning of the adoption process. A new quality management system was seen as important to implement from the start of the lean production project. A number of actions were needed in order to restore operators' confidence in the quality management system and to decentralise the work with quality to operators. The quality management system received additional focus early in the adoption process due to the influence of the large customer. Faced with the customer's demands, the work of installing the quality management system was emphasised early in the adoption process.

There is little doubt the large customer influenced the work with quality. Initiatives to improve quality had commenced prior to the start of the lean production project, but the efforts were intensified after the large customer audited Office Machines's quality management system. The amount of efforts put in the installation of the quality management system was subsequently higher than if the customer had not existed.

It is unfortunately not possible to assess the nature of the work with the quality management system without the customer's influence. Observations indicate the quality management system would still have received attention without the customer's influence. Without the customer, however, other approaches would have been used instead of the formalised approaches the customer demanded.

Important here is not the amount but the timing of efforts devoted to the quality management system. It is plausible management would have devoted effort and resources to the work with quality mostly in the beginning of the adoption process, even without the large customer's influence. Consider the following:

- The status of quality control prior to the start of the lean production project necessitated a new quality management system to enable decentralisation of quality control to operators.
- The amount of management effort and resources devoted to the work with the quality management system diminished over time, even when the work concerned the customer's substantial action list.

From December 1993, the work with the quality management system was no longer a part of the lean production project. Said the quality manager on the final meeting in the quality project:

> *Perhaps we are to terminate the quality project, since the remaining work is more a part of the day-to-day activities? My estimate is that up to eighty percent of all items on the action list are a part of the normal operation and therefore there is no reason to discuss them in a separate project.*

Since the quality routines were to the most part installed and had also started to work in the day-to-day operation, there was no longer a need for separate meetings on the subject of quality.

6.5.2 Starting the Continuous Improvement Initiative Late in the Adoption Process

The continuous improvement initiative was started in January 1995. As a consequence, issues in Continuous improvement arose towards the end of the adoption process. Table 6.8 supports this observation. Continuous improvement was in period one not related to any of the other lean production principles, which is noteworthy, since all other principles were related to each other in period one. Continuous improvement was in period three significantly related to Elimination of waste, Pull instead of push, and Whole Project. These relationships refer to core principles.

The relatively few significant relationships between Continuous improvement and other lean production principles in period three, can be explained by Continuous improvement not being related to the drivers of the adoption process in period three. Recall that the third period of the adoption process was characterised by three action-triggering events. The events were initiated by management to drive the adoption of lean production. The work with the continuous improvement initiative was not a part of the three events, but took place in parallel to them.

Further support for the notion that issues in Continuous improvement arose towards the end of the adoption process is found in Figure 6.5. The figure contains the cumulative percentage of issues as a function of time for each principle. The values for Continuous improvement have been highlighted. Figure 6.5 illustrates how issues in Continuous improvement trails the other lean production principles, almost throughout the whole adoption process.

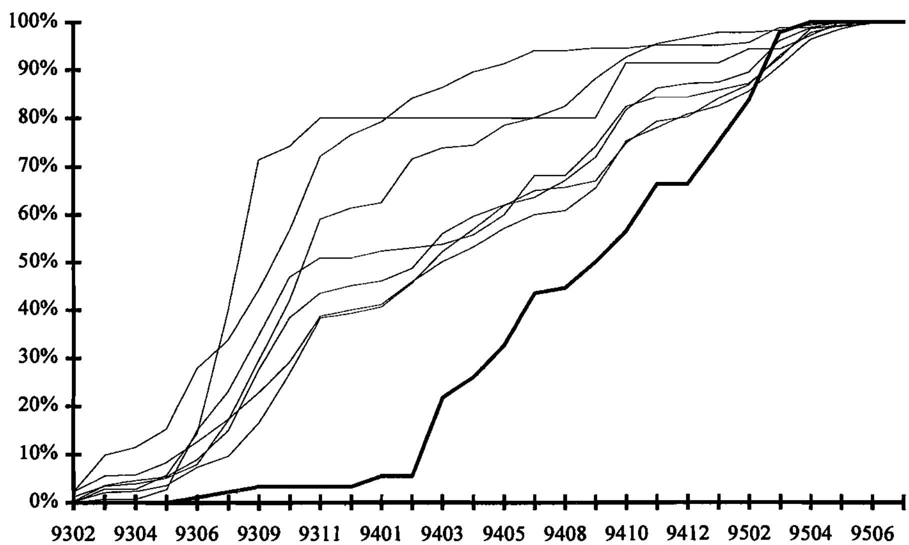

Figure 6.5 Issues in Continuous Improvement Arose towards the End of the Adoption Process

There were several reasons why the continuous improvement initiative was started late in the adoption process. The planning of the initiative was first of all delayed since the production director and a key manager were occupied with the project involving the large customer. The start-up of the initiative was delayed from November 1994 to January 1995, due to the production pressure experienced by operators in the manufacturing cells.

The major reason the continuous improvement initiative was started late was that operators were not considered to have the requisite skills earlier on. Before operators could function well in continuous improvement teams, they needed experience from working in multifunctional teams, preferably in manufacturing cells. Said the production director in January 1995, to those initially trained:

> *You now have a broad overview that makes it easier for you to come up with improvement suggestions, compared with before when you were only working with one operation in the manufacturing process.*

By having worked with different tasks in a manufacturing cell, the operators were judged to have gained an understanding of a much larger part of the manufacturing process than previously. Understanding a larger part of the manufacturing process made it easier for operators to improve the process.

6.5.3 Vertical Information Systems - Supporting the Teams throughout the Adoption Process

Table 6.8, finally, revealed that Vertical information systems was related to all other lean production principles in period one, but only to Multifunctional teams in period three. The reason Vertical information systems was related to all other principles in period one was the productivity decline. The vertical information systems were a part of the actions taken to raise productivity. The multifunctional teams needed performance information to perform their jobs more efficiently, thus contributing to raised productivity

Once installed, the information systems worked well and did not cause any more issues. The majority of issues in Vertical information systems therefore arose in the beginning of the adoption process. The timing of the issues can be seen in Figure 6.6. The figure contains the cumulative percentage of issues as a function of time for each principle, with the values for Vertical information systems highlighted. Figure 6.6 illustrates how the cumulative percentage of issues in Vertical information systems proceeded the other lean production principles in period one; up to January 1994.

However, Vertical information systems was related to Multifunctional teams in period three. The reason for this relationship was the need to equip the planned multifunctional teams with information systems. The information systems were from February 1995 an integral part of the creation of multifunctional teams for the second round of manufacturing cells. The teams also needed information to function properly.

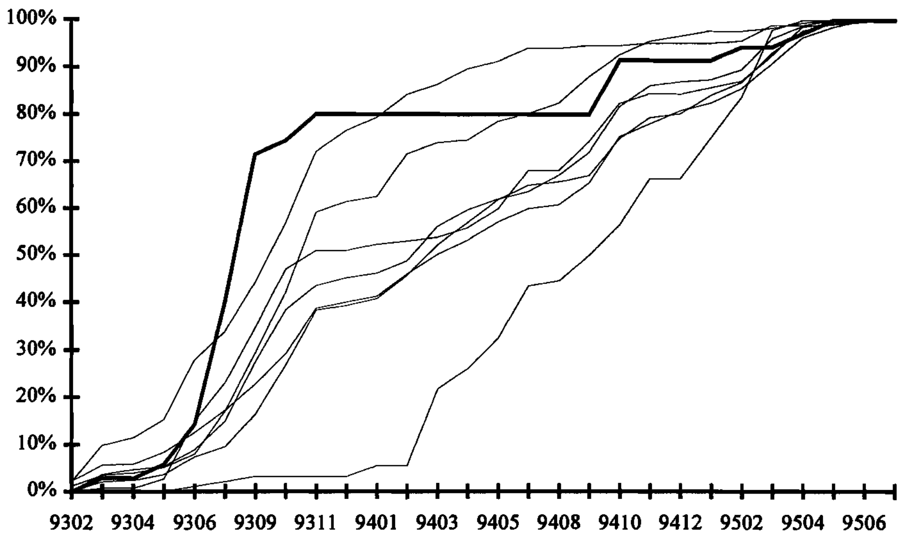

Figure 6.6 Timing of Issues in Vertical Information Systems

6.6 Sequences in the Adoption Process

The analysis of the empirical case can now be summarised. The focus in the present study are sequences of lean production principles in the adoption process. The findings of the analysis can in this respect be grouped according to when management devoted effort and resources to different principles. Four different groups can be distinguished:

1) Zero defects and Delayering required management effort and resources in the beginning of the adoption process.
2) There was a core of principles that required management effort and resources throughout the whole adoption process: Elimination of waste, Multifunctional teams, and Pull instead of push.
3) Team leaders and Vertical information systems required management effort and resources throughout the whole adoption process, but the two principles were not related to the core principles at all times.
4) Continuous improvement required management effort and resources towards the end of the adoption process.

The empirical findings are the basis for the synthesis, where the task is to examine the findings in the light of operations management theory, with the aim of discovering why the sequences occurred.

CHAPTER 7

Interdependence in the Adoption Process

The analysis of the empirical case revealed sequences of lean production principles in the adoption process. The task in this chapter is to explain why the sequences occurred. Explanations are sought through comparing the findings with operations management literature. By using existing literature, the plausibility of the empirical findings is enhanced. First, however, a note on the feasibility of drawing general conclusions from a single case.

7.1 Management Action Versus the Inherent Logic of the Adoption Process

A relevant question when synthesising the empirical findings is whether the sequences were governed by management action or by the inherent logic of the adoption process. The question has implications for the feasibility of drawing general conclusions and essentially regards the opportunities management have to affect the sequences. Particularly relevant is the plan for the adoption of lean production in the empirical case. The role of the project plan in determining sequences of lean production principles, varies with the role of management action:

1) If we acknowledge management to have large opportunities to affect the sequences, the project plan in the empirical case would to a large extent be responsible for the findings on sequences.
2) If we accept that the sequences of lean production principles were governed by the inherent logic of the adoption process, the role of the project plan is diminished.

The project plan in the empirical case needs to be seen against the decision to adopt lean production. Office Machines decided to adopt lean production for several reasons:

- The company had suffered through a recession, which led to the arrival of a new production director with a mandate for change.
- The structure and organisation of manufacturing led to problems of long transports, high cost of quality, high stock and work-in-progress, and long manufacturing and delivery lead times.
- Changes in the market resulted in a pressure on delivery lead times and small lot deliveries.
- The company faced increasing difficulties in hiring new employees.

Following the decision to adopt lean production, the plan was to adopt different lean production principles simultaneously. The simultaneous adoption of several principles can be expected, considering the importance of not adopting individual principles in isolation (Voss and Robinson, 1987). Given the systemic nature of lean production one could even argue, at least before the actual adoption, that a prerequisite for successful adoption is to work with several principles simultaneously.

The way in which the project plan was executed in the empirical case is related to the question of the source of the observed sequences. Office Machines adopted lean production through pilot projects. The use of pilot projects strengthened the opportunity to observe the sequences inherent in the adoption process. The use of pilot projects meant there was no predetermined sequence in which the principles were adopted. Management instead devoted effort and resources to issues as they arose. Regardless of the role we acknowledge managers to affect the sequences, the adoption of lean production through pilot projects is a strength for the generality of the observed sequences.

The use of pilot projects for the types of changes in question is also widespread. Pilot projects serve as experiments and imply a lesser degree of initial commitment, which means individuals will more readily accept a change (Leonard-Barton, 1988). The literature contains several examples of companies who have used pilot projects, for instance: Northern Telecom Electronics in Ottawa, Canada (Pouraghabagher and Young, 1991), Thorn Lighting in Spennymoor, the United Kingdom (Hickman, 1996), and Hewlett-Packard in Vancouver, Canada (Hayes et al., 1988).

The viewpoint taken in the present study is that the sequences of principles were governed by a combination of management action and the inherent logic of the adoption process. The viewpoint has been reinforced by the insights gained during the field work. Management devoted effort and resources to issues as they arose (Cyert and March, 1992). Since management effort and resources were limited, only a certain number of issues could be addressed at once. There was therefore a need to sequence the adoption of lean production.

The viewpoint that the sequences were governed by a combination of management action and the inherent logic of the adoption process, has implications for the feasibility of drawing general conclusions from the empirical case. The viewpoint implies the empirical findings have a value outside the case in which they were derived. Comparing the findings with literature further increases the generality of the findings (Berg, 1981). Please observe that this comparison emphasises the plausibility of the sequences in the empirical case. To conclude the observed sequences are applicable to all situations, is quite premature. Recall that generalisation from case studies takes place towards theory, not towards samples and universes (Yin, 1989).

7.2 Interdependence

When examining the plausibility of the empirical findings on sequences of lean production principles in the adoption process, the concept of "interdependence" is useful. Thompson (1967) was an early writer on the subject of interdependence in organisations. Thompson identified three types of interdependence, which are illustrated in Figure 7.1:

1) *Pooled interdependence* - each part of the organisation renders a contribution to the whole, but is independent from each other.
2) *Sequential interdependence* - one part of the organisation is dependent on another part for input.
3) *Reciprocal interdependence* - the output of one part of the organisation becomes input for the other part and vice versa.

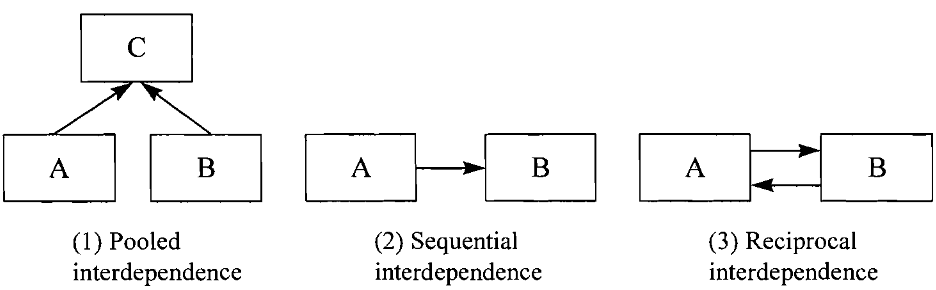

Figure 7.1 Three Types of Interdependence

The concept of interdependence is applied to the different lean production principles in the adoption process. The concept is used to distinguish the four groups of principles that were found in the analysis of the empirical case. Each group exhibited different characteristics, in terms of when management devoted effort and resources to the principles.

