337 VTT PUBLICATIONS

Raimo Hyötyläinen

Implementation of technical change as organizational problem-solving process

Management and user activities

TECHNICAL RESEARCH CENTRE OF FINLAND ESPOO 1998

VTT PUBLICATIONS 337

IMPLEMENTATION OF TECHNICAL CHANGE AS ORGANIZATIONAL PROBLEM-SOLVING PROCESS
MANAGEMENT AND USER ACTIVITIES

Raimo Hyötyläinen

VTT Automation

Dissertation for the degree of Doctor of Technology to be presented with due permission for public examination and debate in Auditorium K216 at Helsinki University of Technology (Otakaari 4, Espoo, Finland) on the 20th of March 1998, at 12 o´clock noon.

TECHNICAL RESEARCH CENTRE OF FINLAND
ESPOO 1998

ISBN 951–38–5216–4 (soft back ed.)
ISSN 1235–0621 (soft back ed.)

ISBN 951–38–6687–4 (URL:http://www.vtt.fi/inf/pdf/)
ISSN 1455–0849 (URL:http://www.vtt.fi/inf/pdf/)

JULKAISIJA – UTGIVARE – PUBLISHER

Valtion teknillinen tutkimuskeskus (VTT), Vuorimiehentie 5, PL 2000, 02044 VTT
puh. vaihde (09) 4561, faksi (09) 456 4374

Statens tekniska forskningscentral (VTT), Bergsmansvägen 5, PB 2000, 02044 VTT
tel. växel (09) 4561, fax (09) 456 4374

Technical Research Centre of Finland (VTT), Vuorimiehentie 5, P.O.Box 2000, FIN–02044 VTT, Finland
phone internat. + 358 9 4561, fax + 358 9 456 4374

VTT Automaatio, Teollisuusautomaatio, Otakaari 7 B, PL 1301, 02044 VTT
puh. vaihde (09) 4561, faksi (09) 456 6475

VTT Automation, Industriautomation, Otsvängen 7 B, PB 1301, 02044 VTT
tel. växel (09) 4561, fax (09) 456 6475

VTT Automation, Industrial Automation, Otakaari 7 B, P.O.Box 1301, FIN–02044 VTT, Finland
phone internat. + 358 9 4561, fax + 358 9 456 6475

Technical editing Leena Ukskoski

LIBELLA PAINOPALVELU OY

Hyötyläinen, Raimo. Implementation of technical change as organizational problem-solving process. Management and user activities. Espoo 1998,Technical Research Centre of Finland, VTT Publications 337. 238 p. + app. 12 p.

UDC 65.01:65.011.8
Keywords technical change, technical progress, innovations, FMS, problem solving

ABSTRACT

During the last two decades the growing innovation and management research has paid attention to the aspects of technical change. However, there are differing assumptions about the nature of the process of change. According to the innovation design dilemma two categories of innovation related to technical change have been identified, technical and organizational innovation. It has been become evident that there is a growing need to unite these two types of innovation into a common approach.

The focus of the study is the planning and implementation process of technical change in the user organization. The aim is to find out what kinds of planning and implementation models, methods and organizational forms can further innovative and organizational problem-solving activity in the implementation process of technical systems, which is contributing to the success of this process.

The study is based on long term and intensive development and research activity concerning the implementation process of three Flexible Manufacturing Systems in two companies. The FMS-study began in 1985 and was completed in 1992. Through the developmental approach based on experimental development research, the study was able to specify in great detail the progress of the implementation process in the cases. Attention was paid to social activity of the implementation process. The issue is how and by whom new techno-organizational solutions are finally brought about and carried out inside the user organization. New training, planning, organization and development methods were introduced and experimented with in the intensive cases, which created a rich and real picture of development potentials of the organization.

The analysis of the case study results showed that the implementation process of technical change consisted of *a series of problem-solving and development steps* taken by the user organization and its actors. This was a controversial, complex and long process in which the management, planners, support persons and users with different interests and ways of acting designed and constructed, mainly in a *step by step* way, the concrete technical and organizational characteristics of the "activity system". This was performed by solving planned and unanticipated problems that

emerged during the definition of the innovation problem and goal setting, planning phase, implementation phase and operation phase.

The *system model* of the implementation process of technical change was created based on the analysis and evaluation of the case study results. The model presents in great detail the connections and relations between the results of the implementation process in the cases and the management´s and users´ ways of acting with their many dependencies and interactions.

According to the system model of the implementation process, the most important factors from the point of view of the success or failure of the results are the following elements: viewpoint on the nature of change; design concept; and organizational patterns. The relations of these elements are described by the *development model* of the implementation process of technical change. The development model is further specified and presented as a solution to the innovation design dilemma.

The case study results proved that the *organizational patterns* carried the most central role in explaining the results of the implementation process. They determined the quality of the problem-solving process in the planning process, implementation phase and "normal" operation phase through which the results were gained. In the cases, the roles of support persons and users, the users´ way of working, actions of the management, co-operation patterns and the use of systematic methods were the factors which contributed mostly to successful results.

In the study, *three planning and implementation models* (techno-centric model, user-centered model, and lean production model) were chosen as the organizational patterns by which the organizational practices of the cases were studied. Comparative analysis of the activities of the management and users showed that the ways of acting in the cases were characterized mainly by the "techno-centric" and "user-centered" models. However, some features could be seen as practices in accordance with the "lean production" model.

The case studies demonstrated that the adoption of new kinds of planning and implementation practices was a controversial process. The planning and implementation process can be seen to form an *"experimental field"* where the difficulties, set-backs and good results experienced may act as a ground for learning and seeking new planning practices, implementation models and management approaches.

PREFACE

The issue of technology has been interesting for me from the times of my engineering studies. In my experience, the teaching given in engineering education focused only on pieces of knowledge of technology. The emphasis was on different tools and on separate “tricks” of how to solve different problems occurring in theory and practice. Historical and holistic approaches were missing. That was one reason for my graduating also in social science, namely in sociology and social and economic history.

Only when I started at VTT Automation at the end of 1984, did it become possible for me to do research on technical change. This study is based on the long term research activity which covered the years 1985 - 1992. The FMS-study was done in the research group which included Leena Norros, PhD, Kari Toikka, M.A., Risto Kuivanen, PhD and myself. Also Pentti Seppälä, PhD participated during the first years of the study. The collaboration created an inspiring ground for developing new kinds of approaches. The members of the research group deserve full recognition and my gratitude for many ideas and results which are a basis for the study.

From the end of 1991 onwards for several years I participated in a large Finnish research program, where I worked closely with the research group where Tuomo Alasoini, PhD, Kari Toikka, M.A, Jyrki Kiviniitty, MSc, Pentti Seppälä, PhD, Soili Klemola, MSc, Magnus Simons, MSc and Kaarin Ruuhilehto, PhD also belonged. Also Antti Kasvio, PhD participated in the discussions. This collaboration raised new issues and questions which have been of great importance for my considerations.

Professor Jukka Ranta has read two different manuscripts of the thesis and given valuable advice for directing further work. Associate Professor Keijo Räsänen has been acquainted with the manuscript and has opened for me some crucial approaches that have had an especially great effect on the final structure of the thesis.

When I was finishing the conclusions of the thesis I had interesting discussions with Rauno Heinonen, PhD and Magnus Simons, MSc. I tested my ideas with them, and I got some additional viewpoints.

I wish to thank Leena Arpiainen, M.A., for proof-reading the English version and suggesting linguistic improvements.

For the financial support received for this thesis, I would like to express my gratitude to The Finnish Work Environment Fund and to Antti and Jenny Wihuri Foundation.

My deepest thanks are reserved for my family; my wife Helena and our daughter Kukka.

Espoo, February 1998

Raimo Hyötyläinen

CONTENTS

1 INTRODUCTION

1.1 INNOVATION DESIGN DILEMMA

The implementation of technical change in industrial production is a major challenge and source of problems in today´s working life. Many studies have shown that companies seem to have great difficulties in efficient organization of the implementation of new technical systems (see, e.g., Köhler & Schultz-Wildt 1985; Sorge et al. 1985; Blumberg & Gerwin 1985; Jaikumar 1986; Boer et al. 1990; Boer & Krabbendam 1992; Lindberg 1992; Small & Yasin 1997). The literature about failures and successes in the implementation of new technical systems often refers to three factors complicating or even blocking the benefits linked to a new system. Various economic difficulties, technical problems and problems in adjusting the work organization are often mentioned as such factors. Less attention has been given to the fourth factor concerning the *planning and implementation process* (Braun 1985; Van de Ven 1986; Voss 1988a and b; Boer 1991; Small & Yasin 1997). The central questions of this study deal with problems in the planning and implementation process of technical change.

Here is the point that can be called an *"innovation design dilemma"* (Holbek 1988; Gjerding 1992). Two kinds of innovation related to technical change have been identified: *technical and organizational innovation*. However, they have mostly been studied separately within the domains of innovation theory and organization theory, respectively. It has become evident that there is a growing need to unite these two types of innovation into a *common approach*.

In this study, the innovation design dilemma is considered to concern the *implementation process* of technical change, from the defining of an innovation problem and the planning of innovation to the implementation of techno-organizational solutions in the user organization (cf. Gjerding 1992; Sabherwal & Robey 1993). A starting assumption in the study is to consider the implementation of technical change as an *organizational problem-solving process*, which is assumed to offer a means to form a solution for the innovation design dilemma (cf. March & Simon 1958; Burns & Stalker 1994; Cyert & March 1992; Holbek 1988).

Traditionally, the common theme in innovation studies has primarily been the topics concerning the origin and diffusion of the innovations. Only recently in some innovation studies has the question begun to be posed in another way. The focus is on the implementation process in the user organization, which is considered also an innovation process (see, e.g., Voss 1988a; Gerwin 1988; Boer 1991; Hietanen 1993; Slaughter 1993).

However, the studies where the role of the user organization is acknowledged as crucial for applying technical systems to their operation environment, do not specify the implementation process in any detail, this is to say in which phases of the implementation process and how innovations are made (cf. Gerwin 1988; von Hippel 1988; Slaughter 1993; Sabherwal & Robey 1993).

Therefore, less attention has been paid to *how and by whom new solutions and innovations are finally brought about and carried out inside the user organization*. The studies have not touched upon *the activities of the management* and *the role of the system users* and especially *their interaction* in the problem-solving activity of the implementation process. That is the focal point of this study.

The study looks at the implementation of technical change as an organizational problem-solving process which is seen to proceed through concrete activity and actions, in other words as *social activity* where the various actors in the organization are involved and interact with one another (cf. Van de Ven & Poole 1990). Thus, technical change and the formation of new techno-organizational solutions are considered *at the micro level*, by defining and analyzing the steps in constructing a new technical system which is seen as a part of the *activity system* (see Engeström 1987; Blackler 1993). It is assumed in the study that the activity approach creates a ground for solving the innovation design dilemma.

1.2 FOCUS AND AIM OF THE STUDY

The *object of the study* is the implementation process of new technical systems. The main *aim* is to understand how technical change can be successfully planned and implemented in the organization. The viewpoint relates the technical change to the stages of the implementation process and the activity patterns of the user organization.

The implementation process is seen as the *adoption, planning and implementation* of a new technical system, yet at the same time as *social activity* by which the user organization and its actors construct a new activity system. A *special focus* is laid on the planning and implementation activities of the management and on the role of the system users and their interaction in the problem-solving activity of the implementation process.

There are three *research problems* which the study tries to address:

- to *describe* how new technical systems are planned and implemented in the user organization;
- to *describe* the planning and implementation activities of the management and users in the implementation process;
- to *explain* why some planning and implementation activities lead to better results than others, i.e. to assess how the planning and implementation activities and the results gained in the implementation process are connected to each other.

The study is based on both the innovation approach and the organization theoretical approach. Innovation research and its approach to the design and adoption of technical change offer a good starting point for forming the first hypotheses on the implementation phenomenon. Through the organization theoretical approach it is possible to conceptualize the planning and implementation models. The study strives to prove the need and opportunity for bridging the gap between the *technical innovation* and the *organizational innovation* in the implementation process of technical change, i.e. to solve the innovation design dilemma.

1.3 RESEARCH APPROACH AND METHOD

This study is based on a *case study approach* and *comparative analysis* of the results of longitudinal case studies. The study is constructed on the results of *intensive case studies* concerning the implementation process of technical systems. The objective of the study is to describe the planning and implementation process of technical change and to understand how technical change can be successfully planned and implemented in the user organization.

The starting point of the study is the fact that the formation of *new planning and implementation solutions* as well as *work organizational practices* is usually connected to the ongoing productional changes in companies. The best way to study new solutions presently taking shape and also new development opportunities is a *case study* where the targets are the real change processes of a company. It is established that a case study is especially suited for the analysis of development mechanisms of very complex change processes (Eisenhardt 1989; Yin 1989; Hartley 1994; Cassell & Symon 1994; Alasuutari 1994; Westbrook 1995).

Because the planning and implementation process of new technical systems is a process of long duration, lasting for several years, it is necessary to organize the acquisition of data for a sufficiently long time and frequency (Eisenhardt 1989; Pettigrew 1990; Sayer 1992; Glaser & Strauss 1967). In the case studies, *different kinds of methods* are used to collect data. The results become more reliable when using many sources in the collection of data and when comparing these data in the analysis phase.

The case studies are originally based on three different projects concerning the implementation process of a Flexible Manufacturing System (FMS) (see, eg., Mortimer 1984 and 1985; ECE 1986). The projects cover the years 1985-1992.

The original case studies were based on the principles of *experimental development research*. The research approach is characterized by four features: (1) the research is intensive case-study; (2) it rests on and aims towards theoretical generalizations; (3) it is based on experimental development intervention; (4) it aims at methodic discipline (Norros et al. 1988a and b; Toikka et al. 1988; Alasoini et al. 1994; cf. Engeström 1987).

Experimental development research is *intensive case-study*, based on the tradition of action research (see, e.g., Argyris & Schön 1978; Westbrook 1995). However, the central feature characterizing the approach of experimental development research is that the ongoing change is not only monitored and analyzed in the study, but the aim is *to actively participate in the change process to create new solutions* (Alasoini et al. 1994; Hyötyläinen et al. 1997; cf. Engeström 1987, 321-337; Fryer & Feather 1994). The main phase of the research is the experimental stage in which new structures and methods are formed, tried out and developed in the organization (cf. Leonard-Barton 1992).

The summary of the original cases studies is presented in Appendix 1. The research phases, methods and study material in the original case studies are analyzed in Appendix 2. In the case studies, the researchers were able to participate and follow-up intensively for several years the implementation process of the case systems by using various kinds of methods.

Due to the intensity and duration of the original case studies, the study material is extensive consisting of thousands of pages of different material and documents (cf. Leonard-Barton 1990; Pettigrew 1990; Glaser & Strauss 1967, 28-31). In this study, I have used only a part of the large research material. The material for the study is chosen from the point of view of how central it is for describing the planning and implementation process of technical systems and the activities of the management and users in that process. However, the material is aimed at illustrating in a many-faceted way the object of the study.

In this study, the material used is explicated within the descriptions of the cases. The researchers introduced research-based elements, *methods, tools and organizational forms and training activities* in the case studies. In this study, the results of the efforts of the researchers are evaluated in connection with the analysis of the cases.

The premise of the study is the theoretical hypothesis of new planning and implementation paradigms, their technical and organizational characteristics and development mechanisms (cf. Miettinen 1993; Eisenhardt 1989). In the study, conceptualization of new paradigms of the planning and implementation practices is attempted through the analysis of the literature on both the *innovation approach* to the design and implementation of technical change and the *planning and implementation models* based on the organization theoretical approach. The change process in each *case study* is examined from the perspectives and concepts of these approaches and models (cf. Sayer 1992).

1.4 STRUCTURE OF THE STUDY

The objective of the study is to describe the planning and implementation process of new technical systems. In addition, the objective is to find out what kinds of planning and implementation models, methods and organizational forms can further organizational problem-solving and development activity in the planning and implementation of new technical systems, which can be assumed to contribute to a successful implementation process. To succeed in this it is assumed that there is a need to solve the innovation design dilemma of technical change.

The structure and phases of the study are described in Figure 1.1. The structure of the study is presented in the following.

The theoretical grounds and models of the study are analyzed in *Part I* of the study. The focus is laid on the *organizational processes* connected to technical change. The innovation approach to the design and implementation of technical change is examined in Chapter 2. First, the design and adoption of process innovation are considered. The adoption model of process innovation is formed. Then, the problem between the process innovation and process improvement is analyzed. Based on that, three factors and their dimensions concerning *the innovation design dilemma* are differentiated. Third, the implementation process of technical change is regarded as *social activity* by which the user organization and its actors construct, implement and use new techno-organizational solutions. Development mechanisms of the implementation process of technical change are considered. An *action model of the implementation process* is summarized. The model acts as the central means in the description and analysis of the implementation process in the cases.

Different *planning and implementation models* are considered and analyzed in Chapter 3. The idea is to consider the models that form basic "alternatives" for the planning and implementation of new technical systems in the companies.

The *research design* of the case studies as well as the *research questions* are discussed in Chapter 4. The description and analysis pattern in the cases is introduced.

The results of the *intensive case studies* are the basis for the study. The implementation process of the case systems is described and analyzed in detail in *Part II* of the study, in Chapters 5-7.

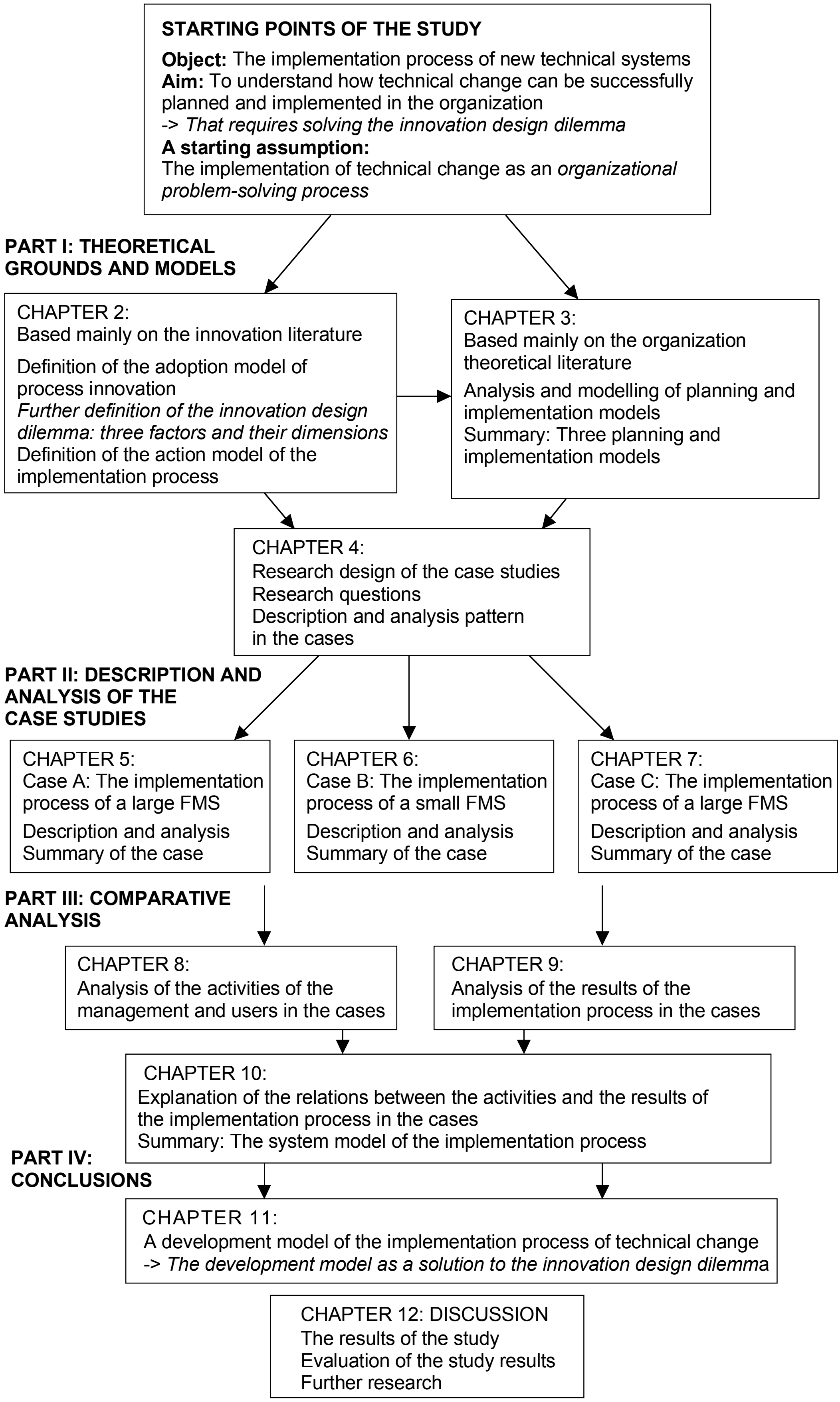


Figure 1.1. The structure and phases of the study.

Part III presents the *comparative analysis* of the case study results. The analysis of the activities of the management and users in the cases constructs Chapter 8. The analysis of the results of the implementation process in the cases is discussed in Chapter 9. Chapter 10 includes the explanation of the relations between the activities and the results of the implementation process in the cases. As a summary, the system model of the implementation process is outlined.

In *Part IV*, *conclusions* of the study results are drawn. A *development model* of the implementation process of technical change is formed and analyzed in Chapter 11. The model is specified for a solution of the innovation design dilemma. Finally, discussion and suggestions for further research are stated and outlined in Chapter 12.

PART I: THEORETICAL GROUNDS AND MODELS

The aim of this part of the study is to discuss the theoretical and practical grounds and models which form the basis for the description and analysis of the implementation process of the case systems in Part II.

The innovation approach to the design and implementation of technical change is examined in Chapter 2. Design and adoption issues of process innovation are considered in Section 2.1. The adoption model of process innovation is formed and analyzed. The distinction between process innovation and process improvement is considered in Section 2.2. As a conclusion, three factors and their dimensions with regard to the innovation design dilemma are differentiated. The main point in the study is to argue that the dichotomy between innovation and improvement has to be overcome in the implementation process of technical change in order to achieve successful results. The argument is that *organizational patterns* have great importance for the management of the implementation process.

The study is based on the view that the implementation process is social activity. Through the analysis of the development mechanisms of the implementation process, an *action model* of the implementation process is formed and analyzed in Section 2.3.

In Chapter 3, the planning and implementation models based mainly on the organization theoretical literature are considered and analyzed. The assumption is that *new planning and implementation models* are taking shape for the building of techno-organizational systems. Three planning and implementation models developed through the analysis act as an evaluation tool for examining the implementation process of the case systems in Part II of the study.

Finally, in Chapter 4, the research design of the case studies is discussed and the research questions are formed. The description and analysis pattern in the cases is considered.

Based on the research design, the case studies are examined in Part II of the study. The aim is to describe the planning and implementation process of new technical systems and to explore the activities of the management and users in that process.

2 INNOVATION APPROACH TO DESIGN AND IMPLEMENTATION OF TECHNICAL CHANGE

2.1 DESIGN AND ADOPTION OF PROCESS INNOVATION

As to process innovation there are three different traditions within the innovation literature. One stream studies the *origin and birth* mechanisms of innovations. The focus is on the process of developing a new item. Innovation is depicted as the creative process that results in something new. Here innovation is considered from the perspective of the developing unit. According to Biemans (1992) most definitions of innovation belong to this category. The conceptualization of the product development process has been tried from different angles, e.g. through activity-stage models and decision-stage models, which represent the product development process by a sequence of activities and a number of decisions to be made in the different phases of the process, respectively (Biemans 1992, 26-41). One of the main goals is to find out the factors which explain the failure or success of new product innovations and to construct solutions for a successful product development process.

Another approach concentrates on the *diffusion* of technical innovation. Diffusion reflects a series of adoption decisions by individual units within the social system over the course of time (Biemans 1992, 51-63; Rogers 1995). Most studies of technological change and innovation have centred on the question of diffusion (Sahal 1981).

The third approach is more recent. The main focus is on investigating the *adoption* of the innovation in an organization. In this case, the innovation is looked at from the point of view of the adopting unit. This view relates innovation to the stages of the adoption process and the characteristics of the adopting unit (Biemans 1992, 41-51; Rogers 1995, 371-404). In many studies, the adoption of the innovation is viewed in the broader context of organizational change (cf. Hartley 1994). It is usual that information technology is seen as one of the most influential forces providing input into the process innovation (Davenport 1993). Within this tradition of innovation research, the analysis deals with the design and implementation of the innovation. One of the main goals is to understand how innovations can be successfully adopted in an organization. This approach lends a valuable perspective to process innovation. First, it lays the main focus on the *implementation process* of an innovation. Second, it emphasizes *mutual adaptation of the organization and the technical system* for successful implementation. These are the two main topics in this study.

The above is a reason to consider here the *stages of the adoption process* in more depth. Understanding the adoption requires understanding the whole innovation process, from the conception of an idea to its consolidation. The adoption is the process an organization goes through to reach the decision to adopt a new product or solution. The process starts with the recognition of a need and the eventual result is the implementation of an innovation (Biemans 1992, 41-51; Rogers 1995, 371-404).

There are numerous attempts to classify the stages of the adoption process of an innovation. Almost all different kinds of models consist of two main stages. The first, *design/planning*, consists of the early actions through which members of the organization search, create and decide about the innovation. The later phase, *implementation*, consists of steps taken to introduce the innovation (Nord & Tucker 1987; Boer 1991, 108-115).

Pelz and Munson (cited in Nord & Tucker 1987, 8-9) have characterized the adoption process in the organization through the sequence of four stages. The stages are: diagnosis, design, implementation, and stabilization (cf. Rogers 1995, 389-404). The stage sequence presented by Pelz and Munson is well suited to describe the implementation process of technical change. The stages can be assumed to form a development cycle. Based on these stages, the *adoption model of process innovation* can be built. The model is presented in Figure 2.1.

The adoption process begins with *diagnosis*, where the motive to start the innovation process is first conceived. The most likely motive for an innovation process is a present or anticipated "performance gap" which is perceived as wide enough to launch a search process (Boer 1991, 109). The motive is translated into an innovation problem so that actitivities can be undertaken to find a solution to it. After defining the innovation problem, goals for a new system are defined and principal ideas and solutions are formulated for filling the performance gap. Rogers (1995, 391-394) calls these activities agenda-setting, which amounts, correspondingly, both to identifying and prioritizing needs and problems on the one hand, and to searching the organization´s environment to locate innovations of potential usefulness to meet the organization´s problems, on the other hand.

In the *design/planning stage*, the principal solutions are worked out into more exact specifications and solutions. The different solutions produced are then evaluated. The selected solution and its different elements are defined and planned (Boer 1991, 19-113). The aim is to develop and plan an innovating solution according to the specifications. Rogers (1995, 394) defines this stage as matching, a stage at which the organizational problem specified in the preceding stage is matched with an innovation, and this match is designed and planned. In a sense, the match between the innovation and the organizational problem is "simulated" in the planning phase to determine the feasibility of the planned solution.

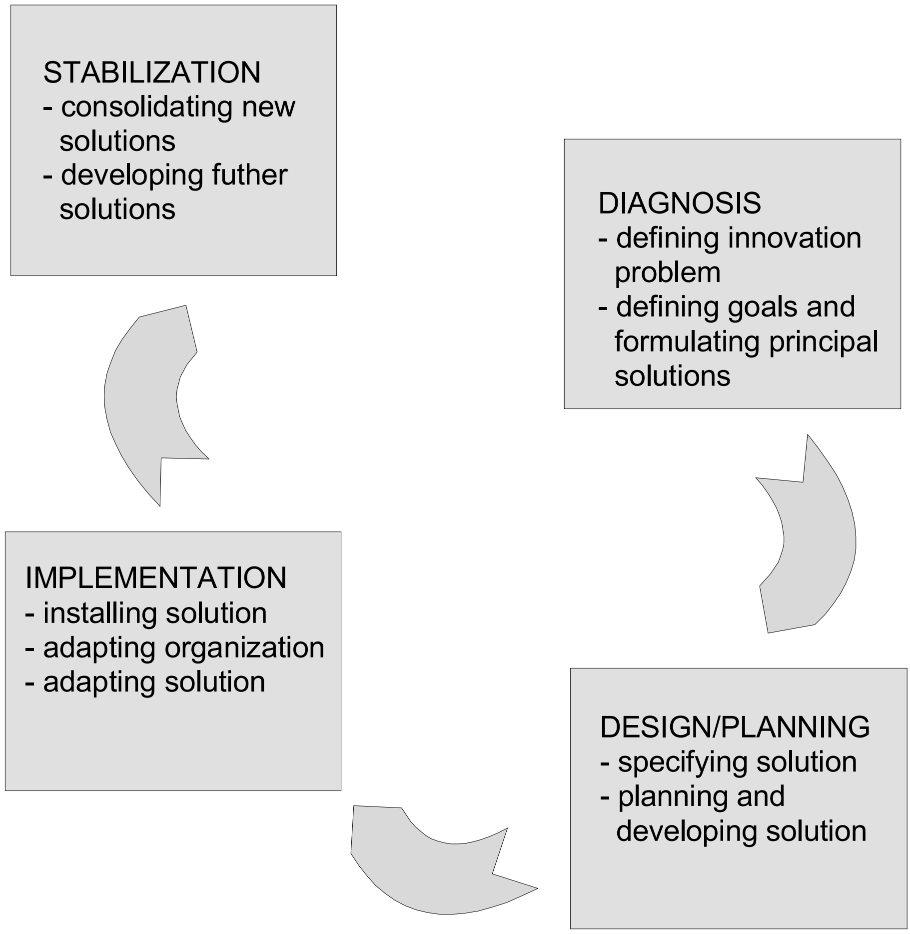


Figure 2.1. The adoption model of process innovation (cf. Pelz & Munson, cited in Nord & Tucker 1987, 8-9; Boer 1991, 109-115).

In the *implementation stage*, the innovation is fitted into place. In this phase, adapting the innovation for the organization becomes the central process. The plan of the innovation is incorporated into practice through the implementation. Rogers (1995, 394-399) calls this stage redefining/restructuring, which occurs when the innovation is "re-invented" to better accommodate the organization´s needs and structure. Correspondingly, the structure of the organization has to be changed to fit the innovation.

Implementation has been rather neglected by researchers (Biemans 1992, 42). It is acknowledged that many of the uncertainties cannot be resolved before an innovation becomes operative. Due to that, many decisions made during the design stage need to be adjusted and reworked. This means planning activity to solve and prevent problems from occurring in the implementation phase (Nord & Tucker 1987). During the implementation, the user organization may be the major agent in changing and modifying the innovation.

Stabilization is the period in which the innovation is consolidated and adapted to the ongoing practice. The innovating practice may become "normal activity" or it may run into problems which can become a danger for the success of the innovation (Nord & Tucker 1987). The stages of clarifying and routinizing according to Rogers (1995, 399-403) can be seen to belong to the stabilization phase. Clarifying occurs when the innovation is put into more widespread use in the organization, and the innovation becomes embedded in the organizational structure. Rogers argues that "routinization" occurs when the innovation has become incorporated into the regular activities of the organization, as part of normal use.

The model presented in Figure 2.1 can be understood as a model with which it is possible to describe the implementation of the process innovation, with its unforeseen events and problems (cf. Biemans 1992, 41-45; Boer 1991, 123). The model forms a basis in developing further the model of the implementation process of technical change in this study.

2.2 PROCESS INNOVATION VERSUS PROCESS IMPROVEMENT: FACTORS OF THE INNOVATION DESIGN DILEMMA

Normally, a clear distinction is made between radical and incremental innovations (Tushman & Nadler 1986; Yin 1994). Incremental innovations are also called "routine" innovations (Biemans 1992, 11-12; Nord & Tucker 1987, 11-13). The central factor determining the category of an innovation is how radical it is. The more an innovation differs from the existing alternatives, the more radical it is said to be. The same applies both to product innovation and to process innovation. In the area of a process, a radical alternative is called simply *process innovation*. An incremental extreme is labelled as *process improvement* (Davenport 1993; Imai 1986 and 1997). According to Davenport (1993, 10-15), the differences between the process innovation and the process improvement activity can be summarized through a dichotomy model. The main dimensions and features of these two forms of process innovation are compared in Table 2.1.

Davenport (1993, 10-15) sees process innovation as an introduction of something new into a process (cf. Imai 1986, 23-41). As such, this brings about *radical change*. More specifically, with process innovation, Davenport (1993) refers to a radical process change based on two factors: the adoption of a process view to business activity; and the application of innovation to key processes. Typical key processes are for example product development, product design, materials process, manufacturing, and post-sales service. Other names for this are business process redesign or business process reengineering (Coulson-Thomas 1994). The application of whatever innovative technologies available, especially information technology, has been seen as the main enabler for the process innovation. The advocates for process innovation can be seen to favour the technology-based approach since they give preference to technical solutions in facilitating the radical redesign of processes and work practices (cf. McKenzie & Wajcman 1987).

Table 2.1. Comparison of process innovation and process improvement (see Davenport 1993, 11; cf. Imai 1986, 23-41).

DIMENSION	**INNOVATION**	**IMPROVEMENT**
STARTING POINT	Clean slate, technology-based approach	Build on existing process, problem-oriented approach
PRIMARY ENABLER	Information technology	Quality control, different follow-up tools, problem-solving tools
NATURE OF CHANGE	***Strong emphasis on the potentials of automation***	***Organizational emphasis***
DESIGN/PLANNING APPROACH	***Top-down***	***Bottom-up***
LEVEL AND PACE OF CHANGE	***Radical change, a one-time, big step***	***Incremental changes, continuous, small steps***

According to Imai (1986, 1-14) contrary to the process innovation defined above, process improvement is *incremental activity* for making gradual changes in the existing processes. The starting point for the improvement is the recognition of a problem, the need for improvement. Thus, the incremental improvement is based on a *problem-oriented approach*. In the improvement activity different kinds of quality and statistical control methods are used to stabilize processes and to pinpoint problems to be solved (see, e.g., Ishikawa 1985). To solve these problems, different kinds of problem-solving and follow-up tools are needed for the use of the organization (see, e.g., Imai 1986, 239-242).

These two approaches differ from each other by their *implementation methods*. The process innovation is seen as a radical alteration. Normally, the adoption of information technology is the starting point. The adoption and design of radical innovation is seen to be based on specialist-oriented design and to proceed as *"top-down"* activity where the role of top and middle management and information specialists is central, due to the large-scale effects of the investment and its complex nature. This limits the opportunities of some members in the organization to participate in the design process. It is a question of a *one-time, big step* to innovate the processes, from the starting point of a relatively clean slate, rather than starting from the basis of the existing process. A *strong emphasis* is laid *on the potentials of automation* and information technology in striving for dramatic results and renewing the work practices (Davenport 1993, 10-15).

Improvement is regarded as incremental, *continuous activity* which means small improvements made to the existing process as a result of the ongoing efforts. The central feature is a *"bottom-up"* approach where the role of the workers is very important. Process improvement activity relies heavily on *the involvement of the whole organization and the operating teams*. Improvement calls for a great deal of continuous effort to maintain the commitment of the personnel in the organization (Imai 1986 and 1997).

These two approaches are relevant from the point of view of the innovation design dilemma and its furher definition. To conclude this discussion on process innovation, the main topics of the study can be defined through *three factors and their dimensions characterizing the innovation design dilemma.* These factors and dimensions of the innovation design dilemma with regard to technical change are:

(1) The first factor refers to the *nature of technical change*. That is related to the question of which viewpoint the implementation of process innovation is considered from. The dimension can be seen to concern the difference between the *"techno-centric" approach* and *organizational emphasis*. The "techno-centric" approach focuses on the technical issues of technical change. The organizational approach emphasizes the importance of *organizational change* in connection with the technical change (cf. Sahal 1981; Winter 1996).

(2) The second factor is related to the *design/planning approach*. It concerns the dimension between *"top-down"* and "*bottom-up"* planning. The question is to what extent all members in the organization have *opportunities to participate and co-operate* in the planning activity (see, e.g., Kanter 1988, 241-277; Boedker & Gronbaek 1996).

(3) The third factor concerns the issue of the *level and pace of change*. The point can be interpreted as the dimension between a radical innovation and incremental innovations, between a *one-time big step* and *continuous, small steps*. This can be seen as a divider between planning and implementation, as the separation of planning and execution (see Ehn 1988, 63-69; Winter 1996).

The argument of the study is that the three dimensions of the factors of the innovation design dilemma have to be covered and overcome in the implementation process. Otherwise, the factors and their dimensions are dysfunctional for the implementation process of technical change (see Kanter 1988, 84-100; Yin 1994). If the technical change is seen merely as a technical issue, "top-down" activity and a one-time big step, the full potential of new technical systems will not be reached. The three factors and their dimensions are intertwined with the *planning and implementation practices* adopted by the management and users.

2.3 DEVELOPMENT MECHANISMS OF THE IMPLEMENTATION PROCESS

The adoption model for process innovation, presented in Figure 2.1, introduced the phases and tasks to be performed in the implementation process of technical change. The model does not, however, contain any description of how these tasks of the implementation process are divided in the planning and use organization and which mechanisms are active in the innovation process.

The study is based on the view that the implementation process of new technical systems is *social activity* consisting of concrete actions carried out by different actors in the user organization for constructing a new activity system, a “socio-technical system” (see Vygotsky 1978; Engeström 1987; Blackler 1993; Kuutti 1994; Norros 1991). In the study, the implementation process of technical change is considered to consist of the following four activities: (1) defining the innovation problem and goal setting; (2) planning activity; (3) implementation activity; and (4) use activity in the “normal” operation phase. These activities correspond to the phases in the adoption model of process innovation. The central point of view in the study is to consider *the connections and dependencies between the planning and use activity*, which is a focal issue according to the innovation design dilemma (cf. Boedker & Gronbaek 1996).

Due to the social activity nature of the techno-organizational change, the realization method and its success depend on the traditions of the user organization and its technical level, the organizational culture of the company, the management and planning practices as well as on the workers´ professional skill, motivation and work orientation (Jones 1989; Corbett et al. 1991, 99-109).

The shaping of the planning and implementation process in the user organization can be seen to be affected by the *development mechanism* proceeding in two ways: (1) the strategic goal setting and the definition of planning and implementation practices performed by the management as well as by the planners; and (2) the worker activity (Norros et al. 1988a and b; Toikka et al. 1991a; Hyötyläinen et al. 1990; Norros 1991; Hyötyläinen 1993 and 1994; Norros 1996; cf. stakeholder approach, Burgoyne 1994; Hietanen 1993). Figure 2.2 summarizes that process as an *action model of the implementation process*. The model is a basis in the analysis of the implementation process of the case systems.

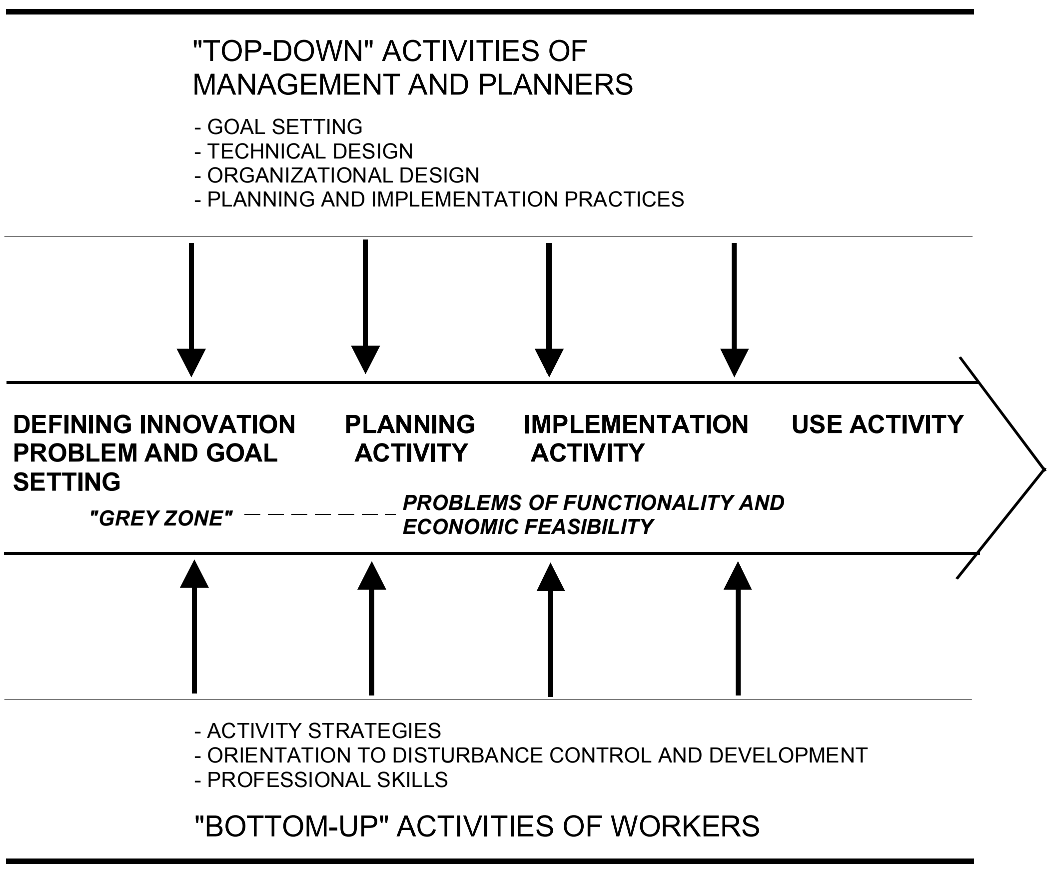


Figure 2.2. Action model of the implementation process.

The two-way development mechanism of the implementation process is discussed in the following:

(1) The *company and production management* can be assumed to define from *"top down"* the goals of the productional change and the framework for planning and implementing this change by strategic choices and goal setting (Clark & Starkey 1988, 98-100; Lundvall 1988). However, the company and production management as well as the planners of the system encounter pressures on various levels. That is why the management has to act on several strategies simultaneously, and it is not always easy to combine these strategies (see, e.g., Räsänen 1986; Tainio et al. 1985; Child 1985; Laurila 1995). The company management has to take into account the market demands and the issues of production management and productivity at the same time. Because of this, the *implementation strategy and practice* adopted by the company and the production management as well as the planners may evolve along the implementation process when affected by the experience gained - especially economic pressures and functional problems (see Urabe 1988, 8-10; Sitkin 1996).

(2) Also the *"bottom up" activity of the workers* can affect the development of the implementation process and the formation of the work organizational arrangements (Jones 1989; Zuboff 1988). The *professional skills* of the workers and the common and individual *work orientation* play a central role here (Norros 1991; Engeström 1987). The *way of working* of the workers draws on the one hand from the organizational structures and conditions and, on the other hand, from personal aims (March & Simon 1958, 122-135; Cyert & March 1992, 30-51; Clark & Starkey 1988, 105-122). When the techno-organizational structures and conditions change, new opportunities and experiences open up for the workers, which can then affect their aims and way of acting.

The solutions forming in the planning and use activity can be assumed more or less unpredictable and continuously evolving due to the development mechanism of the implementation process. In a sense, one can talk about development opportunities as a *"grey zone"* instead of an indisputable implementation practice and system solution (see Norros 1991; Sitkin 1996). The "grey zone" can be seen as a controversial area set out by goals and demands outlined by the company and production management as well as the planners, and by the worker activity, where the implementation practice and the techno-organizational solutions are formed through social activity.

The argument in the study is that the planning and implementation approaches adopted by the management and planners influence the success of the implementation process. The planning and implementation alternatives through the analysis of *planning and implementation models* are looked at in the next chapter.

3 PLANNING AND IMPLEMENTATION MODELS

The study claims that the success of the organizational problem-solving process in the implementation of technical change depends decisively on the *patterns* according to which the change is planned and implemented. In this chapter, alternative patterns are considered and modelled based mainly on the organization theoretical literature.

It has been the practice to distinguish two opposite models in the building of techno-organizational systems of the future factory (Brödner 1985 and 1990a; Bullinger et al. 1985; Senker 1986, 101-116; Gupta 1989; Lay 1990; Rouse 1991; Corbett et al. 1991, 5-19). These opposite planning and implementation models are called the *"techno-centric*" and the "human-centered" or *"user-centered"* models.

The possibility of a new planning and implementation model deviating from the two former models has arisen in recent research. The discussion about this alternative has been spurred on by a critical assessment of planning and implementation practices of the user-centered model and from the need for new kinds of approaches. The new emerging model has been called the *"work-oriented"* model of system design (Ehn 1988; Corbett et al. 1991).

New approaches are coming in from the models based on Japanese management systems and manufacturing experience (see, e.g., Imai 1986; Krafcik 1988; Womack et al. 1990; Nonaka 1991; Nonaka & Takeuchi 1995). The Japanese production concept is called *"lean production"*.

The following is an analysis of the planning and implementation models. The relation between *planning and use activity* is considered especially in the analysis, because according to the definition of the innovation design dilemma the main factor in solving the dilemma is *to overcome the divider between planning and execution*. Also, the work organization forms connected with each implementation model are reviewed. In connection with this, the application of the models to the implementation of FM-systems is studied.

3.1 TECHNO-CENTRIC MODEL

The central feature of industrial tradition has been the separation of the execution of work from its design which is based on the doctrines of Taylorism and *industrial engineering* (Taylor 1913; Pollard 1968; Rose 1975; Davenport 1993, 311-326; Cole 1994). Since the times of Taylor, the development of the work organization has based on "organizational rationalization". According to that, processing activities are sectioned “horizontally” and separated “vertically” from the planning and control functions. This has fundamentally signified two things (cf. Lundvall 1988):

(1) *Differentiation of tasks of the planning and execution personnel.* The workers have been separated from the development of machines and production processes. The *design and development of new manufacturing systems* has become the task for experts alone trained for this purpose. In the work organization, the tasks of the management and planning personnel and the workers have become clearly separate. The task of the workers has been *that of operating and performing*.

(2) *Planning has become a technically oriented function.* The primary target of the manufacturing system planning has been the design of better and more efficient *machines and systems*. Not so much attention has been paid to the work organization which has to be adapted to the planned technical system. The aim has been to develop methods for getting the *workers* to work as effectively and reliably as possible as a part of the technical system.

The design tradition according to the lines of industrial engineering can be called the *“techno-centric” planning and implementation model* (Brödner 1985 and 1990a and b). The techno-centric model has proved resilient since it can be detected also in the planning and implementation of CIM (CIM, Computer Integrated Manufacturing) solutions (Corbett et al. 1991, 6-9). The following looks at the “ideal type” of the techno-centric planning and implementation model and its dimensions according to the different change factors of the planning and implementation (Toikka et al. 1986; Hyötyläinen 1988 and 1994) (Table 3.1).

The *aim* of the “techno-centric” model is to reduce the human role to a mere supervisor of automatic production. The ideal is to come as close as possible to an *"unmanned factory"* (Corbett et al. 1991, 6-9). Man is seen as an uncertainty, a disturbance and cost factor with regard to production efficiency, control and reliability. It is considered possible to reduce and finally eliminate this effect by raising the automation degree of production. The ideal is that the organization is designed to free itself from human intervention, running automatically to produce predictable products.

A machine and computer control centered angle to a great extent associated with centralized system architectures, as well as adherence to standard technical solutions in automation development are characteristic of the “techno-centric” *design concept*, instead of focusing on solutions increasing the use of operator influence. According to the techno-centric design concept, human activity in production is mainly regarded as a "residual term" of technology (Bainbridge 1983). Only the functions not suitable for or not worth mechanising or automation have been left for humans to perform, as a “rest-work” (Corbett et al. 1991, 41-42).

Table 3.1. Dimensions of the techno-centric planning and implementation model according to different change factors of planning and implementation.

TECHNO-CENTRIC MODEL	
CHANGE FACTORS	DIMENSIONS
Strategic aim	**“Unmanned factory”**
Design concept:	
The object of design	Production process and machine system
Control system	Equipment and computer centered angle, centralized system architectures, standard solutions
Human-machine system	Polarization between technology and man: man only supervises production
Organization of planning:	
Planning organization	Segmentalist planning: separate planning organization (no users included), specialized planning functions according to different technical areas
Implementation plan:	
Implementation model	Strict task division between planning and use
Work organization	Work rationalization and strict division of work, “individual” work
Use of professional skill	Strive for replacing human work by automation

According to the “techno-centric” model, technical solutions are *planned* relatively separately from the human operating in production and from the planning of the work organization when implementing automation (Rosenbrock 1981). The segmentalist approach prevails according to which different design areas are planned separately and no users participate in the planning.

According to the “techno-centric” model, work is rationalized. The basis is usually a hierarchical *organizational structure*, strict division of work, monotonous work tasks and low requirements for professional skills.

The “techno-centric” approach can also be detected in FMS implementation, and the corresponding work solution can be called the “tayloristic” type of organization. According to Köhler and Schultz-Wild

(1985), the "tayloristic" type of an FMS organization can be characterized as follows:

> **The "tayloristic" type of FMS organization:** It is typical of this organization type to have a hierarchical work division and a structure of professional skill where the average level of professional skill of the staff is fairly low. The system level planning and control tasks belong to the system manager. There is a separate setter for tools maintenance, preliminary setting and NC-program repairs. The main crew consists of machine operators trained on site with limited supervisory and setting tasks in addition to machine operating. In addition to this, unskilled workers are used for performing manual material loading and unloading tasks only. All more demanding programming, quality management and maintenance tasks belong to operational units outside the FM-system according to the functional division of work.
>
> It is typical of the organization type based on work division that the FMS is manned by choosing the best workers of the old production. Most of the learning takes place by training on site and training outside of work is given mainly to foremen, programmers and maintenance personnel.

The tasks designed according to the Tayloristic principles are largely divided and repetitive. The focus is limited to a narrow range of routine tasks. These tasks are not seen to require complex *problem-solving activity* by the workers who perform them (March & Simon 1958, 12-22). Exceptional situations are thought to be handled by the management and experts (see, e.g., Kanter 1988, 18; Cole 1994).

In reality, this picture is not valid. It is impossible to plan in advance all activities to be performed. According to March and Simon (1958, 25-29) even in a highly routinized environment, the routine has the character of "strategy" rather than a "fixed program". The actual set of activities are conditional. Their times of occurrence may depend on events external to the organization or events and other activities inside the organization. Because the activities are conditional, and not to be fixed totally in advance, that means inevitable problems in performing and coordinating the activities in the organizational settings.

3.2 USER-CENTERED MODEL

Socio-Technical System Design

A new school of *"socio-technical system design"* emerged in the 1950s, based on the research done in the Tavistock Institute of Human Relations in London (van Eijnatten 1993; Ehn 1988, 260-272). The socio-technical approach reached its full scale in the late 1960s and early 1970s as the so called "humanization movement" (see Thorsrud 1980; Trist 1981; Sandberg 1982; Julkunen 1987). According to the socio-technical approach, production systems should be looked at as complex and dynamically developing "open systems" including three separate subsystems: the economic, technical and social system. The production system is effective only if these subsystems operate smoothly, meaning that they have to be coordinated to one another and to the needs of a changing environment (van Eijnatten 1993, 9-20).

The relations between the social system and the technical system, the organization considered as a "socio-technical system", became the object of socio-technical research. The economic behaviour of the organization and the satisfaction of workers were seen as a result of the function of the socio-technical system. The task is the joint optimization of these systems, because striving for separate optimization of only the technical system or the social system does not lead into optimal solutions at the level of the entire "socio-technical system" (Trist 1981; van Eijnatten 1993).

The socio-technical school of thought was not only interested in industrial work as such but also in the planning of production systems. The solution offered was the planning of a socio-technical work system starting from a certain concept of "good work" or "humanized work" and from organizational means of maintaining the characteristics of good work in practice (Trist 1981; van Eijnatten 1993).

In practice, the main output of the socio-technical approach is in the area of organizational design. The most famous organizational form created by the socio-technical school is the concept of an "autonomous work group", based on multi-skilled personnel (see, e.g., Sandberg 1982). Through this group concept a possibility to "enlarge" the jobs of workers so that the job includes several different productional tasks is perceived. Workers rotate their jobs at certain time intervals. Another aspect is "job enrichment". Different kinds of planning and control tasks are included into the jobs of the workers belonging to an "autonomous" work group.