7.3 Sequential Interdependence - Requiring Management Effort and Resources Early in the Adoption Process

If the concept of interdependence is applied to Zero defects and Delayering, the two principles are best characterised by sequential interdependence. The analogy implies that the other lean production principles were dependent on Zero defects and Delayering in the adoption process. Management effort and resources needed to be devoted to Zero defects and Delayering early in the adoption process.

Please note that the concept of sequential interdependence, as used here, does not exclude Zero defects and Delayering from being dependent on the other lean production principles. The sequential interdependence needs to be seen over the life of the adoption process. That is, if a process perspective is taken, the sequential interdependence reveals that Zero defects and Delayering require management effort and resources early in the adoption process.

7.3.1 Installing a System for Zero Defects

The notion that Zero defects requires management effort and resources early in the adoption process is supported by the sandcone model (Ferdows and De Meyer, 1990). To develop lasting improvements in manufacturing, the model suggests managers need to devote effort and resources to quality first. Then, while efforts on quality improvement continue and expand, management can devote effort on other capabilities. Two things need to be observed about the sandcone model.

First, the sandcone model refers to the manufacturing system's capabilities, not how these capabilities are built (Ferdows and De Meyer, 1990). The specific actions a company can take to improve the capabilities may be chosen from a wide range of alternatives. Office Machines's approach to improving quality is thus only one out of several. Whatever approach is chosen, efforts to improve quality need to be put in early in the adoption process. Office Machines's efforts to improve quality began before the start of the lean production project and concerned ISO 9002 certification, quality awareness training, and a system of operator self-inspection.

A second point about the sandcone model is that efforts to improve quality continue even when management effort and resources are devoted to other capabilities. Improvement initiatives are often aimed at a hybrid of capabilities (Ferdows and De Meyer, 1990). As a specific example, Ferdows and De Meyer mention: "giving workers more planning responsibility", which they claim improves both quality and dependability. Another example of an initiative improving a hybrid of capabilities is cellular manufacturing. The ability to easier trace parts to their origin facilitates assigning accountability for quality to cell operators (Hyer and Wemmerlöv, 1984).

Management effort and resources were in the empirical case devoted to the installation of a quality management system early in the adoption process. Efforts to improve quality did not diminish as the system was in place. Other activities, such as the creation of manufacturing cells and multifunctional teams, contributed to the improvement of quality. Would we like support for the notion that manufacturing cells and multifunctional teams improve quality, we have only to consult the extensive literature on total quality management (for a summary see Hackman and Wageman, 1995).

The sandcone model has been tested by Noble (1995), who found support for the model through an extensive analysis of plant-level data in three countries. The findings of Oliver and colleagues (1994) also support the notion of the importance of basing manufacturing improvement on quality: significant relationships were found between performance in lean production terms and items concerning process discipline and control.

The quality literature, finally, points to why quality requires management effort and resources early in the adoption process. Achieving consistently high quality requires a high degree of control over the manufacturing process. The control over the manufacturing process is the driver of subsequent improvements (Corbett and Van Wassenhove, 1993). A lean production system will not work properly without the elimination of scrap and rework (Hall, 1983). The work of achieving zero defects needs to be started as early as possible (Shingo, 1981).

7.3.2 Delayering the Organisation

The importance of delayering the organisation early in the adoption process can be understood if we look at the effects of delayering. Delayering improves communication and co-ordination. Through removing layers in the organisation, responsibility for day-to-day manufacturing decisions is transferred to the teams. Transferring responsibilities to the multifunctional teams is important in a lean production system, due to the gradual removal of inventories.

Decentralising responsibilities counters the effects of reduced inventory. One of the functions fulfilled by inventory is to separate parts of the manufacturing process from each other (Hill, 1995). If one machine breaks down, the following operations can still work on products from stock. Inventory prevents variability in one operation from having an impact on other operations. If inventory cannot be used for handling variability, alternative actions are needed to avoid disruptions. One action is more effective communication and co-ordination mechanisms between the various parts of the manufacturing process (Duimering and Safayeni, 1991).

Delayering also speeds up decision processes (Flynn et al. 1989). Since a manufacturing system working with low inventories lies close to customer demand, changes in demand translates to a need to change schedules rapidly. Rapid schedule changes require decisions being made and implemented rapidly and frequently. Delayering enables decisions to be made at the lower levels of the organisation, where relevant information on demand, production scheduling, and resource acquisition exists. If decisions were made higher up in the organisation, time would be lost sending the relevant information up the hierarchy. Time would also be lost waiting for the decisions to be communicated down, before they could be implemented.

Delayering, finally, increases operator participation in the manufacturing process (Im and Lee, 1989), which is essential in lean production. One aspect of operator participation is that teams act upon the problems they identify. Apart from improving the manufacturing system, operator participation is likely to have a motivating effect. The motivation and commitment gained is a foundation for further improvements of the manufacturing system (Roos, 1990).

Delayering is, with these effects in mind, part of the foundation for subsequent improvement of the manufacturing system. Due to the nature of a delayering exercise, being more of a one-off action rather than a continuous enterprise, we can expect that the delayering of the organisation requires management effort and resources early in the adoption process. Flat organisation hierarchies are a prerequisite for lean production (Storhagen, 1993).

7.4 A Core of Reciprocally Interdependent Principles

The analysis of the empirical case revealed three core principles which were related to each other throughout the adoption process: Elimination of waste, Multifunctional teams, and Pull instead of push. The core principles were not only related to each other, but also to issues at the overall level of the lean production project. The suggestion here is that these findings are due to reciprocal interdependence between the core principles in the adoption process.

7.4.1 Reciprocal Interdependence in the Empirical Case

The reciprocal interdependence in the empirical case can be illustrated in a PERT network. Figure 7.2 displays issues arising in conjunction with the productivity decline in 1993. Since the PERT network is used as an analogy, some room for interpretation of the terminology has been made:

- Events (the circles) illustrate either problems or their proposed solutions.
- Arrows indicate relationships between problems and solutions, which were indicated by the issues that arose in the adoption process.

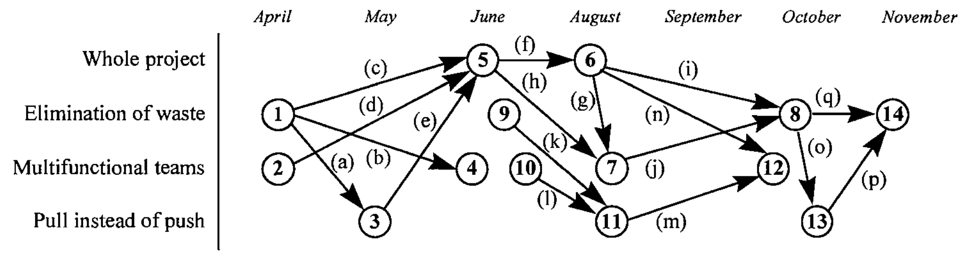

Figure 7.2 Issues in Conjunction With the Productivity Decline in 1993

The issues displayed in Figure 7.2 are only a selection, selected to illustrate the reciprocal interdependence between the three core principles. The display has been simplified for presentational purposes. The relationships were not always as straightforward as they are portrayed. The time scale has been chosen to illustrate the timing of issues, keeping in mind that issues were discussed through periods of time. The relationships between issues arising in conjunction with the productivity decline are expanded upon in Table 7.1.

Table 7.1 Relationships between Issues in Conjunction With the Productivity Decline

Events	*Relationships between events*
1) Relocation and creation of two manufacturing cells	
2) Creation of multifunctional teams for the manufacturing cells and piece-rates replaced with salary	
3) Problems with material control	a) Material could not be stored within cells, due to space limitations
4) Inflexible working hours of operators created problems	b) Decreasing lead times in manufacturing cells required flexibility in allocating operators

Table 7.1 Continued

Events	*Relationships between events*
5) Productivity decline caused discussion at various levels of the organisation	c) Creation of cells and relocation of products made tasks take longer to complete than previously d) New tasks given to the teams and payment change contributed to the productivity decline e) Problems with material control led to unnecessary transports to and from a temporary storage
6) Need for top management meeting on the lean production project	f) Turbulence around the productivity decline was the reason the meeting was inaugurated
7) Pressure on finding a new payment system	g) Top management meeting emphasised the need for a motivating element in the payment system h) Productivity decline exacerbated the pressure on finding a new payment system
8) Positive results needed in the manufacturing cells to continue the lean production project	i) Inauguration of a team to analyse manufacturing cells j) Analysis of manufacturing cells stalled since a production manager was busy creating the new payment system
9) Long set-up times in stamping	
10) Need to train multifunctional teams	
11) Problems with material control in manufacturing cells persist	k) Batch sizes in stamping contribute to problems with material control l) Problems with material control affected by the skills of the multifunctional teams
12) Work with creating team at the stamping department	m) Suggestion to create team at stamping department and establish internal customer relationships to cells n) A team at the stamping department was an issue at the top management meeting
13) Proposal to alter product structure trees	o) Altering product structure trees increased the manufacturing cells' performance
14) Proposal to use permanently set up machines in one manufacturing cell	p) It was necessary to alter product structure trees before changing layout to incorporate new machines q) Installing permanently set up machines was a way of increasing the manufacturing cells' performance

Figure 7.2 and the accompanying Table 7.1 illustrate that, on the basis of the issues that arose, the three core principles were reciprocally interdependent in the adoption process. This does not mean the individual relationships in Figure 7.2 are reciprocal. The core principles were reciprocally interdependent when the time dimension is added; it is the adoption process that is the focus of the study. Consider the following examples:

- *Elimination of waste was reciprocally interdependent to Multifunctional teams through relationships (b) and (j).* The creation of manufacturing cells led to a decrease in lead time which meant that operators' working hours needed to be flexible. Conversely, the analysis of the manufacturing cells was stalled since a production manager was busy with the work of creating a new payment system.
- *Elimination of waste was reciprocally interdependent to Pull instead of push through relationships (a) and (p).* Due to space limitations in the manufacturing cells, material could initially not be stored within the cells and material control problems therefore arose. The proposal to use permanently set up machines was, on the other hand, stalled due to a need to alter product structure trees before changing the layout.
- *Multifunctional teams was reciprocally interdependent to Pull instead of push through relationships (l) and (m).* The problems with material control in the manufacturing cells were affected by the skills of the multifunctional teams. The batch sizes in the stamping operation also contributed to the problems with material control. One solution was to form a multifunctional team at the stamping department and establish internal customer relationships to the manufacturing cells.

7.4.2 Reciprocal Interdependence in the Literature

An examination of operations management literature reveals the close links which exist between the core principles, explaining why the principles were reciprocally interdependent. In the Toyota production system, the relationship between Elimination of waste and Multifunctional teams is exemplified by the concept *shojinka* - the increase of productivity through adjusting and scheduling human resources (Monden, 1983). Two factors are crucial for realising *shojinka*:

1) Proper design of the machine layout, preferably in a U-form, to facilitate increasing and decreasing the number of jobs each operator is responsible for.
2) Versatile and well-trained operators able to perform several jobs.

The concept of *shojinka* indicates interdependence between the layout and the multifunctional teams in a lean production system. For lean production to function properly, changes in factory layout are needed (Harber et al., 1990). An empirical example is Rohm and Haas in Kentucky, the United States: when the company introduced multifunctional teams, the manufacturing facility needed reorganisation (Gupta and Ash, 1994).

The interdependence between Elimination of waste and Multifunctional teams can also be found in the group technology literature. The basic philosophy of group technology is to identify parts manufactured in similar ways, to facilitate manufacturing them as a group (Huq, 1992). The most advanced application of group technology is cellular manufacturing, which often requires changes to the factory layout. Features of the cellular approach are the capacity for wider task variety and the need for higher skill levels. There is also an opportunity for teamwork and for operators to focus on the manufacturing process from raw material to finished part (Hyer and Wemmerlöv, 1984).

A multifunctional team working in a manufacturing cell is also a vehicle for eliminating waste in the manufacturing process. Through working in a manufacturing cell, operators increase their knowledge and overview of a well-defined part of the manufacturing process. This knowledge, combined with training in several jobs, increases the possibility of observing and eliminating waste (Robinson and Schroeder, 1992).

The relationship between multifunctional teams and the layout is finally indicated by the finding of Oliver and colleagues (1994). The authors found that the use of multifunctional teams did not distinguish high-performing manufacturing plants from lower performing plants. However, there was no evidence that the high performers did not use teams, it was simply the case that the lower performing plants also used multifunctional teams. Given reciprocal interdependence between layout and teams; having only multifunctional teams is not enough, the layout needs to be changed.

The reciprocal interdependence between Elimination of waste and Pull instead of push is rather straightforward. A prerequisite for moving towards pull scheduling is a reduction in batch sizes (Schonberger, 1982a). A reduction of batch sizes is feasible through the creation of manufacturing cells around family-like products (Hyer and Wemmerlöv, 1984).

The reciprocal interdependence between Multifunctional teams and Pull instead of push is illustrated by the relationship between the multifunctional team and production control in a manufacturing cell. Managers can simplify production control by considering the cell as one planning point, for which capacity planning is performed and to which jobs are released. However, it is the task of the multifunctional team to balance the load in the cell (Hyer and Wemmerlöv, 1984). The task of balancing the load is part of the previously indirect responsibilities which are transferred to the multifunctional team.

The reciprocal interdependence between the three core principles, finally, is illustrated by one of the key elements in Voss and Robinson's (1987) conceptualisation of just-in-time: 'organisation in modules or cells' (p. 52). The argument is that factories are organised in cells and each cell is totally responsible for its own production. Within the cell, the workforce is trained to work as a team. Activities normally considered as staff functions, such as scheduling and maintenance, are transferred to the team.

7.5 Supporting Principles and Pooled Interdependence

Two principles were in the empirical case related to the three core principles, to various degrees: Team leaders and Vertical information systems. Both required management effort and resources throughout the whole adoption process, but in a different way than the three core principles. Team leaders and Vertical information systems can be seen as supporting the core in the adoption process.

The supporting principles, it is argued here, exhibit elements of pooled interdependence in the adoption process. Recall that pooled interdependence exists when each part is independent from each other, but renders a contribution to the whole. The parts are here represented by Team leaders and Vertical information systems. The whole is represented by the other lean production principles and particularly the core principles.

In the empirical case, the two supporting principles particularly provided support to the principle Multifunctional teams, part of the core principles. However, the two supporting principles were not related to each other directly. The only relationship between the two principles was due to their separate roles in the productivity decline. The pooled interdependence in the empirical case is further exemplified below. The reader should bear in mind that the examples illustrate instances where the issues that arose in the supporting principles affected the adoption process. The issues were discussed through periods of time and not necessarily only at the specified points in time.