The socio-technical approach has contributed to the "traditional" planning practice by introducing new features. "Good planning practice" is no longer limited only to the operation of the technical system but expanded into the planning of a complex "human-machine system" including the specific human requirements and limitations (see, e.g., Rasmussen 1986; Rouse & Cody 1988). However, this planning tradition has taken the traditional expert orientation for granted. This means planning for the workers rather than planning by the workers. This planning paradigm has not broken *the barrier differentiating planning from doing*. The technical system has also been taken to a great extent as given (Rosenbrock 1981). The means of the socio-technical approach have been confined after all only to changing and developing the social system. All in all, it can be argued that the methods of the socio-technical design are largely "mechanistic" in practice since the design of operator tasks is based on the control demands set by the technical system (Corbett et al. 1991, 9-12 and 57-60).

User-Centered Planning and Implementation Model

The socio-technical tradition and its critical evaluation in the 1980s initiated discussion about various planning paradigms. The concept of a *"user-centered" system* or a "human-centered" system was born (Brödner 1985; Rosenbrock 1989; Corbett et al. 1991; Rouse 1991). A theory of the planning of complex systems based on the user-centered approach has been developed and systematized (Rouse 1991). During the past few years, far ranging discussion and experimenting under the heading of the "anthropocentric" manufacturing system has been going on in Europe (Brödner 1990a; Kidd 1990; Lehner 1991; Wobbe 1992).

The roots of the planning of user-centered systems go back to forming an alternative to taylorism and fordism and the models for planning of the manufacturing system based on these concepts. In the planning of user-centered systems, the focus has been away from mere expert-centered planning activity and towards a more *user oriented practice*, where workers become increasingly involved in the planning of technical systems and their own jobs.

User-centered systems can be seen as an alternative to the ideal model of the "techno-centric" concept which is called into question (Gupta 1989; Brödner 1990a). It has proven problematic to achieve the functional and market economic benefits such as operability, flexibility and quality of integrated manufacturing systems when applying the "techno-centric" strategy.

The alternative, the "ideal type" model can be called the *"user-centered" planning and implementation model* (see Toikka et al. 1986; Hyötyläinen 1988 and 1994) (Table 3.2).

The basis is a solid organizational structure of high professional skill and group work, so-called *"skill-based production"* (Brödner 1985).

A vital part of the "user-centered" *design concept* is the implementation of those technical solutions that enhance the use of user influence in production management. This calls for at least *a "decentralized" computer* *system*, as well as for a *software architecture* and database structure enabling solutions fitted to the user needs and supporting decentralized decision making in the organization. *Interactivity* and human-machine interfaces that facilitate the use are also required of the computer systems (Lay 1990, 139-143; Corbett et al. 1991, 60-64 and 72-74). According to the "user-centered" design concept, there is no longer reason to emphasize the controversy of technical possibilities and human limitations. The aim is, on the contrary, to find a division of functions and interaction between man and machine that reflects the strong sides and mutual synergy of both.

The features of the *organization of planning* are simultaneous planning and "participative" planning. Different design areas are planned to a great extent simultaneously. The users participate in the planning organization in close co-operation with the planners.

Table 3.2. Dimensions of the user-centered planning and implementation model according to different change factors of planning and implementation.

USE-CENTERED MODEL	
CHANGE FACTORS	DIMENSIONS
Strategic aim	**"Skill-based production"**
Design concept:	
The object of design	Operating system (user-centered system)
Control system	Operational and user-centered angle, interactive and "decentralized" system architectures
Human-machine system	Communication and task division between man and machine: man supervises and optimizes production, and deals with disturbances
Organization of planning:	
Planning organization	Simultaneous planning; co-operation between planners and users, "participative" planning
Implementation plan:	
Implementation model	User training and training by participation in planning
Work organization	Work reorganization and expansion of tasks, group work
Use of professional skill	Wide-scale use of workers´ professional skills

The *implementation model* is based on group work and large-scale user training. The *group organization* has also been defined as an opposite to the "tayloristic" type organization among FMS-organizations (Fix-Stertz et al. 1986 and 1990). According to Köhler and Schultz-Wild (1985), the FMS "group" organization can be characterized as follows:

> **FMS "group" organization:** In the group organization, the work condenses into new large tasks and group work. The entire FMS-group has a relatively high and similar professional level. The internal functions of the FMS are not characterized by the traditional vertical division of work between the planning and control tasks and operating tasks. All tasks of the system belong to the group as a part of job rotation, also production control, and at least partly, NC-programming, disturbance control, quality control and maintenance. In principle, all members of the group know each task. Many of the tasks left for units outside the FMS in the traditional organization of work division are included in the system. More demanding maintenance and repair tasks are performed in smooth co-operation with the operation organization and the relevant special organizations.
>
> In a group organization, recruitment takes place in worker groups of various levels. The workers also have to adopt plenty of new theoretical knowledge, which means lots of training outside work. The training may include e.g. the following themes: computer systems, machine programming, basics of metal working, raw materials, tools, pneumatics, electronics, interpretation of drawings, quality checking, maintenance, fault location, task timing, planning of task division and co-operation.

In the group organization, the users operate as a group without a fixed work division. Here professional skill is considered as traditional professional ability manifested as versatile command of the work assignments. The starting point of the user-centered model is that the user contribution and the users′ *professional skills* are indispensable for the *system operation* and that a group organization is the best way to utilize them (Brödner 1990a and b; Corbett et al. 1991, 60-64).

3.3 FORMATION OF NEW DESIGN CONCEPTS

Approaches of the "Work-Oriented" System Design

In the tradition of the user-centered approach the insufficiency of user-centered planning principles for the planning and building of complex technical systems is discussed. Attention is paid to four factors (see Corbett et al. 1991, 12-19; Ehn 1988, 3-35):

(1) *The gap between theory and practice.* Theoretical knowledge concerning user-centered planning is difficult to connect to the knowledge and experience of technical planning in practice. "Human-centered" is ultimately a "subjective" concept that cannot easily be translated into operational criteria. There are no methods and tools for creating and building user-centered systems.

(2) *The focus on the individual and work group level.* The main focus in user-centered planning has been on the planning and organization of processes at the individual and group level. The man-machine interface especially has been a central object. Therefore, broader organizational questions have received less attention.

(3) *Low participation of users.* The contribution of the users is left with less attention in the planning of user-centered systems. The main reason to that has been communication problems between the planners and the users, which is caused by the lack of common "language", methods, and tools.

(4) *The difficulty in defining user-centered technology.* There is no real advance in changing and developing technical systems into user-centered systems. There is a need to get rid of the "adaptation attitude" of the socio-technical approach, according to which the social organization is adapted to the technical system. There is also a need to strive for defining technology from a broader perspective and to go deeper into the "shaping" of the technical systems.

The new approach taking shape, based on this critique of the user-centered concept, is called *"work-oriented" system design* (Corbett et al. 1991, 15-19; Ehn 1988; Boedker & Gronbaek 1996). The work-oriented design has been developed as an answer to the problems and limitations of the user-centered planning concept presented above. The development work taking two directions is analyzed in the following:

(1) First, in the ESPRIT-project on "Human-Centred CIM Systems" *user-centered technical systems* were created (a CAM turning cell and visual display screen for the CAM lathe controller, an advanced prototype computer-aided design system with a portable electronic sketch pad, and a computer-aided production and workshop control system) (Corbett et al. 1991, 21-33). It is noted that progress was made in the defining and construction of technical systems but during the development work one encountered, however, the problems of the user-centered planning noted above. It was problematic to unite the user-centered theory with the technical planning done in practice. It was easiest to translate the principles of user-centeredness into the formation of direct interfaces of man-machine systems. It appeared especially difficult to draw the users into the planning

activity, due to the difficulty to conceptualize the complex questions of planning for the users (Corbett et al. 1991, especially, 93-97). As a conclusion, a new kind of *"work-oriented" approach* is presented in which it is an essential part to shape an experimental and "exploring" technology, instead of the traditional hierarchical way of the planning of technical systems proceeding linearly. It is argued that the *systems planning* has to be seen as a "rolling" development activity in which a *technical system is considered from the angle of the process* and in which the management, planners and users take part. The use of different kinds of *prototypes* is seen as an important means for handling and evaluating the solutions (Corbett et al. 1991, 109-131).

(2) Second, Ehn (1988, 3-35) has started to develop the *theory and methods of work-oriented planning* for the needs of the planning of computer systems, as a basis of the analysis of the projects concerning the development of socio-technical work systems undertaken in Scandinavia. He has two principles in the building of a new planning model: the aim of promoting industrial democracy in the work place; and the aim of planning *tools* which enhance professional skills for the work and production process. According to Ehn (1988, 247-366), the use of the final users and their skill in the planning acts as a means for democratic control of the change processes. Moreover, he emphasizes the planning based on the use of the users´ skill and participation as a creative and "communicative" process (Ehn 1988, 145-243).

Ehn (1988, 369-389) tries to set in a new way the use of *descriptions* in the planning and to develop new planning methods which make it possible for the users to foresee the use conditions of the system to be constructed. Ehn sees that in this way the users can also bring their experience into the planning of their work to come. The purpose is to develop *participative planning methods* which allow both the planners´ and the users´ creative activity in the planning process. For that purpose, Ehn offers *"design-by-doing"* methods, such as the use of simulations, mock-ups, scenarios, prototypes, and organizational games. The UTOPIA project presented by Ehn (1988, 327-358) was started by using the traditional description ways and methods of systems planning, but they appeared too abstract and therefore did not function properly as a means of communicating planning questions to the users. The situation improved decisively when the *process and organizational descriptions* in paper form, and different kinds of *simulation tools* were introduced (cf. Boedker & Gronbaek 1996). Based on that, Ehn (1988, 367-416) considers further "design-by-doing" methods and tools by which it is possible to benefit from the knowledge of practical experience in the planning and use of computer systems.

Seeds of New Kinds of Planning and Implementation

The planning concept of user-centered systems as well as work-oriented systems may still be considered to rely on *a rather strict line between the planning and the use* of a manufacturing system to a great extent. The starting point is the task to plan a "user-centered" or "work-oriented" manufacturing system. This planning also relies on user experience and the users´ participation in the planning process. However, from the point of view of the *integration issue between planning and use activity* of the technical system, these planning approaches can be seen to include the following suppositions:

- the user-centered or work-oriented technical system created in the planning process can be implemented almost as such without major adaptation;

- the designed technical system will operate in use without any greater need for development.

These suppositions can be challenged. It can be claimed that the traditional division between the planning and use of the technical system is becoming more and more diffuse. The development towards work-oriented systems is gradually establishing itself as the principle of *continuous development and problem-solving activity* (Brown 1991; Winter 1996). *Two principles* can be seen to take shape *between the planning and use activity* which are concretized in more detail through the analysis of the *case studies*:

(1) It has become obvious that planned technical systems will have to be supplemented, changed and developed during the implementation and operation activity. It is difficult to take into account and solve all issues related to the functional qualities and operating situations of the system in the planning of increasingly wide-scale and complex manufacturing systems (Bainbridge 1983; Hirschhorn 1986; Brödner 1989).

(2) The introduction and implementation of changes during the implementation and operation of the manufacturing system is most successful when based on long term user experience. In this respect, one can talk about "learning by using", i.e. improvements of the production technology, operation practice and functions of the production process based on experience of the user organization (Rosenberg 1985, 120-140; Zuboff 1988; Jones 1989).

In this respect, the models of work-oriented system design include *seeds of new kinds of practice*.

First, according to the conclusion of the ESPRIT project, the technical system developed in the planning has to be seen as *one version of the system*. Therefore, technology is considered as a *process* rather than as a product. Technology is seen to form an adaptive element in the development of the organization, which means that adaptiveness is set as an important characteristic of technical systems and, thus, as a criterion for planning (Corbett et al. 1991, 114-128). This is close to the idea of *continuous development and problem-solving process*, but this view is not developed further in any way. All in all, the idea is presented only as a few mentions (Corbett et al. 1991, 114-116). The focus is on the work-oriented planning, its forms and methods (Corbett et al. 1991, 99-131).

Second, Ehn (1988, 233-243) considers, on the one hand, planning and use as a planning and use activity which is composed of *social processes*. On the other hand, Ehn (1988, 367-389) considers computer systems from the angle of a *tool*. The idea is that when planning new systems not only new tools are planned but, at the same time, the *context of work and use model* with which the workers will operate. The technical systems have to be "transparent" so that in the use activity one is able *to tackle problems and disturbances*, and *to develop the system* to better serve use operation.

The discussion by Ehn comes as to that part close to the principle of *continuous development* and *problem-solving activity*. Ehn (1988, 367-468) himself does not, however, draw a conclusion about what demands continuous development might set from the point of view of planning and use, which is *the main point in this study*. The planning centered view is so dominating with Ehn (1988) that it prevents him from seeing the importance of solving the integration problem between planning and use for the innovation process in the implementation.

The model of work-oriented planning is born on the basis of the concept of user-centered planning, of which one of the indications is the name of the ESPRIT project, "Human-Centred CIM Systems". Ehn (1988, 26) had in his part intended to name his book "Human centered design of computer artifacts". The anchor into the tradition of user-centered planning explains in part the limitations of the work-oriented model. Although the work-oriented model includes many methods and tools required in the new way of planning and implementation the model does not bridge *the gap between planning and use*.

Third, the research and experiment activity conducted within the program of EC FAST (Forecasting and Assessment in Science and Technology) on *"anthropocentric" systems* also belongs to the tradition of user-centered planning (see Kidd 1990; Lehner 1991; Wobbe 1992). According to the anthropocentric model, integrated manufacturing can be achieved only through *organizational structures and activities*. This deviates from the definition of techno-centric CIM (Computer Integrated Manufacturing) which emphasizes the prime importance of technical solutions. According to the anthropocentric concept, technology has to support the formation of a *co-operative way of acting*, especially cellular way of group work and skilled workforce (Kidd 1990). The anthropocentric production model has brought in two ways a new view into the planning and use of technical systems. First, the anthropocentric model emphasizes the idea of a *flexible and adaptive work organization* in which work groups manage the production system and are also able to develop it. Second, the model includes an idea of it being possible to change an organization and the way of acting to reach *simpler technical solutions* than only to automate the present practices. The technical systems so defined also serve the activity processes more efficiently (see Kidd 1990).

The problem with the anthropocentric model is that it lacks concretization (see Kidd 1990; Lehner 1991). It can be seen as a mixture of socio-technical approach, user-centered planning, and partly the models of planning and use going beyond these concepts. The anthropocentric model consists of many elements that reflect the variety in European industry. The anthropocentric production is also "marketed" as a European strategic "weapon" in the competition between the economic areas, with Japan and the USA (Wobbe 1992).

3.4 "LEAN PRODUCTION" MODEL

The relation between *planning and use* is set in a new way in the model of *"lean production"* based on the experience of Japanese industry (Womack et al. 1990). This model also makes it possible to define the innovation design dilemma in a new way.

The main features of the model can be seen to be *co-operation and simultaneous working* between the different functions in a company. In this way, the model is seen to be able to shorten the reaction time of manufacturing and at the same time to create an *innovative and "knowledge-creating" organization* which is able to continuously improve and develop its activity (Womack et al. 1990; Nonaka 1991; Cole 1994).

We can regard the command of product development process as a good example of the co-operative and simultaneous way of working (see Clark & Fujimoto 1991). As the research on car industry has shown, Japanese car factories are superior with respect to the planning of new models compared to the car manufacturers in USA and Europe (Womack et al. 1990, 104-137; Clark & Fujimoto 1991, 67-95). Nearly two times as much engineering work for a product development project was needed in USA and Europe as in Japan. Thus, the time from a product concept to the markets was 5-6 years in USA and Europe but only 3-4 years in Japan. A strong *product concept* which creates the direction and framework for many detailed *decisions* concerning a new product is mentioned as a central factor for a successful product development project, as is the way to *organize* a product development project (Clark & Fujimoto 1991, 97-285 and 337-355).

For success, it is essential to adopt a *way of acting* in the organization which results to crossing the functions. According to this way, marketing, design and production participate together *in dealing with the problems of design and production*. Thus, it is possible to put the distinctive *problem-solving processes* of the different functions into the common organizational "cycles of integrated problem-solving" (Clark & Fujimoto 1991, 205-245). Integration concerns both the scheduling between the different phases of the development process and the ways of communication between the different functions and levels of the organization. The *integrated problem-solving* will succeed only if the functions connected to the product development project *co-operate* closely and the exchange of information between the functions takes place in both directions. Hence, the *problems* and *different views* concerning the product development process can be dealt with immediately (cf. Cole 1994).

The *"ideal model" of lean production* for the planning and implementation of technical change can be crystallized as presented in Table 3.3.

Nonaka (1991) has labelled the practice of Japanese firms as the *"knowledge-creating company"* which can be seen as the strategic aim of the lean production model. Nonaka and Takeuchi (1995) go a step further by contending that Japanese companies have become successful because of their skills and expertise at *"organizational knowledge-creation"* (cf. Kodama 1995). By organizational knowledge-creation they mean the capability of a company as a whole to create new knowledge, disseminate it throughout the organization, and embody it in products, services, and systems. They take *knowledge* as a basic unit of analysis for explaining *firm behavior*. Their basic premise is that the business organization does not merely "process" knowledge but "creates" it as well (cf. Grant 1996; Spender 1996; Tobin 1998).

Nonaka and Takeuchi (1995) put a great emphasis on the concept of knowledge in considering knowledge-creating processes in an organization. Their concept is based on *"tacit"* and *"explicit"* forms of knowledge and their interaction. Nonaka and Takeuchi (1995) note that tacit knowledge, which is not easily visible and expressible, has a central role in knowledge creation (cf. Polanyi 1983). Organizational knowledge is created through a conversion process where tacit knowledge is converted into explicit knowledge, formal and systematic knowledge, to be communicated and shared within the organization, and to be internalized again into an individual´s tacit knowledge base in the form of shared mental models or technical know-how (Nonaka & Takeuchi 1995, 8-11 and 69-70). This knowledge creation and conversion process requires *intensive and laborious interaction, communication and collaboration among the members of the organization*, among the members coming from different disciplines and different levels or parts of the organization. That advances *learning and problem-solving processes* in the organization, which are, at the same time, critical factors in managing innovation (cf. Tushman & Nadler 1986; Aoki & Rosenberg 1987; Cole 1994).

Table 3.3. Dimensions of the "lean production" planning and implementation model according to different change factors of planning and implementation.

LEAN PRODUCTION MODEL	
CHANGE FACTORS	DIMENSIONS
Strategic aim	**"Knowledge-creating company"**
Design concept:	
The object of design	Constantly changing and developing activity system
Control system	Operational and functional angle, interactive and "decentralized" system architectures
Human-machine system	Information system supporting the users in the mastering of work and spotting problems
Organization of planning:	
Planning organization	Tight co-operation between planners and users
Implementation plan:	
Implementation model	Implementation as an extension of the planning
Work organization	Work-group organization, network relations
Use of professional skill	Multi-skilled workers and development work (continuous development work)

According to the "lean production" *design concept*, the creation and use of technical systems can be seen as *constantly changing and developing activity systems* as part of the knowlegde-creating company.

Already the *planning phase* rests on close *co-operation* between the different functions and organizational levels for refining the solutions and for successfully realizing them. The *development work* continues within the work groups in the production as part of the continuous development process in the organization.

Manufacturing is organized into *work-groups* on all levels of the organization according to the "lean production" model. The work-groups within production whose tasks include, besides primary process tasks, activities linked with quality control, maintenance and materials handling, are an important part here. The objective is to move as many tasks as possible on the operative level. One of the cornerstones of lean production is that problems are not only answered in the production, but also *development work* is undertaken. Development work is organized as quality circles activity (see Imai 1986 and 1997; Lillrank 1990, 94-158). The quality circles activity of work groups is concerned with products, processes and work methods and with solving the problems occurring in them.

This alone does not ensure development, however. In order to keep the development work going and to direct it into a strategic factor of the company, two things are required: (1) the network of work-groups; and (2) tools for the development work (see Lillrank 1990, 94-158):

(1) *Co-operation* is needed. Clark and Fujimoto (1991, 239-245) raise the incorporation of *"top-down"* and *"bottom-up"* development cycles as a central requirement for *integrated problem-solving*. This means co-operation between the work-groups operating on different levels of the organization. According to the above, operative groups act in close co-operation with other functions and organizational levels when undertaking incremental development work (Womack et al. 1990, 73-103).

(2) Besides a *skilled workforce* capable of co-operation, the development work requires *methods and tools*, for instance problem-solving techniques and tools for information handling (Clark & Fujimoto 1991). Without systematic methods and training for their use, the development work of the work-groups is easily left as casual dealing with problems. Japanese quality circles have "scientific" tools for quality analysis, such as different statistical tools and tools for value analysis (Ishikawa 1985; Imai 1986; Lillrank 1990, 114-118).

The "lean production" model is illustrated in the following by looking into the different ways of the planning and implementation of FMSs, according to the analysis made by Jaikumar (1986). There is a strive towards a new kind of planning and implementation practice in Japan. On the other hand, practices in line with traditional planning and operation hierarchy are adhered to in the USA. These various planning and implementation practices seem to have a relevant link to the implementation process and activity of the systems.

FMS-example: Jaikumar´s (1986) study was conducted in 1984. A sample of 35 American and 60 Japanese FM-systems were compared. The sample covered more than half of the current FM-systems of each country. The American systems averaged 6 machines, while the Japanese averaged 7. According to Jaikumar (1986):

A separate planning organization is set up for the FMS planning in the USA. This organization consists of several experts each in charge of planning in his own field of expertise. After planning the fully planned system is delivered as such to the user organization which has not participated at all in the planning.

Instead, in Japan, a fixed planning group is established for the FMS planning, where experts of different fields work in close co-operation with one another to solve the planning problems. No strict division of work exists. After planning the group moves to the implementation of the system. The planners are in charge of the system implementation and participate in the solving of problems of that phase and in transferring the planning knowledge to the users.

Jaikumar's article does not throw light on whether the users participate in the planning of the Japanese FMSs. As stated above in section 3.3, it is necessary for the users to become involved in the planning process earlier and more widely than usual in order to solve the integration problem between planning and use.

Jaikumar does not specify the technical solutions of the system based on how they take into account the requirements of operation activity, either. The implementation of an effective FMS calls for technical solutions that widen and support user control of the system, as noted in the discussion of the user-centered model in the two previous sections. In this respect, the control system is especially significant.

Overall, the traditional American way and the new Japanese way yield totally different results according to Jaikumar - in favour of the Japanese FMSs (Jaikumar 1986):

First of all, it took 2,5-3 years in the USA to plan and start up the system, in Japan half of this. Man hours for the design and planning of the system totalled on average 25000 in the USA, but in Japan only a quarter of this. Secondly, the systems differed essentially in use as to their operational qualities. The Japanese systems were altogether superior to the US systems concerning flexibility, degree of use and low number of disturbances.

The differences are considerable. For instance, the size of the product family averaged 10 in the USA systems and 93 in the Japanese. The degree of use in two shifts was 52% in the USA and 84% in Japan. In addition, a third shift was effectively used in some cases in Japan, which was rare in the USA. On average one new product per year was introduced into the system in the USA, whereas in the Japanese systems this number amounted to 22.

Jaikumar presents the *professional skill level of the system users* as an important factor explaining the differences in addition to the differences in the *planning method and practice*. The skill level is much higher in Japan than in the USA. The success of the Japanese systems depends on *continuous development work*, according to Jaikumar. This is reached through *organizational learning and experimentation*. In Japan, the *work organization* also supports full scale use of the operators' skill in system use and development. The users constantly improve the programs and are in charge of both part programming and system programming. In the USA, however, traditional organization practices based on work division are widely adhered to.

The information of Jaikumar on the Japanese systems reflects in an interesting way upon the limitations of the traditional group organization. One could perhaps deduce that the differences of the Japanese and the American systems can be explained by user team work alone, since this is more common in the Japanese systems than in the USA ones. This explanation is obviously incomplete. The differences largely originate from different *planning and implementation practices*, as Jaikumar states. The crucial factor in the Japanese systems was the co-operation of two groups, the planners and the users, that continued all the way to the operation activity. This describes the *network relations* of these groups which is a new element compared to the socio-technical group organization concept (Zuboff 1988; Nonaka 1991; Adler & Cole 1993; Hyötyläinen & Simons 1996).

3.5 SUMMARY: THREE PLANNING AND IMPLEMENTATION MODELS

Three main *"ideal models"* for the planning and implementation of new technical systems were distinguished and modelled, based chiefly on the analysis of the organization theoretical literature. The comparison of these “ideal models“ of implementation and planning is presented in Table 3.4.

The argument of the study is that the *planning and implementation approaches and practices* used by the case companies can be evaluated through these “ideal models” differing from each other. These models form the *reference framework* for describing and analyzing the implementation process in the cases in Part II of the study (cf. Sayer 1992). In the case studies these models are developed further through concrete analysis of the different phases of the implementation process. The models are also a ground for the comparative analysis of the case study results in Part III of the study. In the following, the summary of the models is presented and some conclusions are drawn.

Table 3.4. Comparison of three "ideal models".

	TECHNO-CENTRIC MODEL	USER-CENTERED MODEL	LEAN PRODUCTION MODEL
Strategic aim:	**"Unmanned factory"**	**"Skill-based production"**	**"Knowledge-creating company"**
Design concept: The object of design	Production process and machine system	Operating system (user-centered system)	Constantly changing and developing activity system
Control system	Equipment and computer centered angle, centralized system architectures, standard solutions	Operational and user-centered angle, interactive and "decentralized" system architectures	Operational and functional angle, interactive and "decentralized" system architectures
Human-machine system	Polarization between technology and man: man only supervises production	Communication and task division between man and machine: man supervises and optimizes production, and deals with disturbances	Information system supporting the users in the mastering of work and spotting problems
Organization of planning: Planning organization	Segmentalist planning: separate planning organization (no users included), specialized planning functions	Simultaneous planning; co-operation between planners and users, "participative" planning	Tight co-operation between planners and users
Implementa-tion plan: Implementation model	Strict task division between planning and use	User training and training by participation in planning	Implementation as an extension of the planning
Work organization	Work rationalization and strict division of work, "individual" work	Work reorganization and expansion of tasks, group work	Work-group organization, network relations
Use of professional skill	Strive for replacing human work by automation	Wide-scale use of workers´ professional skills	Multi-skilled workers and development work

The analysis of the planning and implementation models refers to the fact that the *planning paradigm* has influence on whatever is seen as an *aim of the planning* and an *object of design*. That has, again, a solid link to the *way of organizing the planning* and *implementation model*.

The *techno-centric model* focuses on the planning of the production process and machine system, which takes place in a highly specialized and segmentalist planning organization. It is also characteristic that the planning of machine and control systems takes place separately and the division of work between planning and operation is strict. The techno-centric model is well-known. Its aim can be seen to be an "unmanned factory". Despite many warnings, this model is widely used even today in the introduction of new technology.

The *user-centered model* based mainly on the socio-technical approach aims at the planning of user-centered system. The users participate in the planning. The user-centered model is seen to open new opportunities in the implementation of new technology. It is a widely preferred model. However, the analysis showed that the model has certain limitations concerning the three factors of the *innovation design dilemma* of technical change. It solves to a certain extent the dilemmas between two factors: the techno-centric and organizational approaches; and the top-down and bottom-up approaches. It has, however, no answer for the factor between the planning and the execution.

The third model is called the *"lean production" model*. The *main points* in the model are:

- constantly changing and developing activity system as an object of design
- tight connections between the planners and the users of the system
- multi-skilled workers
- work-group organization
- users´ role as active problem solvers
- network relations inside the user organization
- tools and methods for development activity and co-operation in the user organization.

The lean production model strives for evolving operational systems and for active problem solving and development work performed by the users. Co-operation between the planners and users as well as joint implementation activities can be seen central in creating this kind of a practice. The lean production model can be seen to try to create an innovative and "knowledge-creating" organization capable of continuous improvement and of developing the operation system, based on work-group and network organization (cf. Cole 1994; Winter 1996).

4 RESEARCH DESIGN OF THE CASE STUDIES

4.1 RESEARCH DESIGN AND RESEARCH QUESTIONS

The study is constructed on the results of three case studies. The object of the case studies is the implementation process of an FMS (Flexible Manufacturing System). The study looks at the implementation of FMSs with regard to the machine shop industry. This is based on the fact that the application of production automation as a part of new productional thinking has been the most visible in the machine shop industry where opportunities provided by information technology have been applied side by side with organizational solutions during the past decade (Fix-Stertz et al. 1986; ECE 1986; Bolwijn et al. 1986; Edquist & Jakobsson 1988; Kelley & Brooks 1988; Fix-Stertz et al. 1990; Ranta & Tchijov 1990; Brödner 1990b; Lay 1990; Ollus et al. 1990; Boer 1991).

FMS-technology is the most developed machine shop automation applied in practice. FMS is qualitywise a process innovation of a new level in the development history of the machine shop industry. FMS is the first automation system to flexibly combine through computer the functions of the manufacturing process, machining, materials handling and control, all separate until now (Mortimer 1984 and 1985; Boer 1991).

The meaning of FMS and its implementation is enhanced by the fact that FMS is seen as a step towards computer integrated manufacturing (CIM), where FMSs and other automation systems of manufacturing are thought to be integrated to one other and to the plant´s planning and control functions (Bessant & Haywood 1985; Rembold et al. 1985; Hammer 1991). That emphazises the importance of understanding the implementation process of an FMS, because in the case of *larger systems*, failures in the implementation have more serious effects (cf. Kodama 1995).

The material for the case studies described in this study was originally produced through *three intensive case studies* on the implementation of FM-systems carried out in three succeeding projects in the years 1985-1992 (see Appendices 1 and 2). The original case studies are based on the principles of *experimental development research* of which the main phases are basic analysis, experimentation, and follow-up and evaluation (Norros et al. 1988a and b; Toikka et al. 1988; Alasoini et al. 1994; Hyötyläinen et al. 1997; cf. Engeström 1987).

The *FMS-study* began in 1985 and was completed in 1992. Case study A covers the years 1985-89, case study B the years 1986-89 and case study C the years 1989-92.

The researchers *participated actively in and followed up intensively* the implementation process of the case systems. In cases A and C, the researchers participated actively in the implementation process to create and introduce *new methods, tools and organizational forms* in the user organization. In these cases, the researchers participated in the change processes in the companies almost on a weekly basis. Case studies A and C are the main sources in this study. Instead, case study B is by its nature a *follow-up study*, although new methods were applied for the observation of the users′ activity and the operation of the system. Case study B was aimed at producing comparative material especially for the results of case study A. Besides, systems A and C are large FM-systems, whereas system B is a relatively small FMS.

Due to the intensity and duration of the original case studies, the study material is extensive consisting of thousands of pages of different material and documents. Therefore, this study focuses only on three cases. The large case study material of the original studies makes it possible for this study to form a detailed description of the planning and implementation process of the cases. It is impossible to take into the study more cases on that level of depth (cf. Leonard-Barton 1990; Pettigrew 1990; Glaser & Strauss 1967; 28-31).

The case studies are presented in Part II of the study in Chapters 5-7. The objective is to *describe* how the new technical systems in the cases are planned, implemented and used. A further objective is to find out what kinds of planning and implementation models, methods and organizational forms can further *organizational problem-solving and development activity* in the definition of the innovation problem and goal setting, the planning phase, the implementation phase and the operation phase of new technical systems, which can be assumed to contribute to a successful implementation process. A special focus is laid on the *activities of the management and users* in that process.

The *action model of the implementation process* is the ground in the consideration of the activities of the management and users and their interaction in the cases (Figure 2.2). The approaches and activities of the management and users in the different phases of the implementation process in the cases are evaluated through *the three "ideal models" of implementation and planning* (Table 3.4).

A special viewpoint for assessing the case studies is formed by the innovation design dilemma and its three factors (Section 2.2). The division between planning and implementation, which also describes the separation of planning and execution, forms a starting point for the description and analysis of the case studies.

The study considers the implementation process of the technical systems as *social activity* which is governed by the *organizational patterns* of the planning and implementation process in the cases. The research questions are connected to that viewpoint. As the analysis of the three "ideal models" of implementation and planning and especially the "lean production" model showed, some important organizational patterns have a great effect on the successes or failures of the implementation process. The *research questions* in the cases are as follows:

- What is the target of the planning process?
- How is the planning organized and what role do the users have in the planning phase?
- What kinds of implementation of the plans is seen and through which measures is the implementation phase prepared?
- How is the continuous improvement and development activity of the system undertaken in the implementation and operation phases and what is the role of the users here?

In the descriptions of the implementation process in the cases the management´s and users´ approaches and activities are considered from the point of view of the research questions. At the same time the "objective" progress of the implementation process in the different phases is analyzed and the formation of technical solutions is evaluated.

The descriptions of the case studies act as a basis for the comparative analyses to be made in Part III of the study.

4.2 DESCRIPTION AND ANALYSIS PATTERN IN THE CASES

The description of the implementation process in the cases is organized in accordance with the activity phases presented in the action model of the implementation process (Figure 2.2). These are: (1) defining the innovation problem and goal setting; (2) planning activity; (3) implementation activity; and (4) use activity in the "normal" operation phase.

The activity of *defining the innovation problem and goal setting* is analyzed in all cases through three factors of the change process: reason for change; level and pace of change; and goals.

Planning activity in the cases is considered through the following elements of the planning phase: duration of planning activity; products; design concept; organization of planning; and implementation plan and model.

Implementation activity in the cases is divided into the following elements of the implementation phase: duration of implementation; timing; resources of implementation; realization of work organizational goals; problems and development needs in the implementation phase; and users´ activity.

Use activity in the "normal" operation phase is considered in different ways in the cases, depending on the features of the case. The main points are: disturbances and their effect; problems and development needs; and development work and users´ activity.

In cases A and C there are some additional features due to the analysis of the results of the intervention activities by the researchers in these cases. The results of the interventions are assessed in connection with the descriptions of the case studies.

The *preliminary analysis* is done after the treatment of each main activity phase in each case. Finally, as a summary of the case, *the action model of the implementation process* in the case is presented.

PART II: DESCRIPTION AND ANALYSIS OF THE CASE STUDIES

Techno-organizational innovation and problem-solving processes of technical change are described through the implementation process of *three case systems* in this part of the study. The object of the case studies is the implementation process of an FMS (Flexible Manufacturing System). The aim is to describe and explore in depth the implementation process of technical systems as social activity in the user organization. The focus is on *the activities of the management and users and their interaction* and the progress of the implementation process. The case studies (A, B, C) are presented in Chapters 5-7, a case in each chapter.

5 CASE A: IMPLEMENTATION PROCESS OF A LARGE FMS

Case study A is related to a *change process* in a product shop producing cogwheels in a large diesel engine factory that was a part of a major Finnish corporation. The intensive case study covered the years 1985-1989. The number of personnel in the factory was at that time over 800, out of which 600 persons were blue-collar workers (see Seppälä et al. 1988b). Nowadays, in 1997, the factory belongs to another Finnish corporation, because some years ago the original corporation sold a part of its activities when focusing on its core business.

The planning of *large FM-system A* began in 1983 and the investment decision was made a year after that. Then, the technical design was started. The first machines were installed at the end of 1985. The different cells of the system were installed and implemented stepwise, one cell after another. The FM-system reached its full scope at the end of 1987 when the central control system was implemented. It can be seen that "normal" operation of the system began in the spring of 1988, when the crew of the system changed over from two shifts to working in three shifts. Thus, the development process, from the beginning of planning to normal operation of the system, took *over five years*. The development of the system did not, however, end in that, as we will see.

There are three points that form special *aspects for analyzing the implementation process* of system A. First, as is customary according to the "techno-centric" model, the *technical design* was executed in great detail. However, an *organization plan* was sketched only at the end of the technical design. The change was, however, understood by the management as a *big technical and organizational transition*. The extent of the change was emphasized more by the fact that all six users selected to the system had worked earlier on manual and semi-automatic machine tools and had no previous experience of NC-machines.

Second, the tensions due to the *"techno-centric" way of planning* and *"skill-based" organizational concept* are emphasized in the analysis of the implementation process. According to the vision on the organization, the users were to form a highly and homogenously skilled group answering for the operation of the system. Instead, the way of planning was quite traditional.

Another aspect to the description of the case is that the researchers did not only follow up and evaluate the implementation process of system A but *participated in it by innovating new forms of training and organization development*, in accordance with experimental development research. The results of these efforts by the researchers are evaluated within the case description.

5.1 DEFINING THE INNOVATION PROBLEM AND GOAL SETTING

Attempts to Renovate Production

In Case A the *definition of an innovation problem* was by no means a straightforward process. The FMS alternative was not considered until several years after the original need for renovating the production process of the product shop under the study was realized.

The production management made already at the turn of the 1970s and 1980s *first attempts* to change the production system of the product shop. Different alternatives were scrutinized. The production management saw that the production was becoming unprofitable due to obsolete machinery. There were also problems in the ability to keep delivery times, which was caused by the difficulty in managing a broad product range in the traditional functional production system. The organization consisted of many separate and hierarchical departments and functions that planned and controlled in detail all production operations. Besides, each worker was working only on his own machine (Seppälä et al. 1988b, 103-112; Norros et al. 1988a).

In 1980 the production management made an *investment proposal* for the reform of the production in the product shop. According to the proposal, the product range and production methods were to remain unchanged but the machinery was to be *modernized* through replacement investments. The functional production layout and organization were to be replaced by *cellular production*. However, the proposal was not accepted in the headquaters of the corporation. One reason was that changes in the demand of the diesel engines produced by the factory were anticipated in the near future.

The *next time* the profitability of the cogwheel production was analyzed by the production management was in the early years of the 1980s. The *analysis* was done more accurately with regard to different types of cogwheels, based on a make-buy analysis. The result was that most of the cogwheels could be produced as long as the old machine tools functioned. Some, "strategic" cogwheels could be produced profitably also in the future, provided that investment in the development of production methods took place.

Decision on FMS

The *third planning effort* was started in the spring of 1983 when a development plan concerning all manufacturing processes in the plant was drafted by the production management, with an outside consultant as a leader. As a part of the plan the production of cogwheels was also analyzed.

Based on that plan, the *feasibility study* on the production of cogwheels was started in June 1993 and it lasted nearly for a year, organized mainly as a thesis required for a diploma done by an *engineering student* (see Lyytikäinen 1984). The *production management and planners* of the factory as well as an *outside consultant* also participated in conducting the feasibility study. The *workers* did not take part in the process in any way. The starting point set by the plant and production management was that the cogwheels made in the product shop could no longer be produced with traditional methods. The result of the feasibility study was the proposal to organize the production as a *product shop organization* and to move into the *implementation of a large FMS*.

Based on the result of the feasibility study, the production management made an *investment proposal* to the headquarters of the corporation. It was not accepted as such. With new calculations and refinements, the *decision on investment* was made in June 1984. The reasons for the change process and its scope as well as the goals set are presented in Table 5.1 (see Lyytikäinen 1984; Norros 1988a).

The change was seen as an answer to *productional problems* becoming a threat to the continuation of the whole production of cogwheels in the plant. The management saw the change as *a big technical and organizational transition* for it was the purpose to change over from the functional organization based on traditional manual and semi-automatic machines directly to a relatively large FMS and new organization based on the principles of a product shop. Hence, great functional and economic *goals* were set for the implementation of the FMS. The goals concerned the issues of productivity, capacity, flexibility and quality. The possibility for *limited* *unmanned production* was also set as a goal, because the management saw it as offering flexibility with respect to the capacity without adding the work shifts. However, that goal was not achieved due to the choices made in the technical design, as we will see later.

Table 5.1. Factors and dimensions of the change process in case A.

FACTORS OF CHANGE	DIMENSIONS OF THE CHANGE PROCESS
Reason for change	Problems of unprofitability of the production system: productivity, capacity, flexibility, quality
Level and pace of change	Great, radical change: change-over from the functional production organization based on manual and semi-automatic machines to a large FM-system
Goals	To increase capacity by 30 % To shorten throughput time from 12 weeks to 1 week To decrease lot sizes (to 50-250, earlier lot sizes in hundreds and thousands) To decrease costs of inventories by 80% from earlier To increase the quality level (higher quality level, uniform quality, achieving quality with fewer operations) To reduce workforce To increase productivity by 25 % concerning the staff Possibility for limited unmanned production

Analysis

The description of the section raises five important points and questions for further analysis:

(1) The description points out the fact that the *definition of the innovation problem* was not an easy task for the production management. The management made altogether *three different efforts* to renovate the production before the beginning of the *feasibility study* that proposed the implementation of the FMS. *It can be asked how that kind of difficulties in the management's activities describe more widely the planning and implementation phases.*

(2) The earlier investment proposal by the production management was not accepted in the company. That shows that there were *differing views* of development needs at different levels of the company. The second proposal by the production management was not approved directly on the upper level of the corporation due to differing viewpoints to the business. It was accepted only with further calculations and refinements. *It can be asked*

how that kind of differing viewpoints in the management describe more widely the planning and implementation practice by the management.
(3) The management saw the change as a *big technical and organizational transition. It can be asked what effects that has on the management's planning and implementation activities.*

(4) As is traditional, the *workers* did not get to influence at all the decision process on a new production system. *There is reason to ask what implications this has on further implementation processes.*

(5) The definition of the innovation problem was a *long process*, about five years. Three earlier efforts took three years. The feasibility study lasted a year. *It can be asked how long the planning and implementation phases become.*

5.2 PLANNING ACTIVITY

After the investment decision, the *planning activity* was iniated, during which the *technical design* and *realization planning* of the system took place (cf. Rouse 1991; Boer 1991, 108-131). The *main factors and dimensions of the planning activity in case A* are presented in Table 5.2 (cf. Table 3.4).

In the following, the planning phase of system A is described in more detail. The implementation plan is presented in Section 5.3. The system training given by the researchers is considered in Section 5.4.

Duration of and Responsibility for Planning

In Table 5.2, especially two things are worth noting. First, *the plant* itself answered totally for the design and realization of the system. In the early phase of the planning, the production management also considered the possibility to buy a "turnkey" system. That idea turned out impossible. All in all, there were *six main vendors* of whose machines system A was put together by the plant.

Second, the *design of the system* was by no means an easy task for the management. Planning of system A was a *long process*, taking nearly three years. In addition, the planning of the central control system as a whole as well as some other technical design issues were still *continuing* during the implementation phase which began as the implementation of the first cells of the system at the end of 1985.

Table 5.2. Factors and dimensions of the planning activity in case A.

FACTORS	**DIMENSIONS OF PLANNING ACTIVITY**
Duration of the planning phase:	Over 2,5 years (including the feasibility study)
Products:	Cogwheels (rotation parts) Size of product family: 50 Lot size: 50-250
Design concept:	
The object of design	Main emphasis on the design of the production process and machine system
Production process	Compromising with the automation level
Control system	*First version:* an efficient and broad system supporting the activity of the users *Second version:* a trimmed and simple system
Organization of planning:	
Responsibility for the design of the system	The plant alone: an engineering student mainly conducted the feasibility study; an outside consultant helped in the feasibility study phase; the researchers participated in the implementation phase
Planning organization	*Feasibility study:* production management and planners *Technical design:* the planning group comprising the management and planners; segmentalist planning *Realization planning:* the project group consisting of the management, planners, one user (a shop steward) and two other shop stewards
Implementation plan: Implementation model	The plan for job rotation Traditional distinction between planning and use: no special attention to and no resources for implementation *New approach:* the system was planned to be implemented stepwise for helping the users in the learning process; the systems designer was designated to become the leader of the system; the plan for the users´ considerable role in the implementation
Work organization	The plan for homogenous “group” organization
Training and use of professional skills	Large training program for the users; system training given by the researchers as a part of the user training; system training partly acted as a form of planning where the users had a central role

The difficulties of the design came to light, for instance, as *changes* in the technical solutions were made during the planning, as we will see later. On the other hand, the management used *outside help* in the planning and implementation. The feasibility study was mainly done by the engineering student, an outside consultant was used as well. Also, some members of the planning group visited Sweden to familiarize themselves with the use of a corresponding system of cogwheel production and visited an international conference on advanced manufacturing systems.

The researchers came along to the change process when the planning was already far advanced, in the spring of 1985. For example, many machines of the system were already ordered at that time. The study was started by the analysis of the change process.

Products

In case A, the choice of a *product family* proved a multi-phased process. Already before the feasibility study, special cogwheels were ruled out of further consideration, to be produced with traditional manual machines belonging to the domain of the product shop. The feasibility study ended up with a product family of 70 product variants (Lyytikäinen 1984).

In the technical design phase some *changes* were made and *alternatives* were evaluated. A certain type of cogwheels was decided to be left outside the product family whereupon it was *reduced* to 50 different variants. At the same time, the corresponding work phase was left out of the system. After the implementation the product family increased again, as we will see later.

With respect to lot sizes, it was seen that a *lot size* below 50 pieces was not economically feasible to produce in the system, due to the need to change over from one lot to another by performing manually the changes of settings and programs for the machines.

In this respect, an alternative for a more automatic system where *NC-programs* are stored in the central control system and machines have their own *tool systems* was also considered in the technical design phase. However, that alternative was believed not to be economically feasible and technically too risky.

Design Concept

The *object of design* was defined according to the traditional "techno-centric" approach (see Table 5.2; cf. Table 3.4). The main attention focused solely on the design of the *production process and the machine system*. The planning of the *control system* was done apart from the production process design. In fact, the planning of the control system was first started only in the autumn of 1985, when the process plan was complete and the machines of the system had been ordered. Besides, this planning was stopped for over a year due to the prolongation of the implementation of the system. In the process design the question of *work organization* and its requirements were not taken into account.

In the following, the technical design of the production process and the machine system, and the control system are discussed:

Production process and machine system: System A is a relatively *large system*, since it comprises three robotized machining cells (turning, milling, scraping) and one manual machining cell (grinding), an automatic tempering plant, an automized pallet storage and a central control system (see Norros et al. 1988a; Seppälä et al. 1988b, 118-120). There are two NC-machines and one robot in each automatic machining cell. Besides, in two of the three cells there is some semi-automatic equipment. Altogether, there are 20 machines and equipment in the system.

During the technical design *changes* were made to the plan of the system. The flexible guided vehicle system proposed by the feasibility study was replaced by the *fixed transport system* consisting of an automated pallet storage. This change was justified mainly with technical reasons and with referring to the functional limitations of the guided vehicle system. Also cost factors had a certain role. Second, the *finishing cell* (grinding) in the system was changed from automatic and robotized operation, as was planned in the feasibility study, to be carried out on conventional machines also in the future (see Lyytikäinen 1984; Seppälä et al. 1988b, 119). This had a harmful effect on production control in the system, because the important finishing phase became a separate activity from the FM-system. It resulted also in an *organizational division* between the crew of the FMS and the men of the finishing phase. The finishing personnel were defined clearly outside of the FM-system although their work was closely connected to the operation of the FMS through the central control system and automated pallet storage as well as through the machining phases. Moveover, in the planning phase the *automation level of the NC-machines* of the system was reduced, which can be seen as one of the reasons for the abundant disturbances occurring in the system, as we will see later. For example, it was possible to make the change of settings as presetting only in the case of one NC-machine. Hence, unmanned operation was not achieved as aimed. The reason to that lies also in the changes made to the plan of the central control system.

Control system: In the *original plan* of the central *control system* there were many significant features in accordance with “user-centered” systems (see Table 5.2; cf. Table 3.4). One of them was an efficient computer-based control system which was to look after not only the *production control* and the control of cells in the system, but also the control of the materials state and to collect data on the system and its history. An *interactiv*e and *"decentralized"* system architecture with many data base features was also planned for fostering use activity. *Several terminals* by which the users could be in communication with the central control system and the machines under it were planned to parts of the system (see Norros et al. 1988a, 158-160).

The planning of the central control system *was started* on the basis described above but the planning was stopped for over a year, as already stated, because of the prolongation of the implementation process of the system, the central control system not being needed at that time. However, the earlier functional goals were assessed anew and related to the investment cost and economic goals. Hence, when the planning was continued - in the spring of 1987 - the central control system was built on *a simpler and cheaper solution*, based on a programmable logics system than in the original plan.

The change meant reduction in the versatility, flexibility and useability of the control system. The first result was that the system *interactivity* decreased. The number of terminals was reduced to one. A great deal of monitoring was left to direct visual and auditory control, which could be only partially carried out during operation. Although the system was supplied with a certain kind of alarm system, no support for failure diagnostics was available. There was no support for tool and program controls of the NC-machines, either. Secondly, *data base characterictics* were minimized. Although the system supported to a certain extent the implementation of production plans (i.e. route planning, scheduling, and work sequence planning), the system could not create any data on design, materials, production and its history, believed in general to promote the control level of a system (see Norros et al. 1988a; Sections 3.2 and 3.3).

The result from all this was that the action of the users and the control of the system became difficult. This came into light already during the implementation of the system. Among other things, the users tried themselves to keep a record of the materials placed into the automated pallet storage. However, this created "unnecessary" work and difficulties in doing so due to different practices in different shifts. The users had to "peek" now and then to see to which materials were in the storage.

Besides, the production planning of the system was not directly connected to the plant´s *production control system*, necessitating a *manual planning phase*, which became an exclusive task of the system leader.

Organization of Planning

The *planning organization* was quite a traditional one, since the planning was organized in a "techno-centric" way. The feasibility study as well as the *technical design* were produced by the production management and the planners, helped by the engineering student and an outside consultant in the feasibility study phase. In the technical design, the engineer who conducted the feasibility study acted as a full time designer for the technical systems.

Segmentalist planning also prevailed, since the planning of the control system as well as of the work organization were done separately from the design of the production process and the machine system (see Table 5.2; cf. Table 3.4). Moreover, the *workers* did not participate in the planning in these phases at all. Only some "information" meetings were arranged for the personnel about the planned changes.

Also the *realization planning* was organized relatively traditionally, for there was only one user (a shop steward) in the project group answering for the realization planning. In addition, two shop stewards took part in the project group, as "official" representatives. The role of the workers was limited to the transmission of information only. They had no real influence on the design.

However, the exception to that was the *system training* given by the researchers. The training gave a form by which the production manager, supervisors, planners and the users of the system solved problems concerning the realization and implementation of the system together, as we will see in Section 5.4.

Analysis

In the description of the planning practice, there are four points worth further analysis:

(1) The role of the *user organization* was crucial for making the various system parts function together. However, the *design of system* A was not an easy task for the management. The management made many *changes* into the design of the system and considered different *alternatives* concerning the system operation during the planning phase. The planning phase lasted over 2,5 years. *It can be asked how that kind of a pattern describes more generally the development efforts by the management.*

(2) In the case, the *object of design* was defined according to the *"techno-centric" approach*. The *segmentalist approach* also prevailed where the control system is planned separately from the process design and organizational planning. *It is interesting to examine what kinds of impacts that has on the implementation and "normal" operation phases.*

(3) In the planning phase *the automation level of the system and the features of the control system* were trimmed. *One can ask what effects that has on the function of the system and the activity of the users.*

(4) The *planning practice* was a traditional one. The *"basic" innovation* of the system was exclusively answered for by the production management and planners involved as "top-down" activity. The users did not participate at all in the planning process. *There is reason to ask what effects that has on the implementation and the activity of the users.*

5.3 IMPLEMENTATION PLAN

In the planning of system A, the relation between planning and use was seen mainly as traditional, as the plan realized directly into use. Hence, no special attention was paid to resourcing the change process and to development work to be done in the implementation phase of the system, which made the implementation more difficult and prolonged this phase. In the following, the characteristics of the implementation model are discussed (see Table 5.2; cf. Table 3.4).

Implementation Model

Nevertheless, in the *"implementation model"* there were three new approaches, in accordance with the "user-centered" model and even with the "lean production" model. These features are as follows:

(1) The FMS was seen to be technically and with respect to learning so great a change that its implementation in one go would be difficult. Hence, it was planned *to implement the system cell by cell.* The planned order of the installation of different cells is shown in Table 5.3.

Table 5.3. Planned order of installation of different cells in system A.

Tempering plant	1985, November
Turning cell	1986, February
Automated pallet storage	1986, March
Milling cell	1986, April
Scraping cell	1986, April
Grinding cell	1986, August

The implementation sequence and also the timing presented in Table 5.3 were *changed* from the sequence and timing planned in the feasibility study. Especially three points are worth noting. First, the tempering plant wanted implementation first, because tempering was made off-site in the old production. Second, implementation of the turning cell, the first phase in the sequence of machining phases, was seen necessary at an early stage. The reason was that the tolerance demands in turning increased due to the demands set by the automated phases after the turning phase. Third, the automated pallet storage needed to be installed early because the transport system was changed, as already stated. The grinding cell as well as all grinding phases were later decided to be carried out on conventional machines, as stated above.

As seen in Table 5.3, the installation of the whole system was going to be completed in about ten months. The management assumed that the cells would be implemented after they were installed. After a training time, not specified in the planning phase in any way, the cells would be in full production, replacing the old production machines. As we will see, both of these assumptions proved false. The installation time was prolonged, and the implementation turned out to be a sticky process.

(2) The engineer in charge of the design advanced to be the *leader of the system*. The engineer can be seen, in a sense, to form a one-man "link" between the planning and the implementation. He "conveyed" planning knowledge to the implementation in leading the implementation of the system. However, this practice did not proceed without difficulties, as we will see. One reason for that was insufficient attention of the management to the implementation and, therefore, to giving the necessary technical help for the system development in the implementation.

(3) The *role of the users* was planned to occupy a central position in the implementation of the cells. That is reflected also by the *extensive training* given to the users mainly before the implementation and by planning the implementation to proceed stepwise to give time for the users to learn new tasks.

Work Organization

The issues of *manpower and work organization* were not at all considered in the process design, as is traditional (see Section 3.1). Only at a late phase of the planning - in the spring of 1985 - organizational issues were taken into account (see Hyötyläinen et al. 1990). However, the concept of work organization and professional skills were then sketched chiefly in accordance with the *"skill-based" model*. The *traditional manpower strategy* based on strict division of work was represented only by the solution whereby the users of the manual grinding station connected tightly to the function of system A were left outside the automatic system and also without the training concerning its use (Norros et al. 1988a, 160-161). Otherwise, the homogenous and high skill level of the users and co-operation based on group work were set as a target.

The tasks of the users planned by the management are presented in Table 5.4 (classified into main groups by R.H.) (cf. Toikka et al. 1991a, 49 and 59).

Table 5.4. Planned tasks of the users in system A.

Operation tasks
Loading and unloading pallets
Monitoring the operation of cells and system
Change-over of tools to machines
Handling and controlling the tempering plant
Control tasks
Quality control and measurements
Maintenance tasks
Disturbance control
Preparation tasks
Presetting of tools
Tools maintenance
Testing, repairing and optimizing of the programs of NC-machines and robots
Planning and development tasks
Programming NC-machines, robots and the tempering plant
Participating in methods and tools design

The main tasks of the system were planned to be carried out by the users, according to "skill-based" production (see Section 3.2). Later we will see how this plan was realized and how the time distribution of the users´ tasks was formed.

In addition to the workers, a leader was planned to belong to the personnel of the system. The *tasks of the leader* were planned to comprise the following: production control and scheduling; ordering materials and tools; answering for maintenance; quality control; the development and maintenance of the methods level; and helping the workers in disturbance control.

Only some tasks of quality control were left outside the system. Quality personnel did sample tests of the cogwheels produced, with special measurement equipment. Materials procurement was also left outside the FMS as a special function.

Training and Use of Professional Skills

The *concept of recruitment and training* contained also strong elements in accordance with the "skill-based" model. First, all six (later seven) users of the system were selected from the workers working in the old product shop although none of them had earlier knowledge or experience on NC-machines and programming. Second, the production management saw the change-over directly to an FMS as a *great transition*. Hence, the users were planned to have an extensive *training program* which was aimed to develop NC skills, understand the production process, and learn the use of machines and equipment. The *system training*, arranged by the researchers, formed an additional part. That will be presented in Section 5.4.

The technical training was given mainly before the implementation of the system began. The realization of the training program started over half a year before the beginning of the implementation. The training program compiled by the management had two parts: training through participation in the system installation and implementation, and technical training.

The most extensive part of the training program was *user participation in the system installation and implementation*. This training was carried out partly as use training and guidance, on-the-job training, given by the machine vendors in connection with the installation and implementation of the machines. However, the training of the users happened to a great extent through *experimenting and learning* in practice on their own initiative, after the vendors had left. All in all, it can be seen that nearly all users spent *over half a year of working time* to learn to use the machines and equipment of the system and for learning the programming of the machines (the users answered alone for the programming of the machine tools, robots, and the tempering plant). Only the implementation of the first cell lasted for ten months, as we will see.

The extensive off-the-job *technical training* given to the users is shown in Table 5.5.

Table 5.5. Technical training of the users in case A.

OCCASION	ORGANISER	DURATION
Basic course on NC-technique	Vocational training center	2 weeks
Training of automatic cell operation	Another company´s training center	1 week
Learning the use of an NC-machine (some users)	The plant´s own NC turning machine	2 weeks
Products and process training	The plant´s own experts	4 days
Training on the machine tools	Vendors	1 week
Training on robots	Vendor	3 days

Thus, the total duration of course days per user amounted to 27-37, depending on the user. Besides, two users went abroad for one week with some vendors of NC-machines for learning the principles of the machines. Furthermore, the system training was given in 9 course days. Hence, the users got a total of 36-46 training days off-the-job training.

Analysis

There are two important questions for further analysis concerning the implementation plan:

(1) The management acted according to the *"techno-centric" model* in which planning is seen as a separate phase, terminating at the beginning of the implementation (see Section 3.1). *There is reason to ask how that affects the implementation.*

(2) Despite the *"techno-centric" design concept* and *traditional planning practice* the management saw it necessary to plan a new kind of *work organization* and *training practice*. However, the organization concept was considered only at a late phase of the technical design. It is, however, worth noting that the need for the user training program was anticipated and explicated in a specific plan. Also some *new features of implementation* were seen as necessary. The solutions planned were in accordance with "skill-based" production and partly with the "lean production" model. Especially, the implementation planned to proceed step by step and the advancing of the engineer in charge of the design to lead the system can be seen as an indication of the methods of "lean production". *The question is how that may affect the implementation and the activity of the users.*

5.4 SYSTEM TRAINING

Missed "Bottom-up" Potential in Planning

Due to the adopted planning practice, *the users* could not influence the design and plan of the system or during the planning phase adopt and learn design knowledge concerning the system to be implemented. To evaluate the users´ potentials to participate in the planning and implementation, the researchers interviewed all six users intensively, in October 1985, some months before the beginning of the implementation, and just before the *system training* given by the researchers was started.

The purpose of the interview was to consider the *users´s view* on their "old" work and assess *development seeds* concerning their "tacit" and "explicit" knowledge of the whole production. The users were able to conceptualize their views in the form of models on production, formed during the interview based on the "tasks" given in black and white. The result was positively suprising. One could have thought that the knowledge of the workers would be limited near to their own work and product shop. However, all six workers moving to be the users of the FMS were experienced machinists (Norros et al. 1988a).

The interviews tried to give the users´ "tacit" cognitive and other models an "explicit" form. It became clear that these models exceeded the requirements of special tasks restricted to particular machining phases in the old production. The interviews indicated that the users possessed many kinds of knowledge clearly exceeding the requirements of their tasks (see Norros et al. 1988a, 162-163; Toikka et al. 1991b; Norros 1991):

- *product knowledge* concerning the functional significance and requirements of cogwheels in diesel engines (the criteria for cogwheel surface quality and tolerances, for example, were linked to operational requirements for the engines, such as noiseless power transmission and adjoining durability, and this knowledge was further connected to the economic view on the distinction between "sufficient" quality and uneconomic "over-quality" of cogwheels);
- *process knowledge* concerning the sequence of machining phases in cogwheel production and the demands made upon these phases by interconnections between them (e.g. knowledge that successful milling depended on extra allowances in turning, which could not be learned only from drawings but mainly from experience);
- *organizational knowledge* of the plant as a complex functional system (the workers were able to present models on paper that covered the different functions and their interaction in the plant - supervision, work and production planning, methods design, maintenance, tool maintenance, quality control, materials management, product design, and sales);
- *knowledge on product markets* (the economic significance of cogwheel and diesel engine manufacturing appeared to be clear to the workers, who were able to state accurately where the diesel engines and cogwheels made in the plant were sold to and what the market situation was).

It is reasonable to assume that this knowlegde could have been utilized during the planning process. Also two of the users interviewed stated explicitly that, given an opportunity, the users could have made some positive contribution to the decision related, for example, to the choice of new machinery. During the system training that knowledge was used in the modelling and simulation of system A and its operation. The results obtained are discussed next.

The users saw the change-over into the FMS as a necessary step for the continuation of the production of cogwheels. The users assessed that a change would greatly affect their *work*. The change was seen to develop the work. The users felt, however, that they had no influence on the formation of their work in the system.

The Goals of System Training

As a part of case study A, the researchers designed and led the *system training* given to the users, 9 course days in all, lasting 5-8 hours per day. In the first place, the purpose of the system training was to support the other training of the users, coming from different sources. The goal was to give *systematic thinking tools* to the users, aiming at the formation of a *system-oriented way of working* needed for the mastering of the system (see Toikka et al. 1986; Toikka 1987; Norros et al. 1988a, 144-148; Norros 1991; cf. Zuboff 1988).

On the other hand, the researchers aimed at drawing *the users into the planning and implemention process* through the system training (see Norros et al. 1988a, 179-185). There was an opportunity for this, because at the beginning of the system training - in autumn in 1985 - the installation of the cells of the system had not yet started. The implementation began only at the end of 1985, lasting as a whole over two years. Moreover, the design of the central control system was just starting when the system training started. In the beginning of 1986, there was already a first version of the control system based on a computer system to be used as a basis in the system training. The design of a new more trimmed control system started in spring in 1987 and it was implemented in November 1987. Hence, it provided a good chance to include also design questions concerning the system in the system training.

Realization

The course days and the topics of the system training are presented in Table 5.6.

The purpose of the system training *was to give conceptual tools, and models to the users*. The models and their use were connected tightly to the consideration of the questions concerning the planning, implementation and use of the system. Models were produced on three levels in the system training (see Table 5.6) (see Toikka 1987; Norros et al. 1988a, 179-185; see models and their use in instruction, Engeström 1987 and 1994).

Table 5.6. Course days and subject of the system training in case A.

COURSE DAY	DATE	SUBJECT
1. session	26.10.1985	*Developmental models* of machine shop production and its history
2. session	9.11.1985	*Development models* of system A and *analysis of the change process* to the FMS
3. session	6.3.1986	*System models* of the process and control of system A and *simulation* of the system activity
4. session	21.3.1986	*Simulation* of operations of system A with *operation models*
5. session	17.4.1986	*Safety analysis* of system A with system models
6. session	29.4.1986	*Safety analysis* of system A with operation models
7. session	17.6.1986	*Summary* of the safety analysis and of the system training
8. session	18.8.1986	Overview of the implementation phase and start of *intensive follow-up* of the implementation
9. session	4.11.1987	Training on the *central control system* of system A and *simulation* of control functions

Developmental models that concern machine shop manufacturing and the history of its production systems were a starting point. Therefore, a development model of system A could be produced. This model contained the elements and functions of system A. The *functional and economic reasons* for the change-over to system A were analyzed with the model. In that way, a ground for understanding the development mechanisms of the system was created. Secondly, *system models* concerning the production process (layout, material flow, machining processes) and control system (units, activity principles, hierarchy of control functions) of system A were created. With the system models the action of the system was *simulated*, for instance by running several lots of products through the system. Thirdly, *operation models* were formed. These concerned the operations the users would have to conduct in different use situations, e.g. the change of settings, disturbance control, and the formation of the work sequence. In the *safety analysis*, the system models and different kinds of operation models could be used as an instrument for common considerations concerning the danger factors (see Toikka et al. 1991a, Appendix 3; see means for increasing work safety, Kuivanen et al. 1988a, 86-98).

In addition to six users the production manager, the department engineer, two supervisors, the designer of the system (later the leader of the system) and the researchers took part in the training course. Also planners of the central control system participated on the two days when the central control system was discussed.

It was tried to carry out the system training in a way which supported as much as possible the starting and promoting of the users´ own learning and modelling activity. Teaching models did not take place as a traditional course of lectures. The instruction methods consisted of preparatory lectures, teaching by asking, discussion and group working, and tasks in between the training days.

Group working was one of the cornerstones in the system training. After each group work the solutions of the groups were analyzed in common discussion. The result was a new solution commonly developed. The solutions of the groups as well as the common discussions raised into light suprising aspects and some solutions which could not be taken into account in the preparation of the training session.

At the same time, *concrete solutions concerning design and implementation* were created. The following points can be mentioned from the point of view of system A and of the planning of its operation:

- During the second training session *problems* thought to be included in the function of system A and matters needing to be solved were discussed. The connection of the system operation to other functions of the plant, the homogenous quality of materials and quality solutions, failure sensivity of the system, the great impact of human failures (the importance of skills and motivation), the knowledge demands and the many tasks of the leader, and the organization of maintenance and repair were mentioned as such problematic issues. As we will see later, many of these points turned out to be problems in the implementation phase.

- *The activity of the system* and *the tasks of the users* were modelled properly through system models in the third training session. At the same time, the relations between system A and other parts of the plant were modelled. The activity of the system and the tasks of the users were considered more accurately in the fourth training session where the production process of some products, the changing of a lot, and disturbance control in a machining cell were simulated. Only rough estimates of the tasks of the users and of *the relations between the FMS and other plant* were made earlier in the planning.

- *The safety analysis of the system* was done in the fifth and sixth training sessions, by failure mode and effect analysis and the energy analyzing method (see Kuivanen et al. 1988b; Toikka et al. 1991a, Appendix 3; Kuivanen 1990). There were models of the system as well as a concrete lego-model of the system as a help in the safety analysis. All possible danger factors in the system concerning different machines and parts in their different activity states (programming and setup, use, and maintenance) were systematically covered in the analysis. At the same time, means for removing the danger factors were considered. The summary of the safety analysis was presented in the seventh training session. This caused a lively discussion. The users started to propose changes to the summary made by the researchers and to make yet their own propositions for removing the problems. The system leader stated that the safety analysis was quite useful and many of the points could be taken into account for increasing the safety level of the system.

- In the case study, the *intensive follow-up* of the implementation taking place stepwise, one cell after another began after the seventh training session. For that purpose, a separate training session, the eighth session, was arranged. To carry out the follow-up as well as to use the results of the follow-up for developing the way of working of the users as well as for the development of the system were the topics in that session. It was agreed with the users that they register daily events, especially disturbances and development activities, into the *logbooks* kept in each cell.

- In the last training session, *the activity and use principles of the central control system*, just installed, were discussed (see Norros et al. 1988a and b). A *group work* was done based on the activity of the central control system and its displays. The task of the groups was to make two lots of products automatically in the system with the starting data concerning the process and control given. The groups performed the task by *simulating* the layout of the system, with paper symbols describing pallets and products and printed the task into paper form. After working on the simulation task, the three user groups presented their solutions. It became evident that the different groups weighted optimality criteria differently or did not always consider all the criteria. On the grounds of the group work and common discussion, a joint activity alternative for optimal operation was chosen. The optimal strategy aimed at maximizing the system capacity, minimizing the transportation of pallets and minimizing the settings. The optimal solution demanded that a user direct the pallets emptied after palletizing directly back to the loading place, instead of directing them first to the storage. A planner of the central control system noticed, however, that this kind of a procedure would cause a *disturbance*: the central control would be left seeking for a "nonexistent" pallet, which would lead to the stop of the activity of the carriage and the whole central control. The recovery of the system would require a *troublesome starting procedure*.

  In the *discussion* that followed, the cause of this evident deficiency was analyzed. It was found that in an earlier phase of the design, the question was considered as a technical detail among others, and that the system engineer and the planners of the control system, had not seen then the significance of that detail for the system functionality and use either. This is natural and in accordance with our assumption of the unpredictability of the innovation process.

Particularly significant in this case is the fact that the deficiency in the control system could be *diagnosed* in the very first functional simulation of the system, with the users participating in it. Two possible solutions were also suggested: A complete elimination of the problem by changing the major principles of the handling of the pallets or a partial *solution* that would leave some restrictions to be taken into account in the operation. The first solution would have demanded such great changes of programs that the cheaper partial solution was decided to be put into effect.

Analysis

The system training raises four questions for further analysis:

(1) Based on the interviews of the users, one can assume that the *experience and knowledge of the users* might have facilitated the transfer of knowledge concerning use activity into the planning, which would have helped to seek for alternatives and solutions to be implemented and to be used more easily. However, the traditional planning practice prevented the knowledge of use activity of the users from forming a bridge between the planning and the operation. *It can be asked how this knowledge of the users can be used in the implementation phase?*

(2) The strive of the *production management* for new kinds of organizational solutions can be seen to have reflected also in that it accepted the researchers´ offer to arrange the system training. The management saw it necessary to enchance the users´ ability to master the system and the motivation of the users to commit themselves to the implementation of the system. The *users* as well had a great motivation to acquire more knowledge and to get a whole conception of the coming FM-system and working with the FMS. *There is reason to ask what effect the system training may have on the activity of the users and on the operation of the system.*

(3) The *system training* revealed an opportunity for a *new kind of planning practice*. In the training sessions, the operation and problems of the system and its planning and implementation were considered in a *network group* comprising the management, planners and users, where the users had a central role, in accordance with the “lean production” model (see Table 5.2; cf. Section 3.4). *The question is how this kind of networking will be*

established into an organizational practice in the implementation and "normal" operation phases.

(4) The *system training* showed that preventive consideration of design failures, together with the designers and the users, for enhancing the functionality and feasibility of the system already in the planning phase, requires new *conceptual tools and practical methods* (cf. Kanter 1988, 241-277; Boedker & Gronbaek 1996). In the system training, the functional *modelling* of the system and the *simulation* based on this modelling were means consciously created and as such necessary for discovering new aspects and deficiencies of the system design. *There is reason to ask how the organization is able to adopt that kind of methods into its "normal" activity concerning system A and its development.*

5.5 IMPLEMENTATION ACTIVITY

System A was *implemented* stepwise. The whole installation phase of the cells and the control system was planned to take ten months, as shown above in Table 5.3. However, this phase was prolonged to almost three years. The *main factors and dimensions of the implementation activity* are shown in Table 5.7 (cf. Table 5.2 and Table 3.4) These factors and dimensions are analyzed below.

Duration and Timing of the Implementation Phase

The first machines came to the plant in November, 1985. The implementation of the tempering plant and the turning cell were started at the end of 1985. The implementation of the automatic pallet storage began in March 1986. The scraping cell was installed in August, 1986, but the implementation of the milling cell, planned to be implemented before the scraping cell, started only in October, 1987. Likewise, the implementation of the central control system was started only in November, 1987. The phase of "normal" operation can be seen to have been achieved in late spring in 1988, when the system was put into twenty-four hour operation, with the users working in three shifts.

Table 5.7. Factors and dimensions of the implementation activity in case A.

FACTORS	DIMENSIONS OF IMPLEMENTATION ACTIVITY
Duration of the implementation phase	Over 2,5 years
Timing	Implementation: 1985-1988 Starting of "normal" use activity: late spring 1988
Resources of implementation	System designer as a leader integrating design into implementation, leaving the company after the installation of the system A new leader without any previous experience of the system and cogwheel production Implementation was left mainly as a responsibility of the users alone: methods design and programming of all machines and equipment; no additional support
Realization of work organizational goals	"Skill-based" group work with high professional skills as a goal Starting as planned, but difficulties in achieving group working in full
Problems and development needs in the implementation phase	Implementation of the first cell a troublesome process, lasting 10 months High disturbance level and several disturbances (110 different kinds of disturbances, of which one third were design failures) Prolongation of the implementation
Users´ activity	Disturbance control Development measures (removal of causes of disturbances, optimization of the system)

Resources of the Implementation

The engineer in charge of the design of the system later became the *leader* of the system. This kind of practice can be seen to resemble the practice of Japanese FMSs where designers jointly answer for the implementation (see Section 3.4). The engineer can be seen, in a sense, to form a "link" between the planning and the implementation. This practice as such can be seen to represent the "lean production" method.

However, the engineer´s attention was drawn mainly to *solving day-to-day problems* of the system due to many difficulties in the implementation. According to him, he had too little time for systematic *development work* concerning, e.g. the questions of handling of materials and production control, the development of programming principles, and the documentation of development and operation. This can be seen to reflect the insufficient attention of the management to the implementation and, therefore, to giving the necessary *technical help* for system development in the implementation.

To cap it all, the vulnerability of this kind of a solution, based on a one-man “link”, came to light when the engineer left the company just after the central control system was installed - at the end of 1987, when the implementation of the system as a whole was just beginning. A new leader - a technician - had neither had any dealings with the design of the system nor was acquainted with the production process of cogweels so he had to learn the action of the system mainly from the basis of practical experience. This had effects on the implementation of the system.

The *learning process* of the new leader took a long time. At that time, the implementation of the system as a whole, after the implementation of the central control, was beginning. There were many problems concerning the *integration* of different parts of the system and, especially, integration to the central control system. It took nearly a year before all most central faults and shortcomings of the control system could be defined exactly enough and be remedied to that extent to which it was possible and economically feasible within the limits of the structure of the system (Hyötyläinen et al. 1990).

The erection and implementation of the system was left mainly as *the responsibility of six (later seven) users*. The users took part right from the beginning in the installation and implementation of the machines coming to the system. The implementation of the machines and cells was also a training process during which the users learned gradually to use the machines and cells in the system. The users also made all the *programs* for the robots, NC machine tools and the tempering plant and for all the product variants. This task was made yet more difficult by the fact that there were altogether 12 different kinds of materials in the system.

Realization of Work Organizational Goals

A group organization with high skill level of the users, in accordance with the model of “skill-based” production was set as a goal in the planning phase. A training program based on *job rotation* was planned. However, this was not so easy to realize. The start took place as planned with regard to job rotation and task learning.

The learning of the use of the cells and the corresponding tasks were started so that in the beginning of the implementation of each cell two users were trained as *“experts”* of the cell (see Norros et al. 1988a, 175-178; Norros 1991). The purpose was then to teach *“novices”* with these “experts” through *job rotation*, to gradually achieve the common level of system mastering of the users and the way of group working based on that, as planned.

These goals were not realized, however, to a full extent in the implementation phase. In the beginning, the training program was realized consistently, but as the implementation of parts of the system was late due partly to machine deliveries and partly productional pressures this displaced the demands for learning. There was a need to produce as many cogwheels as possible due to the prolongation of the implementation and economic pressures.

Job rotation was stopped twice over half a year. Hence, the work mastering of the users became temporarily *differentiated*. At the end of 1987, some weeks after the installation of the central control system, the users had specialized into three groups: (1) users of the tempering plant; (2) users of the turning cell; and (3) users of two other cells (scraping and milling) (see Seppälä et al. 1988b; Norros et al. 1988a).

Only when the system was moved into three shifts in spring in 1988, due to the increase in production, did it become necessary to get each two-man shift into flexible and co-operative working due to limited manpower per shift and because of the functional needs of the system. Therefore, job rotation was started again. As a result of the continuation of job rotation, all the users were beginning to already *master* all the tasks in the system a year later in spring in 1989 (Hyötyläinen et al. 1990).

Also, *work division* between the leader and the users made it more difficult to fully achieve group working, because *production control* was established solely as the task of the leader. This became evident especially when the new leader was appointed. He adopted a relatively traditional approach to leading. The lack of expertise of the new foreman, as stated above, has, according to the users, led him to adopt a traditional "top-down" activity. The first leader (a design engineer) was more willing to inform and co-operate with the users.

Problems and Development Needs and Users´ Activity

There were *many problems and disturbances* in the system during the implementation phase, which had a great effect on production and thus demanded development measures:

(1) It was a surprise to the management that *the implementation of the first machining cell* (turning cell) turned out to be such a troublesome process taking ten months although planned to take only a couple of months or so. It became obvious that much *tailoring* was needed before the machines and equipment acquired from the different vendors were got functioning with each other programwise and mechanically and before they were adapted to the products to be produced in the system. There were especially great problems in connecting the operation of different parts (two turning NC-machines, one robot, automated pallet storage, many pallet platforms, 50

different product variants in total, and 12 different materials) into a functioning whole. The machine vendors made some experimental programs in the installation phase. According to the users, these programs did not function properly, however. The users had to remake these *programs* and to apply them to the products and the special environment of the cell.

The users were able to use in the implementation of the next two machining cells the experience concerning programming and implementation acquired in the first machining cell. The scraping and milling cells were got into working order considerably more quickly, each of them in about two months (see Norros et al. 1988a, 166-168).

(2) The limits of the planning done in the traditional way also came clearly into light as *problems and disturbances* and *activities of the users for disturbance control and development* during the implementation phase. The implementation proceeding cell by cell was *followed up* during the period of 15 months, September 1986 - November 1987. Data that include the system disturbances and the users´ development and design measures was collected with *logbooks*, kept in each cell by the users. This means that - due to a significant delay in the implementation process - the data only consist of events in three cells (the turning and scraping cells as well as the tempering plant). The last cell (milling) and the central control system were installed just at the end of the follow-up period. Thus, the data gathered describes the events of cells, not those of the system. The distribution of the new disturbances and of the users´ development measures during the registration period are presented in Table 5.8, according to their cause and origin (see Norros et al. 1988a; Norros 1996).

During the time of recording, 110 new disturbances occurred (repeated disturbances could not be presented because of their unsystematic registration; this kind of data will be presented in connection with the operation phase). During the same period the users took 29 design measures which were either direct system development activities or detailed suggestions for such (Norros et al. 1988a, 168-174 and 1988b; Norros 1996).

The disturbances were classified according to their cause. A classification commonly used in mechanical and safety engineering was used (see Kuivanen 1990 and 1996; Norros 1996). The classification of the different disturbance types was as follows: design failure; component or equipment failure; user error; external factor; and undefined. The development measures were correspondingly classified, with one cause, optimization, added.

The *users controlled disturbances* of the system. The numbers in the left column of Table 5.8 can be seen to be congruent with the distribution of the users´ disturbance control activity. The users took measures of different degree for eliminating disturbances in the case of all registered disturbances. Most of these disturbances were diagnosed and eliminated either by the users themselves or in co-operation mainly with the maintenance personnel, in-house or out-of-house.

Table 5.8. New disturbances and users' development measures during implementation according to causes (15 month period) in case A (see Norros et al. 1988a, 168-174; Toikka et al. 1991a, 55).

CAUSE	Disturbances (n = 110) %	Development measure (n = 29) %
Disturbance:		
- design failure	34	34
- component or equipment failure	31	18
- user error	20	7
- external factor	7	-
- undefined	8	-
Prevention and optimization		41
Total	100	100

The 110 different types of registered disturbances were caused mainly by design failures, component or equipment failures or user errors. Many of these disturbances were frequent.

It is especially interesting to note the disturbances due to a *design failure*. Design failure disturbances were due to either a design failure or to a deficiency in design, such as e.g. the unsuitability of the dimensions of a robot gripper or the construction of pallets proving to be a failure. The great number of design failure disturbances (34 %, 37 disturbances) and the need for disturbance control in these cases show that there was a considerable need to continue design in the implementation phase.

(3) The *effect* of the 110 new disturbances *on production, material and work safety* was also registered (see Kuivanen et al. 1988a and b). These effects are shown in Table 5.9.

It can be seen that the disturbances had a strong correlation with decreases in *production* and hindering use activity. The disturbance had no effect on the production in only 20 % of the disturbance cases. All in all, 80 % of the disturbances had an effect on the production in one way or another. In 55% of the disturbances, the production was directly slowed down, one machine was stopped or the function of a cell was stopped. 25 % of the disturbances had no direct influence on the parts produced but they hindered the users´ work. So a system like this seems to tolerate some disturbances without a direct effect on the production. However, some minor failures can stop many of the machines and the effect of a disturbance on critical sections can be multiplied. FMS-stops did not happen because the system as a whole was not yet in operation at that time.

Table 5.9. Effect of the 110 different disturbances registered in the implementation phase during 15 months on production, material and work safety in case A (adapted from Kuivanen et al. 1988a, 83-86; Kuivanen et al. 1988b).

EFFECT OF DISTURBANCES	PRODUCTION (n = 110) %	MATERIAL (n = 110) %	WORK SAFETY (n = 110) %
No effect	20		
Difficulties for work	25		
Slow downs in production	22		
Stops on one machine	17		
Cell stops	16		
FMS stops	0		
No damage		73	
Minor damage		27	
No safety risk			51
Moderate risk			38
Hazardous situation			9
Minor accident			2
Serious accident			0
Total	100	100	100

The disturbances also had an effect on *materials*, for 27 % of the disturbances caused material damages. This can be regarded as rather a high value, because damages must always be taken seriously. They can also be very expensive for the company.

Besides, the disturbances had a negative effect on *work safety*. Altogether, 49 % of all the disturbances registered were assessed to lower the personal safety of the users. In 9 % of the disturbances there existed a hazardous situation. Minor accidents happened in 2 % of the disturbance situations.

(4) Due to these effects of the disturbances on production and the users´ work, it is quite understandable there is a great need to eliminate the causes of disturbances and develop the system further. It turned out that the users took an active part in this kind of development work.

The total number of *user design measures* was 29 in the time span considered (see Table 5.8). These were direct design measures or well articulated suggestions which in some cases included technical drawings, e.g. replacing of the roller used for loading the tempering process into a rail.

All in all, 34 % (10 measures) of the users´ development measures were directed *to eliminating the distubances* due to design failure. This shows that the users were also able to take development measures as a reaction to design failure disturbances. As an example of this kind of a development measure bad fixing of the pieces into the jaws of a machining tool, and repetive measuring errors due to that can be mentioned. The users eliminated the cause by designing a mechanical limiting stop directing the fixing of the pieces to the jaws. Altogether, the users took 59 % (17 measures) of the development measures as a reaction to disturbances in the system.

The rest, 41 % (12 measures), of the development measures were not taken as a direct reaction to disturbances, but they were directed *to preventing disturbances in advance or to optimizing the system functions*. An example of these was the development of a cutting method to prevent the pieces from getting loose. Thus, it seems clear that the development measures of the users have been a response, on the one hand, to continue the design of the system and, on the other hand, to take an iniative to develop further the system in the implementation phase.

It is reasonable to assume that the users neither registered all the disturbances nor registered or mentioned all the development measures. It is difficult for the users to distinguish many small disturbances from the normal operation of the system. Correspondingly, to set a boundary between improvement activities, happening day-to-day and directed to the system, and the normal way of working of the users may sometimes be difficult. Hence, many of these disturbance control and development measures have probably not been registered, so the numbers of events in Table 5.8 could be much greater.

Analysis

The description of the implementation activity raises four issues for further analysis:

(1) The implementation phase of case system A shows that *the "basic" innovation of the system* made by the management in the planning phase seems to be only an introduction to a *long process with many problems and disturbances and their effect on the operation and the users´ work*. The implementation phase took almost three years, although it was planned to last only for about ten months. *There is reason to ask how much "normal" operation differs from the implementation with its high disturbance level and many problems*.

(2) The erection and implementation of the system was left mainly *as a responsiblity of the users*. The designer of the system became the *leader of the system*. However, his time was spent mainly in solving day-to-day problems. He had no time for systematic development work. The *management* did not give technical help for the system development. *One can ask how those kinds of patterns of the users and management prevail in the "normal" operation phase.*

(3) The users did active *disturbance control* and *development activity* in the implementation phase. *It is interesting to ask how the activity of the users develops in the "normal" operation phase.*

(4) All the time the *users* acquired *new skills* in using the system during the implementation phase. However, the "skill-based" goals set by the management were not achieved in the implementation phase. *It can be asked how the users´ skills develop in the "normal" operation phase.*

5.6 USE ACTIVITY IN THE "NORMAL" OPERATION PHASE

As shown, the users did disturbance control in the case of all the disturbances registered in the implementation phase. Likewise, they took development measures to remove the causes for the disturbances. Already in the implementation phase, especially in the late part of the time span considered, the users´ activity widened also to the optimization of the system functions.

More evidence about the users´ activities and opinions was gathered through *intensive performance observation and interviews* in May, 1989, when the system had operated on full scale for eighteen months and in "normal" operation for one year (see Toikka et al. 1991a; Norros 1996). The intensive observation was carried out in two days during which minute to minute registration of the production flow and users´ activities in the three shifts was taken, each of the users being observed separately by several researchers. In the interview, again, questions about the users´ developmental expertise as well as contribution to the system development in the "normal" operation of the system were discussed.

In the following, the registered disturbances and their effect are discussed at first. The users´ activity is analyzed next.

Disturbances and their Effect

During the intensive observation, 36 different *disturbance types*, new disturbances were registered. In all cases the users also did active *disturbance control*. As to development activities, the users had taken 16 *development measures*, according to their own report, during the eighteen months when the system was functioning on a full scale (January 1988 - May 1989):

(1) The disturbances registered and the development measures taken by the users during the normal operation of the system are presented in Table 5.10, according to their cause and origin.

There were suprisingly many *disturbances* in the normal use of the system. During the period of the intensive observation, 36 different disturbance types were registered. All in all, in the period of three shifts, 69 disturbances occurred, i.e. on the average 3 disturbances per hour. The number of the disturbances occuring more than once, i.e recurring disturbances, was 12. The most frequent disturbance occurred 12 times.

To check how typical the result of the intensive observation was, the users were asked about that in the interview. According to the unanimous assessment of the users, the disturbance frequency in the observation period was average (see Toikka et al. 1991a, 36-37).

One can ask why there were so many disturbances in the system (see Hyötyläinen et al. 1990). One answer is that there are many mechanical and electronic events and interactions in the system because of the many machines and components in the system and the short processing times of parts. The processing times of parts in the different machines are from one minute to some minutes, which means continuous changing of the parts in the machines. This creates many possibilities for disturbances. The second point is that the system is producing rotational parts with machines all of which are not standard equipment but applied for special purposes, as stated already above. The third cause surely follows from the “*top-down” and segmentalist approach to the planning*. The view of use as well as the integration of the different designs (process, control, organization) were left in done in the planning phase, causing problems also in normal operation. Fourthly, both *wrong choices* may have been made and too much saved in automating operations in the planning phase, as discussed above. The result is an ill-functioning and unrealiable system due to technical deficiencies.

It is worth noting how frequently *design failure disturbances* (42 %, 15 different ones) occurred also in the normal operation of the system (see Table 5.10). Their frequency is more than registered through the follow-up in the implementation phase (34 % from different ones) (see Table 5.8). This reflects the fact that as the use of the system and the production conditions change *new types of disturbances* are continuously coming into sight.

Table 5.10. Disturbances and the users′ development measures during normal operation of system A according to causes (see Toikka et al. 1991a, 37 and 67; see also Norros et al. 1989).

CAUSE	Disturbances (period of three shifts) (n = 36) %	Development measures (during a year and a half) (n = 16)
Disturbance:		
- design failure	42	31
- component or equipment failure	25	-
- user error	19	-
- external factor	7	-
- undefined	8	-
Prevention and optimization		69
Total	100	100

In the follow-up period in the implementation phase, the system was functioning only on the cell level, therefore, disturbances on the system level could not occur. From the 36 different disturbances observed during normal operation, six were directly due to *disturbances in the central control system* or the automated pallet storage system (see Toikka et al. 1991a, 37-38). Four of these six disturbances were due to design failure only.

Other types of disturbances also occurred (see Toikka et al. 1991a, 38-39). Especially disturbances caused by *component and equipment failure* are of great importance. The share of different disturbances of this type was 25 % (9 disturbances) in normal use. When all the 69 disturbances that occurred in the intensive observation period during normal operation are taken into account, disturbances due to component and equipment failure made up the largest group, 31 disturbances, which is 45 % overall. The reason for this was that recurrence in this group was the most frequent.

The share of different *user errors* remained quite the same in normal use (19 %, 7 disturbances) than in the implementation phase (20 %).

The share of different *undefined disturbances* increased to some extent from the implementation phase (8 %) to normal use (14 %, 5 disturbances), of which two were recurring. This type of disturbances can be seen as typical *"hidden" disturbances of automation*, the causes of which are possible to define only gradually based on the experience of the recurrence of the disturbances and on systematic experimentation.

(2) In Table 5.9, the effects of the 110 new disturbances registered during the implementation phase are presented. The picture was not greatly changed in the case of the 36 new disturbances registered in normal operation during the period of the intensive observation (see Kuivanen 1990; Toikka et al. 1991a). The e*ffects* of the different disturbances *on production, material and work safety* registered in normal use are presented in Table 5.11.

Table 5.11. Effect of the 36 different disturbances registered in normal operation during the period of three shifts by intensive observation on production, material and work safety in case A (adapted from Kuivanen 1990, tables 1 and 2; Toikka et al. 1991a, 39).

EFFECT OF DISTURBANCES	PRODUCTION (n = 36) %	MATERIAL (n = 36) %	WORK SAFETY (n = 36) %
No effect	6		
Difficulties for work	6		
Slowdowns in production	6		
Stops on one machine	14		
Cell stops	68		
FMS stops	0		
No damage		89	
Minor damage		11	
No safety risk			49
Moderate risk			46
Hazardous situation			5
Minor accident			0
Serious accident			0
Total	100	100	100

The number of disturbances having a direct *effect on the number of products produced* increased from the implementation (55 %) to 88 % in normal use, i.e. disturbances that slow down production, cause one machine stops or cell stops. At the same time, an ever-increasing number of the disturbances (68 %, in the implementation only 16 %) stopped the whole function of a cell. Thus, the effects of the disturbances were more serious with regard to production. None of the disturbances stopped the whole FMS.

Material damage happened in 27 % of disturbances in the implementation phase. The company was concerned about the figure, because these damages are very costly. In normal use, according to the intensive observation, this percentage was 11 %. This decrease can be a result of the development work.

With regard to impacts on *work safety* the situation remained the same, 51 % of the disturbances having a decreasing effect on the workers′ safety in normal use (correspondingly 49 % in the implementation phase). As to its profile, the degree of impact remained the same. The existence of a danger factor was observed in 46 % of the cases and a danger situation in 5 % of the disturbances (during the implementation 38 % and 9 %, correspondingly).

Users′ Activity

Because of the large number of disturbances and their great effect on the production and the work safety in the normal use of the system, it is not a suprise that this was reflected also in the *users′ activity*. As already stated, the users performed *disturbance control* in all the 36 different disturbances during the intensive observation period as well as in the cases of their recurrence. According to the interview of the users, this was typical of the *way of working* of the users. The users saw that it was impossible to limit the task of disturbance control only to some users. In the following the tasks of the users and the development measures taken by the users are presented:

(1) In the intensive observation period all *tasks of the users* during three shifts were registered. Based on the protocols of the observation, the duration of the use tasks was assessed. The registered overall duration of the use tasks of the user was on average 7 h 18 min a shift. The average time distribution of the users′ tasks in a shift is presented in Table 5.12.

As can be seen in Table 5.12, the activity of the users consisted of *15 different tasks* during the intensive observation period. Out of these, the four main tasks took over two thirds of the working time of the users. These tasks were as follows: disturbance control (21 %); monitoring automatic operation (18 %); loading and unloading pallets (17 %); and setting and presetting (12 %). Only the monitoring of automated operation is conventionally viewed as automation work. However, the major tasks consisted of manual interventions needed to prepare, compensate for, or correct automated operation. It seems that there is still a long way to the “unmanned factory” (cf. Section 3.1).

Table 5.12. Average time distribution of the users′ tasks in normal operation of system A during three shifts (TP = tasks occurring only at the tempering plant) (see Toikka et al. 1991a, 59).

TASK	DISTRIBUTION OF USE TASKS (%)
Operation tasks	
Loading and unloading pallets	17
Manual control (TP)	5
Monitoring automated operations	18
Tools changing	4
Control tasks	
Quality control	3
Maintenance	3
Disturbance control	21
Materials status control	2
Book-keeping (TP)	5
Preparation tasks	
Setting and presetting	12
Repairing programs	4
Planning and development tasks	
Work planning	5
Programming	<1
Methods design	<1
Development activity	<1
Total	100

Disturbance control took on average 21 % of the working time of each user, which means about 1,5 hours in a shift per worker. This is a great amount but it is understandable due to the great disturbance density registered during the intensive observation.

Planning tasks were also registered during the intensive observation period. As much as 5 % of the working time of the users went into work planning tasks on average. Also programming tasks were registered. Some effort in methods design and development activity were also observed. It is natural that the users tried to remove and to eliminate the causes of the disturbances, which demanded design measures.

The *development activity* of the users has continued further after the implementation phase of the system, as also shown in Table 5.12. This shows that development activity has become a part of the normal operation of the users.

However, during the 24 hour intensive observation it was impossible to get a really good picture of the users´ efforts to develop further the system. Many problems and their resolutions "mature" slowly, taking usually days, weeks, or even months, particularly when co-operation with the system leader, designers or some other part of the organization is needed. Hence, the intensive observation was complemented by the interviews.

(2) The users had taken, according to their own report, 16 *development measures* or suggestions for development (see Table 5.10). In addition, the system leader had taken during the same period 6 development and change measures directed to the system (see Toikka et al. 1991a, 58-69). The material of the development measures was acquired by interviews and by the users together and the leader separately making a list of them. The time span covers the development measures made during a year and a half after the implementation of the system in full. The number of the measures seems to have decreased compared to the 29 development measures in the implementation phase collected during the same time (see Table 5.8). It is likely that this is due to the fact that the users did not remember the development measures taken earlier in the period.

About one third of the development activities of the users (31 %, 5 measures) were *direct answers to design failure disturbances*. These were directed mainly to the individual machines and equipment and their tool systems. Typically, improvement measures were a reaction to recurring disturbances, becoming too troublesome to manage in a "routine" way or a threat to the function of a cell (e.g., a new jaw type to make fixing a part in the lathe easier).

The major share of the development measures of the users (69 %, 11 measures) were directed to *preventing disturbances in advance or to optimizing the system functions*. These measures and suggestions concerned, among other things, improvements in the machines and equipment and the development of machining methods on the cell level. On the system level, the measures were directed to developing the transportation of materials and the organization. These preventive suggestions or attempts to optimize the system were directed to several areas:

- suggestions for improvements to tools (e.g., change of the setbench for the milling tools;

- suggestions for changes in the work methods that affected interactions between different cells or subsystems (e.g., decrease in the turning time through methods improvement that required further mechanical changes in the milling machine);
- suggestions for rationalizing material handling and storage;
- suggestions for organization changes (there was a well argued proposal for organizing the shift work and working hours more optimally).

Users also made suggestions going beyond the boundaries of the system:

- as an example of this kind of suggestion is a proposal made by some users for enlarging and connecting a new separate machining cell into a part of the system, planned by the management; according to the users, by the connection of the systems an increase in flexibility and capacity, and savings in manpower would be achieved.

It is a marked feature that the *users* were interested in eliminating disturbances and making and suggesting development measures. However, it was curious that the *management* became reluctant to make changes and to invest in the extra devices proposed by the users. We can see at least three causes for that (see Hyötyläinen et al. 1990). First, the FMS worked well enough with regard to the production amount and the aimed quality, from the point of view of the management. Second, there was no urgent economic pressure to make the FMS more efficient, because only a minor part of the products went directly into the market. Most of the cogwheels went into diesel engines - produced mainly for the internal production within the corporation.

Moreover, the principles of *"skill-based" group organization* did not exist outside the FMS organization in other parts of the plant. The structure of the organization had remained mainly unchanged during the years on the way to the FMS-implementation, consisting of several distinctive and hierarchical functions, such as sales, product development, technical design, methods design, production control and work scheduling, materials procurement and warehousing (see Seppälä et al. 1988b). This can be seen as an impediment to the progress of the improvement and development activities of the users. Thus, the FMS organization and its users acting in a new way collided with the more *traditional way of acting elsewhere in the organization*.

Hence, in spring, in 1989 the situation was, that the motivation of the users had begun to decrease. Their desire for taking development activities had decreased, because the management did not support the iniative of the users for developing further the system functions nor the realization of their suggestions.

There is, however, no reason to assume that the situation would necessarily remain as such (see Hyötyläinen et al. 1990; Hyötyläinen 1993).

After a year and a half from the installation of the system as a whole and after one year from the beginning of "normal" use, it can be argued that the system was not yet "ready". This is shown, among other things, in the high level of disturbances the decrease of which would require *development measures*. Besides, there was information about the need to increase the *amount of production* by over 30 % a year and, at the same time, to enlarge the *product range* by 10 new cogwheel types. The product range had already increased from the planned 50 variants to 60 variants in the spring of 1989. All this meant that the functionality and economy of the system could become problematic in a new situation. Solving these problems was difficult without further developing the system functions and the participation of the users.

Analysis

Traditionally, it is thought that technical systems are functioning relatively smoothly and without major problems after the implementation phase during which design failures and other deficiencies of the system are removed, repared or replaced with changed solutions (see Section 3.1). In the same way, it is often claimed that the users´ development activities will disappear after the implementation phase is over, due to the "routinization" of activities when the innovation has become incorporated into the regular activities of the organization (see Rogers 1995, 399-403; Hyötyläinen et al. 1990). Also some users of system A imagined, in the interviews done before the implementation, that FMS-work would be demanding in the implementation phase but would later "routinize". However, the results of case study A do not support these claims. On the contrary, there seems to be a need for *continuous development activity* of the system and for *users´ response* to that development demand, also in "normal" operation.

The *users* were eager to develop the system further and took measures towards that. At the end of the implementation phase the attitude of the *management* changed, however, to the direction of withdrawal from further "skill-based" objectives and development programs. That can be partly due to the fact that the system had already achieved the planned production and quality level. The suggestions of the users collided with the reluctance of the maganement and the rest of the organization.

The users did not get any help for their strives from the local trade union, either (see Norros et al. 1989). The trade union did not support by any means the users´ claims to expand their constructive role.

The researchers offered to support the users´ development work by promising to arrange *systematic follow-up and development activity*, as a continuation of the experimentation phase started as system training and follow-up of disturbances in the implementation phase. The *tenth session* forming a part of the system training was already organized for the users on that topic, in January, 1989 (see Norros et al. 1989; Section 5.4). The management refused, however, to take up this offer.

5.7 SUMMARY: ACTION MODEL OF THE IMPLEMENTATION PROCESS IN CASE A

The description of the implementation process of system A raises some interesting points. First, the implementation process was a *long and troublesome process*. Second, it is surprising that there were so *many approaches*, from the "techno-centric" solutions through the "skill-based" objectives even to the practices in accordance with "lean production", at the same time, in the same case. Third, it is interesting to note how these different kinds of elements *interacted* and *directed* the formation of the solutions during the implementation process. Fourth, the results of the *system training* showed an opportunity for a *new way of planning practice* based on taking full use of the viewpoint of the operation and of the users´ knowledge.

The summary of the implementation process of system A is presented in Figure 5.1 as *the action model of the implementation process*, according to the model in Figure 2.2. In Figure 5.1, the *main features* of the implementation process are shown in the middle of the figure, under the headings of the different activity phases. The *main activities* of the management and users and their *interaction* are presented in the figure.

The activities of the management as well as of the users are assessed in Figure 5.1, based mainly on whether the practices were in accordance with the"techno-centric" approach (T), the "user-centered ("skill-based") way (U) or "lean production" (L).

In the following, the implementation process and the activities of the management and users and their interaction are analyzed:

The *implementation process* of system A was a *long process*, taking over 5 years from the beginning of the feasibility study to the starting of "normal" operation. Before the *feasibility study* began, there had already been *many attempts* during three years to define the innovation problem concerning the renovation of the cogwheel production in the product shop. This shows that the definition of the innovation problem was not an easy task for the production management. Moreover, the production management had great difficulties in making the investment decision go through on the upper level of the corporation due to *differing viewpoints* to business.

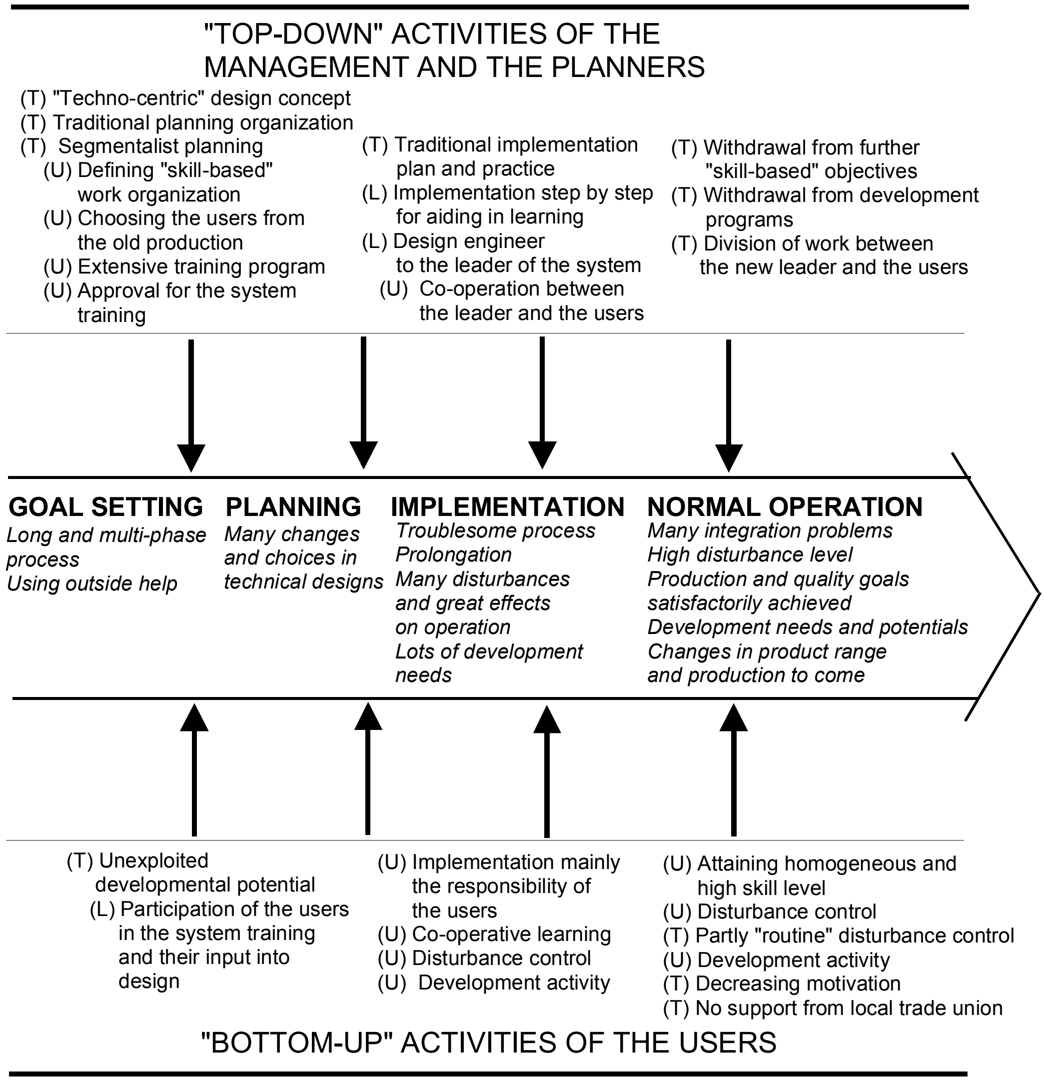


Figure 5.1. Action model of the implementation process in case A.

The *planning phase* took over 2,5 years in all. This shows that the *design of the system* was a difficult task for the management. One reason to that might be that the *plant* answered totally for the design and realization of the system.

The *planning activity* of the management was contradictory. As is traditional, there were strong “techno-centric” elements in the *design concept* (mainly attention to the production process and the machine system, standard solutions) and in the *planning practice* with its planning organization (no users included) and in the *segmentalist planning* (separate design of process, control and work organization).

During the planning phase the management made *many changes* in the design. The changes made in the technical designs were mainly directed away from the solutions resembling the “user-centered” approach to more *“techno-centric” design*. As a result, the *planned system* was more difficult to be used by the users and explains partly the *high disturbance level* of the system discovered during the implementation phase and even in "normal" operation.

However, the management defined the *"group" work organization*, according to the principles of "skill-based" production. Also an *extensive training program* was planned. The reason was that the management saw the change as a *big technical and organizational transition*.

There were also elements in accordance with "lean production" in the planning activity of the management. First, the *implementation* was planned to proceed stepwise, mainly for supporting the users in the learning process. Second, the *design engineer* advanced to become the leader of the system, forming a one man-link between the planning and the implementation. In addition, the management approved the researchers′ proposal to organize the *system training*, carried out in altogether nine training sessions.