The first example of how the team leaders affected the adoption process relates to the loss of team leaders. For various personal reasons, a number of those initially trained for the team leader task left the company during the spring of 1994. In October 1994, the loss of team leaders created material control problems in the manufacturing cells. The multifunctional teams therefore needed assistance with controlling the material.

To alleviate the loss of team leaders, training of new team leaders was started in October 1994. The training had several positive outcomes, which illustrate pooled interdependence. The scepticism certain operators exhibited towards the lean production project was reduced through the training, with positive effects on the adoption process. Team leader training also helped neutralise the negative influence ex-supervisors had over the multifunctional teams.

The final example of how the team leaders affected the adoption process refers to the issues arising in conjunction with the productivity decline. A particularly controversial issue was the pace with which responsibilities could be transferred to the teams. Team leaders did not initially have the proper competence to assume full responsibility for managing the multifunctional teams.

The vertical information systems particularly affected the adoption process through the relationship to the productivity decline. To raise productivity, the multifunctional teams needed information systems. These systems, as well as the development of team leaders, were from February 1995 an integral part of the creation of multifunctional teams for the new manufacturing cells. The teams needed information and team leaders to function properly.

Turning now to the literature, the aim is to discover what other authors have found regarding the relationship between the two supporting principles and the other lean production principles. Oliver and colleagues (1994) found that team leaders had a pivotal role for manufacturing performance. In high-performing plants, the team leader had significantly more responsibilities than in low-performing plants. This finding indicated that the contribution of the team leader in the high-performing plants was a crucial factor for performance.

Vertical information systems are a contributing factor to Japanese manufacturing companies' success of involving employees in manufacturing improvement (Cole et al., 1993). A high amount of business information is distributed to employees, who receive training to understand the information. Japanese managers then empower employees to act on the information. By providing this framework, in which employees are considered part of the improvement process, fear of changing existing routines is reduced.

Vertical information systems are related to a lean work organisation. Providing multifunctional teams with information on performance in relation to targets improves the performance of the teams (Flynn et al., 1989). The information systems are also related to the decentralisation of responsibilities. The information systems are tailored to identify problems and provide raw material for problem solving. The information systems therefore operate less as tools of distrust and providers of criteria for distributing rewards and punishment, which is common in organisations with several management levels (Cole, 1985).

7.6 Sequential Interdependence - towards Continuous Improvement

The analysis of the empirical case finally revealed that Continuous improvement required management effort and resources at the end of the adoption process. The argument here is that this finding indicates sequential interdependence: before being started, Continuous improvement benefited from other lean production principles being in place.

There were two major reasons why the continuous improvement initiative was started late in the empirical case. The first reason was the disturbance caused by the project involving the large customer, which resulted in a lack of time to work with the initiative. The late start of the continuous improvement initiative is an example where lack of resources required the responsible managers to choose between various lean production principles. In making this choice, managers found it necessary to delay the continuous improvement initiative.

The second reason the continuous improvement initiative was started late, was that prior to being in a continuous improvement team, operators needed experience from working in a multifunctional team in a manufacturing cell. Working in a multifunctional team gave operators an overview of the manufacturing process, which made it easier for them to improve the process. This indicates sequential interdependence between Continuous improvement and the other lean production principles.

Please note that by arguing for sequential interdependence, I do not imply Continuous improvement needs to be late in the adoption process. The argument being there is sequential interdependence between Continuous improvement and the other lean production principles given the following:

1) *The definition of continuous improvement.* Instead of using the term to connote a philosophy, the term is in the present study used more in a technique-based fashion.
2) *The approach taken to changing the manufacturing system.* Continuous improvement is here seen as a part of the lean production framework and not as a separate tool to improve manufacturing.
3) *The manufacturing organisation prior to adopting lean production.* The manufacturing organisation in the empirical case required structural changes being made to the manufacturing system.

The three considerations imply there are different strategies for continuous improvement, which need to be kept in mind when the empirical findings are compared with literature.

Hart and colleagues (1996) define three different strategies for designing systematic continuous improvement: organic improvement strategy, directed project strategy, and directed wide strategy. As defined in the present study, Continuous improvement lies close to the organic strategy, where continuous improvement is a natural part of the multifunctional team's day-to-day work.

The three strategies for continuous improvement are a conscious design decision, which require different platforms to build on. The platform required for continuous improvement according to an organic strategy, supports the notion of sequential interdependence between Continuous improvement and the other lean production principles. The platform for an organic strategy has three components (Hart et al., 1996):

- An organisation with well-developed multifunctional teams, advanced in terms of competence, flexibility, and ability to assume responsibilities.
- Decentralised responsibilities, since the improvement needs to take place towards the company's overall goals.
- The possibility for operators to span a large part of the manufacturing process, for instance through organising work in manufacturing cells.

Other literature also supports the notion of sequential interdependence between Continuous improvement and the other lean production principles. A reason why Japanese manufacturing companies have succeeded with the involvement of their employees in quality improvement, is that the market is brought into the organisation (Cole et al., 1993). Japanese manufacturing companies heighten the pressure for change the environment exerts on all parts of the organisation, through for instance pull scheduling, multifunctional teams, and internal customer supplier relationships between multifunctional teams. That is, the success of involving operators in continuous improvement is dependent on the manufacturing organisation.

Increasing the number of perspectives from which the manufacturing process is seen, facilitates improving the process (Robinson and Schroeder, 1992). One way to force the adoption of different perspectives is through training operators in several tasks and through job rotation in a multifunctional team. Increasing the number of perspectives from which the manufacturing process is seen is also accomplished through organising work in manufacturing cells. Operators working in manufacturing cells are able to perceive more clearly the significance of their activities, since they participate in the entire manufacturing process or some significant portion of it (Huber and Hyer, 1985).

Considering the benefits of a platform on which a continuous improvement initiative is built, the finding reported by Voss (1984) may be interpreted. In a case study of a Japanese company in the United Kingdom, Voss found that the company did not use quality circles, with the justification that 'it was too early to introduce them' (p. 36). To achieve the full potential of continuous improvement teams, the teams need to start after the prerequisite philosophy and capabilities are firmly in place (Hayes et al., 1988).

7.7 Interdependence in the Adoption Process

The aim of the comparison with literature was to find explanations to why the sequences of lean production principles occurred in the empirical case. Utilising the concept of interdependence as a framework, we have found support for the four groups of findings from the analysis of the empirical case:

1) Zero defects and Delayering were sequentially interdependent to the other lean production principles. Zero defects and Delayering required management effort and resources early in the adoption process for other principles to take full effect.
2) The three core principles: Elimination of waste, Multifunctional teams, and Pull instead of push, exhibited reciprocal interdependence. The core principles required management effort and resources, and were related to each other, throughout the whole adoption process.
3) The core principles were supported by Team leaders and Vertical information systems, which were related to the core principles, but not to each other. Team leaders and Vertical information systems therefore exhibited pooled interdependence in the adoption process.
4) Continuous improvement was sequentially interdependent to the other lean production principles. A continuous improvement initiative, relying on multifunctional teams to solve problems as a natural part of their day-to-day work, benefited from a foundation to build on to function properly.

With these findings in mind, we now proceed to the study's final chapter, where the findings are further synthesised through a comparison with existing studies on sequences of improvement initiatives in manufacturing. The aim is to determine the present study's contribution to existing knowledge.

CHAPTER 8

Sequences in the Process of Adopting Lean Production

In the final chapter, the present study's findings are compared with existing studies of sequences of improvement initiatives in manufacturing. The comparison spells out the present study's contribution to existing knowledge. The comparison also addresses the issue of generalisation, since findings from single case studies can be made more general through a comparison with existing theory (Berg, 1981). By comparing the present study's findings with existing knowledge, to emphasise, it is not argued that the sequences observed in the present study are the only possible. Neither is the argument that the sequences are preferable, considering the effects on operational performance. Sequences of improvement initiatives in manufacturing are likely to be influenced by a number of factors, which need to be determined in future research.

8.1 Sequences of Improvement Initiatives in Manufacturing

In the literature review made in Chapter One, three studies were found to deal with the problem of interest in the present study - sequences of improvement initiatives in manufacturing (Roos, 1990; Storhagen, 1993; Filippini et al., 1998). The conclusions of the three studies can be compared with the findings of the present study. The aim of the comparison is to discover similarities and differences, and try to ascertain the reasons for the differences. The differences hold clues to the present study's contribution to existing knowledge.

8.1.1 Japanisation in Production Systems - A Comparison

In his study of Japanisation within British industry, Roos (1990) drew conclusions regarding the sequence in which the initiatives in his total quality management model should be implemented. The conclusions were presented in the form of propositions. The four propositions of relevance for the present study are the focus of the comparison.

Proposition One: Achievement of Total Quality Control

> In order to accomplish a change in attitudes to quality and attain the content-related attribute TQC, an initial implementation of operative techniques associated with the central concepts of leadership profile and human relations is required. (Roos, 1990, p. 348)

In the context of the present study, what Roos terms "total quality control" is best understood as the lean production principle Zero defects. The operative techniques are equivalent to what in the present study is termed "practices". Each lean production principle consists of a set of practices: the actions taken, the techniques implemented, and the changes made to the organisation.

To achieve a changed attitude to quality, it is according to Roos necessary to implement operative techniques listed in Table 8.1. The table also indicates the similarities between the operative techniques and the lean production principles. As seen in Table 8.1, there are few similarities between the operative techniques and lean production principles. The similarities that exist refer to the delayering of the organisation and in part to the creation of a multifunctional team.

The major reason for the many differences between the operative techniques and the lean production principles, is that Roos's model contains the role of management, which is not part of the lean production framework. Roos was interested in Japanisation: organisational change that conforms to Japanese management techniques (Giles and Starkey, 1988). Implicit in Japanisation often lies the view that the management techniques are tied to cultural traits. A grounding assumption in the present study, in contrast, is that lean production does not require certain cultural traits (Krafcik, 1988b).

Roos's own conclusions to some extent confirm the assumption that lean production does not require certain cultural traits. Roos distinguishes two types of Japanisation: "direct Japanisation" and "indirect Japanisation". The two types of Japanisation refer to the implementation of Japanese manufacturing management practices in the United Kingdom with or without the direct involvement of Japanese managers. The patterns of changes differed between the two types of Japanisation. To achieve a changed attitude to quality, companies undergoing indirect Japanisation did not implement operative techniques associated with management profile as much as companies undergoing direct Japanisation. That is, where Japanese managers were not involved in the implementation of total quality management, the management style was not changed. This conclusion indicates that lean production can be adopted without adopting a Japanese management style.

Table 8.1 Operative Techniques Necessary for the Achievement of Total Quality Control

	Operative techniques	*Lean production principles*
Leadership Profile		
1. Role	• Person-related • Listening and "bottom-up" • Confidence in increased responsibility	Last item related to Delayering
2. Management	• Authority without title • Delegated responsibility • General order	Second item related to Delayering
3. Leadership	• Decision by consensus • Time for consideration and gradual change	
4. Training/ experience	• Internal training/job rotation • Not employed for specific job	
Human Relations		
	• Lifetime employment • Integration work/private life • On-the-job training • Common eating and parking facilities • Same working clothes for all	Third item is related to Multifunctional teams - the importance of training to achieve multifunctional operators

Despite the differences between the operative techniques and lean production principles, there are similarities between Roos's first proposition and the present study's findings. Most important is the emphasis on the work with quality early in implementation, which is similar to the present study's finding on Zero defects. Furthermore, Table 8.1 revealed similarities concerning Delayering. According to Roos, organisational changes early in a Japanisation are carried out with the aim of increasing operators' participation and commitment. Increasing participation and commitment is accomplished through pushing responsibility down the organisation hierarchy. Roos's conclusion is similar to the finding in the present study: Delayering required management effort and resources early in the adoption process.

Proposition Two: Achievement of Just-in-Time

> The time-related attribute JIT is obtained in the material flow when operative techniques associated with the central concepts of simplicity and being visible and belonging to group have been implemented. (Roos, 1990, p. 349)

Roos uses the term "just-in-time" to refer to the time-planning of material supply: each requirement is provided in the right quantity at exactly the right time. In order to achieve just-in-time, Roos asserts it is necessary to implement operative techniques associated with the concepts "simplicity and being visible" and "belonging to group". The operative techniques are listed in Table 8.2, where similarities with the lean production principles have been indicated.

Table 8.2 Operative Techniques Necessary for the Achievement of Just-in-Time

Operative techniques		*Lean production principles*
Simplicity and visibility	• Painted stock • Warning lamps • Process stop when problems arise • Minimal set up	Many items are related to Elimination of waste and particularly the creation of manufacturing cells
	• Unit flow • Flow layout • Compact material facade	"Unit flow" is related to Pull instead of push
Belonging to group	• Wage by age and qualification	Refers to Multifunctional teams
	• Suggestions • Quality circles	Can be understood as Continuous improvement

The operative techniques in Table 8.2 exhibit several similarities with the lean production principles. Particularly relevant is the close resemblance between the operative techniques and the core principles which were identified in the present study: Elimination of waste, Multifunctional teams, and Pull instead of push. The only difference, compared with the core principles, is Roos's inclusion of quality circles in "belonging to group". Quality circles are in the present study best understood as Continuous improvement.

Proposition Three: Relationship between Total Quality Control and Just-in-Time

> The time-related attribute JIT cannot be achieved in a material flow before the content-related attribute of TQC has been secured. (Roos, 1990, p. 349)

The third proposition emphasises the importance of working with quality early in implementation, which is consistent with the present study's finding. Further interpretation of the proposition is accompanied with problems. The question is whether or not the attribute of total quality control is attained at a discrete point in time, which it is according to Roos. I do not share this view; I see the attainment of total quality control as a continuous task. This difference in view has implications for the interpretation of the fourth proposition.

Proposition Four: Implementation as Sequential Phases

> The implementation of TQM can be described by means of a successive division in to phases, which each represent a number of operative techniques, the number of which increases as the phase develops. (Roos, 1990, p. 350)

The view of implementation as consisting of phases is different from the view taken in the present study. The process view of implementation taken here refutes the idea of distinct phases in the process, each of which contains work with certain techniques. Roos does, however, admit it is difficult to determine the length of each phase and to find criteria for determining the end points of each phase. The view taken in the present study is still different. Recall also that the achievement of a production system characterised by an absence of unnecessary operations is a journey (Hayes and Pisano, 1994). The principles of lean production point out the intended direction of this journey.