The *system training* brought into light an opportunity for a *new kind of design practice*, with its methods of modelling and simulation. The system training was also carried out on new ground, based on a *"network" organization* like in "lean production", with co-operation of the users, management and planners. However, this kind of networking did not form into normal practice in the organization, which became obvious already in the implementation phase but especially in "normal" operation.

The system training also tried to offer a chance for the users to learn a *new kind of system thinking and action models*. The purpose was that the users could model the system and its activity and would be able to use models in using and developing the system.

To evaluate the importance of the system training for the mastering of work two factors must be noted: (1) The system training was given separately from the technical training received by the users so it did not tie into the development of technical knowledge of the users and, thus, did not support the need for integrating the knowledge bases; (2) The system training was timed into the phase of the implementation of the system on cell level so the users did not get to apply the models and simulation solutions developed during the system training in practice and to experiment them in developing the system (see Norros et al. 1988a; Hyötyläinen et al. 1990).

It is not a great surprise that the management did not make an *implementation plan* and did not support in any way the *implementation activity*, as would have been traditional, due partly to the traditional design concept and planning practice. Hence, the implementation was left mainly as the responsibility of the *users*. In case A, the management seems to have thought that, because it chose the best workers from the old production and trained the chosen users extensively, they would manage the implementation of the system by themselves.

This way was not, however, quite efficient. Although the contribution of the *user*s was central in the implementation and in the development of the system, it turned out that its quality and efficiency suffered, because the organization of the implementation was left insufficient. The *system leader*, a design engineer, participated in the implementation but his time was spent mainly in the tasks of production control and tasks concerning different technical questions due to the delay in the implementation of the cells. The *rest of the organization* did not support the implementation. It seems that efficient support of the user contribution in the implementation demands a *"network" approach* from the organization where the users get sufficient support in methods design and in learning the ropes of programming and other development methods.

The *implementation phase* lasted over 2,5 years in total, although it had been planned to take only about ten months. It became a *troublesome process* for the users as well as for the management. Especially, the *implementation of the first machining cell*, the turning cell, turned out to be almost an impossible process taking ten months. A lot of *adaptation and development work* had to be done before the different parts of the cell system were got functioning as a whole system. The following cells were able to be implemented in a considerably shorter time, due to learning. All in all, there were plenty of *disturbances* and *development needs* in the implementation phase.

The users made the system function but it operated with a high disturbance level. Over 20 % of the working time of the users was on average directed to *disturbance control* in the "normal" operation phase. This share must have been probably greater in the implementation phase, although there is not any data on that in the study.

In the op*eration phase*, the situation with regard to the *disturbance level* and the *development needs* did not change from the conditions in the implementation phase. There were yet *integration problems* on the system level. There was also a great number of disturbances due to *design failure*.

The implementation process of system A brought markedly into light the importance of *disturbance control by the users*, and the *users' share in the solving problems* and in eliminating the causes for disturbances occurring in the implementation phase and in "normal" operation. The users did not withdraw from problem situations. It can be argued that due to the many disturbances the function of the system would not have been possible without disturbance control done by the users. It can be seen that the system could function only with continuous exertions from the users. All the time the users also performed *development activity* for eliminating disturbances and optimizing and developing further the system functions.

However, the *motivation of the users* for development work decreased in the normal operation phase, because the *management* did not support the iniative of the users for developing further the system operation. It can be said that the management withdrew from "skill-based" organizational objectives.

6 CASE B: IMPLEMENTATION PROCESS OF A SMALL FMS

Case study B concerns the implementation process of a relatively *small FM-system* in a product shop producing bodies for hydraulic drills that are an essential part in large mining and drilling machinery, which the corporation is manufacturing for the whole the world. The corporation to which the drill factory belonged is one of the leading manufactures. After the case study, new arrangements in the ownership of the corporation have been made.

The follow-up of the implementation process of system B covers the years 1986-1990. System B was disassembled in the autumn of 1991, when a new, relatively large FM-system was installed in a new factory building. The new FMS was system C that will be analyzed in the next chapter.

The planning of system B began in 1983 and the investment decision was made in 1984. The implementation of the system was started in September 1985.

System B was a *small system*. It can be assumed that the small system would be easier to implement and also to adapt to the existing production system than a large one. *This aspect forms a starting point* for the analysis of the implementation process of system B. However, there is reason to remember that there was little experience of the implementation of FM-systems at that time in Finland (see Mieskonen 1989).

The results of the implementation process of system B also acted as *comparative material* for the results of the implementation process of system A. Case study B was by its nature a *follow-up research*, where the researchers did nod have an active role.

6.1 DEFINING THE INNOVATION PROBLEM AND GOAL SETTING

Decision on FMS

FMS as a solution to *the innovation problem* was not considered at the beginning of the planning process, because the management considered *alternative ways* of in renovating the production system. The planning of flexible manufacturing was started in the plant in 1983.

The *feasibility study* was started during 1983, and it continued to the beginning of 1984. During the year 1983 the procurement of the *NC machining center* with six pallets was considered as a possible solution. Only at the beginning of 1984 did the consideration come to the alternative to implement an *FMS*. The primary t*echnical design* of the system was started after that. The final *investment decision* was made only in October, 1984.

Change Process

The reason for the change process and its scope as well as the goals set in case B are presented in Table 6.1.

Table 6.1. Factors and dimensions of the change process in case B.

FACTORS OF CHANGE	DIMENSIONS OF THE CHANGE PROCESS
Reason for change	Demands of the markets: flexibility, capacity, quality
Level and pace of change	Relatively small change: replacement of two NC machining centers by a relatively small FM-system
Goals	To inrease flexibility (production sequence within the product family, changes in capacity, new products) To shorten throughput time in production To increase capacity To increase quality To acquire experience of FMS-technique To create interesting work for the users

The *demands of the markets*, which emphasized the demands for increasing flexibility and capacity in addition to quality, were reasons for the implementation of system B. Demands for increasing the flexibility came from the markets. As a rule, the drilling machines produced by the factory began at that time to be “tailored” to the demands and wishes of the client and the production was based on orders. That called for flexibility and ability to adapt to capacity changes and to product changes from the production.

The *change* in case B can be regarded as relatively *minor* because the production system based on two NC machining centers was replaced by a small FMS (see Seppälä et al. 1986 and 1988a).

The planning was directed to the production of the components which are central parts in the drilling machines. The *goal* was to develop the production of these components. As shown in Table 6.1, the goals concerned mainly the increase of flexibility and capacity. One goal was also to acquire *experience of FMS-technique*. It was also seen that *FMS-work* could offer an opportunity to create demanding and interesting jobs.

Analysis

The description raises five questions for further analysis:

(1) The description refers to the fact that the *definition of the innovation problem* was not a straightforward process. The production management considered other *alternatives* before settling for the implementation of FMS, which happened in the late phase of the *feasibility study*. Altogether, it took almost a year to define the innovation problem. *It can be asked how these kinds of features describe more generally the management´s activities in the planning and implementation phases.*

(2) It is a marked feature that the *investment decision* was made so late, instead of being resolved after the feasibility study. The *technical design* had already progressed for more than half a year before the decision could be made. That refers to *differing views* on development needs on the various levels of the company. The production management had to make exact plans for the decision process. *It can be asked how these kinds of features describe more generally the planning and implementation practice of the management.*

(3) The management saw the change as a *small organizational step*. The change was seen mainly as a *technical issue. It can be asked what effects that has on the management´s planning and implementation activities.*

(4) As is traditional, the *workers* had no influence whatsoever on the decision process of a new production system. *There is reason to ask what implications this has on further implementation process.*

(5) Systems B and A differed from each other with regard to their scope. System B was clearly a *small FMS*, whereas system A was a *large and complicated system*. *There is reason to ask how the implementation process of system B differs from case A.*

6.2 PLANNING ACTIVITY

Before the investment decision made in October, 1984, the *technical design* had already been started. The planning continued after that until the implementation began in the autumn of 1985. The *main factors and dimensions of the planning activity in case B* are presented in Table 6.2 (cf. Table 3.4). The planning process in case B is described in the following.

Table 6.2. Factors and dimensions of the planning activity in case B.

FACTORS	DIMENSIONS OF PLANNING ACTIVITY
Duration of planning phase:	About 2 years (inluding the feasibility study)
Products:	Products: large prismatic parts Size of product family: about 20 Lot size: 1-10
Design concept:	
The object of design	Main emphasis on the design of the production process and machine system; however, the demands for the control system were considered; in addition, a strive for creating new kind of work
Production process	Emphasis on automating processes, the aim to guarantee unmanned operation
Control system	Efficient system supporting use activity
Organization of planning:	
Responsibility for the design of the system	The plant itself answered for the planning of the whole system
Planning organization	*Feasibility study:* management and planners *Technical design:* planning group comprising the management and planners; *Realization planning:* project group consisting of planners, the supervisor, all users
Implementation plan:	No implementation plan
Implementation model	Traditional distinction between planning and use: no special attention to and no resources for implementation
Work organization	Idea of a homogenous "group" organization
Training and use of professional skills	Some off-the-job training for the users

Duration of and Responsibility for Planning

The planning phase lasted about two years. Because FMS was at that time new technology, the management visited some Finnish firms for familiarizing themselves with FM-systems and also visited Sweden to become acquainted with Swedish systems in the spring of 1984. The plant tried to seek a vendor who could have delivered a "turnkey" system but such a vendor did not exist. The result was that the plant itself answered totally for *the planning and realization of the system*.

Products

One of the first tasks within the design of the system was to choose a *product family* for the system. The products were decided to belong to two different product families. The products were large prismatic parts. The product range was planned to be 20 product variants and the *lot size* 1 to 10 pieces. As we will see, the product range later became considerably larger.

Design Concept

In the technical design phase, the *object of the design* was mainly the design of the *production process and the machine system*, as is traditional. However, the technical design consisted also of some new features. In connection with the technical design, a *functional and economic analysis* of the system was also made. Hence, the demands for the *control system* were taken into account in the process design phase. In addition, a strive for creating a new kind of *FMS-work* was also set as a goal. In the following, the design of the production process and the machine system, and the control system are discussed:

Production process and machine system: System B was clearly a *small system* because it was planned to consist of only one NC machining center and storage units for materials, work parts and pallets. The machines were connected to each other by the *guided vechicle system* consisting of one vehicle unit which was in charge of moving materials and parts inside the system. The system was controlled by the central control (see Toikka et al. 1991a, 34-35).

There were also two NC turning machines and one machine center within the range of the system. These machines operated, however, like individual NC-machines. The change of tools and parts was made manually in these machines. The loading of the machines was done through the central control system and the guided vehicle brought parts and took ready work pieces away. The machines were applied to machining also other parts that did not belong to the product family of the primary FMS.

As we will see, the machines planned to the system were not enough for the smooth-functioning of the system. Later, a *robotized chip removal station* and a *washing machine* were installed to the system. The aim was to automate the production process as far as possible. Thus, the NC-machining center had automatic pallets and a tools change system. Also the guided vehicle system was seen to bring flexibility to the operation. As we will see, it brought also about many disturbances in the system.

Control system: There were some *"user-centered" features* in the design of the control system. The planned control system had many features that supported relatively well use activity in the system. Among other things, work sequences were set up in the system.

Organization of Planning

The *feasibility study* as well as the *technical design* were done solely by the management and the planners. A full-time *leader* answered for the technical design. That work was directed by *the planning group* consisting of the plant manager, the product shop manager and planners. The s*upervisors and the workers* did not participate in the technical design, which reflects a traditional practice. Before the investment decision in October, 1984, the management gave information only on the planning of the investment to the personnel.

However, in the phase of the *realization planning* this picture changed totally. The management set a *project group* for that which consisted of the production planning engineer, a methods designer, a tools designer, the supervisor of the product shop, and all four users selected into the system. That group met nearly every week during several months. In the *meetings* the group considered, for instance, the layout of the system, the design of the workplaces and the design of the fixtures for the workpieces. Thus, the management adopted in the last phases of the planning, the practices in accordance with "user-centered" production and partly with the networking features of "lean production".

Implementation Plan

There was no separate *implementation plan*. In this regard, there was a traditional distinction between the planning and the use. That meant also that the management did not pay special attention to or direct any resources into the implementation of the system. However, the concept of work organization included new features as well as a training program, which are presented in the following:

Work organization: The strive for new kind of work was set as a target already in the technical design phase, in accordance with "skill-based" production. System B was planned to be implemented in the product shop whose production system was changed already earlier from a functional shop over to the product shop based on *cellular production*. System B was put into a part of one cell in the product shop, which had its own supervisor. Hence, the implementation of the FMS was not seen to demand *any changes in the organization* of the product shop. Other sections of the plant were still organized according to a functional layout and traditional organization. The whole plant was changed to cellular production in the spring of 1986.

The management planned changes to the *tasks of the users* compared with earlier work as shown in Table 6.3.

Table 6.3. Planned tasks of the users in system B compared with earlier work.

Operation tasks
No changes in these tasks

Control tasks
Quality control and measurement
Minor maintenance

Preparation tasks
Presetting of tools,
Tools maintenance,
Repairing and optimizing programs

Planning and development tasks
More production control than before

As is seen from Table 6.3, new types of tasks were planned to belong to the tasks of the users. Especially quality control, tools maintenance, repairing and optimizing programs and production control were such tasks. There were also a *tools storage* and a *presetting instrument* in the system to help the users do tools maintenance and quality control. We will see later how the tasks of the users formed in the operation phase of the system.

The cell to which the FMS belonged had a supervisor. The *tasks of the supervisor* as to system B were especially planned to consist of the following: answering for production planning, methods design and programming.

It was planned that the separate quality organization would inspect only the first part for every new program and do spot-checks. A separate maintenance department answered for repair maintenance and fixed-period maintenance.

Training and use of professional skills: The *concept of recruitment* and to some extent also *training* contained elements of "skill-based" production. First, the selection of the users was started before the investment decision, in the summer of 1984. The users were selected from the workers in the old product shop, on a voluntary basis. All in all, four workers were selected into the system from six workers who were working in the old production corresponding to the FMS-production. The decrease of manpower with regard to the products to be produced in the FMS was two workers. They moved to work with other machining centers in the same product shop. According to the estimation of the production manager, it would be possible to switch later from four to three users, which also happened, as we will see.

All four users had already good experience of NC-techniques for they had worked on NC machining centers earlier. A *training program* for the users was also set up. The off-the-job *technical training* given to the users is presented in Table 6.4.

Table 6.4. Technical training of the users in system B (see Toikka & Kuivanen 1993, 34).

TRAINING OCCASION	ORGANISER	DURATION	NUMBER OF PARTICIPANTS
Programming training for the new machining center	The importer of the machine center	1 week	4
Training for the use of the machining center	Abroad with the manufacturer	1 week	2
Training for the guided vehicle	Abroad with the manufacturer	3 days	2

Thus, the users got 8-10 days off-the-job training, depending on the user.

However, the largest part of the user training was *user participation in the system installation and implementation*. At the beginning of the implementation of the machining center in the autumn of 1985, a mechanic of the machine centers guided the users in the use of the machine for three weeks. Besides, the vendor of the guided vehicle gave to the users use training in the plant for one week. Thus, the users got from the vendors *four weeks* of training in connection with the implementation.

To a great extent, the users´ training took place, however, through their own independent *experimentation and learning* after the vendors had left. The users can be seen to have used *some months* to their independent learning of the use of the machines.

Analysis

The treatment of the planning activity raises four questions for further analysis:

(1) The *plant* answered for the combining and design of system B. It is interesting to note that the planning phase took nearly as long a time, 2-2,5 years, in both cases A and B, although the systems differed considerably as to their scope. This refers to that the planning of an FMS is a *long process* with many *problems* and *alternatives* to be considered. Moreover, as

indicated in the description of case B, the management was not able to take into account all the needs of the system in the planning phase. *It can be asked how that kind of a pattern describes more generally the development efforts of the management.*

(2) In case B the *control system* was planned as the efficient system supporting the use activity. In addition, the *production process* was *automated* very far. All this differed from case A. *It can be asked what effect that has on the function of the system and the activity of the users.*

(3) It seems that although the idea of *work organization* was directed to solutions in accordance with "skill-based" production, the *planning practice* was a traditional one. That holds in the case of system B as well as in the case of system A. Thus, the "*basic" innovations* of system A and B were made solely by the management and the planners. In both cases, the *feasibility study* and the *technical design* were answered for and carried out by the *management and the planners*. However, in case B, the realization planning was carried out differently with the *users* participating in it. *It is interesting to examine what kinds of impacts that has on the implementation and "normal" operation phases.*

(4) The management acted according to the *"techno-centric" model* after which planning is seen as a separate phase, terminating at the beginning of the implementation (see Section 3.1). *There is reason to ask how that affects the implementation.*

6.3 IMPLEMENTATION ACTIVITY

The *main factors and dimension of the implementation activity in case B* are shown in Table 6.5. The implementation activity is analyzed in the following.

Duration and Timing of the Implementation Phase

The installation of the machines proceeded from June to August in 1985. The function of the system was tested in August with the vendors. The *implementation* began in September in1985. According to the opinion of the production manager, the system achieved its "normal" use already at the end of 1985. In his opinion, the implementation went well in accordance with the planned timetable. Over half a year after the beginning of the implementation, in the spring of 1986, the production manager estimated that the investment was reasonable and successful. However, there is reason to assume that the *implementation phase* took about 0,5 - 1 year.

Table 6.5. Factors and dimensions of the implementation activity in case B.

FACTORS	DIMENSIONS OF IMPLEMENTATION ACTIVITY
Duration of the implementation phase	About 0,5-1 years
Timing	Implementation: 1985-1986 Starting of the “normal” use activity: spring 1986
Resources of the implementation	Central role of the supervisor in methods design and programming However, many implementation tasks for the users (among others, programming of the guided vehicle and the robot)
Realization of work organizational goals	Despite “skill-based” goals, features of work division in the realization
Problems and development needs in the implementation phase	Training of the users insufficient Problems in the action of the machining center Functional problems (sharp edge removal, washing machine) Great amount of manual work Development needs of tools and pallets
Users´ activity	Disturbance control Development of tools and pallets Organizing job rotation

Resources of the Implementation

The implementation was organized in a dual way. On the one hand, the *supervisor* had a central role. He answered for the methods design and made programs for the machining center. On the other hand, many implementation tasks were solely the responsibility of the *users*. The users made, for instance, all the programs for the guided vehicle and robot.

Realization of Work Organization Goals

The goal was to achieve a group organization. That was not, however, so easy to reach. As a small FMS the system was adapted into the existing product shop and its cellular organization. The FMS-organization was carried out within the organizational solution the plant was just learning. Hence, the FMS-organization also contained many traditional features of work division. The tasks of the users diversified at first only to tools maintenance and quality control. Moreover, the supervisor partly had a traditional role of foreman with regard to the FMS.

Problems and Development Needs and Users´ Activity

In the implementation of the system there had been and were still in the autumn of 1989 *problems* the solutions of which called for *development measures*. In the following these problems and the development measures performed or planned are analyzed:

- The users felt that the *programming training* given by the vendor of the machining center had been insufficient. Also, not enough *part programs* existed at the beginning of the implementation. There were also at first problems in the operation of the *machining center*. The share of *disturbances* was at first over 10 % of the operating time. However, half a year after the beginning of the implementation the production manager said that in the use of the machining center they had already reached 14 hours a day, some of that time coming from unmanned operation during the night shift. He estimated that the running time of the machining center could reach 18 hours a day.

- During the implementation phase it came into light that the working time used to *sharp edge removal* by the users had increased greatly. That led to a plan to acquire a robot into sharp edge removal. The robot was installed at the end of 1986. It also proved that *washing machine parts* were problematic. There was a plan in the plant to procure a larger washing machine in the spring of 1986.

- In spite of new preparing and planning tasks in the FMS, the share of *manual work* was almost half of the total working time of the FMS-crew in the spring of 1986. In the implementation phase the users themselves organized *job rotation* within each shift. The users in a shift took turns in the weekly tasks with one another so that one user looked after the control and monitoring tasks (monitoring machines, loading machines and working with terminal, tools maintenance) and the other answered mostly for manual work (loading and unloading pallets, sharp edge removal, measurement, washing parts).

- Organizing the *wage system* took a long time. New grounds for the wage system were introduced only half a year after the beginning of the implementation. The productivity bonus was linked to the operation time of the machining center.

Analysis

The description of the implementation phase raises two issues for further analysis:

(1) The implementation phase of system A already showed that the "basic" innovation made by the management in the planning phase is only the beginning of a *long process* continuing in the implementation. The implementation phase of system B confirmed that assumption. Case B showed that also the implementation of a relatively small FMS is a long process with many *disturbances* and *problems*. *There is reason to ask how much the "normal" operation differs from the conditions of the implementation with regard to many disturbances and problems*.

(2) The users did *disturbance control* and *development activity* in the implementation phase. *It is interesting to ask how the activity of the users develops in the "normal" operation phase.*

6.4 USE ACTIVITY IN THE "NORMAL" OPERATION PHASE

Operation State of the System

The operation of system B and the activity of the users were *analyzed* in the autumn of 1989. By that time over four years had elapsed from the beginning of the implementation of the system. There was a special aspect to the study of system B, because the plant was planning at that time a new FM-system, system C, to replace system B. Thus, the emphasis in the development work was moving to the planning of a new system.

During the four years the operation of system B had developed considerably. In the study concerning eleven Finnish FM-systems it was stated that system B was with regard to its functional and economic characteristics one of the foremost systems in Finland at that time (see Mieskonen 1989). In the following the operational features of system B are presented:

- The *useability* of the system was high. There were two manned shifts and during the third shift the system was used unmanned. The system could run unmanned up to 10 hours. When needed the system could also be used during the weekend, but it had to be manned;
- The *operation ratio* of the system was high, 80-90 % and there were relatively few disturbances; when accounted for 24 hours a day, 7 days a week, the operation ratio can be assessed to have been 60-65 %;

- *Flexibility* was relatively good. The size of the product family was about 70 and the lot size was 1-60, generally 1-10. Every year 10-15 products were coming into production. In the planning phase only 20 products were planned to belong to the product family;
- *Productivity* had also increased. The amount of production had increased but the number of the users had decreased from four to three users.

Development Measures

There is reason to ask which of the changes account for the operation of the system and its development. Three factors can be distinguished: (1) direct measures for improving the system technology; (2) development in the organizational practices; and (3) the FMS-users´ problem-solving and development activity:

(1) *Direct measures for improving the system technology:* The *robot* for sharp edge removal had been installed, as stated. A *washing machine* had been acquired into the system. The *tools system* of the machining center had been extended in order to process the increased product family. The extended tools system also made it possible to use spare tools, which improved the useability of the system in disturbance situations. A *micro computer* had been acquired for recording the programs of the machining center, because the increased number of the programs did not yet fit in to the memory of the control system of the machining center. More attention had also been paid to the *parts quality*, among other things measurement had been made more frequent.

(2) *Development in the organizational practices:* The product shop and *cellular organization* had been developed further. The main functions had been moved to the product shop. The production and work planning had been transferred to the product shop. The product shop manager and supervisors answered for these tasks. The FMS users also participated partly in the control tasks. Quality measurement had been moved to be done solely in the product shop. Also the responsibility for materials activity had been moved to the product shop.

Practices concerning the *FMS organization* had changed to an increasing extent towards the practices in accordance with “skill-based” production. One principle was that all three users master all FMS tasks, looking after them within a flexible work division and job rotation. The *tasks of the users*, the time distribution of the use activity of the users and work division in the FMS organization are presented in Table 6.6.

Table 6.6. Users´ tasks, time distribution of the users´ tasks and work division in the FMS organization in system B in autumn, 1989.

TASK	SHARE OF USERS	TIME DISTRIBUTION OF USERS´ TASKS (%)	SHARE OF OTHERS
Operation tasks			
Fixing parts	all	20	
Parts finishing	all	30	
Monitoring automated operations	all	5	
Control tasks			
Quality control	measurement	3	*Quality controller:* spot-checks, critical parts
Tools maintenance	all	15	
Maintenance	general maintenance	10	*Plant maintenance:* special maintenance
Disturbance control	normal disturbances	5	*Plant maintenance*, *vendors:* greater repairs
Book-keeping	partly	2	
Preparation tasks			
Presetting	all	3	
Preparing programs	all	1	
Planning and development tasks			
Production and materials control	work planning	6	*Supervisor:* production planning
Programming	robot guided vehicle	-	*Supervisor:* machining center
Development activity (methods and equipment design)	suggestions, measures	-	*Supervisor:* systematic development
Total		100	

The table describes the situation in system B in the autumn of 1989, when four years had elapsed since the beginning of the implementation of the system. The time distribution of the users´ activity is based on the *intensive* *observation* of the operation of the system and the users´ activity minute to minute during two shifts. There was one user in both shifts (the other user in the morning shift was ill). A couple of weeks after the intensive observation the users were interviewed in a group discussion. The researchers made some changes to the time distribution of the users´ activity during the period of the observation. The users changed the distribution so that it corresponded better to the normal situation, according to their assessment. This time distribution is the one presented in Table 6.6 (see Toikka et al. 1991a, 69-71).

The *users* answered for most tasks in the FMS as a whole, as shown in Table 6.6. In the case of some tasks, other functions and persons did a part of the task. The quality controller spot-checked parts and controlled some critical parts. The plant maintenance and vendors participated in special maintenance and repairs of the machines when necessary. The *supervisor* did production planning but the users did work planning for the FMS. The supervisor also did systematic development work but the users participated in that activity, as well.

The supervisor stated in the interview that there had been clear shifts in the work division between the users and the other organization. The *role of the users* had increased especially in disturbance control, methods design and production and work planning. According to the view of the production manager the tasks of the FMS users had to be extended further with regard to programming, quality control and preventive maintenance.

As to the time distribution of the users´ tasks, it is shown in Table 6.6 that two *manual tasks*, fixing parts (loading, unloading and transport of parts) (20 %) and parts finishing (30 %), took half of the working time of the users. The great emphasis on manual tasks is a clear difference from system A. Among the control tasks the great share of tools maintenance (15 %) is striking. The time for disturbance control (5 %) was clearly less than in system A (21 %).

In the time distribution of the users´ tasks there is no mention of programming and development. However, the users did both activities. As can be seen in Table 6.6, the users made all programs for the robot and the guided vehicle. The users also took development measures, as we will see next.

(3) *FMS-users´ problem-solving and development activity:* In the group discussion with the users the reseachers asked the users about the development measures and the suggestions made by them. At first, the users mentioned eight development measures:

- the planning of the finishing workplace;
- a roller conveyor for facilitating materials handling;
- the planning of measurement equipment for parts;
- a tools rail in the finishing workplace;

- lighting arrangements in the finishing workplace;
- model pieces for the setting of parts, by which parts could be set directly into pallets;
- jigs in the guided vehicle to stop a pallet from turning sideways or going too far when being driven to the robot;
- a suction apparatus for facilitating the cleaning of the machining center.

All but the last suggestion had already been realized. It was characteristic that the development suggestions were directed to development measures concerning equipment and workplaces, to facilitate working or improve the function of the system. Only two of the development suggestions concerned disturbances or the elimination of their causes directly (model pieces for the setting of parts; jigs in the guided vehicle).

In the discussion it came into light that there were also other measures or suggestions which the users had done. Three other measures were stated:

- The users had determined the use time of all the 200 tools in use, based on experience and experimenting. The exact control of the use time of the tools gave a possibility to optimize the loading of the machining center, to maintain quality and to eliminate causes for disturbances beforehand;
- The users had also made a change in the work planning. The users told that they fixed parts in different machining phases to the same pallet, i.e. pallets were never driven empty. There were always some nearly ready made parts in the pallet. In this way the users were able to quickly answer to the demands of the assembly or the spare parts deliveries;
- The users had made an initiative which extended over the boundary of the system. They had suggested a change of the organization and payment so that the workers working in the FMS and on other machines also served by the guided vehicle (the machining center and two turning machines) would have formed one group which had internal job rotation and a common productivity bonus.

Thus, the users mentioned *eleven development measures* or suggestions in all. However, it is probable that the users did not remember all development measures which they had done over several years. It is also as apparent that the users did not consider many improvement and development measures to belong to development suggestions. These were seen as a part of "normal" activity. The users also themselves confirmed this in the group discussion: "Those suggestions were not written down, they belong to the everyday job. If there is some good idea, we just go ahead and do it."

The importance of the development work of the users was also emphasized in the interview of the supervisor. According to the view of the supervisor, the decrease in the number of the users from four at the beginning to three was a natural consequence of the decrease of the implementation tasks. In the implementation phase the *users* participated in the development and building of tools and pallets. The implementation and programming of the sharp edge removal robot and other peripheral equipment took a lot of the working time of the users. According to the *supervisor*, he did the basic design of the methods but the users did continuous methods design. The supervisor also noted that the competence of the users to repair programs had developed. The user themselves stated that they sometimes made new programs for the machining center if the supervisor did not have the time. The users were willing to extend their knowledge also to programming. Hence, the supervisor did not see it possible to decrease the number of the users further. Continuous increase in the product family caused *new "implementation" tasks*. It was already known that great changes in the products would happen.

Problems and Development Needs

Despite all development work in "mature" system B and its activity, there were still many *problems* which formed development tensions and demanded development measures at the end of 1989. Those problems can be divided into three classes: (1) development needs due to technical and productional factors; (2) problems concerning the use activity and organization; and (3) disturbances of the system:

(1) *Development needs due to technical and productional factors:* The *guided vehicle* was regarded as the most problematic equipment in the system, because it was sensitive to disturbances. Also, there were problems in the use of the sharp edge removal *robot*. According to the intensive observation, the robot was used only four minutes during two shifts. The reason was that the capacity of the program memory of the robot was too small. For the parts to be handled, the users had had to load a program from tape, which had taken about one hour per part. The enlargement of the program memory was coming. One problem was also that there were not enough *pallets*.

Materials had partly changed and become more demanding from the point of view of the production. There were also new materials. There were great problems with the materials, even to the extent that during the previous seven months 300 hours of FMS operation time were lost due to the disqualifying of parts, which meant about 10 % of the operation time of the machine. The disqualifying had also become a threat to the capacity of the system. Materials problems had also made it difficult to use the system unmanned in the night shift.

The introduction of *new products* increased continuously the size of the product family. That was due to the fact that two thirds of the parts and drilling machines produced in the factory went to spare parts for the machines in use. Thus, the old products could not be left out of the production, although the models of the drilling machine were renewed. Due to the increase of the product family, the limits for enlarging the product family of the FMS began to come into sight.

It was already known that the *amount of production* had to be increased by 10 % the following year. The capacity of the system began to be insufficient. The solution was the aim of using the unmanned night shift and of using the system also during weekends. In addition, the aim was to increase the efficiency of the production by continuous rationalization activity. The main responsibility for that was the supervisor´s but also the users participated. For increasing the capacity of machining, an enlargment of the use of the robot as well as the system as a whole were considered.

The increase of the product family was a cause also for problems in the *production and work planning*. In principle, the whole production depended directly on orders. To make a small buffer was a means to try to manage the situation.

(2) *Problems concerning the use activity and organization:* As can be seen in Table 6.6, half of the working time of the users went into two *manual tasks* (fixing parts and finishing parts). So a considerable time was away from other activities. In the interview the users stated that the time used for finishing had to be shortened by using the robot better in the sharp edge removal station. The users experienced also parts fixing as *troublesome and strenuous*.

According to the view of the production manager, the *payment system* was also an obstacle in increasing the useability of the system. The production bonus payment system was in use so that 20 % of the wage depended on the parts done. Hence, a new more encouraging and motivating payment system was under consideration.

(3) *Disturbances of the system:* The disturbances of system B were registered during the *intensive observation* concerning two manned shifts in the autumn of 1989. All in all, seven disturbances were observed. During the unmanned night shift the system operated without disturbances for five hours until the work queue fed into the central control system had been executed. At the same time, the causes for the disturbances were assessed. The placing of events into different disturbance classes is presented in Table 6.7.

Thus, disturbances occurred during the daily operating time of the system (21 hours) on average every three hours and during the two manned shifts on average every two hours.

In the group discussion the users confirmed that the picture formed during the intensive observation of the function of the system was typical of normal operation. However, because the number of the disturbances during the observation period was small, it is possible that chance could have an effect on the cause distribution of the disturbances. In any case, the occurrence of disturbances confirms the fact that in the FM-system been in use for a long time trouble-free operation had not been achieved in spite of many development measures taken during several years.

Table 6.7. Disturbances of system B in normal operation during one day (three shifts) according to causes (see Toikka et al. 1991a, 40).

DISTURBANCE TYPE	NUMBER OF DISTURBANCES
Design failure	1
Component or equipment failure	3
User error	2
External factor	-
Undefined	1
Total	7

As can be seen in Table 6.7, despite the small number of disturbances all the same disturbance types are represented as in the case of system A. There is a reason to note especially that one disturbance was caused by a *design failure*, which revealed the continuous need to develop further the system by design measures. The case where the sensitive element of the loading station did not give any sign of the pallet, and therefore the guided vehicle did not come to fetch the pallet to the machining center was defined as a design failure. The disturbance had occurred many times before. The elimination of the disturbance would have demanded a change in the placement of the sensitive element.

Component and equipment failures numbered three, two mechanical disturbances in the tools of the machining center and one disturbance in the electronics of the robot. One of the *user errors* was a lapse of memory, for the controller affecting the starting of the machine center was left in the wrong position. In the case of the other user error it was a question of the users not having noticed a change made in the drawing by which some parts already machined had to be rejected. One disturbance was left *undefined*. The system stopped due to the wrong placement of the guided vehicle. This problem had also occurred before but any analysis for diagnosing the causes for it and for eliminating the disturbance had not been made.

A proof of the *users´ high skill level* was their activity in the disturbance situations. The users observed and removed all the seven disturbances occurred during the observation period (see Toikka et al. 1991a, 69-72).

Analysis

The description of "normal" operation of system B points to that the operation of the system demands *continuous optimization* of the operation and the *elimination of the problems* impeding the activity. At the same time, it seems that *new problems* appear all the time when the operation of the system develops, as both case B as well as case A show.

Many *technical and organizational changes* had been made during "normal" use of system B, which explains the relatively good useability and operation ratio of the system. New equipment had been acquired into the system. The management had developed the organization further according to principles which can be interpreted as principles of the "skill-based" model. The role of the users had been emphasized with regard to activities and their planning.

However, there were many *problems* and *development needs* in the system although it had already operated relatively well for several years. There were also disturbances which can be seen as design failures. *Causes for the problems* included, among other things, changes in materials, product changes and increase in capacity. There were yet problems with the equipment and itsr use. The great share of manual work also caused problems.

It can be said that it is a question of *limitations of design* with these problems. The enlargement of the use of the system and the change of the operation conditions brought into light new connections and interrelations, which were not anticipated in the planning phase.

The *users* cleared all the disturbances occurred in the observation period. The users also taken development measures. The contribution of the users was regarded as an important one in *adapting* the system into the increasing and changing product family.

6.5 SUMMARY: ACTION MODEL OF THE IMPLEMENTATION PROCESS IN CASE B

As a small FM-system, system B was implemented in a relatively short period compared to system A. However, the planning of system B was already a long process. Especially the implementation and use of the system showed that a relatively small FM-system demands continuous development activities. The results of case B show that the boundary between the implementation process and the "normal" operation of the system is diffuse.

The summary of the implementation process of system B is presented in Figure 6.1 as *the action model of the implementation process*, according to the model in Figure 2.2. In Figure 6.1, the *main features* of the implementation process are shown in the middle of the figure, under the headings of the different activity phases. The *main activities* of the management and users and their interaction are presented in the figure.

The activities of the management as well as of the users are assessed in Figure 6.1, based mainly on whether practices are in accordance with the "techno-centric" approach (T), the "user-centered ("skill-based") way (U) or "lean production" (L).

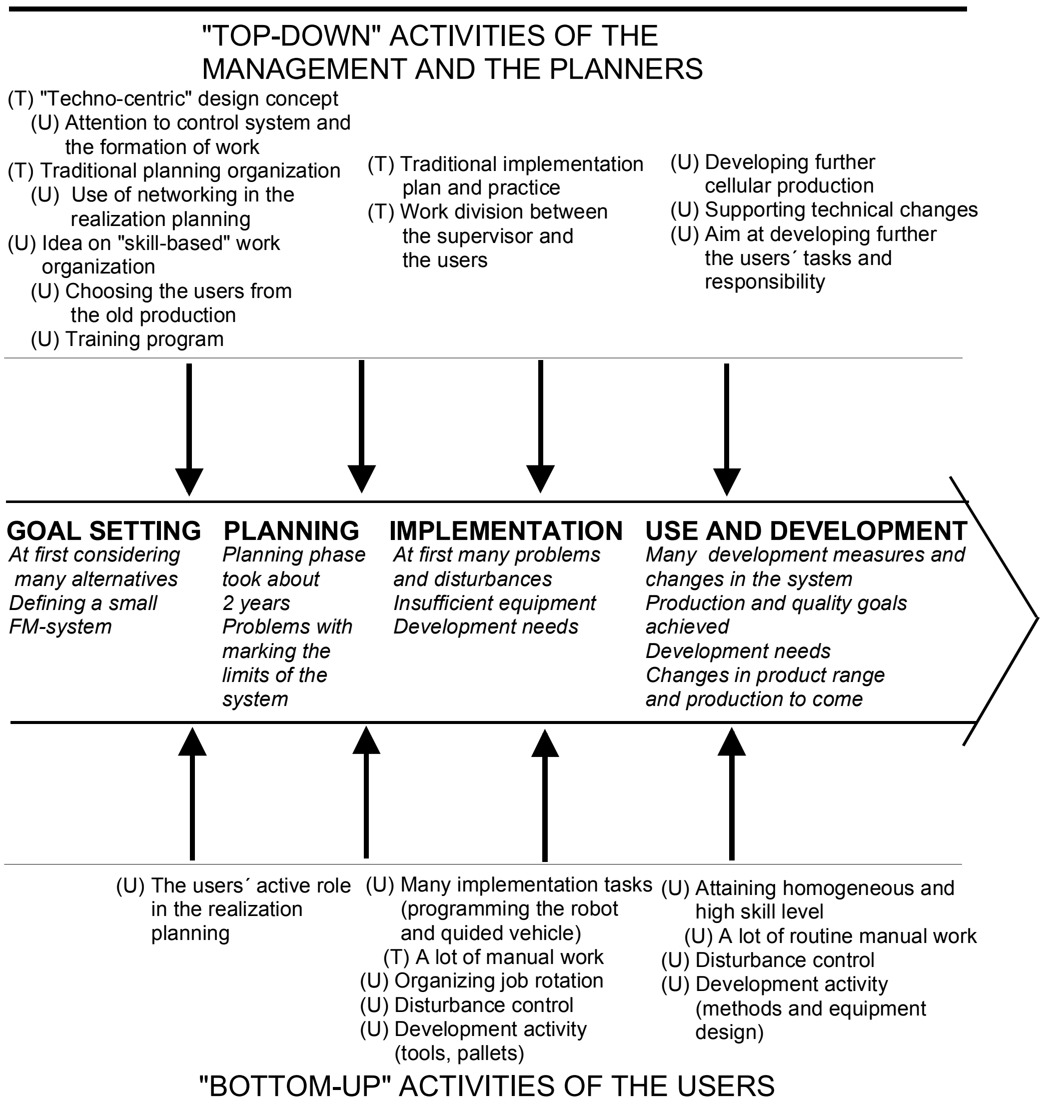


Figure 6.1. Action model of the implementation process in case B.

In the following, the implementation process and the activities of the management and users and their interaction are analyzed:

The *implementation process* of system B was a *long and many-phased process*, although the system was a relatively small one. It took about three years from the beginning of the feasibility study to the starting of "normal" operation. At the beginning of the *feasibility study* other *alternatives* were also considered than the implementation of the FMS. The implementation process of system B illustrates the difficulties which the management had with the *definition of the innovation problem* and getting the *innovation decision* through in the corporation due to *differing viewpoints* to the development needs.

The *planning phase* took about 2 years in total, which is about as long as in the case of large system A (2,5 years). Drawing the line between the FMS and the other part (three machines and their users) of the product shop connected, however, tightly to the materials system and control system of the FMS can be seen as one of the main problems in the planning phase. Later, the users of the FMS made such a proposal for linking these two parts together with the common job rotation and the same bonus payment.

As normal, *the design concept* by the management and planners was "techno-centric", with the main emhasis on the planning being on the design of the production process and machine system. However, the design concept contained at the same time two features in accordance with "user-centered" production. First, the demands of the *control system* were taken into account in the process design. Moreover, the control system was designed as an *efficient system* supporting the use activity well, which can be seen as an indication of the management´s strive for a new kind of solutions. Furthermore, the management set as a target to create *high-skill jobs* for the workers. One reason for these efforts was surely the fact that the management wanted to guarantee high useability of the system and *unmanned operation* in the night shift.

The *planning organization* was, however, a traditional one during the *feasibility study* and *technical design*, with no workers as well as none of the supervisors participating. Thus, the management and planners answered alone for the "basic" design of the system.

However, in the *realization planning* the management adopted a "participative" approach in accordance with the "user-centered" model, with all the *users* participating in the design with different planners and designers, and the supervisor. Also the fact that the *users were chosen* from the old production reflected the management´s "skill-based" attitude. Correspondingly, the users got off-the-job *trainin*g about two weeks before the beginning of the implementation. The users participated also actively in solving the design problems concerning the workplaces and tools in the realization planning phase.

The management did not make any special *implementation plan* and did not support the implementation. The approach of the management was of a dual nature. On the one hand, many implementation tasks were given to the supervisor′s responsibility. On the other hand, some task were left to be carried out by the users alone. That created work division between the users and the supervisor. Thus, the goal for "skill-based" organization was not realized. Another reason to that was also that the cellular production, into which the FMS was adapted, was only in an experimental phase in the plant.

There were many *problems* at first with the machines, especially with the useability of the machining center due to many *disturbance*s in the *implementation phase*. Also, insufficient training of the users had an effect to solving the disturbance problems. There were also *functional problems* in the system due to inadequate equipment (too small washing machine, sharp edge removal). That is a clear proof of the fact that it is impossible to take into account in the planning phase all the conditions of the use. In spite of the many development needs of the system, the management considered that the "normal" operation phase had been reached a little over half a year from the beginning of the implementation.

The *users* did many implementation tasks, among others *programming*. The users answered also for *disturbance control* and for many *development tasks*, especially developing tools and pallets. Due to a lot of manual work, the users also organized *job rotation* within a shift.

During the years of "*normal" operation* of the system many *development measures* and *changes* in the system had been made. The system had reached high useability, flexibility and productivity. However, there were many urgent *development needs* in the system yet after four years from the beginning of the "normal" use phase. It seems that there are many minor *"start-ups" or "implementation" phases* in the system during its "normal" operation. One of the new "implementation" tasks was due to changes in the product range and in the production amount.

Although the *management* had a traditional approach in the implementation phase, it adopted a more "skill-based" approach when moving to the *"normal" operation phase*. The management developed further *cellular production* in the product shop and supported *technical changes* and other *development measures* presented by the users or the supervisor. The aim was also set to enhance the users′ skills and to give them more responsibility for the system. The users answered for *disturbance control* and did *development work*, directed mainly to methods and equipment design. The users had also attained a *homogenous high skill level*. However, about half of their working time went to routine manual tasks, which had a negative effect on their motivation.

7 CASE C: IMPLEMENTATION PROCESS OF A LARGE FMS

The company, in which system B was located, started the planning of a totally *new factory* producing drilling machines for the large mining and drilling machinery assembled by the company. The planning of the new factory began in 1988. The new factory was implemented in the spring of 1991. As a part of the factory, a relatively *large FM-system, system C* was installed for replacing system B situated in the old factory. The planning of system C was started at the beginning of 1989 as a part of the design of the manufacturing system of the new factory. The implementation of system C began in June 1991.

Case study C concerns the implementation process of large system C. The implementation of the system forms an *interesting case* because system C is a system of the second generation in the production of the components which were produced also in system B. Moreover, system C is considerably larger than small system B. This opens *two aspects for assessing the implementation process* of system C. On the one hand, the situation of the company was easier, because one was able to draw from the existing experience of FMS. On the other hand, the experience gained from a small FMS can become a burden, since *new qualitative factors* linked to a new large system can be omitted from the necessary attention. These viewpoints form the starting point in the analysis of the implementation process of system C.

The researchers did not only follow up the implementation process but intervened actively in the creating of *new tools and organizational practices* for the organization in accordance with experimental development research. The result of these efforts of the researchers are evaluated within the case description.

7.1 DEFINING THE INNOVATION PROBLEM AND GOAL SETTING

Decision on a New Factory

The *first ideas* of a new factory were considered in the company in the beginning of 1988. At that time, the first plans for the *layout of a factory* were also made. The management of the company made the *decision on the building of a new factory* at the end of 1988. The decision was based only on a relatively general assessment of the possibilities and realism of a new factory, according to the main designer. The preliminary factory layout was also based on this decision.

The building of the new factory was linked to the organizational rearrangements of the whole company and to the geographical movements of the business units of the company. The new factory was mainly seen as a strategic issue. Thus, *strategic goals* for the factory were set. The first strategic goal was to concentrate the production of the drilling machines from several factories to one independent factory. The second goal was to build a "modern" factory promoting the sale of the machines.

Dimensions of the Change Process

After the investment decision was made at the end of 1988, the *feasibility study* concerning the manufacturing system and technology of the new factory was made in the early spring of 1989. For the *closer goal setting* of the new factory, the needs of the customers (other units of the company) were examined and a prognosis of the future demand of drilling machines and their components was made. The *capacity and operation and activity principles* of the manufacturing system were defined based on these accounts. At the same time, the *layout* of the factory was fixed, based on a separate decision., *Decisions* concerning the construction technique, e.g., different kinds of technical layouts and electrical wiring were also made on that basis.

The reasons for the change, its scope and the goals set for the factory in case C are presented in Table 7.1.

As noted, the main reasons for the new factory were *strategic*. Other reasons arose from the *demands of the markets*: the need to increase considerably the capacity of the production in the new factory, as it was then seen; and to maintain the high quality level. All in all, the *scope of change* can be seen as rather large. A new large FMS was implemented in a totally new factory. The g*oals* concerned especially the increase in capacity, both in the production of the drilling machines and their spare parts, the halving of the throughput time of production and the shortening of the delivery time to one week, as well as the raising of the delivery reliability to 100 %.

The FM-system was considered to be in a central position in achieving these goals. The *capacity need* for system C was separately calculated based on the consideration of the capacity of the factory and on the demand estimate for the drilling machines. The goal was set to increase the capacity by 60 % compared to the capacity of system B in the old factory.

Table 7.1. Factors and dimensions of the change process in case C.

FACTORS OF CHANGE	DIMENSIONS OF THE CHANGE PROCESS
Reason for change	*Strategic goals:* the concentration of production of the drilling machines into one factory; modern factory promoting sale of the machines *Demands of the markets:* capacity, productivity
Level and pace of change	Building a *new factory* Relatively *great change*: the replacement of small FMS B with a relatively large FM-system
Goals	To increase the capacity of the production in the new factory by two thirds in a year To double capacity of the production of spare parts in one year To increase the capacity of FMS C by 60 % compared to the capacity of system B To increase productivity, i.e. capacity increase without increase in manpower To halve throughput time in production in the factory To shorten delivery time from order to delivery to 5 days in the factory To raise delivery reliability to 100 % To maintain excellent customer quality

Analysis

Two questions can be noted for further analysis:

(1) Because no feasibility study was made before the investment decision, decisions on the layout of the new factory and on the solutions of the manufacturing system and technology were left entirely to be made later during the feasibility study and partly in the planning phase. It can be said that the decision on the new factory and its manufacturing system was based on a *vision* rather than on the carefully analyzed conceptual design. *It can be asked what effect that has on the implementation process.*

(2) In the feasibility study the *operation and activity principles* of the manufacturing system were defined. *It can be asked what effects that has on the planning and implementation phases.*

7.2 PLANNING ACTIVITY

After the feasibility study, the primary *technical design* was started. The *main factors and dimensions of the planning activity in case C* are presented in Table 7.2.

In the following, the planning activity in case C is analyzed in more detail. First, the products and design concept of system C are considered. Second, the organization of the planning process as well as a more detailed overview of the planning situation about half way through are discussed. Third, the implementation model is analyzed. Finally, the contribution of the users to the planning and planning practice is evaluated.

Duration of and Responsibility for Planning

The planning phase lasted for almost three years. The plant itself answered for the planning of the new factory as well as the design of system C. Also in cases A and B, the plant did the design of the system.

Products

The products produced in system C are *prismatic parts* which are the basic components in the drilling machines assembled in the factory. The size of the *product family* was planned to be enlarged from system B by including new parts of the drilling machines in the production. The size of the product family was seen to be 100 parts. The l*ot size* was planned to be 1-10 pieces, as in system B.

It was thought that new parts would come into the product family because of regeneration of the drilling machines. It was known that the change of generation in the drilling machines was under design. At the same time, the aim was to stop the production of the old machines. However, old products from the product family disappear only gradually, because parts were also needed as spare parts into the existing drilling machines. Only a small less demanded part of the product family was planned to be produced outside system C in other cells in the new factory.

Table 7.2. Factors and dimensions of the planning activity in case C.

FACTORS	DIMENSIONS OF PLANNING ACTIVITY
Duration of the planning phase:	Over 2,5 years
Products:	Products: prismatic parts Size of product family: 100 Lot size: 1-10
Design concept:	
The object of design	Main emphasis on design of the producion process and machine system; however, attention was paid also to the control system; in addition, a strive for a homogenous and skilled crew
Production process	Emphasis on automating the processes, the aim to guarantee unmanned operation
Control system	Advanced and all-round system supporting use activity
Organization of planning:	
Responsibility for the design of the system	The plant itself answered for the planning of the new factory and the design of system C
Planning organization	*Concept design of the new factory:* the management group and three full-time planners *Technical design of system C:* the planning group comprised of the management and planners; *Realization planning of system C:* the planning group consisting of the management and planners; the *cell group* consisting of one user, a methods designer, and the supervisor
Implementation plan:	No implementation plan
Implementation model	Traditional distinction between the planning and use: no plan and program for the implementation; however, there were some *new features*: - participation of some users in the planning - planning organization was partly incorporated into the implementation
Work organization	Vision on a homogenous “group” and skilled organization
Training and use of professional skills	Some off-the-job training for the users

Design Concept

As usual, in the technical design phase the *object of design* was mainly the design of the *production process and the machine system*. However, there were two new features in the design, due to the consideration of the *operation principles* of the system in the beginning of the planning. First, the demands for the *control system* were taken into account. Second, there was also an idea of a homogenous and *highly skilled system crew*, in accordance with "skill-based" production. In the following, the design of the production process and the machine system and the control system are discussed:

Production process and machine system: The new factory was wholly planned to consist of *flexible cells*. The good experience gained from system B and from cellular production in the old factory affected that decision. Another reason was the aim to realize a modern factory. In addition to system C, there were six production cells for the production of small parts for the drilling machines. Furthermore, there was a tempering cell and an assembly cell in the new factory. Thus, there were *nine cells* in the factory in all.

In the *design of system C* special attention was paid to the system of *materials handling*. The reasons were bad experiences from the material handling in system B, because the guided vehicle had proved functionally problematic and sensitive to disturbances. The result was a fixed transport system consisting of automated storage. The automated storage system served in addition to system C also other production cells, of which five and the tempering cell were planned to be placed in the immediate vicinity of the automated storage system. Only two production cells were placed far away from the storage system. In these production cells the machines were NC-machines, only some auxiliary devices perhaps conventional machines. Within the cells, the change of tools and workpieces is done by hand. Altogether, the *automated storage system* was planned to form the core that would bring all activities in the factory together. The solutions concerning the layout and activity principles of the factory aimed at achieving a process-like production system.

System C was planned to consist of three identical machining centers and one lathe as the key machines (see Toikka & Kuivanen 1993, 21-22; Kuivanen 1996). The system has a storage system where the materials circulation on platforms and pallets is carried out by an automated shelf elevator. In the system, there is a central control system, through which the orders are given to the devices of the system. In each machining center there is an automatic pallet changing system which changes the workpieces into and out of the machining center according to the commands of the central control system. The tool change also happens automatically in the machining centers. The lathe is served by a gantry robot which moves the material delivered by the shelf elevator on a pallet. There is an industrial robot for removing the sharp edge after machining. According to the planner answering for the design of the manufacturing system, no robot is to be used in the sharp edge removal station. However, things developed in another direction. The sharp edge removal robot of system B was moved into system C in the implementation phase.