Conclusions of the Comparison

The comparison between Roos's conclusions and the present study's findings reveals a number of similarities and differences. Consider first the following similarities:

- Delayering the organisation takes place early in implementation and is coupled with the introduction of a multifunctional team with team leaders, to help elicit operators' participation and commitment.
- Work with quality takes place early in implementation. The work with quality requires a changed attitude to quality. Changing attitudes to quality is accomplished partly through the mechanisms supporting operator commitment.
- Lean production's core principles resemble the operative techniques necessary to attain a material flow characterised by just-in-time.

A major difference between Roos's conclusions and the present study's findings regards the existence of distinct phases in the adoption process. Total quality control, as conceived of by Roos, has to be in place before just-in-time. In the present study, the work of attaining a material flow characterised by timely deliveries required management effort and resources in parallel to the work with quality. However, the work with quality required management effort and resources mostly in the beginning of the adoption process.

The notion of phases makes it difficult to relate the findings on the three core principles to Roos's conclusions. The core principles were in the present study found to require management effort and resources throughout the adoption process. The core principles are according to Roos, on the contrary, only applicable after the work with quality has been completed.

Finally, there may be a difference in the timing of Continuous improvement. Continuous improvement was in the present study found to require management effort and resources late in the adoption process. Roos has quality circles as a part of the operative techniques necessary to achieve just-in-time. However, nothing is said regarding whether quality circles are started early or late compared with the other operative techniques. Due to the lack of differentiation between operative techniques, comparing the finding on Continuous improvement is difficult. It is not clear whether the present study's finding on Continuous improvement is supported or contradicted by Roos's conclusions.

8.1.2 Management and Flow Efficiency in Japan and Sweden - A Comparison

The second study with which the present study's findings are to be compared was conducted by Storhagen (1993). The purpose of his study was to describe and analyse the necessary conditions and possibilities for implementing the logistics practices of Japanese companies in Swedish industry.

Classifying and Grouping Techniques Associated with Just-in-Time

A framework Storhagen used was a classification of the techniques he associated with just-in-time in three different categories: process, structural, and interaction factors. Through working with the techniques associated with the three factors, companies can achieve results in various effect factors. The process, structural, and interaction factors are equivalent to lean production practices. Effect factors are equivalent to the performance of a lean production system. A comparison between Storhagen's classification and the lean production framework is made in Table 8.3 to Table 8.5, where the lean production principles have been abridged.

Table 8.3 Comparing Process Factors With the Lean Production Framework

Process factors - support continuous improvement, change, and development			
Teamwork - small, self-governing teams	MF	Carry out decisions that have been made	
Equal status		Decisions just in time	
Physical closeness between employees	EW	Lifetime employment	
Timely decision making		Seniority system	
Tailored measurement systems		Long-term visions and goals	
Job rotation - worker flexibility	MF	Common language at the company	
Simple and well developed information systems	VI	Belonging to group - with decentralised reponsibilities	MF DR
Visibility for all - clear, simple, and timely information	VI	Active suggestion scheme - to achieve continuous improvement	CI
Responsibilitiy for all individuals	DR	Never do anything half-heartedly	
Flat organisations and self-governing teams	MF DR	Direct channels from management into the organisation	
Encouragement of independent work	DR	Payment system	MF
Consensus decisions		Comprehensive training schemes	MF

Table 8.3 reveals a high degree of similarity between the process factors and the lean production principles. The majority of the similarities centre around Multifunctional teams (MF) and Decentralised responsibilities (DR). Decentralised responsibilities includes both Delayering and Team leaders, although it is difficult to differentiate the two from each other. Vertical information systems (VI) and Continuous improvement (CI) are also represented among the process factors.

There are also a number of factors in Table 8.3 which have no equivalent in the present study. These factors most commonly refer to management style and human resource management. Storhagen's interest is the implementation of Japanese companies' logistics practices in Swedish industry. To succeed with implementation, Storhagen finds it necessary for companies to change management style and implement Japanese human resource management practices. Seeing implementation as requiring a change in management style and human resource management is similar to the views subsumed under the banner "Japanisation". As pointed out earlier, I am not convinced changes in management style and adoption of Japanese human resource management practices are necessary to adopt lean production.

Table 8.4 Comparing Structural Factors With the Lean Production Framework

Structural factors - alter the structural features of the manufacturing system			
Kanban - pull system for material control	PP	Meeting peaks through temporary labour	
Production smoothening		Meeting peaks through over-time	
Set-up time reduction	EW	Everything correct from the beginning	ZD
Smaller batch sizes	PP	Clean and safe workplace	
Automatic stop of production	ZD	Simple and tailored machines	EW
Tailored layouts	EW	Increasing automation	

The comparison in Table 8.4 reveals a high degree of similarity between the structural factors and the lean production principles. The structural factors are primarily similar to Elimination of waste (EW) and Pull instead of push (PP). There is also one item referring to Zero defects (ZD).

The factors in Table 8.4 with no direct equivalent among the lean production principles, mainly refer to how peaks and troughs in demand are handled. Handling peaks and troughs in demand is indeed necessary in a lean production system, but the practices needed to accomplish this task are not included in the framework used in the present study. The practices for handling demand are likely to become pronounced at a later stage in the lean journey, when inventory buffers have been reduced to such a degree that market uncertainty is brought right into the manufacturing process.

The comparison between interaction factors and the lean production framework is made in Table 8.5. The comparison reveals few similarities, which is due to the difference in research focus. The focus in the present study is the manufacturing function. The interaction factors mainly concern the principles of lean procurement.

Table 8.5 Comparing Interaction Factors With the Lean Production Framework

Interaction factors - increase physical and organisational interaction along material flow		
Customer in focus		Scheduled transports
Geographical proximity		Supplier development
Modularity and pre-assembly		Quality certified suppliers
Customer order trigger production	PP	Holistic view - generalists versus specialists

Sequences in the Implementation of Just-in-Time Factors

Storhagen's major conclusion is that the different factors he associates with just-in-time are interrelated and cannot be implemented in isolation. The conclusions are summarised in a factor matrix, see Figure 8.1. The arrows inside the factor matrix indicate that a company starts implementing the process factors and then implements structural and/or interaction factors. The implementation of structural and/or interaction factors does not mean the process factors are abandoned. The process factors are supplemented with structural and/or interaction factors. The result of this implementation sequence will be a change in effect factors; the performance of the manufacturing system.

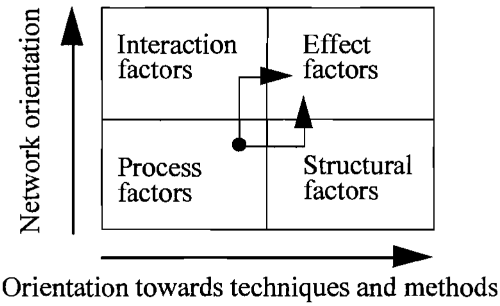

Figure 8.1 The Factor Matrix (Source: Storhagen, 1993, p. 51)

Conclusions of the Comparison

Storhagen's conclusions have a number of similarities with the present study's findings. At a general level, Storhagen concludes that the different factors are interrelated and cannot be implemented in isolation. Storhagen also concludes that the implementation does not consist of phases. The factors are instead implemented in a cumulative manner. These conclusions are consistent with the present study's findings, which identified principles requiring management effort and resources throughout the adoption process.

The findings on the core principles cannot unfortunately be directly compared with Storhagen's conclusions. According to Storhagen, implementation starts with the process factors and moves towards the structural factors. The structural factors are similar to the core principles. Storhagen's conclusions therefore indicates the core principles are not applicable early in the adoption process.

However, concluding that the core principles are not applicable throughout the whole adoption process may be premature, since nothing is said about the timing of the move from process to structural factors. Consider the following two scenarios, which both would imply a high degree of similarity between Storhagen's conclusions and the present study's findings on the core principles:

1) The move from process factors towards structural factors takes place relatively soon after implementation has begun.
2) The initial emphasis in implementation is on the process factors that have no equivalent among the lean production principles, particularly the factors which refer to management style and human resource management.

A similarity between Storhagen's conclusions and the present study's findings is the need for an early focus on decentralising responsibilities. Decentralisation is part of Storhagen's process factors. In the present study, the amount of management effort and resources devoted to Delayering declined as the adoption process progressed. The gradual decline in effort and resources devoted to Delayering can unfortunately not be compared with Storhagen's conclusions.

A difference between the present study's findings and Storhagen's conclusions concerns the timing of the work with quality. Quality is, according to Storhagen, not a main concern initially, since quality is part of the structural factors. Quality was in the present study found to require management effort and resources in the beginning of the adoption process. The difference regarding quality may in part be due to the timing of the move from process to structural factors, which is not made explicit by Storhagen.

A second difference between the two studies concerns the timing of Continuous improvement. Interpreting the finding on Continuous improvement is, however, made difficult by the difference in terminology. Storhagen has "an active suggestion scheme" as a part of his process factors. The suggestion scheme is as close as we come to Continuous improvement, as contrived of in the present study. Storhagen's conclusions indicates that Continuous improvement is important early in the adoption process, which is contrary to the finding of the present study.

8.1.3 Sequences of Operational Improvement - A Comparison

In the third and final study with which the present study's findings can be compared, a survey-based approach was used to investigate sequences of improvement initiatives (Filippini et al, 1998). The use of surveys gives rise to difficulties when comparing the findings. Despite these difficulties, the survey-based approach has strengths of interest here. The use of surveys helps put the present study's findings in perspective. Surveys permits the analysis of sequences of improvement initiatives in many companies with different contexts, to ascertain the influence of the context on the sequences. However, it is prudent to keep the difficulties in translation in mind as we continue.

Comparing Improvement Initiatives With Lean Production

The improvement initiatives and manufacturing contexts considered by Filippini and colleagues are found in Table 8.6.

Table 8.6 Initiatives and Manufacturing Contexts (Source: Filippini et al., 1998)

Initiatives	*Manufacturing context*
• *Design computerisation* (CAD, CAE, CAPP, CAD/CAD) • *Suppliers* (reduction in the number of suppliers and closer collaboration with suppliers) • *Just-in-time* • *Flexible automation* (direct or distributed numerical control, flexible manufacturing systems, automatic stock systems, and cellular manufacturing) • *Quality improvement* • *Human resource management* (employee involvement and reduction of the number of hierarchical levels) • *Manufacturing strategy*	• *Export* (percentage of plant sale exported) • Length of *product life cycle* • *Variety* (number of end products) • *Volume* (annual production volume of the main product) • *Continuity* (manufacturing processes characterised as continuous, repetitive/line flow, large batch, small batch, one of a kind)

The first difficulty in comparing the present study's findings with the conclusions reached by Filippini and colleagues, relates to the fact the improvement initiatives Filippini and colleagues consider go beyond those of interest in the present study. Only three of the initiatives considered seem similar to the lean production framework: just-in-time, quality, and human resource management. Consider the following:

- The initiatives that lie outside the present study's scope are design computerisation, manufacturing strategy, and suppliers.
- The initiative termed "flexible automation" includes cellular manufacturing, but also the adoption of manufacturing technology. As conceived of in the present study, cellular manufacturing is part of Elimination of waste. However, since there is no way of separating cellular manufacturing from the more technologically-oriented initiatives, flexible automation cannot be considered.

The second difficulty in making comparisons is that the content of the improvement initiatives is not defined by Filippini and colleagues. The companies returning the survey indicated when the initiatives on a predetermined list were started. The use of self-reports means that when translating the initiatives to the language of the present study, all we can do is guess the content of the initiatives:

- *Just-in-time* can be interpreted in many ways. It seems prudent to expect *Elimination of waste* to be a base in the content of just-in-time.
- *Quality improvement* is easier to interpret and can be seen as similar to *Zero defects*.
- *Human resource management* has two components: employee involvement and reduction of the number of hierarchical levels. Human resource management can therefore be seen as similar to *Decentralised responsibilities* and *Multifunctional teams* combined.

The final difficulty in comparing the present study's findings with the conclusions of Filippini and colleagues, is the difference in level of detail, provided by the difference in research design - survey versus clinical research.

Two Types of Lean Production Sequences

Filippini and colleagues draw conclusions on sequences of improvement initiatives for the companies in their sample. Using the empirical material as a starting point, four different types of sequences are identified. The sequences are based on two dimensions, that together form a two-by-two matrix:

1) *The number of initiatives undertaken*. Based on how many of the initiatives mentioned in Table 8.6 the company had implemented, two groups were differentiated: full adopters and discriminators.
2) *The order of precedence between initiatives*. "Hard type" companies implemented the more technologically-oriented initiatives prior to those oriented more towards organisation and management. An example is automation prior to changes in human resource management. "Soft type" companies used the reverse sequence.

If we examine the four types of sequences defined by Filippini and colleagues, bearing in mind that only three initiatives are reflected in the lean production framework, we find that only two different sequences exist. The only differentiating factor between the two sequences is the number of initiatives that have been implemented: companies who adopted all the initiatives versus companies who discriminated between the initiatives. The two types of sequences are illustrated in Figure 8.2.

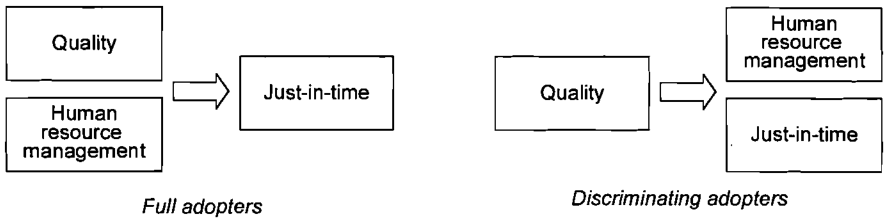

Figure 8.2 Two Types of Lean Production Sequences (Based on Filippini et al., 1998)

Figure 8.2 illustrates a number of themes, which will be developed. Please note first that Filippini and colleagues only consider when initiatives were started, not when initiatives were ended. This does not mean, for instance, that quality is in place before just-in-time. This view on end points is consistent with the view taken in the present study. However, there is no way of knowing the size of the gap in time between the various initiatives considered by Filippini and colleagues.

Conclusions of the Comparison

A number of observations can be made if we compare Figure 8.2 with the present study's findings. Consider first of all the following:

- Consistent with the present study, we find that quality comes early in both lean production sequences.
- Human resource management takes place parallel to just-in-time in both sequences, since there are no end points to the initiatives.
- The sequence for full adopters seems to lie quite close to the sequence of lean production principles found in the present study: quality is emphasised early together with the decentralisation of responsibilities and development of multifunctional teams. Thereafter the work with just-in-time is undertaken.
- Discriminators, on the other hand, seem to start working with quality and then move on to just-in-time and human resources.