The workpieces are washed automatically between the machining phases in a pallet washing machine served by the shelf lift of the automated storage system. The finished parts are washed in a separate workpiece washing machine before delivery to the assembly cell - where the drilling machines are assembled.

The *automation level* of system C was planned to be at least on the same level as in system B. In system C there is also a centralized system for chip disposal and cutting liquid. In the planning phase, a centralized tools system was also considered so that there would be only one place where tools are preset and from which the preset tools are moved automatically into each machine. That plan was later abondoned, due partly to its expense.

Control system: The automated storage system was thought as a separate automation unit which operates under computer based control. However, that control was not planned to have any link with higher level computer systems in the plant, for instance with the *production control system*. It was thought that the control of the automated storage would control the operation of the shelf lift and handle the transport of the materials and pallets. Furthermore, it was planned that the users could give orders to the control system directly from all production cells through a terminal located in every cell.

In the case of system C, it was considered possible to implement a separate control system for the NC programs and tool information. Another possibility considered was that the independent control of each machine in the system would handle these matters.

The solution that the users of every production cell could directly be in connection to the central control system through a terminal for handling the transport of materials in and out of the cell was realized. The plan of the control system was changed later in the case of system C. First, the level of the central control system was much higher than originally planned. Second, the central control contained versatile characteristics.

The central control system represents its vendor´s most advanced concept. The architecture of the central control is a two-layered solution. The programmable logic controller forms the basic level through which the direct commands for the machines are given; the work stack maintenance and the transport of the pallets from one work station to another are taken care of. On the upper level there is a computer system through which the NC-programs and the control of the tool information, connections to the production control, as well as the platform transfer are handled.

The central control system also contains the large control and report activities of the use, the description of the state of the system, the log of the events and disturbances, the simulation of the production and the follow-up of the availability and utilization rate. The central control system has a graphical user interface with two terminals.

A separate workstation computer system is linked to the central control for the *tools management*. Its activities are the creation and maintenance of the tools data, the control of the data of tool presetting, the control of the tool magazines of the machines, and the transfer of the geometric and control data to the machines through the central control system.

Analysis

Three questions can be raised for further analysis:

(1) The description of the planning of system C indicates to that the *management and the planners* considered different kinds of *alternatives* for technical solutions during the planning phase. In addition, it seems that the solutions under consideration were *changing and developing* when new information on new technical possibilities was received and new demands concerning the functioning of the system under design came into light and were analyzed. A good example of that is the consideration of the use of *system B*. In the autumn of 1989 the management considered whether system B should be changed and moved into the new factory or whether it should be left in the old place and possibly to other use. The situation changed later so that system B was broken up in August 1991, just after the beginning of the implementation of system C. *There is reason to ask how this kind of a pattern describes more generally the development efforts of the management.*

(2) In case C the *control system* was planned as an advanced and all-round system supporting the use activity. Moreover, the *production process* was *automated* very far. All in all, the system was large and complicated consisting of many interrelated automation systems. *It can be asked what effect that has on the function of the system and the activity of the users.*

(3) The planning phase of system C took over 2,5 years. It seems that the planning of an FMS is always a *long process*. It lasted also about 2 - 2,5 years in the cases of systems A and B. *It can be asked how long the implementation phase becomes.*

Project Organization

The *factory project* had a *management group* consisting of the managers and planners. The factory project had a *full-time leader* and three full-time *project engineers* of which one engineer answered for the planning of the manufacturing system and technology. The *design of system C* also belonged to the tasks of this engineer. In addition, the leaders of the product shops in the old plant used their time for the design when necessary. Furthermore, separate *project groups* were established for the planning and preparation of certain areas, for instance the quality project, the project for the trial run of the drilling machines, and the project for considering the wage structure.

The *workers* of the production cells and the *supervisors* of the old factory did not participate in any way in the design of the new factory and of system C. Thus, the *concept design* of the new factory as well as of system C were performed solely by the *management and the planners*. The *technical design* of the new factory and of system C were also done mainly by the management and the planners.

In the late autumn of 1989, the planning of the different cells for the new factory was to be started. It was a question, on the one hand, of the finishing of the technical design and, on the other hand, especially of the starting of the *realization planning* of the new factory and also of system C.

For every production cell, *a cell group* was formed, the task of which was to design the details of the layout and workplaces of the cell and to participate in the preparation for the puchase of machines. A *worker* of the cell in question was appointed as the leader of each cell group. There were also the *supervisor* of the area to which the cell belonged and a representative of the *methods design* in the cell groups. The cell groups assisted the *planner* in answering for the manufacturing system and production technology of the new factory and acted under his guidance. The planning of the cells was aimed to be finished in a year by the autumn of 1990, which did not totally succeed since the planning was still going on at the beginning of the implementation of system C.

The management had already earlier experiences from that kind of a new planning practice since the old factory had been organized into product shops and production cells. The supervisors had been at that time key persons. Workers were chosen to be leaders of the cell groups because the managerial personnel were fully engaged in the production and its control due to productional pressures.

The role of the workers acting as leaders of the cell group of the new factory was to be contact persons with whom the planner agreed on procedures and timetables. The task of the leader of the cell group was to take matters further with the workers of the cell.

A cell group was also set for the planning of system C. One of the users of system B was in the cell group and he asked other users for their opinions about the solutions.

Assessment of the Planning Situation

In the case study *the planning situation of system C* was assessed in the beginning of 1990, when the planning phase had proceeded more than a year and it was yet more than a year to the beginning of the implementation of the system.

The evaluation of the planning situation of system C was made during the *feedback occasion* in the plant in January 1990. It was based on a preliminary *report* prepared by the researchers, mainly from the interviews of the management, the planners, the supervisor and the users of system B in the autumn of 1989. The users of system B (three users in all), the supervisor of the production cell to which system B belonged, the manager of the product shop, the production manager, the planner answering for the design of system C, and the researchers participated in that occasion (Toikka et al. 1990).

The aim was first to evaluate the *extent of the change process* from the small FMS to relatively large system C. Second, the aim was to evaluate *how the planning of the system had advanced in the different design areas*. Third, the purpose was to evaluate *what role the users of system B had had in the planning of the different design areas*. Based on that analysis, the researchers made a *development proposal* for the organization. These points are discussed in the following:

(1) Extent of the change: The planning of system C meant the change-over from small system B to relatively large system C. It can be argued that a *realistic view* of the extent of the change process is a critical issue with regard to its planning and implementation. However, the views of the extent of the change differed in different personnel groups.

First, the *work tasks and manpower* of the new factory and of system C were not planned at all in a strict sense, which is quite a usual practice. The idea was that each production cell in the new factory would have its own personnel so that every worker would be able to do all the work tasks in the cell. This goal reflects the management´s aim to carry out organizational solutions in accordance with “skill-based” production.

However, when the technical matters of system C had been planned for more than a year, the idea of the planners about the *FMS-organization* was yet quite hazy. It was assessed that five users would be needed for the system. That was only a guess, because there were eight users in the system when the implementation was started. Later, the number of the users increased to ten, as we will see. Thus, organizational issues were not yet considered more closely, which is a clear indication of the traditional planning practice, i.e. the solution of the organizational issues is left close to the implementation phase.

In addition, the planner answering for the production technology saw that although many users would have to be trained, there was *no leap in view* as to the skill level of the users compared with the skill level in system B. According to the planner, present system B operated already as a cell and the operation was automatic.

Second, the three *users* of system B stated in the interview that they did not yet know anything about *the organization and the division of work* in the new system. The users had no knowledge of the manpower of system C, how many users were to come and whether they themselves would work in system C. According to them, it was also unsolved how quality control, programming and production control were to be handled in the system.

Furthermore, the *users* disagreed with the view of the planner on the *extent of the change*. According to them, the change would be relatively great when switching over to the new system. They stated that "the material flow is different, three machines are producing more than one machine." Demands would increase with regard to the use of automation. Work methods would have to be changed and developed. The meaning and share of tools handling was seen to increase considerably in the new system. Also all pallets would have to be planned anew. The users supposed that programming would also be included partly in the tasks of the users. There were also pressures as to how all the users could work in all operation places, e.g., in the lathe. They also saw that the principles of work planning would become different from the ones in small system B. Also production control would have to be changed, as the users noted: "sure it has to be different, much better planned, due to the difference in the material flow."

The *researchers created a method* by which the differing views of the organization of the new system could be focused and made more coherent. The time and share distribution of the use tasks in system B was taken as a starting point (see Table 6.6). Moreover, it was seen that programming and turning would become new tasks for the users. The share of these two tasks was estimated to form a quarter of all the tasks in the new system. This assessment was jointly considered in the above mentioned *feedback occasion* in the plant in January 1990 (see Toikka et al. 1990; Toikka et al. 1991a, 28-29).

The result of the assessment was that the *workload* in the new system would more than double compared to the work in the old system. Also the contents of work would change. *The quality of the work tasks* in the new system was assessed by three categories:

- the old task done mainly in the same way as in system B;
- the old task done in a new way, by using new tools or new control technique;
- the new task demanding getting acquainted with new issues or technique.

The share of these categories was assessed in percentages. The result was as follows:

- 30% old tasks;
- 30 % old tasks done in a new way;
- 40 % new tasks.

Only two tasks, materials handling (mainly fixing workpieces and partly parts finishing) and maintenance, would be done in the new system almost in the same way as in the old system. Other tasks would contain new elements for the users or be wholly new to them. Such tasks were, in addition to turning and programming of the lathe, the transport of materials by a new type of materials system and the central control system, and disturbance control. It was anticipated that the change in the contents of work would mean increasing demands for learning and the work load at least in the beginning.

It is clear that this assessment was still a simplified version. The change-over from the old system to the new one was considered as if it were only a question of change in the different tasks. However, the greater systemic nature of the new system also meant an increase in the relationships between the different use tasks. It was probable that this would increase the number and standard of the use tasks, e.g. disturbance control, more than one could estimate based on the consideration of separate tasks.

Moreover, the assessment concerned only the users of system B. In system C there were also other users, who had not worked earlier in an FMS. The extent of the change in their case depended on their earlier work experience. However, new tasks could be supposed to have a great emphasis in the change.

(2) Planning situation in different design areas: The researchers assessed how the design of system C had advanced and what the degree of preparedness in the different design areas was.

The degree of preparedness of the different areas of the design was assessed in percentage. At the same time, the participation of the users of system B in the different design tasks was evaluated. The result is presented in Table 7.3. The areas of the design in which the users took part, are marked by the symbol X. The areas of the design that the users had only heard, is marked by the symbol (X). This assessment was discussed together in the feedback occasion in the plant in January, 1990.

There was a certain disproportion in the degree of preparedness between the different areas of the design. The design of the *production process* was already relatively far advanced except for the methods technique. The production process is naturally a starting point for design. However, parallel to the production process the planning of the *control system* and *production control* would also proceed. *Organizational design* would also be linked to that. One can ask if it is possible to guarantee in this way that the design of the organization proceeds at the same time with the technical design of the production process and of the control system to achieve optimal solutions (see Sections 3.2-3.4).

As can be seen in Table 7.3, the functional definitions and the structure of the control system and the principles of the production control system could be largely fixed. Instead, the organization of the production control and the design of the organization received less attention.

The planning of the work organization was already discussed above. The situation of the production control is discussed below.

According to the planner answering for the manufacturing system and production technology, it was not possible to make any great changes to the principles and computer systems of the *production control* used in the old factory, due to the short time for the design. On the other hand, some small changes were possible. According to the planner, the production control system of the old factory would be moved to the new factory and would be adapted to the demands of the new factory.

It is well-founded to ask whether this would not raise problems, because the new factory was to differ by its functional structure from the old factory. Also the planner admitted that production control was as a whole a difficult issue. It was not yet fully known how the production control would be organized.

(3) Participation of the users: As can be seen in Table 7.3, the participation of the users of system B had been the greatest in the design of the layout of the workplaces and of the organizing of the supporting activities. These were also central issues in the planning tasks of the cell groups.

However, the users of system B stated in the interview in the late autumn of 1989, that they had participated in the design of their own workplace in system C, but there were strict limits as to the alternatives. According to the users, there was no reason to emphasize the meaning of their participation, because the layout and the machines had already been designed beforehand.

Nevertheless, the users had had influence in some matters. The users said that they leaned on the planners to acquire a centralized cutting liquid system. This system was promised, and was also later acquired. The users had influenced also the acquisition of the chip disposal system which was also a centralized system.

Table 7.3. Planning situation of system C in January, 1990, a year after the beginning of the planning (see Toikka et al. 1990; Toikka et al. 1991a, Appendix 4).

AREA OF DESIGN	COMPLETENESS OF DESIGN (%)	PARTICIPATION OF THE USERS OF SYSTEM B
TECHNICAL DESIGN		
PRODUCTION PROCESS		
System layout	100	
Definition of machines	70	(X)
Purchasing of machines	5	
Design of work flows	75	(X)
Layout of workplaces	80	X
Design of tools system	40	(X)
Fixing systems	15	
Methods techniques	0	
Design of safety techniques	40	
Organizing of supporting activities	70	X
Quality control	30	
Maintenance	10	
CONTROL SYSTEM		
Functional definitions	75	(X)
Structure of control	70	(X)
Design of interfaces	40	(X)
DESIGN OF PRODUCTION CONTROL		
Principles of control	90	
Organization of production control	10	
Control practices and methods	10	
DESIGN OF ORGANIZATION	5-10	
Work tasks		
Organizational solutions		
Manpower		
Training		

(4) Development proposal: Based on the analysis of the planning situation, the researchers brought up *six important design areas* in which there was yet much “degree of freedom” and which at the same time were very central for guaranteeing the efficient and reliable operation of the system. These areas are as follows (see Table 7.3):

- methods techniques and related tools and fixture systems;
- safety techniques;
- quality control and maintenance;
- functional definitions of the control system and design of interfaces;
- organization of production control and control practices and methods;
- design of organization.

The users had had hardly any influence on the design in these six areas. In the *report* given to the plant, attention was paid to these design areas and the importance of the participation of the users.

7.4 CONTRIBUTION OF THE USERS AND THE PLANNING PRACTICE

Participation of the Users

As stated, *cell groups* were established for *the realization planning of the production cells* of the new factory. There was also a cell group for system C. Through that the users were involved in the design. They had influence mainly on the following matters:

- As noted, they had already leaned in an early phase of the technical design on the planners to acquire a centralized cutting liquid system for the machines of the system;
- They also influenced the acquisition of the centralized chip disposal system;
- They also participated in the decision making about the purchase of some machines. Because the users had good experience of the machining center in the old system, they suggested that three new machining centers be purchased from the same vendor, which also happened;
- They had a great contribution to the design of the layout of the workplaces and the organizing of auxiliary equipment, as noted. For example, the users planned the placement of the hoisting devices;
- The users had the greatest influence on the manual workplaces. For example, a user planned the placement and layout of the workplaces for sharp edge removal. The high quality of that design shows that when the plan was changed in the installation phase by decreasing the sharp edge removal places, the user anticipated that the management would have to come back to the original plan. This also is what

happened. The sharp edge removal workplaces were increased in the autumn of 1992;
- The users also had an influence on the design of pallets. They presented their view on the design solutions.

As noted, the planning practice based on cell groups was in line with the "*participative" planning model* of the "user-centered" model (see Section 3.2). There were also "network" features in accordance with "lean production" in the planning, because the users co-operated in the design issues with their supervisor, the methods designers and the full-time planners for designing the new factory.

However, as noted, there is no reason to emphasize the participation of the users in the planning. There are two direct causes for that. First, the layout and the machines and other basic solutions of the new system had already been designed during the *technical design* before the users came along to the planning. Thus, the users mainly participated in the *realization planning*. Their contribution was restricted to a great extent to the planning of some individual parts of the system. Second, *participation did not concern all users* (see Toikka & Kuivanen 1993, 32). Only one user of system B came to the new factory before the beginning of the installation of the machines. He was the leader of the FMS cell group that planned the issues concerning the new FMS. His contribution was the most important one to the planning. Two other users of the old FMS came in the system only at the same time as the installation of the machines was beginning. Three other users from the old production cell, to which system B belonged, came into the new system only in the installation phase. Thus, three users had the best chances to influence the solutions of realization. The other three users took part only in the installation of one or some of the machines. Two of the eight users entered into the system in the implementation phase.

Limitations of the Planning Practice

However, there were more fundamental factors which affected the participation practice. First, there was no systematically organized *meeting practice*. Design issues were processed unofficially, normally so that the planner gave tasks to the members of the cell group or asked their view about some problems. In the same way, the members communicated directly with each other. One of the planners stated that no need to arrange formal meetings had been seen, because matters could be discussed informally. However, in doing so, it is impossible to form any *program* by which each design issue could be tackled in a systematic way. Furthermore, the *different views* of the members on the design issues did not come into sight at the same time and the discussion on these differing aspects was left for late. All this must have had an effect on the quality of the solutions.

Second, the participation of the users was based on their existing skills. There was no *training* for the users or for other personnel who participated in the planning (cf. system training in case A, Section 5.4). Moreover, no other *tools and methods* than normal technical drawings were used as a help in the design issues. By using some kind of models describing the system and possibly simulations based on them it would be much easier to understand and illustrate the connections and interactions between different issues and parts of the system. These models and simulations would also form a common ground for the participants to discuss and to argue about different aspects of the design issues.

Analysis

Four important issues can be raised for further analysis:

(1) The *views of the organization* of the new system and the extent of the change were yet preliminary and diverse after planning for a year. The *management* saw that there was no leap in the skill level of the users compared with the skill level in system B. However, the views of the *users* about the extent of the change-over to system C seemed to be realistic. That conclusion was also confirmed by the joint consideration in the feedback occasion. All in all, the assessment showed clearly that the change would be *greater than the management and planners had beforehand been able to imagine*. That was also admitted frankly by the planner answering for the planning of the manufacturing system and production technology of the new factory. He said that he was surprised at the result. *It is a question of how that kind of an approach by the management affects the implementation.*

(2) It seems that although the idea of the *work organization* was directed to solutions in accordance with "skill-based" production, the *planning practice* was traditional. That holds also in the case of system C as well as in cases A and B, as we have seen. Thus, the "*basic" innovation* of system C was made solely by the *management and planners*. The *feasibility study* and the *technical design* were answered for and carried out by the *management and planners*. However, in case C the realization planning was carried out differently with some *users* participating in it according to the principles of "participative" planning. *It is interesting to examine what kinds of impacts that has in the implementation phase.*

(3) The planning practice with its *unsystematic methods* was characteristic of the planning phase. *It can be asked how that kind of an unsystematic practice continues in the implementation phase and what effects that has on the implementation and use activity* .

(4) The *assessment of the planning situation* raised six important *design issues*, which were not yet properly planned. In addition, the importance of the participation of the users in the design was shown. The issues raised were methods techniques and design, safety techniques, quality control and maintenance, function of the control system, organization of the production control, and activity of the organization. *There is reason to ask how these points affect the function of the system and the activity of the users in the implementation phase.*

7.5 IMPLEMENTATION PLAN

Implementation Model

The implementation model of system C was based on the experience gained in the old factory. That was reason why it was not seen necessary to prepare any special implementation plan (see Table 7.2). However, there were four new elements in the *"implementation model"*:

(1) As already mentioned, the *cell groups* were set up mainly for the realization planning of the production cells of the new factory. The cell groups consisted of a representative of the workers coming into the cell, the supervisor and a methods designer. *The worker acted as chairman* in each cell group. In addition, the cell groups acted in tight connection with the full-time planners of the new factory (three planners in all). Especially the planner answering for the manufacturing system and production technology co-operated closely with the cell groups.

In the case of *system C* the activity of the cell group concerned only three users of system B. Other users came into grip with the system only in the beginning of the implementation phase.

(2) *Changes in the old factory were started* for the solutions of the new factory already in the old location. The idea was that it would be possible to create in the old factory the solutions which could be moved almost as such into the new factory. Changes in the procedures of the production cells were started for adaptation to the planned practice in the new factory. That succeeded to a certain extent in the other case of production cells but not in the case of the FMS. It was impossible to do this in the case of *system C*. A new layout, new machines and control systems and a new organization were to be experimented only in the new factory.

(3) It was planned that *the implementation of the production cells would be done stepwise* in the new factory. During the transition period the old

factory would operate all the time, while the new factory was started. However, this did not happen. The production was moved in one go into the new factory in the beginning of the implementation phase, and the old production was discontinued at the same time.

(4) It was planned that the *three full-time planners* planning the new factory would continue the planning activity even during the implementation phase, which also happened.

Work Organization

The researchers returned to the plant again in April 1991, over a year after the assessment of the planning situation in January 1990, which was discussed above (see Toikka et al. 1990). The installation of the new factory as well as of system C had just been started. As already noted, the question of manpower and work organization had not been considered at all in the technical design phase, as is traditional.

However, the first ideas of the *work organization* of system C already contained elements of "skill-based" production. The solutions concerning the FMS-organization had been formed during the realization planning. These solutions were connected to the organization concept of the whole factory.

The *organization concept* of the new factory continued and improved the practice formed in the old factory. As stated, in the old factory, the production had organized into product shops and production cells. In the new factory, the independence of the production cells was increased. At the same time, it was tried to lower the hierarchy of the organization, among others, the traditional supervision of work was to be completely abolished. Some of the supervision activities were eliminated or became a task of the workers in the production cells. Other supervision activities were centralized to the plant level, e.g. wages accounting.

In the new system C, a "skill-based" group organization was planned to be implemented. That was natural due to the adopted organization concept in the new factory and to the experience gained in system B. However, the organization concept was only a *vision*.

When the installation of system C began in spring, in 1991, the estimation of the need of *manpower* had increased from the earlier five users to six users, to which two workers were yet added for absences and for the extra work to be caused by the implementation. In addition to these eight *users two methods designers* were planned to connect tightly to system C.

The planned tasks of the users and the division of labour in the work organization of system C are presented in Table 7.4 (see Toikka &

Kuivanen 1993, 29-30; cf. Table 6.6, about the tasks of the users in system B).

Table 7.4. Users´ tasks and division of labour in system C as planned by the management in spring, 1991.

TASK	SHARE OF USERS	SHARE OF OTHERS
Operation tasks		
Fixing workpiece	all	
Finishing workpiece	all	
Monitoring automated operations	all	
Control tasks		
Quality control	all	
Maintenance	general maintenance	*Plant maintenance:* special maintenance
Disturbance control	normal disturbances	*Plant maintenance*, *vendors:* greater problems
Preparation tasks		
Tools maintenance and presetting	all	
Reparing and testing programs	all	
Planning and development tasks		
Production and materials control	work planning, production planning	*Production planner:* production planning *Special function:* materials purchase
Programming and methods design	lathe, gantry robot, sharp edge removal robot	*Methods designers:* machining centers

As is seen in Table 7.4, most of the tasks of system C were planned to belong to the users. The programming and methods design of the lathe, the gantry robot and the sharp edge removal robot were mainly defined as tasks of the users. Instead, the programming and methods design of the three machining centers still belonged to the methods designers, as in system B also. The users would handle production and work planning themselves on the basis of the production plan made by the production planner. Materials purchases would be done centrally in the plant. The users would move materials to the automated storage system.

It was planned that quality control as a whole would become a task of the users. The division of labour in maintenance and disturbance control was planned to remain the same as in system B.

As can be seen in Table 7.4, compared to Table 6.6, the role of the users was planned to increase in system C compared to system B. The role of the users would increase especially regarding *quality control, production and materials control, and programming and methods design*.

Training and Use of Professional Skills

The *recruitment* of the users was done in such a way that the best skilled men were chosen to the system. That can be seen to resemble the traditional "techno-centric" "creaming-off" model (Köhler & Schultz-Wildt 1985).

In the case of two users they had an easy entrance to the system. They were the users of system B and participated actively in the design of system C. The choosing of the other users was postponed until the reorganization of the production and personnel had been done in February 1991. This reorganization was due to economic reasons, as we will see later.

It was seen that the reorganization of the production led to the abolition of the activity of system B. Thus, the third user of system B, who had been originally planned to stay in the old system, moved to the new system. Three other users came from the production cell to which system B belonged. Later in the implementation phase, the manpower of system C was increased by two workers, as we will see.

Thus, most of the users came from the old FMS and the production cell around it. The other two users moved from the other plant of the company. All eight users had long former experience of NC-machines. Moreover, three users had more that five years of experience of FMS. So, the workers were skilled. That was surely a reason for the chosen training concept.

The main part of the *training* was training for the machines given by the vendors. In some cases this consisted of classroom instruction and training, and partly of the introduction to the machines. In addition to the training given by the vendors, the quality controller of the plant gave training concerning the measurement equipment. The training of the basics of FMS-techniques given by a training institute differed from traditional training for the machines. The aim of that training was to adopt the general activity principles of the FMS. Practical training in the training for FMS was an essential part of this course.

The training sessions provided for most or some of the users of system C are presented in Table 7.5.

The total number of person training days was 100,5, which makes on average 12,6 days per user. This is a little more than 8-10 days in case B. Instead, it is much less than 39 days in case A. Moreover, nine days of training formed the system training, which was based on the modelling of the activity and operation of system A.

Table 7.5. Training of the users in system C (see Toikka & Kuivanen 1993, 34).

TRAINING SESSION	ORGANISER	DURATION (in days)	NUMBER OF PARTICIPANTS
Basics of FMS-techniques	Training institute	3	5
Central control system and automated storage system	Vendor	4	4-5
Tools control system and cutting liquid and chip disposal system	Vendor	1	7
Programming and use of the lathe - directed practice	Vendor	5 3	3 5
Programming and use of the gantry robot	Vendor	3,5	3-4
Programming and use of the machining centers - directed practice	Vendor	5 5	3 3
Sharp edge removal robot	Vendor	1	1
Quality measurement equipment	Quality controller	3	2
Workpiece washing machine	Vendor	0,5	2

There were considerable *differences* between the participation of the different users. The greatest number of training days in the case of one user was 23 and the least 4,5 (see Toikka & Kuivanen 1993, 34-35).

The differences were caused by many reasons, of which some were planned. For example, the users of old system B did not participate in the course of the basics of FMS-techniques. Likewise, the *division of labour* in the implementation phase had an effect on the participation. Some users took part only in the training of the machine centers, others only in the training concerning the lathe. Some factors were unplanned. On the one hand, the users came to the system at different times, which was due to the needs of the old production. Latecomers were left without training occasions. On the other hand, a part of the training was given in the implementation phase. Due to productional pressures, some users could not take part in all the training.

Analysis

Three questions can be raised for further analysis:

(1) The management acted according to the *“techno-centric” model* after which planning is seen as a separate phase, terminating at the beginning of the implementation (see Section 3.1). *There is reason to ask how that affects the implementation.*

(2) However, there was a new feature with the implementation model. The *planning organization* continued within the implementation of the system, which can be seen to represent ideas in accordance with “lean production” (see Section 3.4 and especially Table 3.3). *It can be asked how this affects the implementation.*

(3) The first ideas of the *work organization* of system C already contained elements of “skill-based” production. The solutions concerning the FMS-organization had been formed during the realization planning. The management defined the *tasks of the users and the division of labour* in system C in accordance with “skill-based” production and partly with “lean” production”, because tight co-operation between the methods designers and the users was emphasized. However, the *training effort* did not support the new work organization concept. The training concept already contained the idea of the *division of labour* between the users of the machining centers and the users of the lathe. Moreover, the *training program* was focused mainly on *training for the machines* (see Toikka & Kuivanen 1993, 339). *There is reason to ask what effects this kind of practice has on the implementation and the activity of the users.*

7.6 IMPLEMENTATION ACTIVITY

When the installation of the machines of system C began in the spring of 1991, the *productional situation* had changed essentially from the grounds on which the plan of system C was based. According to some assessments, the international markets of the mining and drilling machinery produced by the company had dropped as much as by 40 % in two years (see Toikka & Kuivanen 1993, 23). The machine production of the company fell by more than one third of the normal production level in 1991 and by half in 1992.

That caused *reorganizations* in the factory. The number of personnel was decreased first at the beginning of 1991 and again a year later. The decrease was directed especially to clerical employees. The number of *personnel of the drilling product shop*, where system C was located, was in the end of 1992 52 persons, out of which five were clerical employees.

All in all, the collapse of the markets caused nearly a panic situation in the plant. According to the planner answering for the manufacturing system and production technology, there were even plans to sell away system C as a whole or at least some parts of it. Nevertheless, system C was decided to be implement as planned.

The *main factors and dimensions of the implementation activity in case C* are presented in Table 7.6.

Table 7.6. Factors and dimensions of the implementation activity in case C.

FACTORS	DIMENSIONS OF IMPLEMENTATION ACTIVITY
Duration of the implementation phase	Over 18 months; not yet finished at the time of the case study
Timing	Implementation started in June 1991 Still going on in November 1992 when the case study was finished in the plant
Resources of the implementation	Central role of the methods designers in methods design and programming However, many implementation tasks for the users (for instance, programming of the lathe and the gantry robot and the sharp edge removal robot) Integration of different matters and parts of the system into the operating whole mainly a responsibility of the users Planners participated in implementation tasks and problem-solving
Realization of work organizational goals	Despite “skill-based” goals in the realization, strong features of division of labour
Problems and development needs in the implementation phase	Training of the users insufficient A lot of disturbances and many recurrent disturbances Problems in the operation of the machines and central control Individual way of working of the users Problems in the organizational practices and co-operation patterns Slow implementation of some parts of the system and of the automatic characteristics of the system
Users´ activity	Disturbance control Mainly routine disturbance control activity or random experimentation Dozens of development measures

The factors and dimensions are discussed in the following. First, the duration and timing of the implementation, the resources for the implementation and the realization of the work organizational goals are considered. Second, the problems and development needs of system C in the implementation phase are analyzed. Finally, the development work and the users´ activity are examined.

Duration and Timing of the Implementation Phase

The implementation of system C was started in the beginning of June 1991, when the machines and equipment had been installed and partly tested. The duration of the implementation phase was not so clearly defined in the planning phase, which is normal traditional.

When assessing *the progress of the implementation*, there is reason to take into account at least the following points: (1) the introduction of the product family; (2) the use of the parts of the system; (3) the automation level of the operation; and (4) operation ratio (see Toikka & Kuivanen 1993, 23-27). These points are discussed below:

(1) *The size of the product family* was planned to be 100 parts. In the planning phase - still in April 1991, two months before the beginning of the implementation - the management planned that all parts would be in production *in the next half year*, by the end of 1991. However, this did not happen. In October 1991 it was assessed that the whole product family would be in production in March 1992. However, in February 1992 a new deadline was again fixed. It was estimated that the most central parts, about 70 % of the whole product family, would be introduced in June 1992. But in November 1992, a year after the original deadline, the parts produced in system C comprised only *two thirds* of the total number of parts. The introduction of new parts was going on continuously.

(2) The implementation of the system normally proceeds gradually so that the central machines and equipment are implemented first. It can be seen that *all parts of the system* have to be in use before the starting of "normal" operation. The implementation of some equipment of system C proceeded very slowly, as we will see later. In November 1992, a year and a half after the beginning of the implementation, all other parts of the system were in use but the *sharp edge removal robot* and the *tools management system*.

(3) It is normal that the *automation level* of the system increases gradually when the implementation progresses. In the case of system C the plant had invested in automating operations. The aim was to achieve *unmanned operation* during nights and weekends. This aim was still far from being achieved in November 1992, a year and a half after the beginning of the implementation. Unmanned operation had only been tried a little. One reason was that there was no compelling cause for unmanned use due to the productional situation. However, the main reasons were that there were still many problems in the machines and in the system, which made it difficult to operate the machines unmanned, as we will see later.

(4) The o*peration ratio* describes how effectively the system is used. The operation ratio is generally defined as the ratio of the realized operation time to the planned one. In the case of a single machine, the operation ratio is easy to calculate. In the case of an FMS, that is, however, more difficult. In the case of system C, the operation ratio was defined as the average of the operation ratios of four key machines (three machining centers and the lathe). The operation time was the time, in which the machines carried out the work program. Data for the operation time was based on the log of the machines. The operation time was compared to the maximum working time (24 hours a day, 7 days a week, i.e. 168 hours a week). Thus, the operation ratio was decreased by all activities that stopped or prevented automatic drive of the machines.

The operation ratio was calculated on a weekly basis in the follow-up period of the FMS-research during nine months (February - October 1992) (see Toikka & Kuivanen 1993, 25-26). The resulting operation ratio was during the first three months at the level of about 20 % and during the rest of the follow-up time at the level of about 30 %. The highest ratio in one week was 40 %.

The development of the operation ratio reflects the poor market situation. At the same time it showed that the system had great potential for more production. It was calculated that to produce the full production set as a target in the planning phase, an increase in the operation ratio to 60 % would be demanded.

The four points presented show that the implementation phase of system C had not yet ended after a year and a half from its starting, when the case study was finished.

Resources of the Implementation

Three factors had a great effect on the implementation process. The first was the *drop in the demand* mentioned above. Second, the *decrease in the number of clerical employees* and the *dissolution of the planning organization* affected the problems encountered in the implementation. Third, it was planned that the old production would have continued parallel to the implementation of the new system, even to the end of 1991. However, almost the entire *production was moved in one go to the new system*. Old system B was disassembled in August 1991. Moreover, these issues were linked to the organizational practices referred to above.

As stated, six users moved into system C before the beginning of the implementation. Two users entered into the system in the beginning of the implementation. Thus, there were *eight users* in the system. The users worked mainly in two shifts from the beginning. In addition to the users, there were *two methods designers* who worked only for system C.

The *division of labour* between the users and the methods designers was mainly realized in such a way that the methods designers answered to a great extent for the methods design and programming of the machining centers and partly participated in the methods design of other machines. The users also did methods design partly alone but mainly in co-operation with the methods designers. The role of the users was greatest in the methods design and programming in the lathe, the gantry robot and the sharp edge removal robot.

Ultimately, the *users* had to reconcile different methods designs, programs, tools, parts, pallets and the control systems with each other to an *operating whole*. That was a big task which took a long time. At the same time, the users learned new tasks and deepened their knowledge on the machines and gradually on the operation of the whole system. According to the users, the greatest learning task was formed by the *central control system*. That was new also for the users coming from the old FMS. In the old system, the control system was more compact and its control characteristics were used only to a limited extent due to the simplicity of the materials handling. During manned shifts, pallets were moved mainly by hand, and the control system acted only as a storage of NC-programs. Instead, in system C, the materials traffic was much more complicated and its control was carried out fully through the central control system. Especially those workers who had worked with individual machines, had to learn much.

The product shop for the drilling machine was divided into two areas of supervision of work. One *supervisor* answered also for system B. His role was a little obscure. He dealt with normal foreman tasks and participated in the production planning, especially in the case of the assembly cell of the drilling machines. He was also involved in the *production planning* of system C.

The *planners* of the planning organization also participated in the implementation of the new drilling product shop. There were three project engineers for the design of the new factory in the end of the planning phase. They also took part in the implementation tasks of system C.

The division of labour between the three planners was such that *one planner* managed general tasks regarding the vendors and *some technical design issues*. In the case of system C, he was involved only in the problem-solving for the centralized system for cutting liquid and chip disposal. *Another planner* developed new practices for the *production control* of system C in addition to his normal tasks. The *third planner* was almost totally engaged in the implementation of the *central control system* of system C. All in all, it was calculated that the planning contribution of the three planners to system C corresponded to about the work of one planner in the end of 1991.

The planner answering for the issues of the central control system made a great effort to create the basic data concerning materials, products, pallets, programs and production sequences to the control and to develop further the operation of the central control system and its connections to the machines of the system. He also participated in the implementation issues of the gantry robot for the lathe and of the sharp edge removal robot. In addition, he took part in the development of the operation of the workpiece washing machine and in the integration of the lathe into the system.

The planner worked very closely with the users. He had tried all the time to teach the control system that the users needed in their day-to-day work. He had given at least about two days of *training* to every user, to some users much more. In January, 1992 he saw that when the users had used the control system more than half a year, it would be useful to return to the basics of the system. According to him, almost all the users had still problems with the central control system in some respects.

The planner used two *tools* for his work. First, he wrote down all problems and development measures into a *notebook*. Second, he kept a *list* of the training needs of the users regarding the central control system. However, the use of these tools was entirely up to himself. The tools did not become common tools for the development work. The planner commented that there was no systematic style of doing development work in the factory.

According to him, he had been continuously busy, doing a lot of overtime. In his opinion, there had been a *deficit of resources*. At least one planner had had to concentrate more on the FMS. For example, he had not had any time for giving training to the methods designers and the supervisor.

The *planning organization was abolished* in January 1992, mainly due to economic reasons. The former leader of the whole factory project, the planner answering for the control system as well as the planner for the production control were given notice. The remaining planner was moved mainly to other tasks. All that had a negative effect on the progress of the implementation. Much knowledge of the central control system was lost together with the planner. The users also had *training needs* concerning the central control system.

After that, the implementation of the system was left solely for the *use organization*. That led to a need to increase the *manpower* of the FMS. *Two new users* came to the system during the spring of 1992. Thus, the number of the users rose from eight to ten. The management tried by that measure to speed up the implementation phase.

Realization of Work Organizational Goals

The original goal set in the planning phase was a *homogenous "group" organization*, in which all users could perform all the tasks in the system, in accordance with "skill-based" production. However, this remained to a great extent only a goal. The management did not have *any concrete plan* for realizing this goal. The goal was mainly hypothetical.

The *realization of the goal* “everybody can do every task” was thus left to be *learned through work* in the implementation phase. Because it was a question of a large system with many new machines and activities for the users, it is understandable that learning in this way could happen only gradually. In the following the realization of the work organizational goals is considered first at the beginning of the implementation phase and finally at the end of the case study:

(1) Situation at the beginning of the implementation: The management planned the *division of labour* based on two principles for guaranteeing an efficient implementation and operation. First, separate users were determined both for the machining centers and for the lathe, six users for the machining centers and two users for the lathe. Second, some users were named for learning and implementing *some special equipment*, such as the sharp edge removal robot and the measurement device. The idea was that they learn to use this equipment and later train other users.

In addition, there were two less official divisions of labour. First, the users of the machining centers each specialized only on *one machining center*. Each of the three machining centers focused on the production of certain products, due to the shortage of tools. The implementation of new products to the machining centers favoured further this division of labour. The result was that a separate crew of two users was fixed to each machining center, working in two shifts. Secondly, one division of labour was born based on the level of mastering, between advanced “masters” and “novices”. Because it was a question of a new system for all, this division of labour was relative, depending on parts of the system, use activity or even the problem in case. However, certain basic structures prevailed. On the one hand, the users who had trained the longest in the use of some machines of the system acted as trainers for this equipment. Especially two users of old system B who had also been the longest in the new system had this role. On the other hand, as noted, the methods designers and planners acted as trainers of the users in a “network-like” way. The two methods designers trained the users in programming and program testing in connection with the introduction of new products. The planner answering for the central control system also acted as a trainer for the users.

The implementation organization described above formed the basis for the learning and implementation in system C. This took place mainly by *individual learning through work*, by the *“trial and error”-method*, separately from systematic and formal training. The most characteristic feature was that learning and training related to each situation and were linked mainly to the problems occuring at that time (see Toikka & Kuivanen 1993, 39-44). Typically, the *“trial and error”-sequence* proceeded as follows:

- Learning started when a problem occured. It was followed by a series of individual attempts to solve the problem, which was the best way according to most of the users;
- If the desired result was not achieved, the user could sometimes try to "scan" directions for the machines. However, the use of written material was rare, since directions are seldom made as training material for a beginner. Because directions were not used in the relatively brief machine training given by the vendors, they were difficult to use independently in the work as a means for learning;
- If the user could not solve the problem alone by "trial and error", he had resources for outside help. He asked for help from the other users and in the case of methods issues from the methods designers and in the case of the central control system also from the planner;
- The problem was solved if the expert had experience about it. Otherwise, a new sequence of "trial and "error" began, which took place more or less collectively.

It is apparent that *learning by experience* is a slow way to learn. It is not even an efficient way leading to learning matters profoundly. Learning starts only when there is a problem. Thus the result of the learning depends on the nature of the problem. When one encounters a new problem situation, in which the tried way of acting turns out to be insufficient, the formation of a new way of acting again demands a new series of "trial and error". This slow and unefficient way of learning was probably one of the main reasons to the prolongation of the implementation. Moreover, this way of acting turned out to be difficult to change.

(2) Situation eighteen months after the beginning of the implementation: The *management* started to take measures to complete the development of the group work and the organization in the end of 1991. The users got a task to draw up a *further training program*. It concerned the cross-training of the users between the machining centers and the lathe. The training program also covered the unused parts of the system, such as training for the measurement equipment, the sharpening machine and the sharp edge removal robot.

However, the interview of the *users* done soon after that showed that the users´ relation to the enlargement of their tasks was contradictory. They had made the plan but they were reluctant to carry out it. In principle, the goal "everybody can do every task" was experienced as positive. On the other hand, the users were still unwilling to start to learn new tasks at that time. They saw that they could hardly master the present tasks so that the learning of new machines and equipment would be impossible.

The attitude of the users presented in a sense a realistic view about the implementation phase of the system. The *mastering of the system* was a real problem for the users. At the same time, it was, however, a question of the *way of working* and *work culture of the users* (see Toikka & Kuivanen 1993, 44-47). The extension of the tasks can be seen as a threat to the identity of the traditional skilled worker. Moving to other machines would mean the move from master to novice. That is not easy from the point of view of the orientation of the traditional skilled worker. On the other hand, leaving one´s own machine to a novice was a threat at least in the implementation phase when methods, programs and the way of working were just forming.

Thus, the users reacted to the problems of the implementation by aiming at delaying the relinquish of the benefits of the traditional way of working. The management saw it best to adapt to this. Instead of quick progress the management moved to the policy of small steps.

The term for the extension of the tasks was left undefined. The achievement of the goal of job extension was made more difficult when the planning organization was abolished in the beginning of 1992. Hence, the management increased the *number of users* to ten. The management also started to reform the *payment system*. The new system was implemented in the autumn of 1992. The effect of multi-skills on the wages increased considerably, up to the share of about ten percent.

These efforts of the management made the implementation more efficient. The *situation* a year and a half after the beginning of the implementation - in November 1992 - had changed so that one of the users of the lathe had begun to learn the use of the machining center. Correspondingly, one of the users of the machining centers started to program the sharp edge removal robot on a full-time basis. Also, the use of the measurement device had become a task of the users, which had been planned to happen right from the beginning of the implementation.

Table 7.7 presents the *extent of the system mastering* of the users in system C eighteen months after the beginning of the implementation, in November, 1992.

As can be seen in Table 7.7, nearly all users *mastered the main common tasks at the system level*. These tasks were: loading materials, palletizing, operating with the central control system, maintenance and disturbance control in the automated storage system and in the centralized system for cutting liquid and chip disposal, working with the presetting device, sharp edge removal, and operating the workpiece washing machine.

Instead, *some important tasks for the operation of the system* were not mastered in a proper way. These tasks were: working with the tools management system, measuring on the measurement device, parts assembly, and working with the sharpening device in tools maintenance. The transferring of the parts assembly and the sharpening of tools to the user were given up at least for the present. The parts assembly, which the users had already partly done, was transferred to become a task of the assembly cell. In the same way, the sharpening device was left unused and the maintenance department still did the sharpening of tools for system C.

Table 7.7. Extent of the system mastering of the users in system C eighteen months after the beginning of the implementation (see Toikka & Kuivanen 1993, 49).

WORKPLACE	USER									
	1	2	3	4	5	6	7	8	9	10
Materials loading places	●	●	●	●	●	●	●	●	●	●
Palletizing places	●	●	●	●	●	●	●	●	●	●
Central control system	●	●	●	●	●	●	●	●	●	●
Automated storage system	●	●	●	●	●	●	⊕	●	●	⊕
Centralized system for cutting liquid and chip disposal	●	●	●	●	●	●		●	●	●
Gantry robot		o					●	●		●
Lathe		o					●	●	o	●
Machining centers	●	●	●	●	●	●	o		●	
Sharp edge removal robot	●		●							
Pallet washing machine	●	●		●	●	⊕				
Presetting device	●	●	●	●	●	●	●	●	●	●
Tools management system	o	o	o	o	o		o	o		
Measurement device		⊕			o	●				
Sharp edge removal	●	●	●	●	●	●	●	●	●	●
Parts assembly				●	●	●				
Workpiece washing machine	●	●	●	●	●	●	●	●	●	
Tools maintenance					●					

o Got training

⊕ Worked with someone

● Worked alone

In addition, the *tools management system* was totally unused, as noted earlier. The users considered the system so troublesome to use that they performed the management of the presetting information by hand. Another obvious reason was the work culture of the users and the organization as a whole, because the same tools management system was used widely by another firm in its FMS (see Toikka & Kuivanen 1993, 24). Also, the sharp edge removal robot was left unused. The users took a negative attitude to the possibilities of the robot due mainly to their experience of the sharp edge removal robot in old system B. There were real problems with the robot due to the characteristics of the products and of the robot itself (Toikka & Kuivanen 1993, 24. Nevertheless, the programming and methods design of the sharp edge removal robot were going on in November 1992. There was also discussion about a new attempt to implement the tools management system.

The *way of working* of the users had not changed so much from the beginning of the implementation. The *machine-centered way* of working was still dominant. As can be seen in Table 7.7, users 1-6 and 9 were working in the machining centers and users 7, 8 and 10 in the lathe. In addition, the users of the machining centers worked mainly on their "own" machine. The users moved to another machine only in exceptional situations, such as in the case of an absence.

Analysis

The *FMS-organization* based on the concept in accordance with "skill-based" production. The set of tasks of the users was very broad and the goal was that all users can perform all the tasks in the system. However, the *management* had no *realistic program* to realize that goal. On the other hand, the *users* adhered mainly to the traditional *"machine-centred" orientation*, based on "action-centred" skills (see Zuboff 1988). Also, the training given to the users was directed only to the using of the machines. Thus, the system mastering of the users was based chiefly on their earlier skills and on learning through work by experience.

The *role of the users* was central in the implementation, which can be seen to be characteristic of "skill-based" production. However, there were also "network" features in the implementation. The users acted daily in close co-operation with the *two methods designers*. The users were also in contact with the supervisor but not so often. Moreover, the *planning organization* was within the implementation.

However, the "network" practice was not as efficient as it could have been. First, there was no *common program* for the implementation, in actual fact no program at all. The methods designers proceeded from one situation to another, according to the production situation at a given time. The users learned the machines and the system mainly individually through the *"trial and error"-method*, proceeding from one problem to another, which is a slow and inefficient way to learn. There were some exceptions. The planner for the central control system advanced systematically.

The analysis of the implementation processes of systems A and B shows that the *"basic" innovation* made by the management in the planning phase was only a start to a *long process* that continues in the implementation. The description of system C confirms that picture. The implementation of system C turned out to be a slow and difficult process. Moreover, the examination of system C shows that the *boundary between the* *implementation phase and the "normal" operation* is fuzzy. The change-over from the implementation to "normal" operation is difficult to define clearly. When does the implementation end and when does "normal" operation begin, is not a simple issue.

7.7 PROBLEMS AND DEVELOPMENT NEEDS IN THE IMPLEMENTATION PHASE

Disturbances

Disturbance data from the operation of system C were collected by means of four separate *log books* during the observation period lasting for 16 months from the beginning of the implementation phase (June 1991 - September 1992). There was one log book for the three machining centers, one for the lathe and the gantry type robot, one for the materials handling system and the control system, and a fourth book for disturbances related to the chip disposal and other parts of the system.

The log books contained in total *347 entries of 92 separate disturbances*. The users marked down in the log books on average one disturbance entry per day. This level remained approximately the same during the whole observation period. The culmination month was June 1992, when the number of entries rose to approximately four per day, which means one disturbance for every four hours in the two-shift operation. One reason for that peak was that the researchers introduced a new kind of a log book into the system. It is obvious that the threshold to make entries in the new book was lower than in the old one. However, the level sank again back to one disturbance per day after that entry peak (see Toikka & Kuivanen 1993, 57-58; Kuivanen 1996).

There is good reason to assume that the users did not mark down all disturbances occurred in the system during the observation period. It is probable that the real disturbance level is much higher than one per day. In the peak month the users marked down entries already almost four times as often as in the other months, although the disturbance situation in the factory was considered to be normal during that period. The users themselves also stated that they did not mark down all disturbances. They estimated that they marked down about 50-90 % of the cases which they considered disturbances. However, it is a question of where the border between a disturbance and normal operation is set.

To get a more exact picture about the disturbance frequency of the system the researchers *observed intensively* minute by minute the operation of the system during two shifts in December 1991, seven months after the beginning of the implementation. At that time, *11 disturbances* were registered. The disturbances and their duration are presented in Table 7.8.

Table. 7.8. Disturbances of system C during two shifts in December 1991 based on the intensive observation (see Toikka & Kuivanen 1993, 59).

DISTURBANCE	DURATION (min)
MC3: Automatic tool change failed	49
GR: A part came off the gantry robot and damaged the lathe	619
PWM: No heating	26
MC3: Automatic tool change failed	20
SL: Transfer of a pallet failed	23
MC2: Tools magazine was stuck	3
MC3: Tool alarm stopped the automated shelf lift	26
MC1: Tool break	22
LM: Cutting liquid off	6
LM: Tool alarm	3
LM: Tool alarm	3
Total	800

MC = machining center
GR = gantry robot
PWM = workpiece washing machine
SL = shelf lift in the automated storage system
LM = lathe

The 11 disturbances mean that disturbances occurred on average at 1,5 hour intervals during two shifts. That frequency level is about 10 times higher than one entry per day in the log books.

The disturbances had a considerable effect on the *useability of the machines*, as can be seen in Table 7.8.

The total duration of the 11 disturbances was 800 minutes or over 13 hours. Moreover, the disturbances occurred all over the system. The impact of the disturbances on the production and on the users´ activity was increased also by the fact that almost 70 % of the disturbances marked down in the log books by the users occurred at least twice (see Toikka & Kuivanen 1993, 70-71). In addition, *the recurrence of the disturbances* centered on some disturbances.

Table 7.9 presents five *disturbances of long duration*, the total share of which is more than half of all the 347 disturbance entries in the log books.

The five recurring disturbances in Table 7.9 are by their nature systemic problems. That indicates the complexity of the system. Only disturbances with direct dependencies could be eliminated at their first occurrence. According to the entries in the log books, 30 % of all the disturbances were disturbances with a direct cause. In the case of very frequently recurring disturbances, like the disturbances in Table 7.9 the reason was most often structural defects of the system or a machine (programs, mechanics, electronics).

Table 7.9. Five main disturbances in system C (see Toikka & Kuivanen 1993, 61; Kuivanen 1996).

DISTURBANCES	**FREQUENCY**	**LIFE CYCLE (months from the beginning of the implementation)**
MC: Automatic tool change failed	52	1-16
CC: Loading of the program unsuccessful	42	3-15
SL: Work pallet did not move to the machine	37	5-16
CLS: No coolant to the machines	30	1-13
CC: Loss of control interface	16	7-16
Total	177	

MC = machining center
CC = central control
SL = shelf lift in the automated storage system
CLS = cutting liquid system

As can be seen in Table 7.9, different types of disturbances had different *life cycles*. One disturbance (automatic tool change failed) recurred during the whole observation period. Another disturbance (no coolant to the machines) had also occurred right from the beginning of the observation period but disappeared before the end of the observation. The remaining three types of disturbances appeared later during the observation period.

That pattern also holds to the entire material of the log books (see Toikka & Kuivanen 1993, 62; Kuivanen 1996). The disturbance types changed clearly after the autumn of 1991. The frequency of the most common disturbances during the autumn decreased. Out of all the disturbances occurred during the first five months about 40 % disappeared totally, but other very significant disturbances came in their place, many of them recurrent. From the 26 disturbances most frequently occurring during the last eight months of the observation period, 12 had not occurred at all during the first eight months of the observation period. Thus, 14 common types of disturbances had occurred longer than during eight months. All in all, it was noted that among the 26 most common disturbances, there were ten that had given trouble already for over a year.

Problems and Development Needs

The researchers made a complete identification of the *problems and development needs* in the implementation of system C. The identification was based on the materials of the log books, the researchers´ follow-up visits and the interviews of the users, planners and management. The result was presented to the factory as a *report* in February 1992, eight months after the beginning of the implementation (Toikka et al. 1992). The problems covered the troubles causing the main disturbances in the system, problems caused by the way of working of the users and by organizational practices. Altogether *34 different problems* were distinguished. These are presented in Appendix 3. The problems are discussed in the following:

(1) Problems 1-6 Appendix 3 are of their nature troubles which caused *recurrent disturbances* in the machines or in the whole system. These kinds of disturbances are also presented in Table 7.9. Naturally, measures were taken to eliminate the causes for these disturbances, as we will see later. For example, the planner for the central control stated in January 1992 that dozens of changes had been made to the control system. In that time there were about 40 issues under development. One of the most difficult problems was created by producing from the same material preform several products, which was almost impossible for the control system to manage.

(2) Problems 7-13 in Appendix 3 are mainly deficiencies in the design of the devices and workplaces or shortages of adequate resources having a great effect on the *manual operations* which the users had to perform in the system. The result was extra work and increased exertion and stress for the users. For example, tools for the machining centers had to be built by applying the different kinds of parts available due to the shortage of tools. During the intensive observation, one user made six tools for a machining center for the workpiece to come. It took him a total of 2 hours 38 minutes. The longest time for the preparation of one tool was 46 minutes, after that the user realized that the tool had to be made anew, because it was not adequate. Most of the time went into seeking, fitting and working.

(3) Problems 14-20 in Appendix 3 concern the unused *automatic characteristics* of the system. The most central parts of the system not in use or used only partly were the sharp edge removal robot, the gantry robot serving the lathe and the tools management system. That formed an obstacle for automatic operation and unmanned use of the system. At the same time this resulted in that the users had to do the operations manually, which caused stress and ergonomic problems. In the same way, other automatic characteristics available in the system but not used made it

difficult to achieve automatic operation. The user had to control manually many operations of the machines because of this.

(4) Problems 21-27 in Appendix 3 refer *to the individual and unsystematic way of working of the users*, as already noted earlier. The users worked mainly on their own machines and learned new tasks individually at work. The lack of systematic methods caused failures and made automatic operation difficult. There were problems also in the transfer of knowledge between the different shifts, which resulted in disappearance of use data knowledge. Also the log books were not used systematically for recording incidents and disturbance data. The disorder of the tools and the lack of a tools file of tools and settings had an especially great effect on the amount of work. At the same time that was one of the main obstacles for the use of the automatic tools management system.

(5) Problems 28-30 in Appendix 3 cover *preconditions for the users´ further learning to use the system*. The users expected further working instructions and comments on the use of tools. The users also expected further training, especially on the control system, disturbance control and programming. According to the planner for the control system, the users needed further training on the control system especially in the following issues: the creation of data for new pallets; the removal of the workpieces from the system; and flexible and full use of the control display. Also, the wage system had a negative effect on the users´ work motivation, group spirit and motivation for training.

(6) The rest of the problems, problems 31-34 in Appendix 3, describe the *organizational practices* in the factory and especially their relations to system C. It seems that the unsystematic way of acting was also evident in the case of the support personnel and in particular in the patterns of co-operation. There were "holes" in the organization preventing the systematic flow of information in the use organization. For example, it came into light in the interviews of the users that they had no exact knowledge of matters such as the phase of the implementation, the division of labour in the project organization and the timetable for further training.

There was also great confusion concerning the *supervision of work*. The supervisor had many tasks and he had no time for the FMS. On the other hand, the methods designers had a great role in their field in the case of the FMS. Also the planner for the central control used the main part of his working time on the FMS and the users. Moreover, the supervision of work in the drilling product shop was reorganized in the beginning of 1992 due to the decrease in the manpower made at that time. The other methods designer of the FMS also became a supervisor for the FMS and the tempering cell.

Work planning in the system was a big problem. There was no systematic work program but impulses for production came from many sources for the users. The reason was that there was only an idea of how to organize work planning in the system but no concrete measures had been carried out to realize that goal. One planner started to make a plan for organizing the work planning practice in the system in the end of 1991, but that was left unfinished due to the dismissal of the planner.

One of the greatest problems with regard to *further development of the system* was that knowledge of the problems and development needs was scattered with different persons in the organization without common goals. This is illuminated by the result of the interview of two planners and two methods designers. They were asked to mention the central problems and development needs in system C (see Toikka & Kuivanen 1993, 71). The result is presented in Table 7.10.

Table 7.10. Opinions of the support persons about the central problems and development needs in system C.

CENTRAL PROBLEMS AND DEVELOPMENT NEEDS			
The planner for the manufacturing system	**The planner for the central control**	**Methods designer 1**	**Methods designer 2**
Production control	Further training for the users on the central control	Production control	Tools management
Report of the control system to production control	Development of the central control system	Use of the industrial robot for removing sharp edges	Use of the industrial robot for removing sharp edges
Use of the industrial robot for removing sharp edges	Production control	Methods design	Use of the gantry robot
Use of the gantry robot	Learning of the use of the control system for the user	The centralized cutting liquid system	Use of the lathe
		Flow of information between the central control and machines	Use of the central control
		Tool change in one machining center	Use of the measuring device
		Tools maintenance	
		Parts assembly	

As can be seen, there is no common mention for all four persons. This is so although the persons had worked with the system together in co-operation on a day-to-day basis during nearly a year.

Analysis

The results concerning the *disturbance level* of system C, one disturbance during two shifts according to the log books and one disturbance per every 1,5 hours according to the intensive observation, correspond to the results from systems A and B. It seems that the disturbance frequency in FM-systems is much higher than normally believed. In case C that frequency describes the situation in the implementation phase. However, the frequency seems to remain high also in normal operation. Disturbances occurred in small system B on average at 3 hour intervals of and in complicated system A at 20 minute intervals.

Moreover, the disturbances in system C had a considerable *effect* on the useability of the machines and the system. The disturbances occurred nearly everywhere in the system. The impact of the disturbances on the production and the users´ activity was increased also by the fact that almost 70 % of the disturbances occurred at least twice. Recurrence of the disturbances centered on some difficult disturbances. Moreover, two patterns prevailed. Firstly, many recurring disturbances were really persistent occurring during a long time, even during the whole observation period. Secondly, some disturbances disappeared, but at the same time new recurrent disturbance types appeared.

However, disturbances alone do not give a comprehensive picture on the system and the organization and their development needs. All in all, 34 different *problems* and *development needs* were discerned.

7.8 DEVELOPMENT WORK AND USERS´ ACTIVITY

Tasks and Disturbance Control Activity of the Users

As stated, the users had a central role in the implementation of the system. Ultimately, the users had to reconcile different methods and the different parts of the system with each other to an operating whole. That had also an effect on *the tasks of the users*. Due to the high disturbance frequency level of the system and many problems in the implementation, the users had to deal with disturbances and to participate in development work. In the following the time distribution of the users´ tasks and the disturbance control activity of the users are discussed:

(1) The *intensive observation* of the operation of the system gave a detailed picture of the use of the system in December 1991, when almost seven months had passed since the beginning of the implementation. *The average time distribution of the users´ tasks* in system C is presented in Table 7.11. For comparison, the time distribution of the users´ tasks in system B in the autumn of 1989 is also presented in the table.

There is a marked *difference* to the old system, namely in that the typical automation tasks, such as disturbance control, the monitoring and control of automatic operations, testing and repairing programs, and production and materials control, had a greater share. Correspondingly, the share of the manual tasks, such as fixing and finishing workpieces, had decreased. Programming and development activity was not registered during the intensive observation. However, the users also made programs, as noted earlier. The users participated also in the development work, as we will discuss next.

(2) As can be seen in Table 7.11, *disturbance control* took on average 18 % of the working time of the users. The *nature of the disturbance control activity of the users* could be considered through the entries in the *log books* and the *follow-up visits* made by the researchers (see Toikka & Kuivanen 1993, 62-66; Kuivanen 1996; cf. Norros 1996). It appeared that the users did not *withdraw* from the disturbance control situations. That happened only very rarely and was mainly caused by the insufficient skills of the user or the shortage of time. In such a case, the user normally made a *repair request* to other users or special persons. According to the work culture among the users, every user was encouraged to participate in disturbance control and that was also a central way for learning.

The users approached the disturbances mainly through *routine disturbance control and random experimentation* in about half of the cases. Routine disturbance control did not require the analysis of the systemic connections of the disturbances. The user´s activity was limited to the perceptible, immediate causes for the disturbances and correction of the disturbance. Examples of simple basic procedures are that the disturbance was eliminated by running the machine back and forth or resetting the control system. In the mode of random experimentation the user was acquainted with common procedures to rectify the problem, but the problem could not be solved by these means. In such cases, the user tried to develop a new way of disturbance control. However, it was not a question of systematic investigation of the causes for the disturbance but of experimentation taking place randomly.

Another large category, over one fifth of the cases, was formed by *rectifying or clearing the situation*. In these cases the cause of the disturbance could be easily deductible. Because of this, the elimination consisted of repairing the damage or of restoring the automatic run of the system. This was the case when a part that could be repaired by the user broke down mechanically, a bolt broke, or a wire sprang loose.

Table 7.11. Average time distribution of the users´ tasks in system C seven months after the beginning of the implementation (compared with the time distribution in system B in the autumn of 1989) (see Toikka & Kuivanen 1993, 50; see also Table 6.6).

TASK	TIME DISTRIBUTION OF USERS´ TASKS IN SYSTEM C (%)	TIME DISTRIBUTION OF USERS´ TASKS IN SYSTEM B (%)
Operation tasks		
Fixing workpieces	7	20
Finishing workpieces	8	30
Monitoring automated operations	14	5
Washing parts (loading)	3	-
Parts assembly	0	-
Control tasks		
Control of machines	5	-
Transfer of programs	2	-
Quality control	2	3
Tools maintenance (presetting)	16	18
Maintenance	1	10
Disturbance control	18	5
Book-keeping	-	2
Preparation tasks		
Testing and repairing programs	12	1
Planning and development tasks		
Production and materials control	12	6
Programming	0	0
Development activity (methods and equipment design)	0	0
Total	100	100

The material of the log books refers to the fact that the methods of disturbance control of the users did not change much during the whole observation period (June 1991 - September 1992) (see Toikka & Kuivanen 1993, 65-66; Kuivanen 1996). That is a logical result in line with the above results of the disturbances of the system. The disturbance rate of the system did not sink essentially. Moreover, 70 % of the disturbances recurred, even dozens of times. Many problems were also of very long duration.

Development Measures during the First Phase of the Case Study

The users took development measures and participated in the development work for eliminating the causes for the disturbances. In the *log books* there were six entries on *development measures* during *the first phase of the case study* (experimental phase) (June 1991 - February 1992) (see Appendix 1). It is certain that the users had taken further development measures but that happened as a part of "normal" activity, proceeding from one problem to another. This way of working made it unnecessary to register the development efforts.

However, 23 *development measures* taken during that phase of the study got registered, mainly through the interviews of the users and the support personnel. This number is too small, since the planner for the central control for example stated that dozens of development measures were taken in the central control. According to him, it had taken from the vendor between ten minutes and some hours per a change measure in these cases. Moreover, there were about 40 development subjects. Furthermore, according to the planner, the best ideas for development came from the users themselves.

Nevertheless, these 23 development measures probably represent the main measures in the system. The measures during the first eight months from the beginning of the implementation of system C are presented in Table 7.12.

The development measures in Table 7.12 were directed to the elimination of the causes for the central disturbances and problems in the system, which are presented in Table 7.9 and in Appendix 3. For example, there were many problems connected with the central control and chip disposal and cutting liquid system. However, many of these problems were systemic by their nature. Hence, the elimination of these problems was not an easy task.

Table 7.12. Development measures in system C during the first eight months after the beginning of the implementation.

Central control and automated storage system
Increase of the reporting characteristics
Change in the connection between the central control and the cell control system
Installation of a program transfer switch
Lowering of the speed of data transfer

Chip disposal and cutting liquid system
Installation of bigger pumps
Lowering of pressure
Installation of alarm for the disturbance in the cutting liquid
Installation of alarm for the disturbance in chip disposal
Installation of a timer to the chip disposal conveyor

Workpiece washing machine
Change in the motion velocity of valves
Change of the bottom for improving chip disposal
Change of the liquid flow (continual flow at the bottom)

Machining centers
Improvement in the grippers of the tools change system
Change in the motion of the pallet changing system
Change in the motion velocity of the tools change system
Improvement of the cooling valve

Lathe and gantry robot
Securing of the position of the pallet
Change in the logic of the gantry robot for tools check
Installation of a hoist device for the change of tools in the lathe

Sharp edge removal robot
Change in the activity of the pallet detector
Enlargement of the memory

Other workplaces
Change in the cages of the part washing machine
Installation of hoist devices and their development for the palletizing place

---

One good *example* of that is the development activity to eliminate the disturbances in the machines due to the variation of pressure in the cutting liquid system when using the workpiece washing machine. In the autumn of 1991, several measures took place (see Table 7.12). First, bigger pumps were installed in the centralized cutting liquid system for increasing pressure. Second, the motion velocity of the valves was changed for leveling the pressure. Third, the bottom of the washing machine was changed for eliminating the sticking of chips to the bottom. However, these measures did not eliminate the whole problem, although the situation improved. In the beginning of 1992 the liquid flow in the washing machine was changed so that liquid flowed continuously at the bottom. At the same time, the pressure in the cutting liquid system was lowered. After that the situation was still not satisfactory, as can be seen also in Table 7.9. The problem disappeared only 13 months after the beginning of the implementation, and required further development measures.

The role of the users was central in proposing and implementing development measures in most cases. The users were active at least in the following measures (Table 7.12): installation of a program transfer switch; installation of bigger pumps; improvement in the grippers of the tools change system; installation of a hoist device for the change of tools in the lathe; change in the cages of the part washing machine; and installation of hoist devices and their development for the palletizing place.

New Methods and Tools for the Development Work

The aim of the *first phase* of the case study (experimental phase) concerning the implementation of system C was to bring *new methods and tools* for the development work of the organization. The first phase began by the forming of a *development group* to help the organization in the development work. The group consisted of the product shop manager, the planner for the manufacturing system, the two methods designers, all eight users, the shop steward and three researchers. The group met three times. In the *first meeting* in June 1991 it was decided to introduce the log books. In the *second meeting* in October 1991, the researchers made the *analysis* of the material of the log books and demonstrated how that material could be used as a means for systematic development of the system. In the *third meeting* in February 1992 the researchers presented the summary *report* of the problems and development needs of the implementation (see Appendix 3). In the same report, measures were suggested for solving the problems.

The goal of the third meeting was to help the organization to form a common view of the development problems of the system and to form a *development program* for solving these problems of the implementation.

To start the discussion of the development program, a *group work* was done. The three groups were asked to record the five most serious problems and five problems that can be easily solved. The results are presented in Table 7.13.

The conclusion from the group work was that the members of the organization had quite a *concrete and versatile view* of the problems and development needs of the system. However, there was not only one view but *many views*. The lists of the groups differed almost totally from one another, as was already the case with the planners and methods designers (see Table 7.10). The cutting liquid system was the only common point on all lists. Work planning was also on all lists, but on the list of the support persons it was in the category of worst problems and on the users´ lists among the easiest problems.

Table 7.13. Opinions of the members of the development group about the development targets in system C.

USERS, 1. SHIFT	USERS, 2. SHIFT	SUPPORT PERSONS
Five worst problems		
1 Variation of pressure in the cutting liquid system	1 Difficulty of the use of the central control	1 Difficulties in keeping the production plan
2 Problems in the feed of cutting liquid to machines (M 50)	2 Program transfer from the central control to machines	2 Problems in the operation of equipment (central control, cutting liquid system, machining centers, gantry robot)
3 Shortage of palletizing places	3 The cutting liquid system	3 Mastering of the central control (way of using)
4 Slow implementation of the gantry robot	4 Difficulty in the fixing in the lathe and gantry robot	4 Ability to produce quality products
5 Shortage of tools	5 Updating materials data into the central control	5 Use of the industrial robot for removing sharp edges
Five problems solved the most easily		
1 Further training for the central control	1 Flow of information	1 Order to things
2 Loading workpieces into the cage of the parts washing machines	2 Hoisting devices	2 Implementation of the gantry robot
3 Use of the tool control in the system	3 Confusion in the work planning	3 Setting drawings of pallets
4 Week lists for work planning	4 Ending of the supply of guide lubrication oil	4 Instructions for maintenance (guide lubrication oil etc.)
5 Shortage of men	5 Obsolete wage system	5 Activity at one´s own initiative

In the *third meeting* of the development group the researchers made a proposal for making the development work more effective. The proposal contained the model of the *tools and organizational practices* for the development activity (Toikka et al. 1992; Toikka & Kuivanen 1993, 72-77). The model is presented in Figure 7.1.

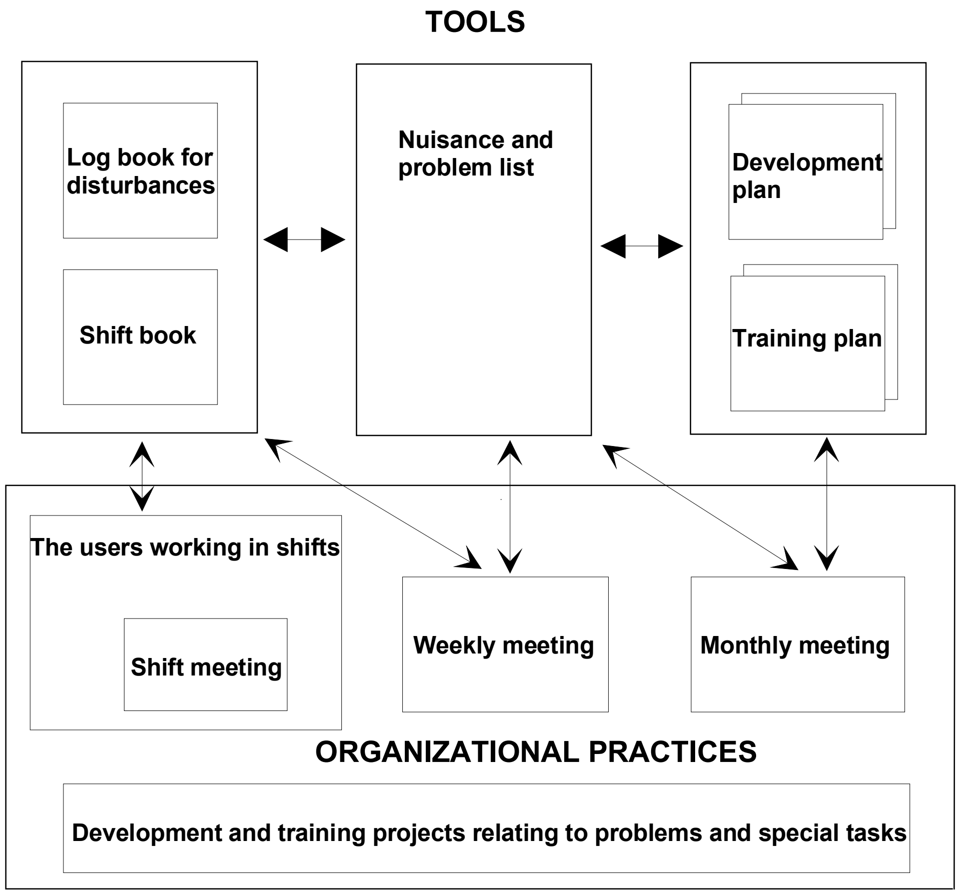


Figure 7.1. Researchers´ proposal for the tools and organizational practices for the development activity in case C.

The model presented by the researchers is not in any way revolutionary. The new methods are in principle simple and easy to use. There were many seeds for these methods already in practice in the organization. However, it became obvious that the change was greater than one could have thought. It is not only a question of filling in papers and of having meetings but of changing the *traditional way of working* based on individual orientation and learning through work.

The development group did not make any decision on the adoption of the methods of the model in its third meeting. The matter was left to be decided later in the organization. It became the task of the *second phase* of the study to *follow up* how the organization would adopt new practices and what results would be achieved. This phase lasted nine months (March - November 1992). the methods and results are discussed in the following:

Log book: As noted, the users recorded disturbance entries into the log books. The aim of the introduction of the *log books* into the system was that they would act *as a tool for the planning of the development measures* for eliminating the causes of the disturbances. However, the books were not used in this way. The books mainly served the users *as a source for advice*.

Some of the entries contained supplementary instructions for elimination of the disturbances. There were only some entries of the development measures, as shown.

Shift book: The users took *notes for the next shift*. However, the notes were written down only on separate pieces of paper and not on a regular basis. Nevertheless, shift books on the machines were introduced in the autumn of 1992. The shift book can also act *as a tool for gathering data* on the problems in the system.

Nuisance and problem list: It was decided to reform the use of the log books. *A new nuisance and problem list* was taken into use in May 1992. A separate nuisance list was drawn at the top of the log book to declare at once on opening the book the new disturbances that had to be recorded, and whether or not the organization had taken the new kind of disturbance under observation and rectified it. The users considered the format to be a good one. Especially the users of the lathe were active in using the nuisance list. It acted also *as a tool of co-operation* between the users and the methods designers. The methods designers took some problems from the list under closer study and also attended to that the problems were solved.

Development and training plans: After the second meeting of the development group the users had made a *training plan*, as shown. That plan was a basis for further training of the users. Also some kind of *development plans* relating to the elimination of problems were made later, as we will see.

Shift meeting: In the second meeting of the development group - in October 1991 - a practice that the different shifts would overlap for quarter of an hour was agreed upon. This enabled the users working in the same machines to discuss about the problems and the situation in the machines. However, this practice was abandoned in the beginning of 1992, because there was no similar practice in the rest of the factory. However, the users regarded this kind of practice as necessary.

Weekly meeting: The researchers proposed that the users could keep a meeting weekly in the workplace for discussing common matters and problems. The users considered this kind of practice to be necessary. However, the practice was not adopted.

Monthly meeting: The idea was this the meeting could act as a *development meeting* where the materials of the log books and the problems of the system would be processed systematically. The task of the meeting was also to set development projects and control their progress. The organization of the meeting required that the users, planners and representatives of the management would participate in discussing the common development efforts.

The working of the *development group*, which held three meetings, can be seen as a form of this kind of meetings. Moreover, in the first meeting of the development group it was decided to start monthly meetings led by the supervisor.

The idea was that the supervisor would organize a *meeting* in every month, where all the users of system C would participate. One meeting was accordingly held in October 1991. According to the minutes of the meeting, matters were discussed in a relatively organized form. Unfortunately, the meeting practice was not established later. The reason was the confusion prevailing in the organizational tasks between the supervisor, the methods designers and the planning organization, as illustrated above.

After the third meeting of the development group the product shop manager called a *cell meeting*, in which the users of system C, both methods designers, the product shop manager and the production manager participated. All in all, seven cell meetings were held during the second phase of the study (in March - November 1992). The representatives of the assembly took part in the second meeting, when the production control and parts assembly were considered. An expert of the vendor was present in the last cell meeting, in which the disturbances and problems of the central control were addressed. The researchers followed up the last four cell meetings.

Development and training projects relating to problems and special tasks: This organizational form was aimed at carrying out the development and training plans made earlier. These kinds of projects had existed, for example the group consisting of two users of system C and the planner for the manufacturing system for analyzing the problems of the centralized cutting liquid system. At the end of the follow-up period of the study, new groups were set, for example for the implementation of the chip disposal robot and for the organization of further training of the users.

Development Measures during the Second Phase of the Case Study

As stated, 23 development measures were registered during eight months in the first phase of the case study. It was characteristic of these development measures that the organization itself had not registered them systematically. It was mainly a task of the *researchers* to rake up these measures. The situation changed in the second phase of the study. The *organization* registered the measures and started to solve the problems discovered, as we will see next:

(1) As stated, the nuisance and problem list was taken into use especially in the lathe. However, the users of the lathe were not satisfied with the speed of the development work. Hence they drew up a *separate list* of the problems in the operation of the lathe and gantry robot in the autumn of 1992. There were 18 problems on the list. These problems were discussed together with one of the methods designers. He made a memo of the problems and measures to eliminate in October 1992. He assessed which of the problems could be managed by the users, internal maintenance personnel or the vendors. The users had already eliminated the problem concerning some magazine places in the lathe.

(2) In the first *cell meeting,* three development targets were chosen from the report discussed in the third meeting of the development group (see Appendix 3). *Development measures* were planned to solve these problems. In the following meetings the development plan was followed up and more targets were taken under consideration, altogether 16 targets in seven meetings. These development targets are presented in Table 7.14.

(3) In addition to the list of 18 targets in the lathe and 16 development targets discussed in the cell meetings, a third list was also made. That was connected to the *productivity effort* of the factory in the autumn of 1992. The users of the system defined six central *development targets:*

- use of the sharp edge removal robot;
- improvement of the quality level;
- availability of cutting edges;
- instruction for fixing the pallets;
- new grouping of the cast blanks.

There are on the three lists mentioned above a total of 40 development targets of which 38 are different. In most cases, also development steps had been taken.

(4) In addition, information on eight other development measures not recorded on the above mentioned lists surfaced in the interviews. These measures are as follows:

- improvement of the reliability of programs in the central control;
- change in the liquid flow in the workpiece washing machine;
- increase of pressure in the machining centers;
- change in the switch in the gantry robot;
- change in the cylinder in the gantry robot;
- installation of a safety zone for the gantry robot;
- installation of a transverse line for the palletizing place;
- assignment of one user as an operator for the central control.

Table 7.14. Development measures discussed in the cell meetings of system C during nine months of the second phase of the study (March - November 1992).

Cutting liquid and chip disposal system
Change in the sensing devices
Change in the chip disposal chain
Change in the flow of liquid
Change in the operation of pumps
Change in the filter

Sharp edge removal robot
Implementation of the robot

Tools
Organizing of the tools

Loading and unloading place for pallets
Reform of the hoist devices

Automated storage
Increase of platform space

Central control
Problems and disturbances
- Prevention of wrong use
- Removal of the cast defective workpieces from the system
- Updating of blank data
- Jams in the pallet places
- Black-out of control display

Production control
Organizing of the connection between the FMS and the assembly
Removal of parts assembly to the assembly

Thus, a total of 46 development measures were initiated during the nine months (March - November 1992), covered by the second phase of the study. As shown, there had been 23 development measures during the previous period of eight months (June 1991 - February 1992) in the first phase of the study. Consequently, the total number of development measures was 69, which makes about one measure per week for the entire period of the eighteen months considered.

Disturbance control took on average 18 % of the working time of the users, which was about the same amount as 21 % in system A in the normal operation phase. The users participated actively in disturbance control and corrected disturbances. However, the users approached the disturbances mainly through routine disturbance control and random experimentation. That is not suprising when the individual and unsystematic way of working of the users is taken into account. Scant training of the users and the central position of learning at work are the factors which also affected the disturbance control activity of the users.

It can be said that the disturbances which were controlled through routine methods or random experimentation, were by their nature vague and systemic and their causes were not known. Hence, the disturbances recurred. Instead, correcting or clearing the situation was connected to clear and often non-returnable disturbances. To eliminate the disturbances required that the users *investigate the causes* of the disturbance and take *development action* or make a *developmental proposal*. Development action was not possible without a clear picture of the basic causes of the disturbances and the operation of the system (see Norros 1996).

Nevertheless, the users did *development work* for eliminating the causes of the disturbances. The *production manager organized the practice of cell meetings* for directing the development work.

However, the progress of the cell meetings was *unsystematic*. The meetings lasted for about an hour. There was *no agenda* for the meeting. Matters were processed in the meeting without *proper tools*. The meetings served partly as a means for information transfer and the exchange of opinions. Problems and development measures came up *according to the situation*, depending on the opionions of the participants at a given time. Also the development measures agreed upon were *not recorded*. Minutes were drawn up only from the last three meetings.

The *last meeting* was a clear exception to the above (see Toikka & Kuivanen 1993). The question of the central control was considered. The other methods designer and the users of the FMS had drawn up a list of the five central problems and disturbances of the control system (see Table 7.14). Also a planner of the vendor took part in the meeting and in dealing with the problems. As a result of the discussion the *concrete development steps* were agreed on and the measures were recorded on a transparency during the meeting.

7.9 SUMMARY: ACTION MODEL OF THE IMPLEMENTATION PROCESS IN CASE C

The implementation of system C turned out to be a *slow and difficult process*. In the planning phase the management and planners planned that the system would be in full operation in half a year. However, there were suprisingly many *disturbances* and *problems* in the system, which made it difficult to achieve the planned targets. The implementation remained still incomplete at eighteen months after the beginning of the implementation.

Case C brings up in an interesting way the meaning of *organizational practices of the management* and the *way of working of the users* in the organization´s ability to tackle the problems occurring in the system and its organization. Many *new kinds of practices* were adopted in the planning and implementation phases. However, there were problems in carrying out effectively the planning efforts with the users involved in the planning phase and the development work in the implementation phase. Many efforts failed because of *unsystematic organizational practices and co-operation patterns*. Nevertheless, at the same time case C shows clearly the possibility to form more *systematic organizational models*, methods and tools to control disturbances and to form development programs.

The *summary of the implementation process* of system C is presented in Figure 7.2 as *the action model of the implementation process*, according to the model in Figure 2.2. In Figure 7.2, the *main features* of the implementation process are shown in the middle of the figure, under the headings of the different activity phases. The *main activities* of the management and users and their interaction are presented in the figure.

The activities of the management as well as of the users are assessed in Figure 7.2, based mainly on whether the practices were in accordance with the "techno-centric" approach (T), the "user-centered ("skill-based") way (U) or "lean production" (L).

In the following, the implementation process and the activities of the management and the users and their interaction are analyzed:

The *decision* on the building of the new factory was based only on a relatively general assessment of the possibilities of the factory. The goals were set for high capacity. The manufacturing system and technology of the new factory were not defined in the *goal setting phase*. There was also only an idea of a *large FMS* to be implemented. That approach had a great effect on the implementation of the system. First, the demand forecast did not come true. The fall in the demand led to *organizational measures* and made it difficult to implement the system quickly. Secondly, certain kinds of *unsystematic organizational practices* turned out to be of permanent nature in the organization.

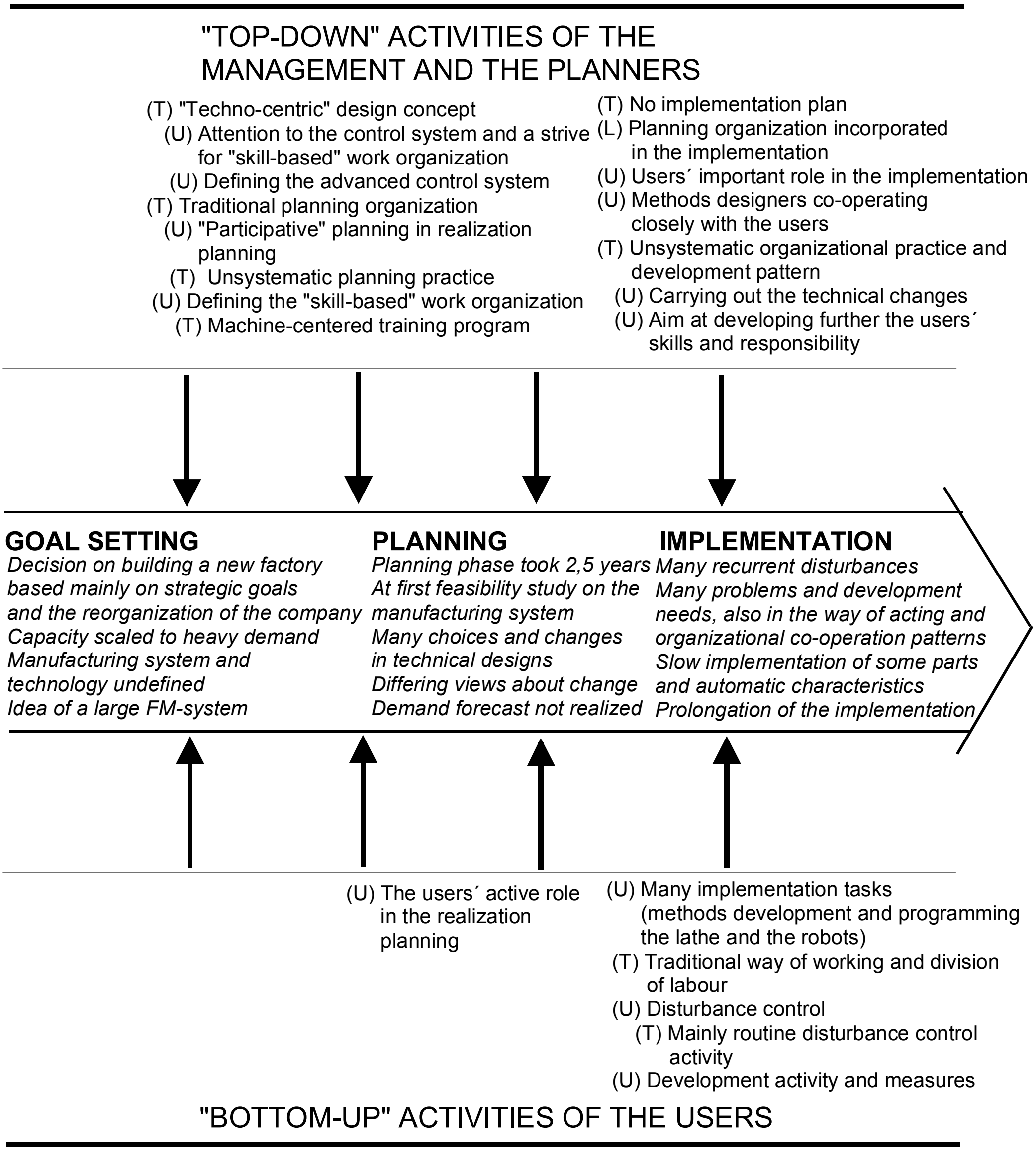


Figure 7.2. Action model of the implementation process in case C.

The *planning phase* of system C took about 2,5 years, as in the cases of systems A and B. The concept of the manufacturing system and the technology were defined only in the planning phase. When planning the system many technical *alternatives* and *changes* were considered and made in the technical designs. There were *differing views* about the change process. The management and the planners saw the change as a minor one. Instead, the workers expected that the change would be a large one. These views had also an effect on the approach and measures adopted by the management.

The *design concept* of system C was “techno-centric” with the main emphasis on the design of the processes and the machines, as seemed to be the normal practice also according to cases A and B. However, the design concept contained at the same time two features in accordance with “skill-based” production. First, the demands of the control system were taken into account in connection with the process design. In addition, the control system was designed as an advanced system supporting the use activity, which can be seen an indication of the management´s strive for a new kind of solutions. Second, the management strived for and also defined a "skill-based" work organization for creating high-skill jobs for the workers. The main reason for these efforts was the fact that the management had good experiences on system B and the cellular organization in the old factory.

During the concept design of the new factory and the technical design the *planning organization* was, however, a traditional one with no workers as well as none of the supervisors participating. Thus, the management and the planners alone answered for a "basic" design of the system. However, in the realization planning the management adopted a new approach, a *"participative" planning* practice in accordance with the "user-centered" pattern. There were also network features in accordance with "lean production", for the users of old system B participated in the planning together with different planners and methods designers, and the supervisor. Also the fact that the users were chosen from the old production reflected the management´s "skill-based" attitude. The users participated also actively in solving the design problems especially concerning the workplaces and tools in the realization planning phase. However, the planning practice was unsystematic, which meant that there was no systematic meeting practice and methods for supporting co-operative efforts. Also, the training program of the users was directed only to the machines and their technical use, as is traditionally done.

There was no distinctive *implementation plan* for the system. However, there were some new features in the *implementation phase*. First, the users had an important role and many tasks in the implementation, as is usual in the "skill-based" model. Second, there were two network characteristics in accordance with "lean production". The planning organization participated in the implementation and its problem-solving activity. Also, the methods designers co-operated closely with the users.

In the *implementation* there were a lot of *disturbances* many of which were recurrent. At the same time, there were many *problems and development needs* several of which concerned the *way of working of the users* and the *organizational patterns*. Hence, some parts and automatic characteristics of the system were implemented slowly or not at all. All in all, the implementation proceeded considerably more slowly than anticipated.

The *users* participated actively in many implementation tasks, especially in the *methods design* and *programming*. The users answered also for *disturbance control* and elimination of disturbances, which took a great share of their working hours due to the many disturbances occurring in the system. The users made *proposals for eliminating problems* in the system and in the organization. They also carried out themselves several *development measures*. The *management was willing to realize technical* *changes* for eliminating the disturbances. At the same time, the management set *a target to develop further the users′ skills and their responsibility* for the system and its development.

Despite these many efforts, there were some *traditional features* in the organizational patterns, which made it difficult to reach efficient development activity. The *users* worked traditionally *in a machine-centric way.* Also the *division of labour* among the users was traditional, with each user working mainly only on his “own” machine. The *machine centered training* got by the users could not break the way of working of the users, rather the opposite. The users controlled disturbances mainly with *routine disturbance control activity*, which is understandable, on the one hand, because there were so many recurrent disturbances in the system and, on the other hand, because of the way of working of the users. All in all, the *organizational practices* were *unsystematic*. There were no meeting practices and necessary tools for managing the development activity in the implementation.

The researchers made an analysis of the situation and problems and presented a *development model* with tools and organizational practices for the organizing of the development activity. The organization started to adopt the model at the end of the follow-up period of the study, and the development work was progressing at good speed.

PART III: COMPARATIVE ANALYSIS

This part of the study performs the comparative analysis of the case study results. The central questions deal with the essential issues of the implementation process of technical change.

The aim of the study is to understand how technical change can be successfully planned and implemented in the organization. The implementation process of new technical systems was considered through *three intensive case studies* in Part II of the study. The objective of the case studies was to *describe* how new technical systems are planned and implemented in the user organization. In addition, the objective of the study is to find out *what kinds of planning and implementation practices, methods and organizational forms* can further *organizational problem-solving and development activity* in the implementation process of new technical systems, which can be assumed to contribute to a successful implementation process.

The task of this part of the study is to analyze the planning and implementation activities of the parties in the cases and to discuss the successes and failures of the implementation process in the cases. Furthermore, an analysis of the case study results is made.

In Chapter 8, a comparative analysis of the activities of the management and users in the cases is made. The analysis is based on the planning and implementation models which were formed through the organization theoretical analysis done in Chapter 3. These models were used and developed further in connection with the description and analysis of the case studies. The models are concretized further through the comparative analysis.

In Chapter 9, the successes and failures of the implementation process in the cases are analyzed and compared. The result factors of the implementation process are evaluated in three categories: success, partial success and failure. Altogether fourteen result factors are distinguished in the different phases of the implementation process.

In Chapter 10, the results of the implementation process in the cases are analyzed. The case study results are further specified. As a summary, the system model of the implementation process is outlined.

8 ANALYSIS OF THE ACTIVITIES OF THE MANAGEMENT AND USERS IN THE CASES

Based on the description and analysis of the implementation process in the cases, the *ways of acting* of the management and users and their interaction in the cases are considered through the comparative analysis. Finally, the *analysis framework*, on which the description and analysis of the cases is based, is evaluated.

8.1 WAYS OF ACTING OF THE MANAGEMENT AND USERS IN THE CASES

It is suprising that there were so *many approaches by the management* in the different planning and implementation phases in the cases. The approaches can be interpreted to cover the applications from "techno-centric" solutions through "user-centered" models even to practices in accordance with "lean production". In addition, many concepts were adopted at the same time in the same case. In Tables 8.1, 8.2 and 8.3 *the ways of acting* of the management and users in the cases during the different phases of the implementation process are analyzed according to the three planning and implementation models. The factors of the main phases of the implementation process presented in the tables are compiled from the tables describing the progress of the implementation process in the cases and partly also from the texts detailing the progress. The ways of acting of the management and users are analyzed in more detail in the following according to the main phases of the implementation process.

Planning Process

(1) The management´s *view of the nature of change* differs from case to case. The management in *case A* regarded the change as a *big technical and organizational transition*, which can be seen to resemble the "user-centered" model. The management experienced the change-over from the functional production organization based on manual and semi-automatic machines directly to the product shop organization based on a large FMS as a radical step. The extent of the change was emphasized further by the fact that the workers selected to the system had no previous experience of NC-machines.

Table 8.1. Ways of acting of the management and users in the planning process in the cases according to the main factors of the planning and to the planning and implementation models.

FACTORS OFTHE PLANNING PROCESS	TECHNO-CENTRIC MODEL	USER-CENTERED MODEL	LEAN PRODUCTION MODEL
Management´s viewpoint of the nature of change	Emphasis on technical issues, minor organizational step: **Case B, Case C**	A big technical and organizational transition: **Case A,** *Case B, Case C*	Organizational development process
Design concept	Production process and machine system as an object of design: **Case A**, *Case B*, *Case C*"	Operating system as an object of design: *Case A,* **Case B**, **Case C**	Constantly changing and developing activity system
Planning organization and practice	Traditional practice and engineering methods; segmentalist design: **Case A**, *Case B; Case C*	"Participative" planning practice; "simultaneous design": **Case B**, **Case C**	Network co-operation based on systematic methods; simultaneous design: *Case A*
Contribution of the users	No contribution: **Case A,** *Case B*	Some contribution: **Case B**, **Case C**	Major role
Planned technical system	Trimmed system not supporting use activity: **Case A,** *Case B*	Interactive and automated system supporting use activity: **Case B**, **Case C**	Interactive and automated system supporting use activity and development work
Planned work organization	"Tayloristic" organization, individual work*:* *Case B*	Skill-based organization, group work: **Case A**, **Case B**, **Case C**	Work-group with multi-skilled workers and network organization: *Case C*
Training program	Machine-centered training: **Case B**, **Case C**	Extensive training program: **Case A**, *Case C*	System oriented program: *Case A*
Implementation plan and model	No implementation plan and resources for implementation: *Case A*, **Case B, Case C**	Plans for the achievement of skills : **Case A**	Implementation as an extension of the planning: *Case A*, *Case C*

Key to symbols: **Case** in bold refers to the main group in the case
Case in italic refers to other groups in the case

Table 8.2. Ways of acting of the management and users in the implementation phase in the cases according to the main factors of the implementation and to the planning and implementation models.

FACTORS OF THE IMPLEMENTATION PHASE	TECHNO-CENTRIC MODEL	USER-CENTERED MODEL	LEAN PRODUCTION MODEL
Support persons´ role	Hierarchical way of working: **Case B**, *Case A* (a new leader)	Co-operative and "participative" working: **Case A**, **Case C**	Network way of working aiming at organizational learning: *Case C*
The role of the users	Supervising production: **Case B**	Supervising and optimizing production: **Case A**, *Case B*, **Case C**	Supervising, optimizing and systematically developing production: *Case A, Case C*
Users´ way of learning and working	Individual and machine-oriented way of working: *Case B*, **Case C**	Co-operative way of working: **Case A**, **Case B**	Co-operative and system oriented way of working: *Case A*
Disturbance control style of the users	Routine disturbance control and random experimentation: *Case A*, **Case C, Case B** (not reliable data)	Co-operative disturbance and problems control: **Case A,** *Case C*	Development oriented disturbance control: *Case A*
Users´ participation in the development work	Some measures: **Case B**	Active participation: **Case A**, Case B**,** **Case C**	Active participation in the development activity with the organizational network: *Case C*
Actions of the management	No support measures: **Case A**	Development efforts concerning technology and organization: **Case B**, **Case C**	Development activity together with the organization: *Case C*

Key to symbols: **Case** in bold refers to the main group in the case
Case in italic refers to other groups in the case

Table 8.3. Ways of acting of the management and users in "normal" operation in cases A and B according to the main factors of operation and to the planning and implementation models.

FACTORS OF OPERATION PHASE	TECHNO-CENTRIC MODEL	USER-CENTERED MODEL	LEAN PRODUCTION MODEL
Support persons´ role	Hierarchical way of working: **Case A** (a new leader), *Case B*	Co-operative and "participative" working: **Case B**	Network way of working aiming at organizational learning
Role of the users	Supervising production: *Case B*	Supervising and optimizing production: **Case A**, **Case B**	Supervising, optimizing and systematically developing production: *Case A*
Users´ way of learning and working	Individual and machine-oriented way of working: *Case B*	Co-operative way of working: **Case A**, **Case B**	Co-operative and system oriented way of working: *Case A*
Disturbance control style of the users	Routine disturbance control and random experimentation: *Case A*, **Case B** (not reliable data)	Co-operative disturbance and problems control: **Case A**	Development oriented disturbance control: *Case A*
Users´ participation in the development work	Some measures: **Case B**	Active participation: **Case A**, *Case B*	Active participation in the development activity with the organizational network
Actions of the management	No support measures: **Case A**	Development efforts concerning technology and organization: **Case B**	Development activity together with the organization

Key to symbols: **Case** in bold refers to the main group in the case
Case in italic refers to other groups in the case

In *case B* the management underlined the *technical issues*. The gaining of experience on new technology, the step to a new technical base was emphasized. The work organization was thought to adapt directly to the practice of the product shop changed earlier into cellular production. That can be seen as a characteristic of the “techno-centric” model. However, there was an idea of “group” organization in the background in case B, which resembles the features of the “user-centered” model.

In *case C* the management emphasized the *technical issues* concerning the layout of the new factory, the principles of the manufacturing system and the strive for automating the processes. As far as the workers´ skills and the work organization were concerned, the management regarded the change as a minor one. The idea was that the experience gained in older system B based on the principles of cellular production could be transferred directly to the new environment in the new factory. The approach of the management resembled the “techno-centric” model. However, the management had an idea to strive for creating high-skilled jobs in accordance with “skill-based” principles, which refers to some extent to the “user-centered” model.

(2) The *design concept* differed between the cases. In *case A* the main object of design was the *production process and machine system*. That can be seen as a characteristic of the “techno-centric” model. However, the system outlined in the feasibility study was to some extent in accordance with the “user-centered” model. In the beginning of the technical design phase, the management and planners considered designs first from the viewpoint of the operating system. The management slid, however, back into the traditional patterns.

In *case B* the techno-centric emphasis prevailed with the main object of design being the *production process and machine system*. However, in case B the management and planners made a *functional analysis* of the system under design. That resulted in more attention to the connections between different parts of the system and to its operating whole. This can be seen as a characteristic of the “user-centered” model.

Case C resembled to a great extent case B. The main emphasis was on the techno-centric view, the object of design being the *production process and machine system*. The management and planners made, however, an *analysis of the operation principles* of the manufacturing system. Hence, the operating system was the main object of design, which is in accordance with the “user-centered” model.

(3) Four different factors characterize the *planning organization and practice*: (a) responsibility for the design and integration of the system; (b) the planning approach; (c) the planning organization and contribution of the users; and (d) the planning practice with its methods.

(a) It is a common feature that the role of the *user organization* is crucial for combining the system from different parts. In all the cases, the plant itself fully answered for the design, integration and realization of the system.

(b) The planning approach differed from case to case. In *case A* each of the different design areas was planned separately. The *control system* was designed totally separately from the process design. Also the needs of the *work organization* were not taken into account in the technical design. The issue of *production control* was left without consideration. Thus, the *segmentalist planning approach* prevailed. That can be seen to be a characteristic of the "techno-centric" model.

In *case B* the *simultaneous planning approach* was followed to some extent, since the different design areas were taken into account in the technical design, based on the *functional analysis* of the system under design. That meant more attention to the connections between the different parts of the system. The *control system* received attention in the process design. The *work organization* was considered in connection with the process design, too. In addition, some attention was paid to the *production control* in the planning phase. Thus, the management´s and planners´ approach can be mainly seen to be characteristic of the "user-centered" model.

In *case C* a *more simultaneous planning approach* prevailed than in case B. The *control system* received attention in the process design. The *work organization* was considered in connection with the process design, too. Some attention was also given to the *production control* in the planning phase. Thus, the management´s and planners´ approach in case C can be seen to resemble the "user-centered" model.

(c) Mainly the *traditional planning organization* prevailed in the cases. The planning organizations in the cases are presented in Table 8.4.

The *production management and planners* answered almost exclusively for the planning of the system in the cases. As is traditional, the *users and supervisors* had no influence at all to the decision process on a new production system during the *period of the definition of the innovation problem* and the *technical design*. In case A, an outside consultant was also used. In case C, a full-time leader was appointed for the planning effort. The role of the "bottom-up" efforts of the users was small in the planning phase. However, there were some differences between the cases.

In *case A* the planning practice was *traditional*. The workers had no influence at all on the planned technical system, which can be seen to represent the "techno-centric" model. However, the *system training* given by the researchers acted as a *new kind of planning practice*. In the training sessions, the operation and problems of the system and the issues of its planning and implementation were considered in the *network group* comprising the management, planners and users, where the users had a central role, in accordance with the "lean production" model. Moreover, the *functional modelling* and the *simulation* were used as systematic methods for simultaneously considering the different aspects of the system.

Table 8.4. Planning organizations in the cases.

PLANNING ORGANIZATION	SYSTEM A	SYSTEM B	SYSTEM C
Period of defining the innovation problem:	Production management; a consultant involved at a late phase	Production management	Management group with a full-time leader and three planners
Feasibility study	Engineering student, then the management, planners and a consultant	Management and planners	Management group and planners
Technical design	Planning group: management and planners; engineer doing the feasibility study acted as a full-time designer	Planning group: management and planners; a full- time leader	Management group and three full-time planners Special project groups for particular issues
Realization planning	Project group: management, planners and three shop stewards	Project group: planners, the supervisor and all the users	Cell group: a worker as a leader, the supervisor, a methods designer

In *case B* the planning organization was a *traditional one*, expect in the *realization planning*. A *project group* was set up, consisting of planners, the supervisor and all the users. The project group met every week during several months, discussing the design of the layout, workplaces, fixtures and workpieces. That is "participative" planning that represents the "user-centered" model.

In *case C* the planning took place following the *traditional organization*. However, in *the realization* planning the management adopted the practice of "participative" planning. The *cell group* was intoduced. A worker was the leader of the group to which the supervisor and a method designer also belonged. The cell group worked over a year. The group participated in the purchase of the machines and in the design of the layout and the workplaces.

(d) In the cases the *planning practice* was based mainly on traditional engineering practice. In *case A* the *system training* given by the researchers revealed an opportunity for a new kind of a planning method based on network-like co-operation and using systematic tools. In *case B* in the realization planning the management adopted a systematic meeting practice, where the users had some role. In *case C* the users participated actively in solving design problems in the realization planning phase. However, the planning practice of the management and planners was unsystematic going on without any meeting procedure or proper methods.

(4) There are some differences between the cases with regard to the *planned technical system*. In *case A* the management decided at first to design a highly automated system based on the propositions of the feasibility study. Also in the *original plan* of the central *control system* there were many significant features in accordance with "user-centered" systems, with an *interactiv*e and *"decentralized"* system architecture and with many *data base characteristics*. However, the management compromised with the *automation level* of the machine system. A *trimmed and simple control system* not supporting use activity was installed. A *division* between the automated and manual parts of the system was made. Moreover, there was no connection between the control system of the FMS and the *production control system* of the plant. That can be seen to be a characteristic of the "techno-centric" model.

In *case B* the management designed an *automatic system capable of unmanned operation* in the night shifts. An *efficient control system* supporting use activity was also installed. That can be seen to represent the "user-centered" model. However, there was no connection between the control system of the FMS and the *production control system* of the plant, but that did not cause any big problems because of the small size of the system. Moreover, a *division* between the automated and semi-automatic parts of the system was made. These features can be seen to refer to the "techno-centric" model. The workers later made a suggestion to combine these parts organizationally for increasing the flexibility of the whole system.

Case C resembled closely case B. The result was a *complicated automated system* that had great potential for unmanned operation. An *advanced and interactive control system* supporting use activity was installed. The system was *integrated* to other flexible cells in the new factory. The planned system represents the "user-centered" model. However, no connection to the *production control system* of the plant was constructed.

(5) There were some differences between the *work organization concepts* defined by the management in the cases. In all the cases, the main emphasis was on a skill-based organization with group work, which is a characteristic of the "user-centered" model.

In *case A* the management set as a target a *homogenous and high skill level* of the users and co-operation based on *group work*. The *traditional* *manpower strategy* based on the strict division of work was represented only by the solution that the users of the manual grinding station, connected tightly to the function of the system, were left outside the automatic system and also without the training concerning the use of the automatic system. In addition to the workers, a *leader* was planned among the personnel of the system. The tasks of the leader were planned to include some production control tasks and development efforts and to help the users in disturbance control.