Thus, there are similarities between the present study's findings and the conclusions of Filippini and colleagues. The most similar findings are the emphasis on quality early in implementation and human resources in parallel to just-in-time. It is unfortunately difficult to make a more detailed comparison, due to the differences in research design and definitions.

On the other hand, comparing the effects of manufacturing context on the two sequences is of interest here. The following conclusions can be drawn from such a comparison:

- Whether a company was a full adopter or a discriminator did not depend on which industry sector the company operated in or the volume, variety, and continuity of the plant.
- Country of origin differentiated the full adopters from the discriminators. The Japanese plants in the study were mainly full adopters, the American plants more frequently discriminators, and the Italian plants equally divided between the two groups.

These conclusions indicate that sequences of initiatives, translated to the lean production framework, were rather robust. Of the different factors in the manufacturing context in Table 8.6, the only factor which differentiated full adopters from discriminators was country of origin. It is encouraging that the Japanese companies were full adopters, which means their sequence lies closest to the sequence identified in the present study. The conclusions on the effect of manufacturing context indicate that the present study's findings may be applicable outside the company in which they were derived.

8.2 The Present Study's Contribution to Existing Knowledge

The comparison between the present study's findings and the existing studies of sequences of improvement initiatives in manufacturing can now be taken one step further. The task is to synthesise the comparison and arrive at the present study's contribution to existing knowledge. In this respect, the differences between the present study and the existing studies hold clues to the present study's contribution to existing knowledge.

8.2.1 The Notion of Sequential Interdependence Is Supported by Existing Studies

The present study found two lean production principles that required management effort and resources early in the adoption process: Zero defects and Delayering. The two principles were sequentially interdependent to the other lean production principles. These conclusions are supported by the existing studies. There is support for the need to assure product quality early in manufacturing improvement:

- The importance of working with quality early in implementation is stressed both by Roos and by Filippini and colleagues.
- Storhågen, however, has the work with quality taking place later. How much later is not possible to tell.

The importance of delayering the organisation and decentralising responsibilities early in implementation is supported by all three studies:

- Roos concluded that delayering the organisation helps elicit operators' participation and commitment.
- Storhagen saw decentralisation as way of creating a platform for further change and development.
- Filippini and colleagues found that the removal of organisational layers took place early in manufacturing improvement, despite the company's manufacturing context.

8.2.2 First Contribution: A Core of Reciprocally Interdependent Principles

The present study found a set of core principles that required management effort and resources throughout the whole adoption process: Elimination of waste, Multifunctional teams, and Pull instead of push. The core principles were mutually related throughout the whole adoption process and exhibited characteristics of reciprocal interdependence. These conclusions constitute the present study's first contribution to existing knowledge.

The content of the core principles closely resembles those techniques Roos see as necessary to attain a material flow characterised by just-in-time. However, the timing of the core principles is not consistent with Roos's conclusions. Roos concludes that the work with just-in-time is possible only after the work with quality. This indicates sequential interdependence in the adoption process.

The content of the core principles is reflected in Storhagen's structural factors, but also in his process factors. Storhagen recommends a company to start implement the process factors and continue building on the process factors while implementing the structural factors. Although Storhagen says nothing about the timing of the move from process to structural factors, the conclusion indicates the core principles are not applicable at all times.

Filippini and colleagues, finally, have two initiatives taking place in parallel: (a) human resource management and (b) just-in-time. However, there may be a gap in time between the two, but it is difficult to tell, given the research design.

The comparison reveals that existing studies indicate a sequential interdependence between the core principles and the other lean production principles. The sequential interdependence implies the core principles do not require management effort and resources throughout the whole adoption process. This is contrary to the present study's conclusions.

8.2.3 Second Contribution: Supporting Principles and Pooled Interdependence

The present study found two lean production principles which supported the core principles throughout the whole adoption process: Team leaders and Vertical information systems. The two principles exhibited pooled interdependence in the adoption process, particularly to the core principles. Pooled interdependence implies the core principles depended on the supporting principles, but the supporting principles were not related to each other. These conclusions constitute the present study's second contribution to existing knowledge.

The conclusions on the supporting principles are particularly difficult to relate to the existing studies. The only study to provide some basis for comparison is Storhagen's. The supporting principles are reflected in Storhagen's process factors. The process factors are the base which a company should build on while improving manufacturing. This base is important throughout implementation. This conclusion is in line with the conclusion of the present study. However, due to the lack of differentiation between the various practices associated with the process factors, it is difficult to make comparisons regarding the more exact timing of Team leaders and Vertical information systems.

8.2.4 Third Contribution: Sequential Interdependence - towards Continuous Improvement

The present study, finally, found sequential interdependence between Continuous improvement and the other lean production principles. The sequential interdependence implies Continuous improvement benefits from a foundation to function properly. The foundation consists of multifunctional teams with responsibilities decentralised to them, working with a broad spectrum of tasks in the manufacturing process. This conclusion constitutes the present study's third contribution to existing knowledge.

Two of the existing studies provide a basis for comparing the timing of Continuous improvement:

- Quality circles are part of the operative techniques Roos see as necessary to achieve just-in-time and are important towards the end of implementation. Since the various operative techniques associated with the achievement of just-in-time are not differentiated from each other, difficulties in further interpretation arise. We do not know if quality circles are started early or late relative to other operative techniques.

- An active suggestion scheme is a part of Storhagen's process factors and could be interpreted as being similar to Continuous improvement. However, Storhagen see the suggestion scheme as important early in implementation, which runs contrary to the present study's conclusions.

The comparison with existing studies reveals that Continuous improvement is subject to problems of definition. It is therefore, to emphasise, important to keep in mind the following:

1) The definition of continuous improvement is in the present study different from that often used. Instead of using the term to connote a philosophy, Continuous improvement is here used more in a technique-based fashion.
2) Continuous improvement is in the present study seen as a part of the lean production framework and not as a separate tool for manufacturing improvement.
3) The manufacturing organisation prior to adopting lean production in the empirical case required making structural changes to the manufacturing process.

The implication of the three considerations is mainly that the term "continuous improvement" may be used differently in the present study, compared with existing studies. It is with these differences in mind one must see the present study's contribution to existing knowledge of sequences of improvement initiatives in manufacturing.

8.2.5 The Process View Lies behind the Contribution to Existing Knowledge

Concluding the comparison with existing studies, we find the present study has contributed to existing knowledge of sequences of improvement initiatives in manufacturing. The contention here is that the source of the present study's contribution is the approach taken to the study of sequences. Before developing this argument, however, it is necessary to discuss the difficulties in translating improvement initiatives. The difficulties are related to the lack of consistent terminology for characterising best practice in manufacturing management.

The present study utilises the term "lean production" to characterise best practice in manufacturing management. The result of this definition of improvement initiatives is that the sequences identified in the present study are related to the lean production framework. Although being rather obvious, the relationship between the identified sequences and the chosen framework has implications for the comparison with existing studies.

Since existing studies used different terms, translation was necessary. The translation was difficult, particularly when definitions of improvement initiatives was different or difficult to ascertain. The difficulties in translation were compounded if we consider the differences in research design and the obtained level of detail. A two and a half year longitudinal study in one company produces a level of detail which cannot be matched by surveys or short case studies.

The difference in research design is the source of the present study's contribution to existing knowledge. The approach taken to the inquiry in the present study was to see implementation as a process of adoption. The adoption process was studied through longitudinal and real-time research. Existing studies have either used surveys (Filippini et al., 1998) or short case studies, carried out at one point in time (Roos, 1990; Storhagen, 1993).

The difference in research design particularly helps us understand the present study's contribution regarding the three core principles and the two supporting principles. Both the core and the supporting principles were found to require management effort and resources throughout the whole adoption process. Translating the conclusions to the language of the existing studies, initiatives similar to the core and supporting principles do in the existing studies not require management effort and resources throughout the whole adoption process. The process is instead seen in either of two ways: (a) as consisting of different phases with various content, or (b) as a cumulative move from one set of initiatives to another.

With the process view of implementation taken in the present study, the idea of distinct phases with various content in the adoption process is refuted. Seeing the adoption process as consisting of a cumulative move from one set of initiatives to another, is more in line with the present study's conclusions. The cross-sectional research design of the existing studies unfortunately prevents the drawing of conclusions of the same nature as those possible to draw using a longitudinal and real-time research design. Indeed, the rationale for conducting the present study was the lack of research studying the implementation process through longitudinal and real-time research. With this in mind, the present study is now summarised.

8.3 Sequences in the Process of Adopting Lean Production

The present study set out to examine sequences of manufacturing improvement initiatives. The background was the questioning of the traditional notion of trade-offs between manufacturing capabilities. The basis for questioning the notion of trade-offs is certain Japanese companies' manufacturing management practices (Voss, 1995b). The practices imply that manufacturing capabilities are not the result of trade-offs, but are instead built cumulatively (Ferdows and De Meyer, 1990). The sequence of the initiatives with which manufacturing capabilities are built has, however, received scant attention in literature.

The studies addressing the problem of sequences of Japanese manufacturing management practices increase our knowledge of the subject, but share one weakness - the studies do not take a process view of implementation. A process view implies studying implementation through longitudinal research, as opposed to cross-sectional research (Kimberly, 1976). The present study was designed to fill this gap in knowledge, by studying the process of adopting lean production through longitudinal and real-time research.

The study's perhaps major contribution to existing knowledge is the finding that the adoption of lean production requires management effort and resources being devoted to different principles simultaneously. The present study separated these principles in core and supporting principles. The need to devote management effort and resources to a set of principles throughout the adoption process, is supported by the suggested importance of not seeing individual principles in isolation during implementation (Voss and Robinson, 1987). The conclusion is also supported by the suggestion that every layer of manufacturing capability requires continuous attention, to build lasting improvements in manufacturing performance (Ferdows and De Meyer, 1990).

However, there are also sequences of lean production principles in the adoption process. The present study confirmed the need to devote management effort and resources early in the adoption process to the installation of a quality management system and to delayering the organisation. A quality management system and a flat organisation hierarchy serve as foundations for subsequent improvement of manufacturing capabilities.

The present study also found that a continuous improvement initiative, where multifunctional teams solve problems in a structured manner in their day-to-day work, benefits from a foundation before being launched. The foundation consists of well-developed multifunctional teams with indirect responsibilities transferred to them. The teams work with a broad spectrum of tasks in the manufacturing process. The present study adds to the literature on sequences of improvement initiatives in that continuous improvement is seen, not as a separate improvement tool, but as an integrated principle of lean production.

What do the present study's conclusions imply for the problem of managing the adoption of lean production? An interest in the present study was to provide conclusions with potential practical applicability. When generalising from single cases to the practical arena, to emphasise, the receivers of the information must determine whether or not it applies to their own situation (Kennedy, 1979). What I can do is summarise the conclusions in a succinct and clear manner. The present study set out to examine the patterns of issues in the adoption process, assuming issues were an indication of the effort and resources management had to devote to different principles. In this light, the study's conclusions can be expressed in terms of Figure 8.3.

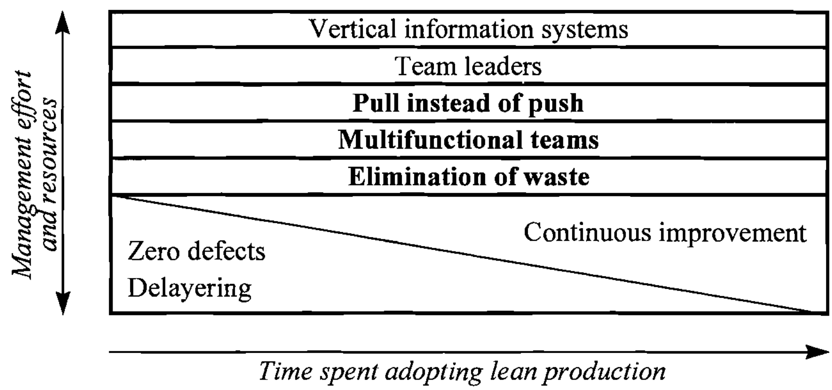

Figure 8.3 Sequences in the Process of Adopting Lean Production

Figure 8.3 illustrates how management devoted effort and resources to different lean production principles during the adoption process. The horizontal dimension represents the time the company spent adopting lean production and the vertical dimension represents management effort and resources. Management effort and resources were initially devoted to three parallel tasks:

1) Laying a foundation for subsequent improvement through delayering the organisation and installing a system for achieving zero defects.
2) Working with a core of principles which meant an elimination of waste, particularly through manufacturing cells, manned by multifunctional teams which were working with a pull production scheduling system.
3) Ensuring the core principles were supported by vertical information systems and team leaders in the multifunctional teams.

As the time spent adopting lean production progressed, Figure 8.3 illustrates how management effort and resources continued to be devoted to the work with the core and supporting principles. However, as the foundation, consisting of zero defects and delayering, had been laid, management devoted effort and resources to the launch of a continuous improvement initiative. The initiative relied on multifunctional teams to solve problems in a structured manner during their day-to-day work. To function properly, the initiative benefited from well-developed multifunctional teams with responsibilities transferred to them, working with a variety of tasks in the manufacturing process.

Finally, it needs to be pointed out that the height of the block representing management effort and resources in Figure 8.3 is not to be interpreted literally. The height is a necessary simplification and the amount of management effort and resources that could be devoted to the adoption of lean production shifted over time. Neither is the limited size of the horizontal dimension to be interpreted literally. Lean production does not have a defined end point, but points out the direction in which a company should move.

8.4 Suggestions for Future Research

Where can research on sequences of improvement initiatives in manufacturing move? There are a number of directions which future research on the problem can take. These directions can be seen against the background of the present study's limitations and contributions. The comparison with operations management literature suggested the present study's conclusions were plausible. However, this is not to say the sequences of lean production principles found in the study are the only plausible sequences. Many factors are likely to have influenced the conclusions. These factors are related to the nature of the empirical case.

First, it is likely the adoption process is affected by the state of existing manufacturing management practices prior to the adoption of lean production. The company in the present study provided an opportunity to study a rather drastic reorganisation. It would be of interest to study the adoption process in companies with other types of starting points, in terms of existing manufacturing management practices.

Second, it is likely the adoption process is affected by the circumstances surrounding the way in which adoption is planned and executed. The company in the present study took a rather long-term approach to the adoption. A company may be in a situation where time is of the essence. When there is an immediate threat to survival, the adoption process may look different. It would be of interest to study the adoption process in companies with different circumstances surrounding the adoption decision.

Third, it is likely the adoption process is affected by the nature of the manufacturing process. The company in the present study manufactures standard products in large volumes. The adoption process may look different in companies in other industries, such as process industries. The adoption process may also look different in companies with a different type of manufacturing process, such as companies manufacturing a high variety of products in low volumes. It would be of interest to study the adoption process in companies from different industries and with different manufacturing processes.

The present study's contribution to existing knowledge also points to areas for future research. The present study's contribution to existing knowledge particularly concerns the existence of a set of core and supporting principles which require management effort and resources throughout the whole adoption process. It would be of interest to determine the external validity of this conclusion through conducting the same type of study in other companies and industries.

A final task for future research is to identify factors affecting the nature of the adoption process. This task calls for a study of adoption processes in more than one company. The studies would ideally take place using a longitudinal and real-time research design. One problem arises here; the demands on time to carry out a number of longitudinal and real-time studies is overwhelming. One solution to the problem of time consumption may be to combine retrospective and real-time research. Another solution may be to follow several cases longitudinally, but with less detail than I did in the present study. I am certainly not the person to repeat the same type of study in several cases.

APPENDIX
List of Issues

The Appendix contains a list of the codes used to code incidents for issues. The codes are given in the form of the label used for the issue and a short description of the issue.

Action	Used to code incidents where actors expressed a need for something being done. Refers more to the need to take action, rather than what was actually done.
Administration	During certain periods of the adoption process, extra administrative employees were added. This practice is contrary to lean production principles and caused discussion in the adoption process.
Administrative worry	Discussions often arose between those responsible for the lean production project and the administrative function, whose main concern was to minimise the impact of productivity losses.
Batch sizes	The reduction of batch sizes in the manufacturing cells encountered several problems, which are indicated by this code.
Blueprints	Blueprints needed revision to enable for operators to carry out quality inspection. The revision was a time consuming task, which created problems in the adoption process.
Board decision	The decision in the company's board was whether or not to continue the adoption of lean production. Discussions on this decision had impact on the adoption process.
Buffers	Refers to the issue of whether or not to have inventory buffers, either in the manufacturing process or when relocating tasks between the company's two sites.

Change master	There were at times a lack of people who drove the adoption of lean production forward. The code was also used in the positive sense of the word, illustrating when the adoption of lean production was driven by someone.
Circuit boards	Whether or not circuit boards should be assembled from components or be out-sourced was part of the discussions on the manufacturing cells created around the summer of 1995.
Comparability	Part of the discussions on the management accounting system. Refers to a need for an ability to compare management accounting data with historical values. The demands on comparability impeded the efforts of finding a new system.
Competence lack	A lack of competence in certain areas of the organisation at times impeded the adoption of lean production.
Complete assembly	In complete assembly, one operator assembles a complete product. Whether or not to have complete assembly was often discussed during the creation of manufacturing cells for one product family.
Computer system	The computer system at times affected the adoption process negatively, since it could not provide the necessary information.
Co-operation	Indicates co-operation problems between operators within a multifunctional team or between different multifunctional teams.
Daily orders	The attempts to manufacture against customer orders in the manufacturing cells met with several problems, indicated by this code.
DFM	Design for manufacturability; the design of the products at times affected attempts to make the manufacturing system leaner.
Energy lack	Managers at times indicated there was a lack of energy to make the necessary changes. The reasons for this lack of energy may have been different.
External input	The code indicates input from external sources on how to solve certain problems. Used when input was requested or received.
Floor space	The aim was to have machines as close to each other as possible in a manufacturing cell. This was often resisted, with reference to a lack of space.

Flow	The issue of creating a manufacturing cell with an efficient material flow. Often emphasised by the production director, although with limited success at times.
Funding	Indicates the influence the agency funding parts of the lean production project had on decisions and actions in the project.
Goal conflict	Concerns the goal conflicts that arose, often between maintaining quality and productivity. Refers to observations at all levels of the organisation.
Group initiatives	Having worked in multifunctional teams for a certain time, operators in the teams started to initiate changes to the manufacturing process, which facilitated the adoption of lean production.
Group size	The size of the multifunctional teams in the manufacturing cells caused problems in the adoption process.
Indirect employees	Around the summer of 1993, indirect tasks had been transferred to the multifunctional teams. It was, however, not possible to reduce the number of indirect employees immediately, which caused problems in the adoption process.
Information	The code was used for incidents indicating that information was being discussed in the adoption process. Was used either when information was requested or when managers had given information to employees.
Involvement	Indicates the involvement of employees in organisational changes, which facilitated the changes.
Kanban	Refers to the issue of whether or not to use a kanban-based system for material control. Also used when the system was being created.
Layout	Used when the layout of the factory was an issue in the adoption process.
Machine need	Refers to issues arising in the work of estimating the need for machines in the manufacturing cells.
Maintenance	The maintenance department played a role in the adoption process. The code particularly indicates the attempts to stall physical layout changes.

Manning	Refers to a need for employees or situations where there were too many employees. Was also used to indicate the selection of employees for different tasks.
Material control	Refers to problems of material control in the manufacturing cells. Was an issue for quite some time; before a system for material control was devised.
Material storage	The problem of storing material in the manufacturing cells was an issue before batch sizes had been lowered.
Management accounting	Used for incidents indicating that the management accounting system, including cost control and productivity measurement, affected the adoption process.
Management involvement	Used when involvement by top managers in the adoption process was requested. Also used to indicate when this involvement had taken place.
Measurement demand	Part of the discussions on the management accounting system. The code was used to indicate different types of demands on the management accounting system, which contributed to the delay in devising a new system.
MRP primacy	Refers to some managers' tendency to put the MRP system in the first hand, which affected the adoption of lean production negatively.
Order situation	The order situation at times affected the adoption process, often in an impeding way, since there was no time left for adopting lean production.
Overload	Used for incidents where managers expressed they had too much to do and lacked resources for working with the adoption of lean production.
Pack material	Refers to the problem of convincing suppliers of packaging material to deliver in smaller batches.
Paperwork	The quality management system created a lot of paperwork, which needed to be dealt with in manufacturing. This disturbed the adoption of lean production.

Pause area	Refers to the creation and appearance of the pause area in the multifunctional teams, a recurring debate in the initial part of the adoption process.
Payment	Indicates that the payment system affected the adoption process.
Payment transition	Many discussions were caused by the transition from the piece-rate system, to a payment system based on the individual's competence and the team's performance.
PDM Project	A project to create a product database management system to keep track of documents associated with products, influenced the adoption process negatively.
PD Schism	Indicates a schism between manufacturing and product development, which affected the adoption of lean production. Also used for other observations where the product development department affected the lean production project's success.
Permanent m/c	Issues concerning the buying and installation of machines dedicated to the manufacture of parts in one manufacturing cell.
Pile of problems	The quality management system, once it was installed, created more work than could be handled. This was due to the emphasis on following up each deviation from specifications.
Pilot project	The use of pilot projects had both negative and positive consequences. The code also refers to the transfer of learning from the pilot projects.
Planning	Used when the work of planning the adoption process was discussed.
Positive feedback	Indicates a need to show positive outcomes of the adoption of lean production and particularly the work with the pilot manufacturing cells. Was also used when positive outcomes supplied new energy to the adoption process.
Production engineering	Problems at times arose as a consequence of the way the production engineering department was structured.
Productivity	Used when the productivity outcome caused turbulence in the lean production project and when there were questions concerning how to measure productivity.

Product structure	Issues associated with the attempts to alter the product structure trees to simplify material flow and lower batch sizes.
Product traceability	The debates concerning the work of creating a system for tracing products, demanded by the quality management system.
Quality inspection	Refers to issues associated with the work of delegating the inspection task to operators.
Quicksand	Management experienced uncertainty over a period of time, since it was difficult to know the effects of the adoption of lean production on operational performance, due to the way the management accounting system operated.
"Relationship"	Is a "dummy" issue, used to relate lean production principles to each other. The code was used when incidents indicated a direct relationship between principles: when activities in different principles affected each other directly.
Relocation	Refers to the issue of moving the production manager's office out on the shop floor, which became an activity and was stalled several times.
Reporting	Multifunctional teams' execution of reporting tasks caused problems, particularly keeping the MRP system up-to-date.
Resistance	Indicates resistance to change. Used when managers themselves indicated that the adoption of lean production was resisted.
Resource lack	When lack of action to adopt lean production was due to a lack of resources.
Schedule slip	Indicates that a previously agreed upon project schedule for various reasons was changed. Also used for discussions on the schedule's appropriateness.
Service units	Used when operations external to the manufacturing cells, such as stamping and hardening, affected the adoption process, and particularly the elimination of waste.
Set-up time reduction	Used for incidents when the need to reduce set-up times was mentioned and where attempts were undertaken to reduce set-up times.

Simplicity	Indicates requests for simplified procedures, for instance in terms of management accounting and vertical information systems.
Sister site	Refers to the turbulence the company's smaller site caused in the adoption process during the autumn of 1993, by not producing efficiently enough.
Social simulation	A tool used for planning the manufacturing cells and to give employees a view of the way of working within a cell. Had positive effects on the adoption process.
Stamping	Operators at the stamping department caused problems, since they resisted the reduction of set-up times.
Supervisors	Used when ex-supervisors had an impact on the adoption process, either positively or negatively.
Task balance	The tasks to be divided between the company's two sites at times caused discussion. The code refers to the, by some managers, expressed need to balance the tasks between the sites.
Task rotation	The issue of making operators rotate among different tasks in the multifunctional teams. Often referred to a lack of rotation, whatever the reason.
Technical problems	Used when technical problems with machines affected the adoption process.
Timing	There were at times a need for timing various activities in the adoption process to each other, for instance training and the usage of the new skills.
TPM	Refers to the use of preventive maintenance and the issues surrounding it.
Training	Used when training of operators was needed or when training was carried out.
Trust	Indicates a lack of trust between different interests in the adoption process. The code was used when actors used the term or similar terms in talking about problems.
Uncertainty	Refers to uncertainties about how the future organisation would look, which is related to fear and worry.

Union	Used to indicate union involvement or influence in the adoption process; either when the influence facilitated or impeded the adoption process.
Visibility	Indicates the quest for making the manufacturing process more visible, to simplify for operators to manage the operation.
Work environment	Refers to incidents indicating the adverse effects on the work environment by the creation of manufacturing cells.
Working hours	The lack of flexibility in operators' working hours was at times brought up by management as an impediment in the adoption process.

References

Abernathy, W. J., Clark, K. B. and Kantrow, A. M. (1981), "The New Industrial Competition", *Harvard Business Review*, September-October, pp. 68-79.

Agar, M. H. (1986), *Speaking of Ethnography*, Sage University Paper series on Qualitative Research Methods, Volume 2, Sage, Beverly Hills, California.

Ainosuke, M. (1989), "Preventive Maintenance", in Nakajima, S. (Ed.), *TPM Development Program: Implementing Total Productive Maintenance*, Productivity Press, Cambridge, Massachusetts, pp. 219-286.

Ansoff, H. I. (1980), "Strategic Issue Management", *Strategic Management Journal*, Vol. 1, pp. 131-148.

Aquilano, N. J. and Chase, R. B. (1991), *Fundamentals of Operations Management*, Irwin, Homewood, Illinois.

Argyris, C. (1968), "Some Unintended Consequences of Rigorous Research", *Psychological Bulletin*, Vol. 70, No. 3, pp. 185-197.

Arogyaswarmy, B. and Simmons, R. P. (1991), "Thriving on Interdependence: The Key to JIT Implementation", *Production and Inventory Management Journal*, Vol. 32, No. 3, pp. 56-60.

Barley, S. R. (1990), "Images of Imaging: Notes on Doing Longitudinal Field Work", *Organization Science*, Vol. 1, No. 3, pp. 220-247.

Becker, H. S. (1958), "Problems of Inference and Proof in Participant Observation", *American Sociological Review*, Vol. 23, pp. 652-660.

Becker, H. S. and Geer, B. (1957), "Participant Observation and Interviewing: A Comparison", *Human Organization*, Vol. 16, No. 3, pp. 28-32.

Berg, C. (1974), *Samrådssystemet: En klinisk undersökning i ett växande företag* (The Participation System: A Clinical Study of a Growing Company. in Swedish), EFI, Stockholm.

Berg, P-O. (1981), *Emotional Structures in Organizations: A Study of the Process of Change in a Swedish Company*, Studentlitteratur, Lund.

Brown, K. A. and Mitchell, T. R. (1991), "A Comparison of Just-in-Time and Batch Manufacturing: The Role of Performance Obstacles", *Academy of Management Journal*, Vol. 34, No. 4, pp. 906-917.

Chen, F. (1991), "Issues in Just-in-Time Implementation: A Survey of Western Michigan Firms", in Satir, A. (Ed.), *Just-in-Time Manufacturing Systems: Operating Planning and Control Issues*, Elsevier, New York, pp. 361-369.

Clark, J., McLoughlin, I., Rose, H. and King, R. (1988), *The Process of Technological Change: New Technology and Social Choice in the Workplace*, Cambridge University Press, Cambridge.

Clark, K. B. (1996), "Competing through Manufacturing and the New Manufacturing Paradigm: Is Manufacturing Strategy Passé?", *Production and Operations Management*, Vol. 5, No. 1, pp. 42-58.

Clark, P. A. and Ford, J. R. (1970), "Methodological and Theoretical Problems in the Investigation of Planned Organisational Change", *Sociological Review*, March, pp. 29-52.

Cole, R. E. (1980a), "Will QC Circles Work in the U.S.?", *Quality Progress*, July, pp. 30-33.

Cole, R. E. (1980b), "Learning from the Japanese: Prospects and Pitfalls", *Management Review*, September, pp. 22-42.

Cole, R. E. (1985), "Target Information for Competitive Performance", *Harvard Business Review*, May-June, pp. 100-109.

Cole, R. E., Bacdayan, P. and White, B. J. (1993), "Quality, Participation, and Competitiveness", *California Management Review*, Spring, pp. 68-81.

Cooper, R. and Kaplan, R. S. (1988), "Measure Costs Right: Make the Right Decisions", *Harvard Business Review*, September-October, pp. 96-103.

Corbett, C. and Van Wassenhove, L. (1993), "Trade-offs? What Trade-offs? Competence and Competitiveness in Manufacturing Strategy", *California Management Review*, Summer, pp. 107-122.

Cusumano, M. A. (1988), "Manufacturing Innovation: Lessons from the Japanese Auto Industry", *Sloan Management Review*, Fall, pp. 29-39.