In *case B* the management had an idea of a "skill-based" work organization in accordance with the "user-centered" model. However, the management did not see any reason to develop the product shop organization where system B was to be implemented. Also the *supervisor* was planned to have a great role in the FMS. These features refer to a traditional "Tayloristic" organization that is described by the "techno-centric" model.

In *case C* the management planned to implement a "skill-based" work organization. The tasks of the users were planned to diversify compared with the tasks in system B. This represents the "user-centered" model. Besides, two *methods designers* and some special *support persons* were planned to join the system and to operate closely with the users. The concept of *multi-skilled users and network organization* can be seen to be characteristic of the "lean production" model.

(6) The *training programs* set up by the management differed from case to case. In *case A extensive and many-sided off-the-job training* was given to the users mainly before the implementation of the system began. The total duration of course days per user numbered 27-37, depending on the user. The training program is described by the "user-centered" model. In addition, the system training given by the researchers lasted 9 course days. The system training was system oriented training, which can be seen to be a feature of the "lean production" model.

In *case B* the users got 8-10 days off-the-job technical training, depending on the user. However, the training program focused totally on machine specific matters and was thus *machine-centered training*, which is described by the "techno-centric" model.

In *case C* the training program focused mainly on the *training for the machines* in accordance with the "techno-centric" model. The training concept already contained the idea of *division of labour*, because there were considerable differences in the participation of different users in the training, from 4,5 days to 23 days. However, three days of training of the basics of FMS given by a training institute can be seen to represent the principles of the "user-centered" model.

(7) In the cases the management acted mainly according to the *"techno-centric" model* after which planning is seen as a separate phase, terminating

at the beginning of the implementation. There was no distinctive *implementation plan* for the system in the cases. The management´s and planners´ viewpoint in the cases can be said to have been based on the assumption that the plans are realized straightforwardly into use. That viewpoint represents the "techno-centric" model. However, the cases differed with regard to the question of the implementation model.

There were some new features in the management´s implementation model in *case A*. It was planned that the *role of the users* would occupy a central position in the implementation. The management made a *job rotation program for the users for skill improvement*. The extensive training program also served the learning needs of the users. These features can be interpreted to belong to the "user-centered" model. Furthermore, the management took explicitly two other *actions* for guaranteeing the learning process of the users. First, the system was planned *to be implemented stepwise*, one cell after another. Second, the management promoted the *design engineer* of the system to the leader of the system. These two features can be seen to represent the principles of the "lean production" model.

In *case B* the management did not take *any actions* for quaranteeing the implementation of the system plans. Only some off-the-job training for the users was arranged, mainly for the use of machines.

In *case C* the management did not take *any major actions* for skill improvement. The exception was that the *planning organization* continued working also during the implementation. The many issues of the new factory can be assumed to be the main reason for that, not only the need for getting the FMS into function. In any way, this kind of practice represents the viewpoint of implementation as an extension of the planning, which can be interpreted as a feature of the "lean production" model.

Implementation Phase

The ways of acting of the management and users in the implementation phase in the cases are presented in Table 8.2. These activities are analyzed in the following.

(8) The *support persons´ role* differed in the cases. In *case* A the designer became the *leader* of the system. However, his time was spent solving day-to-day problems. He had no time for development work. Nevertheless, he *co-operated* closely with the users helping them to learn the system. This practice is partly a characteristic of the "user-centered" model and partly a principle of the "lean production" model. The situation changed when a new leader was selected. He adopted partly the role of a traditional supervisor. That *hierachical way of working* represents the "techno-centric" pattern.

In *case B* the *supervisor* had a central role. He also acted as a traditional foreman, which hindered the development of the users′ way of working. That can be seen as a practice according to the “techno-centric” model.

In *case C two methods designers*, the *supervisor* and *three planners* participated in the implementation tasks and problem solving. That helped to solve some of the most difficult problems in the system and to speed up the users′ learning. However, there was *no common program* for the implementation tasks, which made it difficult to progress in a systematic way in the development work. The practices represent mainly the “user-centered” model. There are also some “network” features resembling the “lean production” model.

(9) The *users had an important role* in the implementation phase in the cases. In *case A* the erection and implementation of the system was left mainly as a *the responsibility of the users*. The users took part in the installation and implementation of the machines coming to the system right from the beginning. The users made all the *programs* for the machines. The users also took numerous *development measures* during the implementation phase. This practice can be seen to represent the “user-centered” model but partly also the “lean production” model.

In *case B* the users had some role in the implementation, although the supervisor had the main role. The users made *programs* for the guided vehicle and robot. The users also participated in the *development work*. The users′ task was to some extent only to supervise the production, which resembles the practice of the “techno-centric” model. There were features of the “user-centered” model, too.

In *case C* the *role of the users* was central in the implementation. The users participated actively in many implementation tasks, especially in methods design and programming. That can be seen to be characteristic of the “user-centered” model. However, there were also “network” features in the implementation. The users acted daily in close co-operation with the *two methods designers*. The users were also in contact with the supervisor, but not so often. In addition, the *planning organization* was incorporated within the implementation. This is in line with the practice of the “lean production” model.

(10) The users′ w*ay of learning and working* differed in the cases. In *case A* the users learnt new tasks in a *co-operative way*, which refers to the “user-centered” model. They dealt with all the disturbances and took development measures. The users also adopted some elements of the *systemic way of working* in accordance with the “lean production” model.

In *cases B and C* the users had mainly a *“machine-oriented” way of working* in accordance with the “techno-centric” model. However, in *case B* the users themselves organized *job rotation* for alleviating the stress from the great amount of manual work. The users did also disturbance control and some development work. In *case C* the users had mainly an *individual way of learning and working.*

(11) It is a striking feature that the users in all three systems *cleared almost all disturbances* and participated in and did *development work* in the implementation phase. There was a great number of disturbances in the systems. *Disturbance control* took about 20 % of the working time of the users in large systems A and C.

In *case A* the users dealt with disturbances and problems mainly in a *co-operative way*, which can be seen to be in line with the “user-centered” model. In case A, 29 development measures were registered during the 15 month follow-up period. 41 % of the development measures by the users were directed for further development of the system. One third of the measures were taken for eliminating the causes of *design failures*. That refers to *development oriented disturbance control*, which can be seen to have characterisics of the “lean production” model. However, the users dealt with many disturbances in a *routine way*, which represents the “techno-centric” concept.

In *cases B and C* the users controlled disturbances mainly in a *routine way* and by *random experimentation*, which is characteristic of the “techno-centric” model. In case C there was also some *co-operative problem control*, which refers to the “user-centered” model. In addition, the users participated in the development work. In case B the users participated in the development of tools and pallets. In case C, 69 different development measures were registered during the 17 month follow-up period. That makes about one measure per week for the whole period. The users *participated actively* in the development efforts, which is in accordance with the “user-centered” model. The users also participated in *development activity* together with the methods designers, planners and production management, according to the principles of “network” patterns. That refers to the practices of the “lean production” concept.

(12) The *progress* in the cases started to take different directions during the implementation phase due mainly to the *actions of the management*. In *case A* the management did not give *any support* for the users, which is a feature of the “techno-centric” concept. This was beginning to have an effect on the users´ way of working, which came into light particularly in the operation phase. In *case B* the management made a *plan* to acquire additional machines for making the system function better. Also the wage system was changed, which can be seen to represent the principles of the “user-centered” model. The result was an increase in the skill level of the users. In *case C* the management made a *further training program* and increased *manpower*, which increased the skill level of the users and promoted the users´ way of working. The management´s development activity took place together with the users and other partners, which can be seen to represent

partly the practices of the “user-centered” model and partly of “lean production”.

Operation Phase

The ways of acting of the management and users during the “normal” operation phase in cases A and B are presented in Table 8.3. The activities are discussed in the following.

(13) The *role of the support persons* diverged in the cases. In *case* A the new leader adopted the role of a traditional supervisor, which made co-operation difficult. In *case B* the progress conributed more directly to enhancing the users′ skills and their role in the operation and its development. The supervisor was more willing to co-operate with the users.

(14) In *case B* the *role of the users* was enhanced during the operation phase. In *case A* the users′ role remained about the same as in the implementation phase.

(15) In *cases A and B* the users′ way of working did not change significantly from the practice in the implementation phase.

(16) In *cases A and B disturbance conrol* remained an essential task of the users. *Development activity* also played a central role in the system operation, especially in disturbance reduction and continuous optimization and development of the system. In case A, 21 % of the working time of the users was spent in disturbance control, compared to 5 % in small system B. Due to a high disturbance level, the users controlled disturbances partly in a routine way in system A. In case A the users performed 16 development measures during eighteen months. In addition, the system leader made during the same time 6 development measures. One third of the development measures of the users were direct responses *to design failure disturbances*. The rest of the measures were directed to prevent disturbances in advance or to *optimize* production. In case B the users mentioned 11 development measures.

(17) The progress in cases A and B was contradictory. In *case A* the *management* re-started job rotation. Nevertheless, skilled “group” working was achieved only after a year from the beginning of normal operation. However, the management withdrew from further development measures, which decreased the motivation of the users. In *case B,* the progress was more in line with enhancing the users′ skills and their role in the operation and its development. The management emphasized the role of the users more as experience from the system was gained. The management acquired

new equipment to the system for improving its function. Also the supervisor increased co-operation with the users. That raised the motivation of the users to participate more intensively in matters concerning the system.

8.2 EVALUATION OF THE ANALYSIS FRAMEWORK

The three "ideal" planning and implementation models were outlined and analyzed in Chapter 3, based mainly on the analysis of the literature on organization theory. The models are: the *"techno-centric",* the *"user-centered"* and the *"lean production" models*.

The description and analysis of the implementation process in the cases showed that these models acted as a practical method to distinguish different aspects and approaches in the activities of the management and users in the different phases of the implementation process. Although the "ideal models" in Table 3.4 concerned almost exclusively the goal setting, design and planning practices and implementation models, they could be used also elsewhere the case studies. The factors of the change process and planning activity could to be used almost as such in the cases. The factors for the activities in the implementation and "normal" operation phases were partly developed further and concretized through the empirical material of the case studies.

In the comparative analysis of the ways of acting of the management and users in this chapter, the three models have been concretized further with the case material. The contents of the dimensions of the models, according to each factor of the implementation process, are depicted with the concrete formulations based on the case study results.

As can be seen in Tables 8.1-8.3, the ways of acting in the cases mainly followed the "techno-centric" model or the "user-centered" model. However, some features of the cases can be seen to reflect the practices of the "lean production" model. Through this, the dimensions of the "lean production" model could be defined at a more concrete level.

The models in Tables 8.1-8.3 can be seen to replace and extend the models in Table 3.4. This claim is based on the results of the empirical case studies.

9 ANALYSIS OF THE RESULTS OF THE IMPLEMENTATION PROCESS IN THE CASES

The descriptions of the three cases showed that the implementation process of new technical systems turned out not to be a straightforward but complex and multi-phase process. In this chapter the *indicators* of the change process in the cases are first considered. Then, the *"successes" and "failures"* of the implementation process in the cases are evaluated through comparative analysis.

9.1 INDICATORS OF THE CHANGE PROCESS IN THE CASES

The main factors and indicators of the change processes in the cases are presented in Table 9.1, based on the descriptions of the case studies.

Table 9.1. Factors and indicators of the change process in the cases.

FACTORS OF THE CHANGE PROCESS	**CASE A Large system**	**CASE B Small system**	**CASE C Large system**
Reason for change	Problems of the *production system*	Demands of the *markets*	*Strategic goals*
Level of change	Great, radical change	Relatively small change	Major change
• Size of product family	Planned to be 50, lot size 50-250	Planned to be 20, lot size 1-10	Planned to be 100, lot size 1-10
Period for defining the innovation problem	Over 3 years	About a year	About a year
Duration of the planning phase	Over 2,5 years	About 2 years	Over 2,5 years
Duration of the implementation phase	1985-88	1985-86	June 1991-
• Planned	10 months	About 3 months	About 0,5 year
• Realization	Over 2,5 years	About 0,5 - 1 year	Over 1,5 years; not finished during the study
Beginning of "normal" operation	Late spring 1988	Spring 1986	Not yet started at the end of 1992

There are three change factors which *differed* clearly according to case. The first is the *reason for the change*. Problems of the production system were in the forefront in *case A*. The main goals were productivity and capacity. In *case B* demands coming from the markets were a central motive to renovate the production. The main goals concerned flexibility and capacity. Strategic goals led to the building of a new factory and to the implementation of the FMS in *case C*. The main goals were capacity and productivity.

Second, the "objective" *level of change* in the cases differed from case to case. In cases A and C, where a large FMS was implemented it was a question of *a relatively great, radical change*. The change in case B was a less dramatic one because of the small size of system.

Third, the systems were implemented at different *points in time*. The implementation process of systems A and B took place in the middle of the 1980s, when there were only a few FM-systems in Finland (Mieskonen 1989). Normal use began, however, only in 1988 in case A. System C was correspondingly a much later installation, representing technologically a system of a different generation than systems A and B. Moreover, system C replaced system B. Thus, the plant had already earlier experience on FMS-technology.

In other respects, a *similar pattern* in the implementation process of the cases can be discerned. In the cases the aim was to insert flexibility in the system. The planned *size of the product family* varied from 20 to 100, depending on the case.

9.2 "SUCCESSES" AND "FAILURES" OF THE IMPLEMENTATION PROCESS IN THE CASES

"Successes" and "failures" of the implementation process in the cases are presented according to the "result" factors in Table 9.2. The result factors for the table have been gathered from the analysis categories and the questions presented after the main phases in the descriptions of the cases. The duration factors of the different phases of the implementation process in the cases are presented in Table 9.1. In addition, the treatment of the three models in Chapter 3 has been a background element for considering the results factors. Especially the models in Chapter 3 have partly influenced the assessment of whether the case was a success, a partial success or a failure. Particular focus here is on the practices of "lean production".

The "successes" and "failures" are discussed in the following according to the main phases of the implementation process.

Table 9.2. "Successes" and "failures" of the implementation process in the cases according to result factors.

RESULT FACTORS	CASE A	CASE B	CASE C
Planning process:			
1) Easiness in defining the innovation problem	0	x	+
2) Realism of the management´s viewpoint of the nature of change	+	x	0
3) Success with regard to the operation and automation level of the planned technical system	0	x	+
4) Success with regard to the level and concreteness of the work organization concept	+	x	x
5) Success in the training program	+	x	0
6) Level of the implementation plan and model	+	0	x
7) Duration of the planning phase	0	0	0
8) Success in the integration of the system during the planning phase	x	x	x
Implementation phase:			
9) Achievement of the organizational goals set as a target in the planning process	x	x	0
10) Functionality and operation of the system during the implementation phase	x	x	0
11) Achievement of the implementation time set as a target in the planning process	0	x	0
Operation phase:			
12) Achievement of the organizational goals set as a target in the planning process	+	+	n.a.
13) Functionality and operation of the system during the operation phase	x	+	n.a.
14) Achievement of the productional goals set as a target in the planning process	+	+	n.a.

Key to symbols:

+ success	x partial success
0 failure	n.a not applicable

Planning Process

(1) The *definition of the innovation problem* was not an easy task for the management. It was a long process to reach the decision on the implementation of the FMS, one to three years depending on the case. In addition, there were *differing views* about the development needs of the different parts of the company and of the levels of management in *cases A and B*. Especially in case A, the production management had difficulties in making an investment proposal. In *case C* the decision on the new factory and its manufacturing system was based on a *vision* rather than on the carefully analyzed conceptual design, which caused problems in the implementation phase. Also in case C different alternatives were considered before finally deciding on the system.

(2) The management in *case A* regarded the change as a *big technical and organizational transition*. This can be considered a relatively *realistic viewpoint*. The transition was radical both for the workers and for the work organization and as to the technical base. In *case B* the management underlined the *technical issues*, although the strive to create demanding and interesting jobs was also emphasized. The viewpoint was to some extent a realistic one. It can be assessed that it would have been realistic to emphasize organizational issues more, which was manifested as the users´ measure to organize job rotation in the implementation phase. In *case C* the management emphasized *technical issues* but regarded the matters concerning the workers´ skills and the work organization as having minor importance. That viewpoint turned out to be a totally unrealistic approach, which became obvious as many organizational and skill related problems in the implementation phase.

(3) There are some differences between the cases with regard to the *success with the operation and automation level* of the planned technical system. In *case A* the system can be seen as a "failure", because there were many deficencies in its operation level due to the choices made in the technical design by the management and planners. The system was not so "useable", which made the system more difficult to use. In *case B* the system was partially a success, because a relatively efficient system capable of unmanned operation was planned. *Case C* went further than case B. The result was a *complicated automated system* that had great potential for unmanned operation. The planned system can be seen as a success from this point of view.

(4) In *case A* the management succeeded with regard to the *level and concreteness of the work organization concept* relatively well. The concept was based on a well defined model. In *cases B and C* the management

succeeded in this only partially. The management had only a preliminary idea of a highly skilled crew. This can be seen as partial success.

(5) The *training of the users* differed in the cases. In *case A* the management set up a large and extensive training program which was explicated in a specific plan. The training was mainly given before the beginning of the implementation, which can be seen as a right move. In *cases B and C* the training program contained only some off-the-job training focused mainly on machine-specific issues and instruction on work routines. In case B the training was a partial success, but in case C the training can be seen as a failure with regard to the complicated demands set by the system.

(6) The issue of the *implementation plan* was considered only in the realization planning phase in the cases. The cases differed with regard to the level of the implementation model. In *case A* the management explicitly performed *several actions* for guaranteeing the implementation of the plans. Case A can be seen as a success from this point of view. In *case B* the management did not perform *any actions* for guaranteeing the implementation of the system plans. *Case C* can be seen as a partial success, because the planning organization continued working during the implementation, although there were no concrete plans on how to proceed in the implemention phase.

(7) The *duration of the planning phase* was in the cases relatively long, from two to almost three years. This time can be compared to the duration of the planning times in the USA and Japan (Jaikumar 1986; see Section 3.4). It took 2,5-3 years to plan and start up the system in the USA but only half of this in Japan. Besides, the systems studied by Jaikumar averaged 6-7 machines, which is a comparable size especially to cases A and C. Thus, the case systems resembled the systems in the USA with regard to the planning time.

(8) In all the cases the *user organization* had the *responsibility for the design and integration of the system*. However, the design of the system in the cases was not an easy task for the management and planners. The aim was to combine different kinds of machines and techniques into an operating system. In addition, in case C the task was to plan the new factory and its production systems. In all the cases the management and planners can be seen to have succeeded only partially in the planning task, because many changes had to be made to the systems in the implementation and even in the operation phase.

Implementation Phase

(9) In the cases the *work organization and the tasks of the users* were defined mainly as a "group" organization and skilled work, in accordance with "skill-based" principles. However, there were great difficulties in the *realization of the work organizational goals* in the cases. The goals set by the management were not achieved. In *cases A and B* one can see partial success with regard to the progress concerning the goals. In case A, the management had originally made the plan for *job rotation* aimed at skilled "group" working. Job rotation was suspended twice, due to productional pressures. The result was that the mastering of work was differentiated. In case B the users´ skills widened at first only to some new tasks. However, the users organized job rotation with each other. Ine *case C* there were strong features of division of labour in the realization despite the "skill-based" goals set by the management.

(10) The *functionality and operation of the technical system* during the implementation phase was only mediocre in the cases. There were a lot of problems and disturbances. A suprisingly *high disturbance level* prevailed in the implementation phase in the cases. In *case C*, where the disturbance frequency was observed, disturbances occurred on average at 0,7 hour intervals. In *case A* 110 new disturbances were registered during the 15 month follow-up period. In *case B* the disturbances occurring in the machining center alone took 10 % of the operation time.

It can be seen that there were *six features* characterizing the disturbances and their effect on production, work, material and work safety:

- First, it is a surprise that the cause for a great number of disturbances was *design failure*. In case A the share was over one third of all the new disturbances registered during the 15 month period.
- Second, *user error* was the cause for disturbances in 20 % in case A.
- Third, a great share of the disturbances were *recurrent* by their nature. In case C during the 16 month follow-up period almost 70 % of the disturbances registered occurred at least twice. Some disturbances occurred 16-52 times according to the regisration.
- Fourth, it is a suprise that some disturbances were so *persistent*. Some central disturbances in case C occurred during a long time, even during the whole follow-up period.
- Fifth, although some of the recurrent problems disappeared, *new recurrent disturbance types* appeared continuously in case C.
- Sixth, the disturbances had a *great effect* on production, work, material and work safety. In case A 80 % of the new disturbances registered in the 15 month period had an effect on the *production* one way or another. In 55 %, disturbances slowed down the production directly, stopped a

machine or stopped the function of a cell. Out of these disturbances 25 % had no direct impact on the production level but hindered the *users´ work*. Disturbances had also an effect on *materials,* since 27 % of the disturbances caused material damages. In addition, the disturbances had a negative effect on *work safety*. Altogether, 49 % of all the disturbances registered were assessed to lower the personal safety of the users. Also in system C, disturbances had a great effect on the production and on the users´ activity. For example, the total duration of the 11 disturbances registered during two shifts was over 13 hours. In case B the disturbances occurring in the machining center alone took 10 % of the operation time.

(11) The *implementation phase* in the cases, especially in *cases A and B*, took a long time, from a year to three years, which is surprising. Moreover, the system was not got to full operation at once. To assess the implementation time one can compare that to the implementation time planned in the cases (see Table 9.1). The realization was about three or over three times as long as planned in the planning phase. Although in *case C* eighteen months had elapsed from the beginning of the implementation, the system was still not even near to its full operation level.

Operation Phase

(12) The cases differed with regard to the *achievement of the organizational goals*. In *case A* the management re-started job rotation, when the skilled group working was achieved about a year after the beginning of the "normal" operation phase. Also in *case B* the progress was aimed more directly at enhancing the users´ skills and their role in the operation and its development. In *case C,* the organizational goals were not achieved during the considered period, although some development took place in the users´ mastering of the system at the end of the period.

(13) The main performance factors and indicators of the case systems in the "normal" operation phase are outlined in Table 9.3. The presentation is based on the descriptions of the case study results.

It becomes clear when looking at Table 9.3 that the systems had *big problems* with their *functionality and operation*. System A had been in "normal" operation for a year and system B over four years at the time of consideration. Instead, system C was still not wholly implemented at eighteen months from the beginning of the implementation.

Table 9.3. Performance factors and indicators of the case systems in the "normal" operation phase (system C in the implementation phase).

PERFORMANCE FACTORS	CASE A Large system	CASE B Small system	CASE C Large system
Time of consideration:	A year after the beginning of the "normal" operation	Over four years after the beginning of "normal" operation	About eighteen months after the beginning of the implementation
Features of the users´ tasks:	Two major manual tasks took 30 %	Two major manual tasks took 50 %	Major manual tasks took 35 %
Disturbances:			
• Disturbance frequency	3 disturbances/hour; about 40 % due to design failure	1 disturbance/three hours	0,7 disturbances/ hour; many persistent disturbances
• Effect on the users´ working time	21 % to disturbance control	5 % to disturbance control	18 % to disturbance control
• Productional effects	1) 94 % had a direct effect on production or caused difficulties to work 2) 11 % caused material damage	During the previous seven months 300 hours of system time were lost due to material changes, which is about 10 % of the operation time in this period	Total duration of breakdowns of different machines caused by 11 disturbances observed during two shifts of the system was over 13 hours
• Work safety effects	About 50 % decreased work safety	Ergonomic problems in major manual tasks	Increased stress due to manual operations
Production state:			
• Product family	60 variants, lot size as planned	70 variants, lot size 1-60	About 60 % of the planned product family
• Operation time	Three manned shifts, unmanned operation was not possible	Two manned shifts, third shift unmanned; operation ratio about 60- 65 %	Two shifts, unmanned operation was not achieved; operation ratio about 30 %
• Amount of production	Planned target achieved	More than planned	About half of that planned
Changes to come:	1) 10 new product variants 2) Increase in the amount of production by over 30 %/year	1) 10-15 new products/year 2) Great changes in the products 3) Increase in the production by 10 % the following year	

The first feature is the great amount of *manual work* in the systems. Two or more major manual tasks took 30 % to 50 % of the working time of the users. In addition, *disturbance control* took about 20 % in large systems A and C, due to the high disturbance frequency, whereas this was 5 % in small system B. Hence, a few major manual tasks and disturbance control took altogether over 50 % of the working time of the users in all the systems.

There was a surprisingly great number of *disturbances* in *cases A and B* in the "normal" operation phase. In case A, 36 new disturbance types were registered during the period of three shifts. Altogether 69 disturbances were registered. That means a very *high disturbance level*, on average 3 disturbances per hour. In case B, 7 disturbances were registered during two manned shifts, which makes 0,5 disturbances per hour.

Disturbances had a great *effect* on the production, work, material and work safety. It is obvious that the disturbance situation had not changed significantly from the implementation phase. It can be seen that there were *five features* characterizing the disturbances:

- First, it is really suprising that the cause for a great number of disturbances was *design failure*. In case A the share, 42 %, was greater than in the implementation phase. Also in case B the cause of one disturbance out of 7 was design failure.
- Second, *user errors* remained at the same level as in the implementation phase. In case A the share of user errors was 19 %. In case B the cause of two disturbances out of 7 was user error.
- Third, the share of *undefined disturbances* had increased from the implementation phase (8 %) to the "normal" operation phase (14 %). In case B the cause of one disturbance out of 7 remained unclear.
- Fourth, a major number of disturbances were *recurrent* by their nature. In case A, 12 disturbances of the 36 registered disturbance types recurred. The largest frequency in the case of a disturbance was 12. Also in case B many disturbances of the 7 registered ones recurred several times.
- Fifth, disturbances had a *great effect* on the production, work, material and work safety. The picture did not change so much from the implementation phase. In case A the number of the disturbances having a direct *effect on the number of products produced* increased from the implementation phase (55 %) to 88 % in "normal" operation. At the same time, an ever-increasing number of the disturbances (68 %, in the implementation only 16 %) stopped the whole function of a cell. Thus, the effects of the disturbances were more serious with regard to the production than in the implementation phase. Disturbances had also an effect on *materials,* for 11 % of the disturbances caused material damages. Moreover, the disturbances had a negative effect on *work safety*. Altorgether, 51 % of all the disturbances registered were assessed to lower the personal safety of the users. In case B the disturbances

occurring during many months in the machining center alone took 10 % of the operation time.

(14) Nevertheless, *systems A and B* had achieved the production level set as a target in the planning phase. Also the number of product variants had increased from that planned. Instead, in *system C*, the production was only about half of that planned and the realized product family about 60 % of the planned even eighteen months after the beginning of the implementation. It must be remembered, however, that there were many great technical, organizational and learning problems in system C.

In systems A and B *new changes* were also on the way. In *case A* there was a need to increase the amount of production by over 30 % a year and, at the same time, a need to enlarge the product family by 10 new cogwheel types. The product family had already increased from the 50 variants planned to 60 variants a year after the beginning of the "normal" operation phase. In "mature" *system B* materials had partly changed and become more difficult from the point of view of the production. There were also new materials. There were great problems with the materials, even to the extent that during the previous seven months about 10 % of the operation time of the machining center was lost. The introduction of new products increased the size of the product family continuously. Also the amount of production had to be increased in the year to come. The increase of the product family caused problems in the production and work planning.

10 EX PLANATION OF THE RELATIONS BETWEEN THE ACTIVITIES AND THE RESULTS OF THE IMPLEMENTATION PROCESS IN THE CASES

The basic question in the analysis of the case study results is to *explain* how different *ways of acting* of the management and users *influenced* the *result*s of the implementation process in the cases. The analysis of the case study results is made first. Then, the results are specified further. The analysis and specification of the case study results together form the *system model* of the implementation process. Finally, the system model of the implementation process is summarized.

10.1 ANALYSIS OF THE CASE STUDY RESULTS

In the case studies, the implementation process of the FM-systems was examined as *social activity* by which the various actors in the organization designed and constructed the *new activity system*. The main point was to consider the activities of the management and users and their interaction during the implementation process. At the end of the description and analysis of each case study a summary of the case was made with the help of the action model of the implementation process. Based on the comparative analysis of the cases made in the two previous chapters, it is possible to form a *revised model of the implementation process*, by which we can explain the case study results. The model is presented in Figure 10.1.

According to the results of the case studies, it seems that the management and planners answered for the planning process. The role of the users was a minor one in that phase. In the implementation phase and in the "normal" operation phase the situation was the opposite. The users had the main responsibility for these phases. The role of the activity of the management was not so central in the implementation phase and in the operation phase. In Figure 10.1 the central role is indicated by a bold line and the minor role by a dotted line.

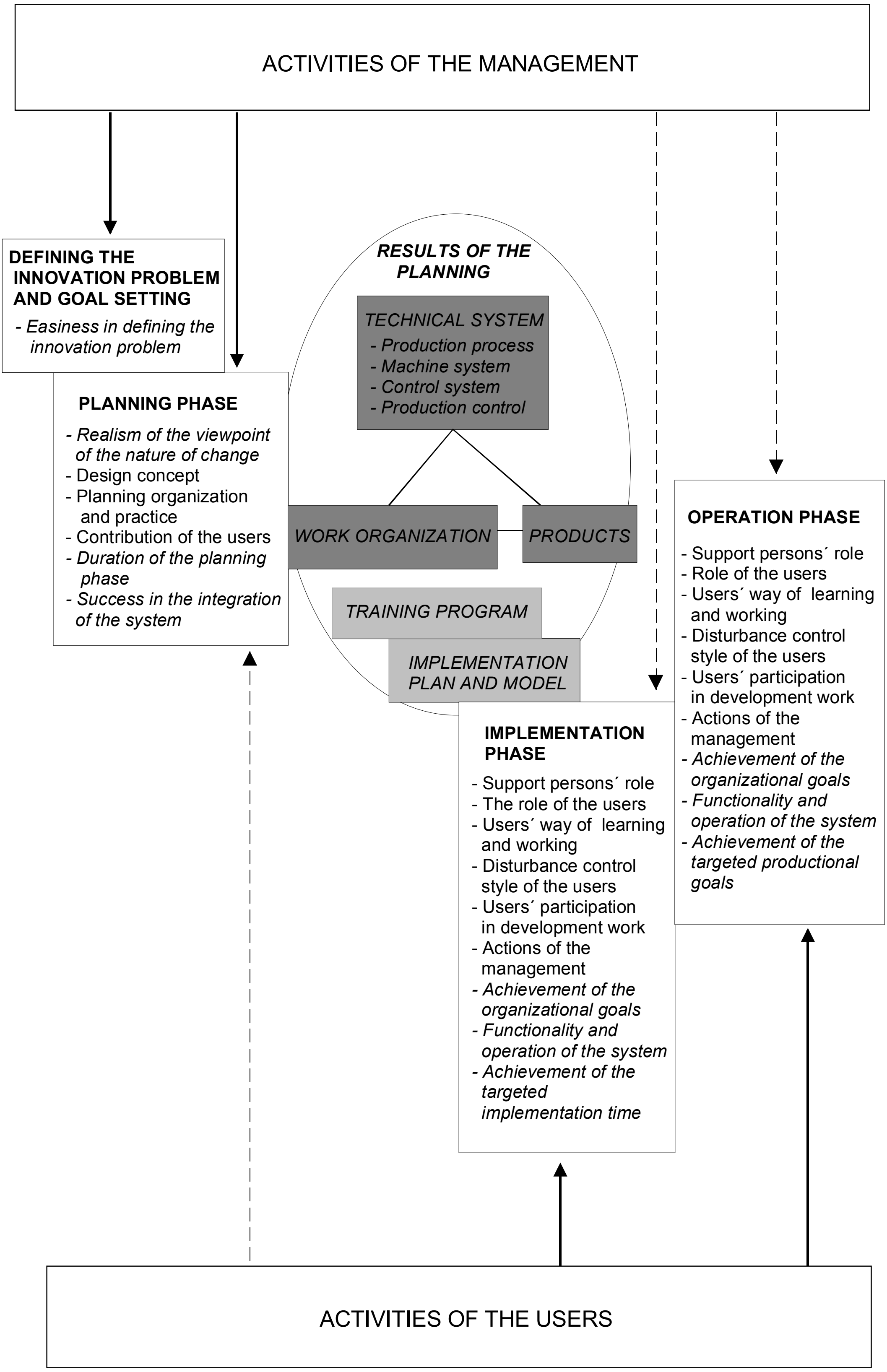


Figure 10.1. Revised model of the implementation process (regular type refers to activities; *italic* refers to result factors).

It is striking that *similar acting patterns* in the implementation process of the cases concerning the factors of the planning process can be discerned. There are five different dimensions of the approach of the management and planners which were to some extent *the same* in all the cases. These are: (1) the management´s "user-centered" viewpoint of the nature of the change; (2) the "techno-centric" design concept; (3) the traditional planning organization and practice; (4) the plan or idea of a "group" organization; and (5) no implementation plan. However, when studying more closely the activities of the management and the users, one can notice some *differences*, which turned out to be of importance with regard to the implementation practice and organizational problem-solving process and, thus, to the results of the implementation process.

The ways of acting of the management and the users and their effect on the results of the implementation process in the cases are discussed in the following, based on Figure 10.1 and Tables 8.1-8.3 and 9.2 and according to the main phases of the implementation process.

Planning Process

(1) It is somewhat odd that there seems to be an inverse relation between the *easiness* in defining the innovation problem and the *realism* of the management´s viewpoint of the nature of the change. In *case A* the definition of the innovation problem was a difficult problem-solving task to the production management. The production process was *analyzed* thoroughly and many *alternatives* were considered. The management made *many efforts* to renovate the production. Upper levels of the company were involved in the decision making but had *differing viewpoints*. As a result, the management´s viewpoint of the change was realistic. The management saw the change as a big technical and *organizational transition*. In *case C,* the investment decision was made quickly and lightly without an adequate concept design of the manufacturing system. The result was that the management´s viewpoint of the *organizational change* was unrealistic. *Case B* is in the middle. There was partial success in defining the innovation problem as well as in the realism of the management´s viewpoint. The production process was analyzed and upper levels of the company were involved.

The connection between these two factors is strongly linked to the *organizational patterns*, not only to the time used for defining the innovation problem. When the production process is analyzed from different organizational viewpoints with different organizational levels involved, the organizational questions seem to be in the forefront in the viewpoint concerning the change. This points to the fact that the *many-sided organizational problem-solving process* raises into sight realistic points of the production process and its development (cf. Kanter 1988).

However, the *users and supervisors* did not get to influence at all the decision process on a new production system in the cases. As the analysis of "bottom-up" potential in *case A* demonstrated, the *users* had much "tacit" know-know about the products, process, organizational structures and product markets. They were also able to conceptualize that knowledge into *"explicit" models* during the interviews (see Section 5.4). The users also saw the change as a great leap in their work. It can be argued that this kind of knowledge could have been utilized in the definition of the innovation problem and in the planning phase, which would have helped to solve problems and define development needs. Also in *case C* the *users* had already in the technical design phase a realistic view of the extent of the organizational change. They saw it as *a great organizational challenge*.

(2) It is unexpected that there seems to be no direct interdepency between the *realism* of the management´s viewpoint of the change and the *design concept* of the management and the planners. The first factor of the *innovation design dilemma* concerns the division between the "techno-centric" approach and organizational emphasis with regard to the viewpoint of the nature of the change (see Section 2.2). It could be assumed that the great emphasis on organizational issues in the viewpoint concerning the change would lead to look at the "*activity system"* as an object of design (technical system with its different components, *work organization* and products, see Figure 10.1). However, that was not the case. In *case A* the main object of design was the production process and the *machine system* in spite of the great emphasis on organizational issues in the early phase of the planning process.

It seems that there was an *intervening factor*, namely *the functional analysis of the operation principles* of the manufacturing system made in the beginning of the planning phase. In *cases B and C* the operation system was mainly the object of design, although the organizational change was regarded as a minor one. In cases B and C the functional analysis covered the different elements of the *"activity system"*. It seems that the functional analysis formed a *detailed organizational problem-solving process*, which widened the viewpoint concerning the design object.

(3) The *management and the planners behaved differently* and adopted different development lines concerning the *operation and automation level of the system* under planning during the technical design phase in the cases:

- In *case A* the changes made by the management and the planners in the technical design phase were directed away from the solutions resembling those of the "user-centered" approach towards more "techno-centric" design.

- In *cases B and C* the management and the planners used “techno-centric” starting points in the technical design but progressed towards new kinds of solutions in accordance with the principles of the “user-centered” model.

The reason to that would seem to be in the different *design concepts* adopted in the cases. That refers to the fact that the “activity system” as an object of design leads to success with regard to the operation and automation level of the planned technical system. *Systems B and C* were the automated systems supporting use activity.

There is, however, reason to point out an *intervening link* to this relation. It is the *planning practice*. In *case A,* segmentalist design prevailed. In *cases B and C* different design areas were planned according to the principles of *simultaneous design*. So, it was a question of new kind of *organizational arrangements*, which explains to a great extent the success or failure of the operation and automation level of the planned technical system in the cases.

In addition, the *planning organization and the contribution of the users* can be seen to be *another intervening factor*. In *case A,* the users had no influence on the planned system. In *cases B and C* the users participated actively in the realization planning through “participative” planning. That emphasizes further the meaning of *common organizational problem-solving processes* for the formation of a many-sided and automated technical system supporting use activity.

Does the nature of the *design concept* determine directly the *planning organization and practice*? The results of the cases show that the design concept had a crucial role for the formation of the planning organization and practice. However, the planning practice may also be formed by some other organizational factors and patterns.

(4) The success with regard to *the level and concreteness of the work organization concept* differed in the cases. In *case A* it was a success but in *cases B and C* only a partial success. This is unexpected. One could assume that in cases B and C the work organization concept would have been a success due to the design concept and planning organization and practices adopted. However, only case A was a success. The reason for the success in case A was mainly the *realistic viewpoint of the change* with its great emphasis on *organizational issues*. Correspondingly, the minor emphasis on organizational issues in cases B and C can be seen as a reason to partial success only.

The above considerations describe only the activities of the management. The *users* in all the cases regarded the change as a great organizational issue, which demanded new organizational patterns and further training. That refers to the benefits of a *large organizational problem-solving process* including people from different corners of the organization.

(5) *Success in the training program* follows the same pattern as in the case of the work organization. In *case A* a large and extensive training program was set up due to the need experienced based on the management´s *viewpoint of the change*. In *case B* training was a partial success, but in *case C* a failure. The management in case C regarded the organizational change as such a minor one that the training was confined to the "machine-centered" approach only.

(6) It is peculiar in the cases that the management did not make any proper *implementation plan*. However, in *case A* the level of the implementation plan and the model can be seen as a success and in *case C* as a partial success. In *case B* it was a failure. It seems that there is no single reason to that. In any way, in case A the management made concrete plans and actions for the implementation for aiding the learning process of the users. That was due to the consciousness of the *organizational transition*. In case C the management experienced the implementation of the new factory as such a great effort that the planning organization continued with in the implementation phase. That lasted, however, only six months.

(7) *Duration of the planning phase* can be seen as a failure in all the cases. The planning phase lasted two to three years. There is reason to ask what can explain a planning phase of such long duration.

The design and planning efforts of the management and the planners during the feasibility study and the technical design in the cases are described in Table 10.1. Correspondingly, the efforts during the realization planning are summarized in Table 10.2.

Many design and planning efforts partly explain the *long duration of the planning phase* in the cases. In the cases, a *feasibility study* was made for considering different alternatives to develop the production system before the specification of the FMS alternative. In *cases A and B,* the management visited different places to familiarize themselves with the use of flexible manufacturing systems. Also a turnkey system was sought but that turned out impossible. After many stages, the FM-system was specified. In case A, the first investment proposal made by the production management was not accepted, which shows that there were *differing views* of the development needs at the different parts and levels in the company. Instead, in *case C,* the feasibility study was only made after the decision on the new factory. The feasibility study was made for defining more closely the manufacturing system and technology, as a part of that also the model of system C was outlined.

Table 10.1. Design and planning efforts of the management and planners during the feasibility study and the technical design in the cases.

EFFORT	CASE A	CASE B	CASE C
PLANNING PHASE:	Over 2,5 years	About 2 years	Over 2,5 years
Feasibility study:	About a year	Almost a year	About 0,5 years
Actions	1)Alternatives were considered 2) Visits to Sweden and an international conference 3) A turnkey system was sought 4) FMS was specified; first investment proposal was not accepted	1) NC-machining center was considered 2) Visits to Finnish firms and Sweden 3) Arriving at the FMS-alternative 3) A turnkey system was sought 4) FMS was specified	1) Activity principles of the manufacturing system and technology were considered 2) The layout of the factory was fixed 3) Different kinds of technical matters for the new factory were planned
Technical design:	Over 1,5 years	Over one year	About 2 years
Design task	Large system; machines from six main vendors	The task to combine different kinds of techniques together	The task to plan a new factory and its production systems
Alternatives and changes	1) Some products and production phases were left out 2) Two or more automatic solutions were considered 3) Changing the material transport system 4) The finishing cell into manual mode 5) Automation level of the NC-machines was reduced 6) Original large plan of central control was changed into a simpler system: design continued in the implementation phase	1) Automatic operations of machines were planned 2) Transport system was specified 3) Planning of the control system 4) Connection between the FMS and other NC machines was considered	1) Product families and production cells were defined 3) Material handling alternatives were considered 4) The possibility to move system B to the new factory was considered 5 Planning of the machine system and consideration of different alternatives 6) Design of the automation level of the system and consideration of some alternatives 7) Design of the control system and consideration of some alternatives

Table 10.2. Design and planning efforts during the realization planning in the cases.

EFFORT	CASE A	CASE B	CASE C
Realization planning:			
Actions	1) Planned order of implementation was changed 2) Training to be arranged by the plant was planned 3) Job rotation plan	The *project group* met every week during several months: design of the layout, workplaces, fixtures and workpieces	The *cell group* worked over a year: 1) Participation in the purchase of the machines 2) Design of details of the layout and workplaces

The design task in the *technical design* was relatively *large and complex* by its nature in the cases, as can be seen in Table 10.1. Therefore, it was not an easy task for the management and the planners. There were many *problems* to be tackled and considerations of different *alternatives* and *changes* to be made to the technical issues in the different phases of the technical design. The management and planners answered also in case A for the *realization planning* during which the changes were made (see Table 10.2). In cases B and C the realization planning was organized in a different way with the users involved, but it took a long time despite that.

It can be stated that the task of the design and planning was to define new alternatives and gradually a new system, which took place through *development steps*. The decision making by the management and the planners proceeded *step by step* rather than through the decisions based on the guiding vision on the development needs of the production systems and the future system (cf. Rosenberg & Steinmuller 1988). This picture seems to describe largely the nature of the design and planning activity in the cases.

In addition to the nature of the planning activity of the management and planners, there is reason to raise the followed *planning practice* as one of the central causes for the long duration of the planning phase in the cases. The traditional planning practice mainly prevailed, which is characterized by the following matters: no users were involved; only traditional engineering methods were used; and co-operation in the planning was unsystematic. To make planning and its problem-solving more efficient *organizational and methodic innovations* would have been neeeded. In *case A* the *system training* given by the researchers was an example of the *new kind of planning practice*. Also in *case C* the analysis of the planning practice by the researchers raised into sight the *model for new kinds of methods*.

(8) In all the cases, the *user organization* had the main role in the *design and integration of the system*. It could be assumed that the integration task should have succeeded well because of the long duration of the planning. However, that can be seen to be only a partial success in the cases. This became obvious through many problems in the implementation phase.

It can be asked how the design and *planning practice* influenced the integration problems. That was certainly one cause for the problems. Another interpretation would be that it is impossible to plan a *large and complex system* completely in the planning phase (cf. Rosenberg 1985, 120-140; Rouse & Cody 1988; Brödner 1989).

Implementation Phase

(9) It was a suprise that the *achievement of the organizational goals* was really difficult in the cases. Partial success was achieved in *cases A and B*, but in *case C* this was a failure during the implementation phase. It could be supposed that the management had placed great emphasis on the work organizational issues, because the implementation was left to a great extent as the responsibility of the users in the cases.

The success in the *training program* and the *implementation model* can be seen as the main factor explaining the success in the achievement of the goals. The two types of training seem to have produced different results. In *case A* the users adopted some elements of a *systemic way of working* as a result of the large and extensive training program. In *case B* and especially in *case C* the users had mainly a *"machine-centered" way of working* due to the "machine-centered" training program. That hindered the achievement of the "skill-based" objectives. Moreover, in cases B and C the management had no realistic program or actions to realize the goals. In case A the management made for instance the job rotation program.

It is also striking that the *users´ way of learning and working* differed so much in the cases. In case A the users worked mainly in a co-operative way but in case C in an individual way. In case B the users organized job rotation themselves, which refers to some form of co-operation. The *training program* certainly explains that to a great extent, but the *work orientation patterns* of the users had to have some effect on the goal achievement, too.

The *implementation model* determined the *support persons´ role* as well as the *role of the users*. The *way of acting of the support persons* had an effect on the achievement of the organizational goals. In case A the leader co-operated with the users. In case B the supervisor acted partly as a traditional foreman, nevertheless some co-operation took place. In case C it is curious that the planning organization did not support clearly the achievement of the organizational goals during the implementation phase.

The explanation to that is the *unsystematic way of working of the planners,* based mainly on the "trial and error" -pattern.

The *management's actions* during the implementation also had some effect on the achievement of the organizational goals. In case A the management suspended the job rotation program twice. In cases B and C the management made some actions for progressing the achievement of the goals. In case B the management changed the organizational arrangements and in case C the management increased the manpower of the system and set up a further training program.

(10) It is more complicated to assess the success in the *functionality and operation of the technical system* in the cases. First, there were a lot of problems due to *design failures* and to *shortcomings in the integration of the system* in all the cases. These required development measures.

Second, the success of the *technical systems* differed with regard to the operation and the automation level. In case C the system was the most advanced but even so it failed as to its functionality and operation. Instead, system A was a trimmed one but only partially successful with its functionality and operation. Case B was in the middle in this respect.

It seems evident that the *work organization practice* and the *ways of acting of the users and support persons* are the most important factors that explain the success with the functionality and operation of the systems in the cases. In case C the organizational goals were not achieved. Also success as to functionality and operation was not achieved. In case A the organizational goals were partially achieved. The users compensated the shortcomings of the system.

(11) *Achievement of the implementation time* set by the management was a failure in *cases A and C*. In *case B* this was a partial success. The reason to this can be seen in the level of functionality and operation of the systems and the achievement of the organizational goals.

One could suppose that the systems would function in a proper way or a really smoothly in the "normal" operation phase, because they were planned so thoroughly, and much time was used for the implementation. This issue is considered next.

Operation Phase

(12) The *organizational goals* were achieved in *cases A and B*. The *management actions* explain to a great extent this result. In case A the management continued the job rotation program. In case B the managament developed organizational practices towards the principles of "skill-based" production. Also the way of working of the support persons had an

influence on the achievement of the organizational goals. In case B the supervisor increased co-operation, which enhanced the role of the users.

(13) The *functionality and operation* of *systems A and B* did not change greatly from the implementation phase. Case B can be seen as a success, because a high operation ratio was achieved. The reason to that was the many technical and organizational actions made by the management. In case A the operation of the technical system did not change.

(14) The *productional goals* set in the planning process were achieved and partly exceeded. The main reason to that can be seen in the many *technical and organizational development measures* made by the management and by the users. Especially the *disturbance control activity* of the users had a central role for achieving the productional goals.

10.2 SPECIFICATION OF THE CASE STUDY RESULTS

The management´s and planners´ role was central in the planning process, as shown above. The *approaches and activities of the management and the planners* was the main key factor that explained the successes or failures of the implementation process in the cases The definition of the innovation problem, the viewpoint of the nature of the change, the design concept, the planning organization and practice, the work organization, the training program, and the implementation plan and model were the main factors. *A specified model of the planning process* is presented in Figure 10.2. The model is based on the analysis of the case study results presented in the previous section (see Figure 10.1).

The *viewpoint of the nature of change* was of great importance for the management of the implementation process. It determined mainly the success or failure with regard to the work organization, the training program, and the implementation plan and model. The *design concept* was another central factor. It defined chiefly the planning organization and practice including the users´ contribution, which had a direct influence on the planned technical system.

These *"basic" innovations of the system and its implementation* were exlusively made during the planning process by the management and the planners involved through "top-down" activity.

Here are the *basic contradictions* in the management´s planning approach in the cases. First, although the *idea of the work organization* was directed to solutions in accordance with "skill-based" production, the planning practice was a traditional one. Neither the users nor the supervisors participated in the definition of the innovation problem and in the technical design.

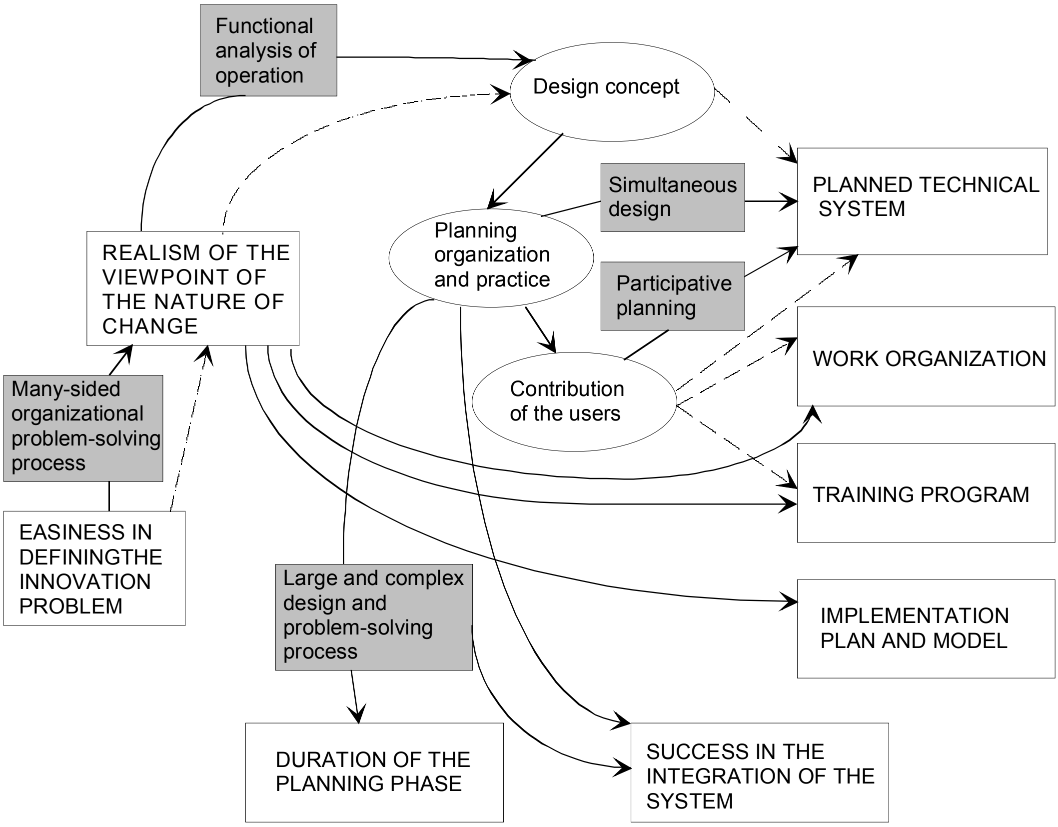


Figure 10.2. Specified model of the planning process in the cases.

Key to symbols: ——→ strong connection - - - -→ weak connection

result factor; way of acting; intervening factor

It is an interesting point that the *picture of the traditional planning way* of the management and the planners changed when *the realization planning* began. The planning became "user-centered" or it contained even elements in accordance with the "lean production" patterns. The management involved the users in the planning process. However, in *case A* the management only took representatives of the workers into the realization phase. It can be seen that the management was willing to involve the users in the *realization planning*, because their knowledge and experience were needed for the planning of details and workplaces in the system. The entrance of the users into the realization planning foretold already the fact that their contribution was seen to be crucial in the implementation process of the plans.

Another basic contradiction in the management´s and planners´ planning approach in the cases was that *technical design issues* were executed in great detail. Instead, an *organization plan* was sketched only mainly during the realization planning, which is customary according to the "techno-centric" model.

There were many *intervening factors*, which influenced different results and activity factors and their relations, as can be seen in Figure 10.2. They describe different kinds of *organizational problem-solving processes* and the *organizational patterns* through which the design and problem-solving tasks were tackled.