Cyert, R. M. and March, J. G. (1992), *A Behavioral Theory of the Firm* (Second Edition), Blackwell, Oxford.

Czarniawska-Joerges, B. (1992), *Exploring Complex Organizations: A Cultural Perspective*, Sage, Newbury Park, California.

Czarniawska-Joerges, B. (1993), *The Three-Dimensional Organization: A Constructionist View*, Studentlitteratur, Lund.

Daft, R. L. (1983), "Learning the Craft of Organizational Research", *Academy of Management Review*, Vol. 8, No. 4, pp. 539-546.

Daniel, W. W. (1990), *Applied Nonparametric Statistics* (Second Edition), PWS-KENT, Boston, Massachusetts.

Dawson, P. (1994), *Organizational Change: A Processual Approach*, Paul Chapman, London.

Dean, J. W. Jr. and Bowen, D. E. (1994), "Management Theory and Total Quality: Improving Research and Practice through Theory Development", *Academy of Management Review*, Vol. 19, No. 3, pp. 392-418.

Diesing, P. (1991), *How Does Social Science Work? Reflections on Practice*, University of Pittsburgh Press, Pittsburgh, Pennsylvania.

Duimering, P. R. and Safayeni, F. (1991), "A Study of Organizational Impact of the Just-in-Time Production System", in Satir, A. (Ed.), *Just-in-Time Manufacturing Systems: Operating Planning and Control Issues*, Elsevier, New York, pp. 19-31.

Dutton, J. E. and Dukerich, J. M. (1991), "Keeping an Eye on the Mirror: Image and Identity in Organizational Adaptation", *Academy of Management Journal*, Vol. 34, No. 3, pp. 517-554.

Dutton, J. E., Fahey, L. and Narayanan, V. K. (1983), "Toward Understanding Strategic Issue Diagnosis", *Strategic Management Journal*, Vol. 4, pp. 307-323.

Dutton, J. E. and Ottensmeyer, E. (1987), "Strategic Issue Management Systems: Forms, Functions, and Contexts", *Academy of Management Review*, Vol. 12, No. 2, pp. 355-365.

Eisenhardt, K. M. (1989), "Building Theories from Case Study Research", *Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.

Emory, C. W. and Cooper, D. R. (1991), *Business Research Methods* (Fourth Edition), Irwin, Homewood, Illinois.

Ferdows, K. and De Meyer, A. (1990), "Lasting Improvements in Manufacturing Performance: In Search of a New Theory", *Journal of Operations Management*, Vol. 9, No. 2, pp. 168-184.

Filippini, R., Forza, C. and Vinelli, A. (1997), "Sequences of Operational Improvement: Some Empirical Evidences", *International Journal of Operations and Production Management*, Forthcoming.

Flanagan, J. C. (1954), "The Critical Incident Technique", *Psychological Bulletin*, Vol. 51, No. 4, pp. 327-358.

Flynn, E. J., Flynn, B. B. and Schroeder, R. G. (1989), *World Class Manufacturing: Theoretical Foundation and Strategic Implications*, Working Paper 89-18, Department of Operations and Management Science, Curtis L. Carlson School of Management, University of Minnesota, Minneapolis, Minnesota.

Garud, R. and Van de Ven, A. H. (1992), "An Empirical Evaluation of the Internal Corporate Venturing Process", *Strategic Management Journal*, Vol. 13, pp. 93-109.

Garvin, D. A. (1984), "What Does 'Product Quality' Really Mean?", *Sloan Management Review*, Vol. 26, No. 1, pp. 25-43.

Garvin, D. A. (1986), "Quality Problems, Policies, and Attitudes in the United States and Japan: An Exploratory Study", *Academy of Management Journal*, Fall, pp. 653-673.

Garvin, D. A. (1988), *Managing Quality: The Strategic and Competitive Edge*, The Free Press, New York.

Giles, E. and Starkey, K. (1988), "The Japanisation of Xerox", *New Technology, Work and Employment*, Vol. 3, No. 2, pp. 125-133.

Giorgi, A. (1994), "A Phenomenological Perspective on Certain Qualitative Research Methods", *Journal of Phenomenological Psychology*, Vol. 25, No. 2, pp. 190-220.

Glaser, B. G. and Strauss, A. L. (1967), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine de Gruyter, New York.

Gomes, R. and Mentzer, J. T. (1988), "A Systems Approach to the Investigation of Just-in-Time", *Journal of Business Logistics*, Vol. 9, No. 2, pp. 71-88.

Gunn, T. G. (1987), *Manufacturing for Competitive Advantage: Becoming a World Class Manufacturer*, Ballinger Publishing, Cambridge, Massachusetts.

Gupta, Y. P. and Ash, D. (1994), "Excellence at Rohm and Haas Kentucky: A Case Study of Work-Team Introduction in Manufacturing", *Production and Operations Management*, Vol. 3, No. 3, pp. 186-200.

Hackman, J. R. and Wageman, R. (1995), "Total Quality Management: Empirical, Conceptual, and Practical Issues", *Administrative Science Quarterly*, Vol. 40, No. 2, pp. 309-342.

Hall, R. W. (1983), *Zero Inventories*, Dow Jones-Irwin, Homewood, Illinois.

Harber, D., Samson, D. A., Sohal, A. S. and Wirth, A. (1990), "Just-in-Time: The Issue of Implementation", *International Journal of Operations and Production Management*, Vol. 10, No. 1, pp. 21-30.

Hart, H., Berger, A. and Lindberg, P. (1996), *Ständiga förbättringar: Ännu ett verktyg eller en del av arbetet i målstyrda grupper?* (Continuous Improvement: Yet Another Tool or a Part of the Work in Goal Orientated Teams? in Swedish), Arbetslivsinstitutet, Solna.

Hayes, R. H. (1981), "Why Japanese Factories Work", *Harvard Business Review*, July-August, pp. 57-66.

Hayes, R. H. and Clark, K. B. (1986), "Why Some Factories are More Productive Than Others", *Harvard Business Review*, September-October, pp. 66-73.

Hayes, R. H. and Pisano, G. P. (1994), "Beyond World-Class: The New Manufacturing Strategy", *Harvard Business Review*, January-February, pp. 77-86.

Hayes, R. H. and Pisano, G. P. (1996), "Manufacturing Strategy: At the Intersection of Two Paradigm Shifts", *Production and Operations Management*, Vol. 5, No. 1, pp. 25-41.

Hayes, R. H., Wheelwright, S. C. and Clark, K. B. (1988), *Dynamic Manufacturing: Creating the Learning Organization*, The Free Press, New York.

Hickman, A. (1996), "Best North East Factory: Thorn Lighting", in Whitford, B. and Bird, R. (Eds.), *The Pursuit of Quality*, Beaumont Publishing, Hemel Hempstead, pp. 316-327.

Hill, T. J. (1995), *Manufacturing Strategy: Text and Cases*, MacMillan, London.

Hinterhuber, H. H. (1994), "The European Way to Lean Management", *The International Executive*, Vol. 36, No. 3, pp. 275-290.

Homans, G. C. (1949), "The Strategy of Industrial Sociology", *American Journal of Sociology*, Vol. 54, pp. 330-337.

Huber, V. L. and Hyer, N. L. (1985), "The Human Factor in Cellular Manufacturing", *Journal of Operations Management*, Vol. 5, No. 2, pp. 213-228.

Huberman, A. M. and Miles, M. B. (1983), "Drawing Valid Meaning from Qualitative Data: Some Techniques of Data Reduction and Display", *Quality and Quantity*, Vol. 17, pp. 281-339.

Huq, F. (1992), "Labor Issues in the Implementation of Group Technology Cellular Manufacturing", *Production and Inventory Management Journal*, Vol. 33, No. 4, pp. 15-19.

Hyer, N. L. and Wemmerlöv, U. (1984), "Group Technology and Productivity", *Harvard Business Review*, July-August, pp. 140-149.

Im, J. H. and Lee, S. M. (1989), "Implementation of Just-in-Time Systems in US Manufacturing Firms", *International Journal of Operations and Production Management*, Vol. 9, No. 1, pp. 5-14.

Imai, M. (1986), *Kaizen: The Key to Japan's Competitive Success*, McGraw-Hill, New York.

Inman, R. A. and Mehra, S. (1989), "Potential Union Conflict in JIT Implementation?", *Production and Inventory Management Journal*, Vol. 30, No. 4, pp. 19-21.

Jackson, S. E. and Dutton, J. E. (1988), "Discerning Threats and Opportunities", *Administrative Science Quarterly*, Vol. 33, No. 3, pp. 370-387.

Jaques, E. (1951), *The Changing Culture of a Factory: A Study of Authority and Participation in an Industrial Setting*, Tavistock, London.

Johansen, P. and McGuire, K. J. (1986), "A Lesson in SMED With Shigeo Shingo", *Industrial Engineering*, October, pp. 26-33.

Johnson, H. T. and Kaplan, R. S. (1987), *Relevance Lost: The Rise and Fall of Management Accounting*, Harvard Business School Press, Boston, Massachusetts.

Kanter, R. M., Stein, B. A. and Jick, T. D. (1992), "The 'Big Three' Model of Change", in Kanter, R. M., Stein, B. A. and Jick, T. D. (Eds.), *The Challenge of Organizational Change: How Companies Experience It and Leaders Guide It,* The Free Press, New York, pp. 3-19.

Kaplan, R. S. (1983), "Measuring Manufacturing Performance: A New Challenge for Managerial Accounting Research", *The Accounting Review*, Vol. 58, No. 4, pp. 686-705.

Kaplan, R. S. (1984), "Yesterday's Accounting Undermines Production", *Harvard Business Review*, July-August, pp. 95-101.

Kaplan, R. S. and Norton, D. P. (1992), "The Balanced Scorecard: Measures that Drive Performance", *Harvard Business Review*, January-February, pp. 71-79.

Karlsson, C. (1992), "Knowledge and Material Flow in Future Industrial Networks", *International Journal of Operations and Production Management*, Vol. 12, Nos. 7/8, pp. 10-23.

Karlsson, C. (1996), "Radically New Production Systems", *International Journal of Operations and Production Management*, Vol. 16, No. 11, pp. 8-19.

Karlsson, C. and Åhlström, P. (1995), "Change Processes towards Lean Production: The Role of the Remuneration System", *International Journal of Operations and Production Management*, Vol. 15, No. 11, pp. 80-99.

Karlsson, C. and Åhlström, P. (1996a), "Assessing Changes towards Lean Production", *International Journal of Operations and Production Management*, Vol. 16, No. 2, pp. 24-41.

Karlsson, C. and Åhlström, P. (1996b), "The Difficult Path to Lean Product Development", *Journal of Product Innovation Management*, Vol. 13, No. 4, pp. 283-295.

Karlsson, C. and Åhlström, P. (1997), "Perspective: Changing Product Development Strategy: A Managerial Challenge", *Journal of Product Innovation Management*, Vol. 14, No. 6.

Karmarkar, U. (1989), "Getting Control of Just-in-Time", *Harvard Business Review*, September-October, pp. 122-131.

Kennedy, M. M. (1979), "Generalizing from Single Case Studies", *Evaluation Quarterly*, Vol. 3, No. 4, pp. 661-678.

Kimberly, J. R. (1976), "Issues in the Design of Longitudinal Organizational Research", *Sociological Methods and Research*, Vol. 4, No. 3, pp. 321-347.

Kirk, J. and Miller, M. L. (1986), *Reliability and Validity in Qualitative Research*, Sage, Beverly Hills, California.

Kotter, J. P. and Schlesinger, L. A. (1979), "Choosing Strategies for Change", *Harvard Business Review*, March-April, pp. 106-114.

Krafcik, J. F. (1988a), *Comparative Analysis of Performance Indicators at World Auto Assembly Plants* (Masters Thesis), Massachusetts Institute of Technology, Cambridge, Massachusetts.

Krafcik, J. F. (1988b), "Triumph of the Lean Production System", *Sloan Management Review*, Fall, pp. 41-52.

Lee, S. M. and Ebrahimpour, M. (1984), "Just-in-Time Production System: Some Requirements for Implementation", *International Journal of Operations and Production Management*, Vol. 4, No. 4, pp. 3-15.

Leonard-Barton, D. (1988), "Implementation Characteristics of Organizational Innovation: Limits and Opportunities for Management Strategies", *Communication Research*, Vol. 15, No. 5, pp. 603-631.

Leonard-Barton, D. (1990), "A Dual Methodology for Case Studies: Synergistic Use of a Longitudinal Single Site With Replicated Multiple Sites", *Organization Science*, Vol. 1, No. 1, pp. 248-266.

Leonard-Barton, D. (1991), "The Role of Process Innovation and Adaptation in Attaining Strategic Technological Capability", *International Journal of Technology Management, Special Issue on Manufacturing Strategy*, Vol. 6, Nos. 3/4, pp. 303-320.

Leonard-Barton, D. (1992), "The Factory as a Learning Laboratory", *Sloan Management Review*, Fall, pp. 23-38.

Lowe, J. (1993), "Manufacturing Reform and the Changing Role of the Production Supervisor: The Case of the Automobile Industry", *Journal of Management Studies*, Vol. 30, No. 5, pp. 739-758.

Martin, P. Y. and Turner, B. A. (1986), "Grounded Theory and Organizational Research", *The Journal of Applied Behavioral Science*, Vol. 22, No. 2, pp. 141-157.

Miles, M. B. (1979), "Qualitative Data as an Attractive Nuisance: The Problem of Analysis", *Administrative Science Quarterly*, Vol. 24, No. 4, pp. 590-601.

Miles, M. B. and Huberman, A. M. (1984), *Qualitative Data Analysis: A Sourcebook of New Methods*, Sage, Beverly Hills, California.

Miller, D. and Friesen, P. H. (1982), "The Longitudinal Analysis of Organizations: A Methodological Perspective", *Management Science*, Vol. 28, No. 9, pp. 1013-1034.

Miller, D. and Mintzberg, H. (1983), "The Case for Configuration", in Morgan, G. (Ed.), *Beyond Method: Strategies for Social Research*, Sage, Newbury Park, California, pp. 57-73.

Miller, J. G. and Vollmann, T. E. (1985), "The Hidden Factory", *Harvard Business Review*, September-October, pp. 142-150.

Monden, Y. (1981a), "What Makes the Toyota Production System Really Tick?", *Industrial Engineering*, January, pp. 36-46.

Monden, Y. (1981b), "Adaptable Kanban System Helps Toyota Maintain Just-in-time Production", *Industrial Engineering*, May, pp. 29-46.

Monden, Y. (1981c), "Smoothed Production Lets Toyota Adapt to Demand Changes and Reduce Inventory", *Industrial Engineering*, August, pp. 41-51.

Monden, Y. (1981d), "How Toyota Shortened Supply Lot Production Time, Waiting Time and Conveyance Time", *Industrial Engineering*, September, pp. 22-30.

Monden, Y. (1983), *Toyota Production System: Practical Approach to Production Management*, Industrial Engineering and Management Press, Atlanta, Georgia.

Morgan, G. (1983a), “Research as Engagement: A Personal View”, in Morgan, G. (Ed.), *Beyond Method: Strategies for Social Research*, Sage, Newbury Park, California, pp. 11-18.

Morgan, G. (1983b), “Research Strategies: Modes of Engagement”, in Morgan, G. (Ed.), *Beyond Method: Strategies for Social Research*, Sage, Newbury Park, California, pp. 19-42.

Morgan, G. and Smircich, L. (1980), “The Case for Qualitative Research”, *Academy of Management Review*, Vol. 5, No. 4, pp. 491-500.

Nakajima, S. (1989), “An Introduction to TPM”, in Nakajima, S. (Ed.), *TPM Development Program: Implementing Total Productive Maintenance*, Productivity Press, Cambridge, Massachusetts, pp. 1-26.

Nakane, J. and Hall, R. W. (1983), “Management Specs for Stockless Production”, *Harvard Business Review*, May-June, pp. 84-91.

Noble, M. A. (1995), “Manufacturing Strategy: Testing the Cumulative Model in a Multiple Country Context”, *Decision Sciences*, Vol. 26, No. 5, pp. 693-721.

Normann, R. (1980), *A Personal Quest for Methodology* (Fourth Edition), SIAR Dokumentation, Stockholm.

Oakland, J. S. (1993), *Total Quality Management: The Route to Improving Performance* (Second Edition), Butterworth-Heinemann, Oxford.

Oliver, N. (1990), “Human Factors in the Implementation of Just-in-Time Production”, *International Journal of Operations and Production Management*, Vol. 10, No. 4, pp. 32-40.

Oliver, N. and Davies, A. (1990), “Adopting Japanese-Style Manufacturing Methods: A Tale of Two (UK) Factories”, *Journal of Management Studies*, Vol. 27, No. 5, pp. 555-570.

Oliver, N., Delbridge, R., Jones, D. and Lowe, J. (1994), “World Class Manufacturing: Further Evidence in the Lean Production Debate”, *British Journal of Management*, Vol. 5, Special Issue, pp. S53-S63.

Pepper, S. C. (1942), *World Hypotheses*, University of California Press, Berkeley, California.

Pettigrew, A. M. (1985), “Contextualist Research and the Study of Organisational Change Processes”, in Mumford, E. et al. (Eds.), *Research Methods in Information Systems*, North Holland, Amsterdam, pp. 53-78.

Pettigrew, A. M. (1990), “Longitudinal Field Research on Change: Theory and Practice”, *Organization Science*, Vol. 1, No. 3, pp. 267-292.

Pouraghabagher, R. and Young, A. H. (1991), "Applications of Just-in-Time Manufacturing Concepts at Northern Telecom (Canada): Emphasis on Human Factors Issues", in Satir, A. (Ed.), *Just-in-Time Manufacturing Systems: Operating Planning and Control Issues*, Elsevier, New York, pp. 45-57.

Rapoport, R. N. (1970), "Three Dilemmas in Action Research", *Human Relations*, Vol. 23, pp. 499-513.

Robinson, A. G. and Schroeder, D. M. (1990), "The Limited Role of Statistical Quality Control in a Zero Defect Environment", *Production and Inventory Management Journal*, Vol. 31, No. 3, pp. 60-65.

Robinson, A. G. and Schroeder, D. M. (1992), "Detecting and Eliminating Invisible Waste", *Production and Inventory Management Journal*, Vol. 33, No. 4, pp. 37-42.

Roos, L-U. (1990), *Japanisering inom produktionssystem: Några fallstudier av Total Quality Management i brittisk tillverkningsindustri*, (Japanization in Production Systems: Some Case Studies of Total Quality Management in British Manufacturing Industry. in Swedish), Handelshögskolan vid Göteborgs Universitet, Göteborg.

Safayeni, F. and Purdy, L. (1991), "A Behavioral Case Study of Just-in-Time Implementation", *Journal of Operations Management*, Vol. 10, No. 2, pp. 213-228.

Safayeni, F., Purdy, L., van Engelen, R. and Pal, S. (1991), "Difficulties of Just-in-Time Implementation: A Classification Scheme", *International Journal of Operations and Production Management*, Vol. 11, No. 7, pp. 27-36.

Sanday, P. R. (1979), "The Ethnographic Paradigm(s)," *Administrative Science Quarterly*, Vol. 24, No. 4, pp. 527-538.

Schein, E. H. (1987), *The Clinical Perspective in Fieldwork*, Sage, Newbury Park, California.

Schonberger, R. J. (1982a), *Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity*, The Free Press, New York.

Schonberger, R. J. (1982b), "Some Observations on the Advantages and Implementation Issues of Just-in-Time Production Systems", *Journal of Operations Management*, Vol. 3, No. 1, pp. 1-11.

Schonberger, R. J. (1986), *World Class Manufacturing: The Lessons of Simplicity Applied*, The Free Press, New York.

Schroeder, D. M. and Robinson, A. G. (1991), "America's Most Successful Export to Japan: Continuous Improvement Programs", *Sloan Management Review*, Spring, pp. 67-81.

Schwartz, M. S. and Schwartz, C. G. (1955), "Problems in Participant Observation", *American Journal of Sociology*, Vol. 60, pp. 343-353.

Schön, D. A. (1983), "Organizational Learning", in Morgan, G. (Ed.), *Beyond Method: Strategies for Social Research*, Sage, Newbury Park, California, pp. 114-128.

Scott, W. R. (1965), "Field Methods in the Study of Organizations", in March, J. G. (Ed.), *Handbook of Organizations*, Rand McNally, Chicago, Illinois, pp. 261-304.

Sexton, C. (1994), "Self-Managed Work Teams: TQM Technology at the Employee Level", *Journal of Organizational Change Management*, Vol. 7, No. 2, pp. 45-52.

Shadur, M. A. and Bamber, G. J. (1994), "Toward Lean Management? International Transferability of Japanese Management Strategies to Australia", *The International Executive*, Vol. 36, No. 3, pp. 343-364.

Shingo, S. (1981), *A Study of the Toyota Production System from an Industrial Engineering Viewpoint*, Productivity Press, Cambridge, Massachusetts.

Shingo, S. (1985), *A Revolution in Manufacturing: The SMED System*, Productivity Press, Cambridge, Massachusetts.

Silverman, D. (1993), *Interpreting Qualitative Data*, Sage, London.

Simon, H. A. (1991), "Bounded Rationality and Organizational Learning", *Organization Science*, Vol. 2, No. 1, pp. 125-134.

Skinner, W. (1969), "Manufacturing: Missing Link in Corporate Strategy", *Harvard Business Review*, May-June, pp. 136-145.

Skinner, W. (1974), "The Focused Factory", *Harvard Business Review*, May-June, pp. 113-121.

Skivington, J. E. and Daft, R. L. (1991), "A Study of Organizational 'Framework' and 'Process' Modalities for the Implementation of Business-Level Strategic Decisions", *Journal of Management Studies*, Vol. 28, No.1, pp. 45-68.

Smircich, L. (1983), "Studying Organizations as Cultures", in Morgan, G. (Ed.), *Beyond Method: Strategies for Social Research*, Sage, Newbury Park, California, pp. 160-172.

Sofer, C. (1961), *The Organization from within: A Comparative Study of Social Institutions Based on a Sociotherapetuic Approach*, Tavistock, London.

Spencer, L. and Dale, A. (1979), "Integration and Regulation in Organizations: A Contextual Approach", *Sociological Review*, Vol. 27, No. 4, pp. 679-702.

Staw, B. M. (1975), "Attribution of 'Causes' of Performance: A General Alternative Interpretation of Cross-Sectional Research on Organizations", *Organizational Behavior and Human Performance*, Vol. 13, pp. 414-432.

Stjernberg, T. (1977), *Organizational Change and Quality of Life*, EFI, Stockholm.

Storhagen, N. G. (1993), *Management och flödeseffektivitet i Japan och Sverige,* (Management and Flow Efficiency in Japan and Sweden. in Swedish), Linköping University, Linköping.

Strauss, A. and Corbin, J. (1990), *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*, Sage, Newbury Park, California.

Stymne, B. (1970), *Values and Processes: A Systems Study of Effectiveness in Three Organizations*, Studentlitteratur, Lund.

Sugimori, Y., Kusunoki, K., Cho, F. and Uchikawa, S. (1977), "Toyota Production System and Kanban System: Materialization of Just-in-Time and Respect-for-Human system", *International Journal of Production Research*, Vol. 15, No. 6, pp. 553-564.

Symons, R. T. and Jacobs, R. A. (1995), "A Total Quality Management-Based Incentive System Supporting Total Quality Management Implementation", *Production and Operations Management*, Vol. 4, No. 3, pp. 228-241.

Taylor, F. W. (1911), *The Principles of Scientific Management*, Harper and Row, New York.

Thompson, J. D. (1967), *Organizations in Action: Social Science Bases of Administrative Theory*, McGraw-Hill, New York.

Turnbull, P. J. (1986), "The 'Japanisation' of Production and Industrial Relations at Lucas Electrical", *Industrial Relations Journal*, Vol. 17, No. 3, pp. 193-206.

Turnbull, P. J. (1988), "The Limits to 'Japanisation': Just-in-Time, Labour Relations and the UK Automotive Industry", *New Technology, Work and Employment*, Vol. 3, No. 1, pp. 7-20.

Turner, B. A. (1981), "Some Practical Aspects of Qualitative Data Analysis: One Way of Organising the Cognitive Processes Associated With the Generation of Grounded Theory", *Quality and Quantity*, Vol. 15, pp. 225-247.

Turner, B. A. (1983), "The Use of Grounded Theory for the Qualitative Analysis of Organizational Behaviour", *Journal of Management Studies*, Vol. 20, No. 3, pp. 333-348.

Van de Ven, A. H. (1993), "An Assessment of Perspectives on Strategic Change", in Zan, L., Zambon, S. and Pettigrew, A. M. (Eds.), *Perspectives on Strategic Change*, Kluwer Academic Press, Dordrecht, pp. 313-325.

Van de Ven, A. H. and Huber, G. P. (1990), "Longitudinal Field Research Methods for Studying Processes of Organizational Change", *Organization Science*, Vol. 1, No. 3, pp. 213-219.

Van de Ven, A. H. and Poole, M. S. (1990), "Methods for Studying Innovation Development in the Minnesota Innovation Research Program", *Organization Science*, Vol. 1, No. 3, pp. 313-335.

Van de Ven, A. H. and Poole, M. S. (1995), "Explaining Development and Change in Organizations", *Academy of Management Review*, Vol. 20, No. 3, pp. 510-540.

Van Maanen, J. (1979), "The Fact of Fiction in Organizational Ethnography", *Administrative Science Quarterly*, Vol. 24, No. 4, pp. 539-550.

Van Maanen, J. (1983), "Epilogue: Qualitative Methods Reclaimed", in Van Maanen, J. (Ed.), *Qualitative Methodology*, Sage, Beverly Hills, California, pp. 247-268.

Voss, C. A. (1984), "Japanese Manufacturing Management Practices in the UK", *International Journal of Operations and Production Management*, Vol. 4, No. 2, pp. 31-38.

Voss, C. A. (1988), "Implementation: A Key Issue in Manufacturing Technology: The Need for a Field of Study", *Research Policy*, Vol. 17, pp. 53-63.

Voss, C. A. (1995a), "Operations Management: From Taylor to Toyota: And Beyond?", *British Journal of Management*, Vol. 6, Special issue, pp. S17-S29.

Voss, C. A. (1995b), "Alternative Paradigms for Manufacturing Strategy", *International Journal of Operations and Production Management*, Vol. 15, No. 4, pp. 5-16.

Voss, C. A., Blackmon, K., Hanson, P. and Oak, B. (1995), "The Competitiveness of European Manufacturing: A Four Country Study", *Business Strategy Review*, Vol. 6, No. 1, pp. 1-25.

Voss, C. A. and Robinson, S. J. (1987), "Application of Just-in-Time Manufacturing Techniques in the United Kingdom", *International Journal of Operations and Production Management*, Vol. 7, No. 4, pp. 46-52.

Weick, K. E. (1979), *The Social Psychology of Organizing* (Second Edition), McGraw-Hill, New York.

Wheelwright, S. C. (1981), "Japan: Where Operations Really are Strategic", *Harvard Business Review*, July-August, pp. 67-74.

Wheelwright, S. C. (1984), "Manufacturing Strategy: Defining the Missing Link", *Strategic Management Journal*, Vol. 5, pp. 77-91.

Wheelwright, S. C. (1985), "Restoring the Competitive Edge in U.S. Manufacturing", *California Management Review*, Spring, pp. 26-42.

Wheelwright, S. C. and Bowen, H. K. (1996), "The Challenge of Manufacturing Advantage", *Production and Operations Management*, Vol. 5, No. 1, pp. 59-77.

Womack, J. P. and Jones, D. T. (1994), "From Lean Production to the Lean Enterprise", *Harvard Business Review*, March-April, pp. 93-103.

Womack, J. P. and Jones, D. T. (1996), *Lean Thinking: Banish Waste and Create Wealth in your Corporation*, Simon and Schuster, New York.

Womack, J. P., Jones, D. T. and Roos, D. (1990), *The Machine that Changed the World*, Rawson Associates, New York.

Yin, R. K. (1989), *Case Study Research: Design and Methods* (Revised Edition), Sage, London.

Young, S. M. (1992), "A Framework for Successful Adoption and Performance of Japanese Manufacturing Practices in the United States", *Academy of Management Review*, Vol. 17, No. 4, pp. 677-700.

Zelditch, M. Jr. (1962), "Some Methodological Problems of Field Studies", *American Journal of Sociology*, Vol. 67, pp. 566-576.

Zipkin, P. H. (1991), "Does Manufacturing Need a JIT Revolution?", *Harvard Business Review*, January-February, pp. 40-50.

Åhlström, P. and Karlsson, C. (1996), "Change Processes towards Lean Production: The Role of the Management Accounting System", *International Journal of Operations and Production Management*, Vol. 16, No. 11, pp. 42-56.

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1996

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1997

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