The *duration of the planning process* in the cases was relatively long. The main reason to that was the *large and complex design task*, which was made more difficult by the followed *planning practice*. In the same way, the success in the integration of the system in the cases was only partial.

The management influenced further the implementation and operation through different actions concerning the technical and organizational matters and development activity. *A specified model of the implementation phase* is presented in Figure 10.3. The model is based on the explanation of the case study results presented in the previous section (see Figure 10.1).

The i*mplementation plan and model* determined the roles of the support persons and users. The users had a major role in the implementation phase. The users´ major role resulted in that they controlled all disturbances and participated actively in the development work.

The *training program* had a decisive impact on the formation of the *users´ way of learning and working*. The *division of labour* between the support persons and the users influenced also the role of the users and their way of learning and working. The users´ way of working had a direct connection to their disturbance control style and their approach to the development work.

The *actions of the management* were directed mainly on the improvement of the planned technical system and on the advancement of the work organization. They had some link to the *achievement of the organizational goals*, but the main reasons were the development of the users´ way of working and the work division between the roles of the support persons and the users.

The planned technical system and the achievement of the organizational goals were the main reason to the *functionality and operation of the system*. The a*chievement of the implementation time* set as a target depended on the function of the system and the achievement of the organizational goals. However, there is reason to note that the role of the users was central for the function of the system and its operation level.

There are two controversial things concerning the implementation phase in the cases. First, the management did not make any proper *implementation plan*. Second, the management left the *erection and implementation of the system* to a great extent as a *responsibility of the users* in the cases, which can be interpreted as a practice according to "skill-based" production. However, there were some additional "techno-centric", "user-centered" or even "lean production" features depending on the case and its different dimensions. For example, in case A the designer of the system became the leader of the system. In case B the supervisor had a central role. In case C the planning organization was involved in the implementation process for half a year. Moreover, the two methods designers had a great role.

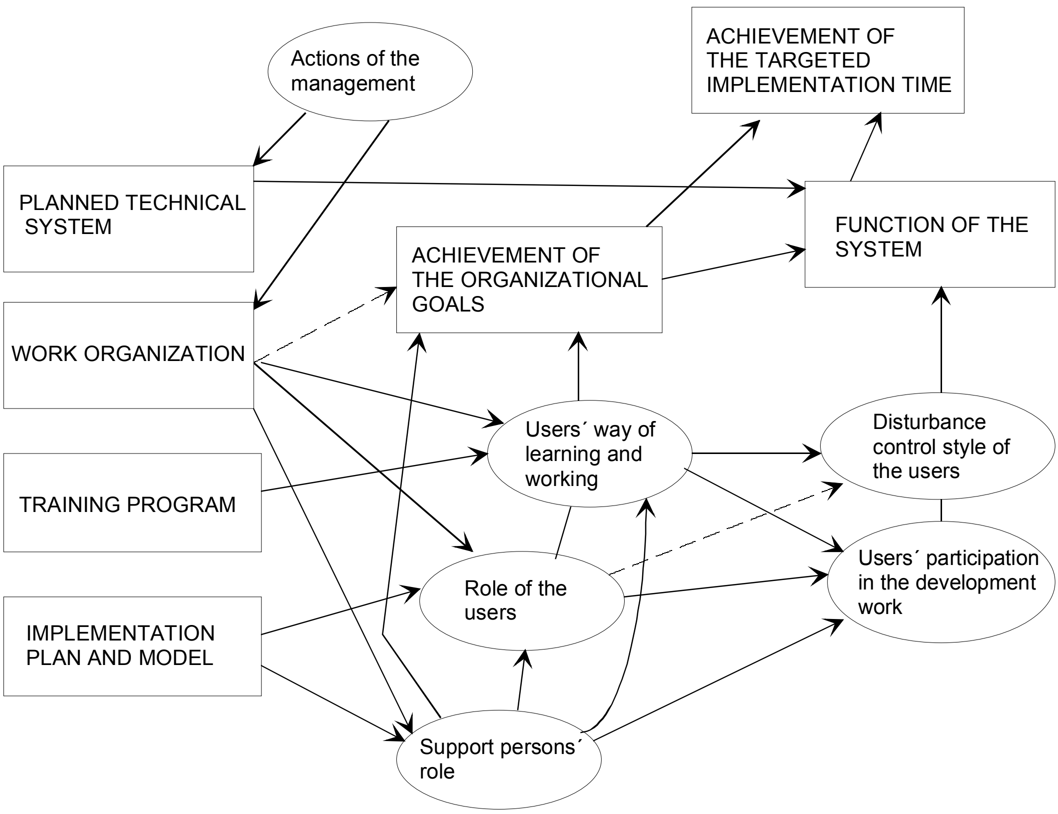


Figure 10.3. Specified model of the implementation phase in the cases.

Key to symbols: ——→ strong connection - - - -→ weak connection

▭ result factor ⬭ way of acting

It is curious about the cases that although the *work organization* and *the tasks of the users* were defined by the management in the planning phase mainly as a “group” organization and skilled work, in accordance with the “skill-based” principles, the *realization of the work organizational goals* was really difficult. There were great problems in carrying out the work organizational goals, which made it difficult to achieve the planned productional goals.

Moreover, a suprisingly *high disturbance level* prevailed in the implementation phase in the cases. It was a marked feature that a great number of the disturbances were due to *design failure*. For example, in case A, over one third of the new disturbances registered during the follow-up period were design failures, which implicated the need to continue the *planning and design activity* in the implementation phase.

It was a common characteristic in the cases that the disturbances had a great *effect* on the production, work, material and work safety. These factors were of great importance for achieving the productional targets. Moreover, unmanned operation was not at all achieved in systems A and C. Therefore, the production systems could function only through the efforts of the system users.

Numerous *development measures* were made in the cases during the implementation phase. It was a striking feature that the users in all the systems *controlled almost all disturbances* and made and participated in the *development work* in the implementation phase.

The implementation phase was a *long and troublesome process*. The case study results refer strongly to the fact that the *implementation phase was not only the direct execution of the plans* made in the design and planning phase, because a lot of adaptation and development work had to be done before the different parts of the system were made to function as a whole in the cases. For example, in case A much *tailoring* was needed before the machines and equipment acquired from the different vendors were adapted programmatically and mechanically to function with each other and before they were applied to the tens of products produced in the system.

The role of the users remained central in the "normal" operation phase. *A specified model of the "normal" operation phase* is presented in Figure 10.4. The model is based on the analysis of the case study results discussed in the previous section (see Figure 10.1).

It is also interesting to note that the *same ways of acting patterns* prevailed to a great extent in the "normal" operation phase as already in the implementation phase. The approaches which the *management* adopted in the implementation continued furher in the operation phase. In case A the management mainly withdrew further development efforts, but in case B the management was willing to take both technical and organizational action for developing the function of the system. It seems that the management *interpreted* differently the results gained in the implementation process and thus adopted different kinds of *development strategies*.

Nevertheless, the *productional goals* set in the planning phase were achieved and partly exceeded, especially with regard to the product family produced.

However, the need for development was urgent also in the "normal" operation phase, due to the *many problems* and the *high disturbance level*. The *development activity* by the users continued in the "normal" operation phase on the same level as in the implementation phase. In the same way, *disturbance control* remained an essential task of the users in the systems.

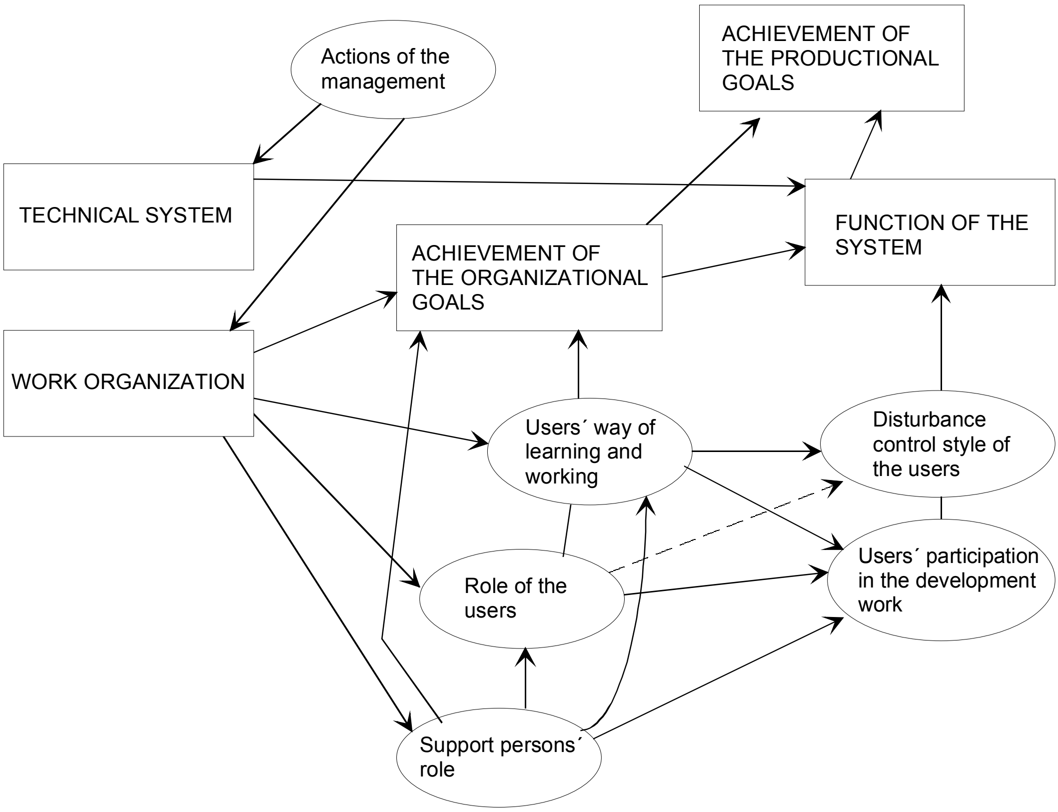
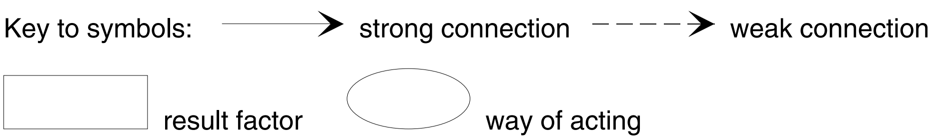


Figure 10.4. Specified model of "normal" operation in the cases.



It is a special surprise that the same characteristics described the *disturbance level and the cause and effect patterns of the disturbances* in the "normal operation phase as already in the implementation phase. Normally, it is expected that the disturbance level would clearly sink after problems are eliminated in the implementation phase (see Norros 1996). That was not the case in the systems.

Because the implementation and operation were mainly left as the responsibility of the users, the importance of the users′ *skill level and way of working* as well as the *co-operation patterns* inside the user organization were emphasized. The case study results showed that the questions of work organization, task division and professional skills were critical factors with regard to the operation and other functional qualities of the system. The results proved that the implementation and use of the technical system depend on the user activity more than perhaps expected.

However, some major *manual tasks and disturbance control* took altogether over 50 % of the working time of the users in all the systems. This shows that there is still a long way to an "automatic" and "unmanned factory", visualized by the "techno-centric" approach (see Section 3.1).

Instead, the results refer to an increasing role of the users in automated systems (cf. Zuboff 1988; Jones 1989).

The case study results strongly suggest that *the boundary between the implementation phase and the "normal" operation phase* is fuzzy (cf. Rogers 1995, 399-403). Especially the results of case study C showed that the change-over from the implementation to "normal" operation was hard to define exactly. The results of the "normal" operation in systems A and B showed that the operation of the system demanded the *elimination of the problems* impeding the operation and *continuous optimization* of the operation. In case A changes to the control system were also made. Many *technical and organizational changes* were made during "normal" operation of system B. For example, new equipment was acquired into the system. At the same time, it seems that *new problems* appeared all the time when the operation of the system developed, as the results of cases A and B showed. This was also clearly obvious in case C in its implementation phase.

One of the surprising features in the systems was that certain kinds of *"implementation steps"* seemed to take place during the life span of the system. There was strong evidence in cases A and B of new "implementation steps" in the "normal" operation phase triggered by changes in the material, products, product family and technology. It seems that the implementation steps caused *problems in adapting* to the changed situation.

10.3 SUMMARY: SYSTEM MODEL OF THE IMPLEMENTATION PROCESS

In Chapter 10, in Sections 10.1 and 10.2, the connections and relations between the results of the implementation process in the cases and the ways of acting of the management and users are presented. This presentation can be seen to form the *system model of the implementation process* with its many dependencies and interactions. The system model of the implementation process is illustrated in Figure 10.1 and Figures 10.2-10.4. Figure 10.1 gives a *general picture*. Figures 10.2-10.4 present the *zoomed pictures* of the revised model of the implementation process presented in Figure 10.1.

PART IV: CONCLUSIONS

This final part of the study draws conclusions from the case study results. Based on the system model of the implementation process, it is possible to interpret further the case study results and to assess the meaning of the results for wider applications. A development model of the implementation process of technical change is formed and analyzed in Chapter 11. The model is further specified for a solution of the innovation design dilemma.

Finally, Chapter 12 discusses and evaluates the study results. Also suggestions for further research are outlined.

11 DEVELOPMENT MODEL OF THE IMPLEMENTATION PROCESS OF TECHNICAL CHANGE

11.1 DEVELOPMENT MODEL

According to the *system model of the implementation process*, based on the case study results, the most important factors from the point of view of the successes and failures of the results the implementation process of technical change are the following elements: (1) viewpoint of the nature of change; (2) design concept; and (3) organizational patterns. The relations of these elements are described by the *developmental model* of the implementation process of technical change. The model is presented in Figure 11.1.

According to the system model of the implementation process the *viewpoint of the nature of change* defines mainly the work organization, the training program and the implementation plan and model. The *design concept* determines correspondingly the planning organization and practice and through this the planned technical system (see Figure 10.2). As the case study results showed, the most crucial factor for the achievement of the planning, implementation and productional goals is the *organizational patterns*.

As the case study results implicated, the *realism* of the viewpoint of the nature of change is dependent on the *many-sided organizational problem-solving process*. Especially case A demonstrated that. In the same way, the formation of a successful *design concept* rested on the *organizational problem-solving process*. In cases B and C the functional analysis of the operation principles of the system under design acted as that kind of a process (see Figures 10.2 and 11.1).

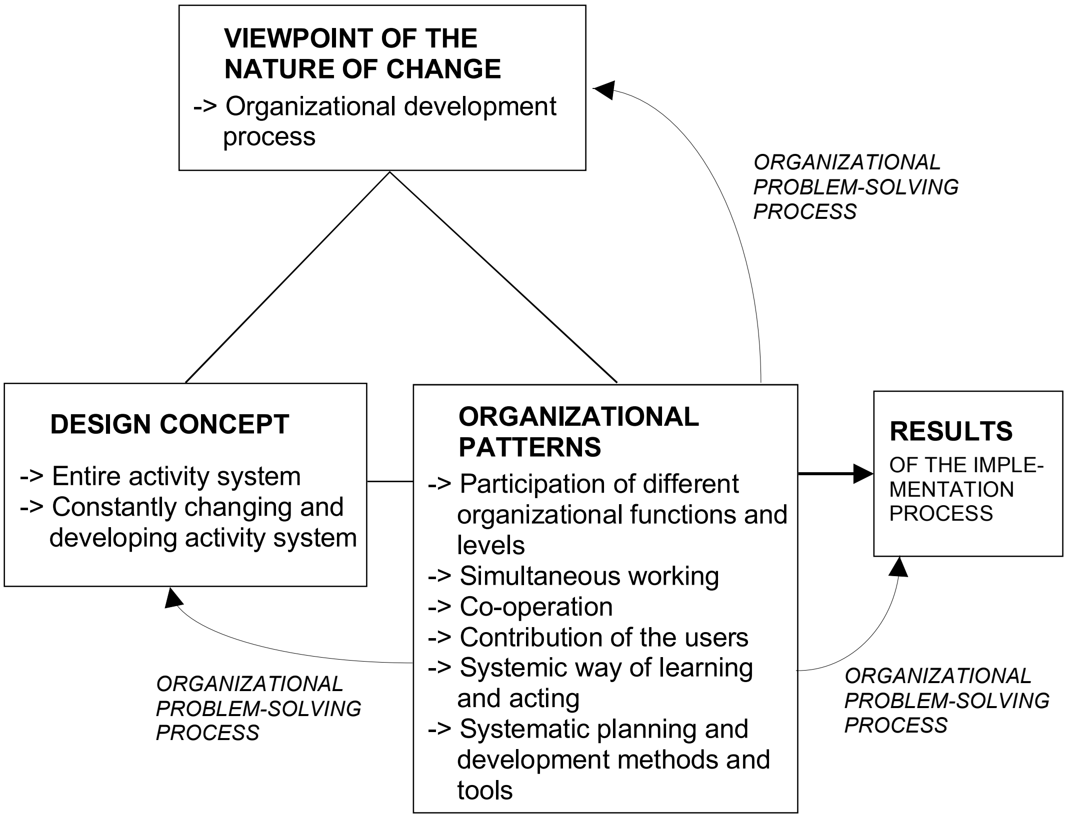


Figure 11.1. Developmental model of the implementation process of technical change.

As the case study results proved, the *organizational patterns* occupied the most central role in explaining the results of the implementation process. They determined the *quality of the problem-solving process* in the planning process, in the implementation phase and in the "normal" operation phase through which the results were obtained. In the cases the roles of the support persons and the users, the users´ way of working, the actions of the management, the co-operation patterns and the use of systematic methods were the factors which mostly contributed to successful results.

11.2 DEVELOPMENT MODEL AS A SOLUTION TO THE INNOVATION DESIGN DILEMMA

The analysis of the case study results has shown that the "*lean production" model* would have been a more realistic approach and probably brought better results in the cases than the *organizational patterns* of the *techno-centric model and the user-centered model* which mainly characterized the ways of acting of the management and the users in the cases (see Tables 8.1-8.3). In any case, the "lean production" model can be seen to to be able to forecast many results in the cases, e.g., the need to continue planning in the implementation phase and to develop the system continuously during its operation phase and the role of the users in that, and the meaning of systematic methods and tools in co-operation.

The case study results are considered from the viewpoint of the *"lean production" model* in the following (see Tables 8.1-8.3). Special attention is paid to the aspects necessary to overcome the *innovation design dilemma* and its three factors and especially in solving its basic factor, the gap between the *planning* of the system and the *use* of the system (see Section 2.2). The analysis specifies further the development model of the implementation process of technical change in Figure 11.1:

(1) The most *realistic viewpoint of the nature of change of the management* was in case A. The management regarded the change as a big technical and organizational transition. The question is connected to the *first factor of the innovation design dilemma*. As the case study results showed, it would have been more realistic to consider the change as an *organizational development process*, according to the "lean production" model. In all the cases the achievement of the organizational goals was one of the greatest problems. This hindered the achievement of the implementation and the productional goals.

Another important factor was the *design concept*, which had a crucial role for the formation of the planning organization and practice and for the technical solutions made in the planning phase. Thus, the design concept is an important means for the *designers and planners* in directing their work. The design concept has two dimensions according to the "lean production" model. First, the object of design has to cover the *whole activity system*, not only the production process and the machine system, to which the design concept of the cases was mainly restricted. However, in cases B and C the design concept was conceptualized from more extensive viewpoints. Second, the object of the design has to be seen as the *constantly changing and developing activity system*. This was not realized in the cases in the planning phase. The result was that the integration of the case systems turned out not to be a success. Moreover, the case study results showed that the planned technical system had to be developed considerably in the implementation phase, but the need for development continued further in the "normal" operation phase.

When the changing and developing activity system is as an object of design, that has profound implications for the *technical solutions* and *work organizational practices* to be chosen. High automation level, automated materials handling and flexibility for productional changes become emphasized, as the case studies demonstrated. The control system has to be an interactive and "transparent" system with data base features supporting the users in the mastering of the system and its development activity. With regard to the work organization, multi-skilled workers, group working and network co-operation in the organization are central features (see Sections

3.2-3.4 and Tables 8.1-8.3). Some of these technical and organizational features were also implemented in the cases.

(2) The *second factor* of the innovation design dilemma is connected to the *planning approach* culminating into the division between *"top-down" and "bottom-up" planning*, which is the central line in overcoming the border between the *planning* and the *use*. There are especially two basic elements for solving this dilemma: the planning organization; and the planning methods and tools.

The change in the *planning organization* especially means that the users become involved in the planning process earlier and more deeply than usual (Kanter 1988, 241-277; Jones 1989; Hyötyläinen et al. 1991; Odagiri & Goto 1993; Boedker & Gronbaek 1996). The *participation of the users* in the planning has a double effect, as cases A and C demonstrated:

- by being involved in the planning process, the future operators of the system can adopt and transfer the planning knowledge to the operation, which may also shorten the implementation period of the system;

- the users can participate in the processing and solving of the planning problems and, thus, bring operational knowledge into the plans, which may reduce problems and disturbances in the realization of the plans in the implementation phase.

However, at best these changes only lead to so-called "participative" planning, in accordance with the "user-centered" model. The integration of the planning and use activities depends crucially on the *systematic planning methods and tools* (Kanter 1988, 241-277; Boedker & Gronbaek 1996). Models, methods and tools are needed, by which the planners, users and the user organization as a whole can manage the techno-organizational system under design in *co-operation* through the principles of *simultaneous working*. There were problems with the unsystematically organized planning practice and the shortage of adequate planning methods only in case C, although the users were involved in the planning. In case A the *system training* given by the researchers acted as *a new kind of planning practice*.

(3) The *third factor* of the innovation design dilemma describes the division between the *planning and the execution*. There are three important points for overcoming that dilemma. The first one is the *implementation plan and model*. It is important to see the implementation as an *extension of the planning*. As the case results showed, this had a central impact on the realization of the organizational goals. The second point is *training*, which determined to a great extent the users′ *way of learning and working*. The third matter is the *systematic development activity* in the implementation

and "normal" operation phases. This is a crucial factor in crossing the boundary between the planning and the execution. This means that the system is a permanent *object of planning* even in "normal" operation (Nadler & Robinson 1987; Nonaka 1991; Adler & Cole 1993; Sitkin 1996; Winter 1996). As cases A and B showed, the need for development and planning activities in the use of the systems was real. Several development measures were made in the cases. In case C, the researchers developed *the model of tools and organizational practices* for the development activity which was partly tested in the case.

In all the cases, the *organizational patterns* were not up to the demands of the *new complicated technical systems*, as shown above. In this respect, one can say that there was an *organizational lag* in the cases. According to March and Simon (1958, 117-131), when an organization meets a new and complex situation of decision making, the past experience gathered in the organization is not necessary valid for choosing the "right" actions. Especially in the conditions of developing new "performance programs" the search for new organizational patterns occurs rather according to a step-by-step principle than by the "rational" planning of ready solutions, due to "limited aspirations" and "bounded rationality" (March & Simon 1958, 172-210; Cyert & March 1992, 214-215).

The case studies demonstrated that the adoption of new kinds of planning and implementation practices progressed as a controversial process. The planning and implementation process can be seen to form an *"experimental field"* where the experienced difficulties, set-backs and good results may act as a ground for learning and seeking for new planning practices, implementation models and management approaches (cf. Dean 1987; Senge 1990; Leonard-Barton 1992; Adler & Cole 1993; Garvin 1993; Sitkin 1996).

12 DISCUSSION

12.1 SUMMARY OF THE STUDY RESULTS

The objective of the study has been to describe the planning and implementation process of new technical systems. In addition, the objective has been to find out what kinds of planning and implementation models, methods and organizational forms can further organizational problem-solving and development activity in the planning and implementation of new technical systems, which is assumed to contribute to a successful implementation process. It has been assumed that there is a need to solve the innovation design dilemma of technical change to succeed in this.

The *description and analysis* of the implementation process of the three case systems has been done in Chapters 5-7 with the main focus on describing how new technical systems are planned and implemented and how the implementation process in the cases progressed. A special focus has been laid on the planning and implementation activities of the management and on the role of the system users and their interaction in the problem-solving activity of the implementation process.

The analysis of the case study results has showed that the implementation process of technical change consists of *a series of problem-solving and development steps* taken by the user organization and its actors. This is a controversial, complex and long process in which the management, planners, support persons and users with different interests and ways of acting design and construct, mainly *step by step*, the concrete technical and organizational characteristics of the "activity system". This is performed by solving planned and unanticipated problems that have emerged during the definition of the innovation problem and goal setting, the planning phase, the implementation phase and the operation phase.

In the study, *three "ideal" models of planning and implementation* (techno-centric model, user-centered model, and lean production model) have been formed in Chapter 3, based mainly on the organization theoretical literature. The models are chrystallized in Table 3.4. At same time, these models act as a reference structure in the description and analysis of the case studies. The comparative analysis of the activities of the management and users has shown that the ways of acting in the cases were characterized mainly by the "techno-centric" and the "user-centered" models. However, some features could be seen as practices in accordance with the "lean production" model.

The specification of the three *planning and implementation models* has been done based on the comparative analysis of the ways of acting of the management and users in the implementation process in the cases. The models are presented in Tables 8.1-8.3.

The *system model of the implementation process* of technical change has been created and specified based on the analysis of the results of the implementation process in the cases in Chapter 10. The model presents in great detail the connections and relations between the results of the implementation process in the cases and the management´s and users´ ways of acting with their many dependencies and interactions.

According to the system model of the implementation process, the most important factors from the point of view of success or failure of the results are the following elements: the viewpoint on the nature of change, the design concept and the organizational patterns. The relations of these elements are described by the *development model* of the implementation process of technical change in Chapter 11. The development model is further specified and presented as a solution to the innovation design dilemma.

The case study results have proved that the *organizational patterns* carry the most central role in explaining the results of the implementation process. They determine the quality of the problem-solving process in the planning process, the implementation phase and in the"normal" operation phase through which the results were obtained. In the cases, the roles of the support persons and the users, the users´ way of working, the actions of the management, the co-operation patterns and the use of systematic methods were the factors which contributed mostly to successful results.

12.2 EVALUATION OF THE STUDY RESULTS

Significance of the Results

The issue of *technical change and its implementation process* has been the object of many studies coming from different disciplines (Burns & Stalker 1994; Gould 1980; Gerwin 1988; Hirsch-Kreinsen & Schultz-Wild 1990; Boer 1991; Kuitunen 1991; Lindberg 1992; Hietanen 1993; Yin 1994; Yoshitomi 1996; Rosenberg 1976; Sahal 1981; Freeman 1982; Dosi 1984; Perez 1986; Nelson 1987; Soete 1987; Dosi 1988; von Hippel 1988; Lundvall 1988 and 1992; Silverberg 1990; Slaughter 1993; Kodama 1995).

The object of this study has been the *implementation process* of new technical systems in the user organization. Considering this process as an *organizational problem-solving process* is a relatively new approach in the innovation research (cf. March & Simon 1958; Burns & Stalker 1994; Cyert & March 1992; Van de Ven & Poole 1990). This is so especially because the implementation process is looked at as *social activity* through which the different actors of the organization design and construct by concrete actions the techno-organizational solutions of the new "activity system" (see Engeström 1987; Blackler 1993). Moreover, the implementation process of technical change is defined to cover the *whole process*, from the defining of the innovation problem and the planning of innovation to the implementation of techno-organizational solutions in the user organization and to the “normal” operation of the system.

Normally, the *innovation design dilemma* is defined as the division between the two sides of technical change, technical innovation and organizational innovation (Holbek 1988; Gjerding 1992). In this study, the starting point has been to combine these two types of innovation into a common approach. Hence, the three factors and their dimensions of the innovation design dilemma have been differentiated. This is a *new approach*, which can also offer a starting point for further research.

The *action model* of the implementation process has acted as the central means in the description and analysis of the case studies. The model is based on the work of the research group (Norros et al. 1988a; Hyötyläinen et al. 1990; Norros 1991; Hyötyläinen 1993 and 1994; Norros 1996). However, the model is further developed in this study and applied to the implementation process of the case systems. As such it could act as a *framework* for further development in the studies concerning productional and organizational change processes.

The formation of the *three “ideal” models* of planning and implementation is a *new approach* developed in this study. There are many studies on organization theories and their applications, but they are not usually considered as a means for the analysis of the planning and implementation process of technical change (Burns & Stalker 1994; Rose 1975; Thorsrud 1980; Kanter 1988; Brödner 1990a; Corbett et al. 1991; Rouse 1991; van Eijnatten 1993).

The researchers participated actively in and followed up intensively the *implementation process of the three case systems (FMSs)* in two companies. The *FMS study* began in 1985 and was completed in 1992. Case study A covered the years 1985-89, case study B the years 1986-89 and case study C the years 1989-92.

In cases A and C, the researchers participated actively in the implementation process to create and introduce *new methods, tools and organizational forms* in the user organization. In these cases, the researchers participated in the change processes in the companies almost on a weekly basis. Instead, case study B was by its nature a follow-up study although new methods were applied for the observation of the users′ activity and the operation of the system.

Through three different projects succeeding each other, the researchers were able to *participate in and follow-up intensively* for several years the implementation process of the case systems by using *various methods*. Hence, a rich and many-sided picture was formed of the implementation process of the case systems and their development mechanisms. This abundant material has been the basis for the description and analysis of the cases in this study. Hence, a *thorough and detailed description* of the implementation process in the cases has been possible. The implementation processes have rarely been described in such detail (see Burns & Stalker 1994; Nord & Tucker 1987; Clark & Starkey 1988; Ehn 1988; Kanter 1988; Boer 1991; Hietanen 1993).

The specification of the *three planning and implementation models* for the ways of acting of the management and the users based on the empirical case study results makes a *new approach*. The models created through the comparative analysis of the case study results can lay the *ground* for further research.

The *system model of the implementation process* of technical change based on the analysis and specification of the results of the implementation process in the cases is *uniquely* detailed. There are many approaches and models of the implementation process of technical change (Gould 1980; Braun 1985; Dean 1987; Lay 1990; Boer 1991; Sabherwal & Robey 1993; Boedker & Gronbaek 1996; Small & Yasin 1997). However, these models are mainly based on the material acquired by questionnaires or merely on theoretical reasoning.

The unique feature of the *development model* of the implementation process of technical change is that the three factors influencing the most the success or failure of the implementation process are distinguished, based on the case study results. The development model can be seen to form a "holistic" approach to the implementation process of technical change (cf. von Wright 1987; Gjerding 1992) The model and the treatment of the factors of the innovation design dilemma from the point of view of the "lean production" model can be used as a *practical tool* for the development of the organizational patterns for organizational problem-solving processes in the implementation process of technical change in the user organization (cf. Glaser & Strauss 1967; Corbett et al. 1991; Rouse 1991; Adams 1995).

Limitations of the Results

In *assessing* the results of the study it must be noted that the role and activity of the *designers* and *planners* coud not be discussed in enough detail in the cases. Their activity has not been distinguished so clearly from the activity of the management. However, the planning and construction of increasingly complex manufacturing systems demands more and more planning input. In the cases the planning phase lasted for several years.

According to the development model of the implementation process presented in Figure 11.1, the determinination of the viewpoint of the *nature of change* can be seen to be a major task of the *management*. In addition, the management defines the *organizational patterns and resources* for the planning and implementation process. The *design concept* is a matter of the *designers and planners*. It forms a directing tool for the planning process.

Another shortcoming in the study is that the *role of different organizational functions and levels* in the implementation process in the cases could not be addressed, because of the material for the study. Only some references have been included to the differing views of the upper levels of the company and the organizing of other functions in relation to the case systems.

The results of the study are based only on *three cases*. There is a risk that some characteristic organizational features outside of the consideration of this study could have influenced strongly the formation of the results. Taking more cases into the study would have made it easier to control such factors (Pettigrew 1990; Leonard-Barton 1990).

However, the study has penetrated deeply into the real implementation process in the cases through the results of the *intensive case studies*. The planning and implementation models through which the research problems were addressed act as a framework. This guarantees that the study is able to form a many-sided and reliable picture of the implementation process in the cases. Moreover, the reseachers participated actively in the implementation process of cases A and C to create and introduce *new methods, tools and organizational forms* in the user organization. In these cases the researchers participated in the change processes in the companies almost on a weekly basis for several years (cf. Pettigrew 1990). Because of this, it has been possible to make some *theoretical conclusions and generalizations* of the patterns of the implementation process of technical change in the study based on the empirical case study results and their comparison (cf. Eisenhardt 1989; Yin 1989; Westbrook 1995; Glaser & Strauss 1967; Glaser 1978; Strauss & Corbin 1990; Sayer 1992).

Furthermore, it may be asked what effect the fact that the *user organization* itself answered for the design and integration of the system in the cases had on the results. Are turnkey systems easier to implement? (Small & Yasin 1997) In the cases, the management tried to seek a turnkey system but this turned out impossible. This seems to be a general practice in the case of the FMS (Mieskonen 1989; Ollus et al. 1990, 78-81). This shows that vendors of machines and systems do not have enough knowledge about the needs and conditions of the production system in case to offer an entire solution applied for the special requirements of the complicated processes and products. Therefore, the user organization has a central role in the problem-solving process concerning a new technical system. This is due to the fact that the user organization has operational knowledge based on experience and learning and can, therefore, solve problems and create innovations to make the system function in the conditions of the organization (Slaughter 1993; von Hippel 1988; Lundvall 1988).

Yet another question can be asked. The systems were implemented at a *time* when there was relatively little experience of FM-systems (Mieskonen 1989; Ollus et al. 1990; Ranta & Tchijov 1990). One can ask what effect that may have had on the results in the cases. However, it can be stated that the implementation of a new technical system is always an actual new task for the organization (Sahal 1981; Rogers 1995). The implementation process of case systems B and C show this clearly. In *case B* some NC machines were replaced by the relatively small FMS. Nevertheless, many technical problems as well as organizational issues had to be met in the implementation. Moreover, new problems emerged during the "normal" operation. The same plant replaced the system with large *system C*. Despite the early experience on FMS-technology, there were numerous problems with the organizational and technical issues. The result was that the problems and disturbances experienced in the implementation became a threat to the operation of the system and to the achievement of the level of "normal" use.

12.3 FURTHER RESEARCH

The results of the case studies raise new questions for *future research* on technical change and its planning and implementation process. First, further research is needed on the *users′ way of learning and working* and the *formation of their work orientation* and on their development during the implementation process. Special focus has to be laid on individual development processes. Most developed orientation approaches can form models for the *systemic way of working*. Second, the *role of planners* in the organizational *problem-solving process* and in the formation of the *planning and implementation practices* is a central topic. Technical systems are becoming more complex and the need for planning is increasing. Third, the *models and methods* used by the planners for designing techno-organizational systems are essential questions for the realization of the *planning practices* according to the *"lean production" model*. Fourth, the practices of a *network organization* are an important research issue. The practices are essential for continuous development activity in the organization and for developing further the organizational patterns. In this respect, the participation of the *different functions and levels of the organization* in the planning and implementation process and in its problem-solving processes is an important issue for further research. Finally, the *economic aspects* of technical change and especially the economic mechanisms of different planning and implementation models are crucial factors for the diffusion of the new models which can become the dominant "best practice" in the future.

REFERENCES

Adams, J. 1995. Insinöörin maailma. Jyväskylä: ART HOUSE. (In Finnish.)

Adler, P.S. & Cole, R.E. 1993. Designed for Learning: A Tale of Two Auto Plants. Sloan Management Review, Spring, pp. 85-94.

Alasoini, T., Hyötyläinen, R., Kasvio, A., Kiviniitty, J., Klemola, S., Ruuhilehto, K., Seppälä, P., Toikka, K. & Tuominen, E. 1994. Manufacturing Change. Interdisciplinary Research on New Modes of Operation in Finnish Industry. Tampere: University of Tampere, Work Research Centre, Working Papers 48/1994.

Alasuutari, P. 1994. Laadullinen tutkimus. Jyväskylä: Vastapaino. (In Finnish.)

Aoki, M. & Rosenberg, N. 1987. The Japanese Firm as an Innovating Institution. Standford University, Center for Economic Policy Research, Publication No. 106, September.

Argyris, C. & Schön, D.A. 1978. Organizational Learning: A Theory of Action Perspective. Reading, Massachusets - Menlo Park, California - London - Amsterdam - Don Mills, Ontario - Sydney: Addison-Wesley.

Bainbridge, L. 1983. Ironies of Automation. Automatica, Vol. 19, No. 6, pp. 775-779.

Bessant, J. & Haywood, B. 1985. The Introduction of Flexible Manufacturing as an Example of Computer Integrated Manufacturing. Innovation Research Group, Department of Business Management, Brighton Polytechnic, Final Report, October.

Biemans, W.G. 1992. Managing Innovation in Networks. London - New York: Routledge.

Blackler, F. 1993. Knowledge and the Theory of Organizations: Organizations of Activity Systems and the Reframing of Management. Journal of Management Studies, 30:6, November, pp. 863-884.

Blumberg, M. & Gerwin, D. 1985. Coping with Advanced Manufacturing Technology. In: Rhodes, E. & Wield, D. (Eds.), Implementing New Technologies: Choice, Decision and Change in Manufacturing. Oxford: Basil Blackwell. Pp. 209-218.

Boedker, S. & Gronbaek, K. 1996. Users and Designers in Mutual Activity: An Analysis of Cooperative Activities in Systems Design: In: Engeström, Y. & Middleton, D. (Eds.), Cognition and Communication at Work. New York: Cambridge University Press. Pp. 130-158.

Boer, H. 1991. Organising Innovative Manufacturing Systems. Aldershot - Brookfield USA - Hong Kong - Singapore - Sydney: Avebury.

Boer, H., Hill, M. & Krabbendam, K. 1990. FMS Implementation Management: Promise and Performance. International Journal of Operations & Production Management, Vol. 10, No. 1, pp. 5-20.

Boer, H. & Krabbendam, K. 1992. Organizing for Manufacturing Innovation: The Case of Flexible Manufacturing Systems. International Journal of Operations & Production Management, Vol. 12, No. 7/8, pp. 41-56.

Bolwijn, P.T., Boorsma, J., van Breukelen, Q.H., Brinkman, S. & Kumpe, T. 1986. Flexible Manufacturing. Integrating Technological and Social Innovation. Amsterdam -Oxford - New York - Tokyo: Elsevier.

Braun, E. 1985. Constellations for Manufacturing Innovation. In: Rhodes, E. & Wield, D. (Eds.), Implementing New Technologies: Choice, Decision and Change in Manufacturing. Oxford: Basil Blackwell. Pp. 86-94.

Brown, J. 1991. Research that Reinvents the Corporation. Harvard Business Review, January-February, pp. 102-111.

Brödner, P. 1985. Skill Based Production - the Superior Concept to the "Unmanned Factory". In: Bullinger, H.-J. & Warnecke, H.J. (Eds.), Toward the Factory of the Future, Proceedings of the 8th International Conference on Production Research and 5th working Conference of the Fraunhofer-Institute for Industrial Engineering, University of Stuttgart, August 20-22. Pp. 500-505.

Brödner, P. 1989. In Search of the Computed-Aided Craftsman. AI & Society, 3, pp. 39-46.

Brödner, P. 1990a. The Shape of Future Technology. London - Berlin - Heidelberg -New York - Paris - Tokyo - Hong Kong: Springer-Verlag.

Brödner, P. 1990b. Technocentric - Anthropocentric Approaches: Towards Skill-Based Manufacturing. In: Warner, M., Wobbe, W. & Brödner, P. (Eds.), New Technology and Manufacturing Management. Strategic Choices for Flexible Production Systems. Chichester - New York - Brisbane - Toronto - Singapore: John Wiley & Sons. Pp. 101-111.

Bullinger, H.-J., Warnecke, H.-J. & Lentes, H.-P. 1985. Toward the Factory of Future. In: Bullinger, H.-J. & Warnecke, H.J. (Eds.), Toward the Factory of the Future, Proceedings of the 8th International Conference on Production Research and 5th working Conference of the Fraunhofer-Institute for Industrial Engineering, University of Stuttgart, August 20-22. Pp. XXIX-LXXII.

Burgoyne, J.G. 1994. Stateholder Analysis. In: Cassell, C. & Symon, G. (Eds.), Qualitative Methods in Organizational Research. A Practical Guide. London - Thousands Oak - New Delhi: Sage Publications. Pp. 187-207.

Burns, T. & Stalker, G.M. 1994. The Management of Innovation. Oxford: Oxford University Press, Third Edition (first edition in 1961).

Cassell, C. & Symon, G. 1994. Qualitative Research in Work Contexts. In: Cassell, C. & Symon, G. (Eds.), Qualitative Methods in Organizational Research. A Practical Guide. London - Thousands Oak - New Delhi: SAGE Publications. Pp. 1-13.

Child, J. 1985. Managerial Strategies, New Technology and the Labour Process. In: Knights, D., Willmott, H. & Collinson, D. (Eds.), Job Design - Critical Perspectives on the Labor Process. Aldershot: Gower. Pp. 107-141.

Clark, K.B. & Fujimoto, T. 1991. Product Development Performance. Strategy, Organization and Management in the World Auto Industry. Boston: Harvard Business School Press.

Clark, P. & Starkey, K. 1988. Organization Transitions and Innovation-Design. London and New York: Pinter Publishing.

Cole, R.E. 1994. Different Quality Paradigms and their Implications for Organizational Learning. In: Aoki, M. & Dore, R. (Eds.), The Japanese Firm. Sources of Competitive Strengh. Oxford - New York: Oxford University Press. Pp. 66-83.

Coulson-Thomas, C. 1994 (Ed.), Business Process Re-engineering: Myth & Reality. London: Kogan Page.

Corbett, J.M., Rasmussen, L.B. & Rauner, F. 1991. Crossing the Border. The Social and Engineering Design of Computer Integrated Manufacturing Systems. London -Berlin - Heidelberg - New York - Paris - Tokyo - Hong Kong: Springer-Verlag.

Cyert, R.M. & March, J.G. 1992. A Behavioral Theory of the Firm. Oxford: Blackwell, Second Edition (first edition in 1963).

Davenport, T.H. 1993. Process Innovation. Reengineering Work through Information Technology. Boston, Massachusetts: Harvard Business School Press.

Dean, J.W. Jr. 1987. Building the Future. The Justification Process for New Technology. In: Pennings, J.M. & Buitendam, A. (Eds.), New Technology as Organizational Innovation. The Development and Diffusion of Microelectronics. Cambridge, Massachusetts: Ballinger Publishing Company. Pp. 35-58.

Dosi, G. 1984. Technical Change and Industrial Transformation. The Theory and an Application to the Semiconductor Industry. Hong Kong: MacMillan Press.

Dosi, G. 1988. The Nature of the Innovative Process. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G. & Soete, L. (Eds.), Technical Change and Economic Theory. London - New York: Pinter Publishers. Pp. 221-238.

Economic Commission for Europe (ECE). 1986. Recent Trends in Flexible Manufacturing. New York: United Nations.

Edquist, C. & Jacobsson, S. 1988. Flexible Automation. The Global Diffusion of New Technology in the Engineering Industry. Oxford: Basil Blackwell.

Ehn, P. 1988. Work-Oriented Design of Computer Artifacts. Stockholm: Arbetslivcentrum.

Eijnatten, F.M. van 1993. The Paradigm that Changed the Work Place. Stockholm: The Swedish Center for Working Life - Assen: Van Gorcum.

Eisenhardt, K. 1989. Building Theories from Case Study Research. Academy of Management Review, Vol. 14, No. 4, pp. 532-550.

Engeström, Y. 1987. Learning by Expanding. An Activity-Theoretical Approach to Developmental Research. Helsinki: Orienta-Konsultit Oy.

Engeström, Y. 1994. Training for Change: New Approach to Instruction and Learning in Working Life. Geneva: International Labour Office.

Fix-Stertz, J., Lay, G. & Schultz-Wild, R. 1986. Flexible Fertigungsssysteme und Fertigungsellen. VDI-Z, Bd. 128, Nr. 11, pp. 369-379. (In German.)

Fix-Stertz, J., Lay, G., Schultz-Wild, R. & Wengel, J. 1990. Flexible Manufacturing Systems and Cells in the Federal Republic of Germany. In: Warner, M., Wobbe, W. & Brödner, P. (Eds.), New Technology and Manufacturing Management. Chichester: John Wiley & Sons. Pp. 191-212.

Freeman, C. 1982. The Economics of Industrial Innovation. London: Frances Pinter, Second edition.

Fryer, D. & Feather, N.T.1994. Intervention Techniques. In: Cassell, C. & Symon, G. (Eds.), Qualitative Methods in Organizational Research. A Practical Guide. London - Thousands Oak - New Delhi: Sage Publications. Pp. 230-247.

Garvin, D.A. 1993. Building a Learning Organization. Harvard Business Review, July-August, pp. 78-91.

Gerwin, D. 1988. A Theory of Innovation Processes for Computer-Aided Manufacturing Technology. IEEE Transactions on Engineering Management, Vol. 35, No. 2, May, pp. 90-100.

Gjerding, A.N. 1992. Work Organisation and the Innovation Design Dilemma. In: Lundvall, B.-Å. (Ed.), National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning. London: Pinter Publishers. Pp. 95-115.

Glaser, B.G. 1978. Theoretical Sensivity. Mill Valley, California: The Sociology Press.

Glaser, B.G. & Strauss, A.L. 1967. The Discovery of Grounded Theory. Strategy for Qualitative Research. Chicago: Aldine Publishing.

Gould, B. 1980. On the Adoption of Technological Innovations in Industry: Superficial Models and Complex Decision Processes. OMEGA The International Journal of Management Science, Vol. 8, No. 5, pp. 505-516.

Grant, R.M. 1996. Towards a Knowledge-based Theory of the Firm. Strategic Management Journal, Vol. 17 (Winter-Special Issue), pp. 109-122.

Gupta, Y.P. 1989. Human Aspects of Flexible Manufacturing Systems. Production and Inventory Management Journal, Second Quarter, pp. 30-35.

Hammer, H. 1991. Flexible Fertigungssysteme realisieren die Computerintegrierte Fertigung. Werkstatt und Betrieb 124, Nr. 5, pp. 355-360. (In German.)

Hartley, J.F. 1994. Case Studies in Organizational Research. In: Cassell, C. & Symon, G. (Eds.), Qualitative Methods in Organizational Research. A Practical Guide. London - Thousands Oak - New Delhi: SAGE Publications. Pp. 208-229.

Hietanen, A. 1993. The Adoption of New Manufacturing Technologies. Elaborating a Stakeholder Approach. Tampere: Acta Universitatis Tamperensis, ser A vol 362.

Hippel, E. von 1988. The Sources of Innovation. New York - Oxford: Oxford University Press.

Hirschhorn, L. 1986. Beyond Mechanization: Work and Technology in a Postindustrial Age. Cambridge, Massachusetts: The MIT Press.

Hirsch-Kreinsen, H. & Schultz-Wild, R. 1990. Implementation Processes of New Technologies - Management Objectives and Interests. Automatica, Vol. 26, No. 2, pp. 429-433.

Holbek, J. 1988. The Innovation Design Dilemma: Some Notes on its Relevance and Solutions. In: Gönhaug, K. & Kaufmann, G. (Eds.), Innovation: A Cross-Disciplinary Perspective. Oslo: Norwegian University Press. Pp. 253-277.

Hyötyläinen, R. 1988. FMS ja työorganisaatio. Julkaisussa: Joustava tuotanto ja rakennemuutos. Helsinki: SITRA, Sarja A nro 89. Pp. 235-248. (In Finnish.)

Hyötyläinen, R. 1993. FM-järjestelmän käyttöönotto innovaatioprosessina - valmistuksen näkökulma. The Implementation of FM-System as an Innovation

Process - The Viewpoint of Manufacturing. Helsinki University of Technology, Mechanical Engineering Department, Industrial Economy, Unpublished LicTech Thesis. (In Finnish.)

Hyötyläinen, R. 1994. The Implementation of FMS as an Innovation Process. In: Kidd, P.T. & Karwowski, W. (Eds.), Advances in Agile Manufacturing. Integrating Technology, Organization and People. Amsterdam - Oxford - Washington DC - Tokyo: IOS Press. Pp. 181-184.

Hyötyläinen, R., Norros, L. & Toikka, K. 1990. Constructing Skill-Based FMS - A New Approach to Design and Implementation. In: Utkin, V. & Jaaksoo, U. (Eds.), Preprints of 11th IFAC World Congress, 13-17 August 1990, Vol. 9. Tallinn, IFAC. Pp. 49-54.

Hyötyläinen, R., Simons, M., Tuominen, L., Ruuhilehto, K. & Aronen, K. 1991. Tuotannollinen muutos ja organisaatioinnovaatiot. Helsinki: Kaupunkiliiton painatuskeskus. (In Finnish.)

Hyötyläinen, R. & Simons, M. 1996. The Network Cell as a Step to Network Factory. Automation Technology Review 1996. Espoo: VTT Automation. Pp. 89-100.

Hyötyläinen, R., Tarvainen, K., Mikkola, M. & Simons; M. 1997. Networks as a Means to Develop New Modes of Operation for Industrial Finnish SMEs. In: Alasoini, T., Kyllönen, M. & Kasvio, A. (Eds.), Workplace Innovation - A Way of Promoting Competitiveness, Welfare and Employment. Ministry of Labour, National Workplace Development Programme, Reports 3, Yearbook 1997. Pp. 200-224.

Imai, M. 1986. Kaizen. The Key to Japan´s Competitive Success. New York: McGraw-Hill Publishing Company.

Imai, M. 1997. Gemba Kaizen A Commonsense, Low-Cost Approach to Management. New York: McGraw-Hill.

Ishikawa, K. 1985. What is Total Quality Control? The Japanese Way. Englewood Cliffs, N.J: Prentice-Hall.

Jaikumar, R. 1986. Postindustrial Manufacturing. Harvard Business Review, November-December, pp. 69-76.

Jones, B. 1989. When Certainty Fails: Inside the Factory of the Future. In: Wood, S. (Ed.), The Transformation of Work. London: Unwin Hyman. Pp. 44-58.

Julkunen, R. 1987. Työprosessi ja pitkät aallot. Työn uusien organisaatiomuotojen synty ja yleistyminen. Tampere: Vastapaino. (In Finnish.)

Kanter, R.M. 1988. The Change Masters. Corporate Entrepreneurs at Work. London - Sydney - Wellington: Unwin (originally published in 1983).

Kelley, M. & Brooks, H. 1988. The State of Computerized Automation in U.S. Manufacturing. Research Report, Harvard University, Center for Business and Government, Boston, October.

Kidd, P. (Ed.) 1990. Organization, People and Technology in European Manufacturing. CEC, FAST, APS Research Series, Vol. 3, FOP 247, November.

Kodama, F. 1995. Emerging Patterns of Innovation. Sources of Japan´s Technological Edge. Boston, Massachusetts: Harvard Business School Press.

Krafcik, J. 1988. Triumph of the Lean Production System. Sloan Management Review, Fall, pp. 41-52.

Kuitunen, K. 1991. Paradigms of Technological Innovation within the Firm. Scandinavian Journal of Management, Vol. 7, No. 3, pp. 205-217.

Kuivanen, R. 1990. The Impact on Safety of Disturbances in Flexible Manufacturing. In: Karwowski, W. & Rahimi, M. (Eds.), Ergonomics of Hybrid Automated Systems II. Amsterdam - Oxford - New York - Tokyo: Elsevier. Pp. 951-956.

Kuivanen, R. 1996. Disturbance Control in Flexible Manufacturing. The International Journal of Human Factors in Manufacturing, Vol. 6 (1), pp. 41-56.

Kuivanen, R., Tiusanen, R. & Lepistö, J. 1988a. Joustavien tuotantojärjestelmien ja -solujen käyttövarmuus ja turvallisuus. Julkaisussa: Ranta, J. & Huuhtanen, P. (toim.), Informaatiotekniikka ja työympäristö. Osa III: Informaatiotekniikka metallituote- ja konepajateollisuudessa. Helsinki: Työsuojelurahasto, Julkaisuja n:o A3. Pp. 67-100. (In Finnish.)

Kuivanen, R., Tiusanen, R. & Lepistö, J. 1988b. Disturbances in Flexible Manufacturing. In: Preprints of the IFAC/IFIP/IEA/IFORS Conference on Man-Machine Systems, Oulu, Finland, June 14-16. Pp. 472-475.

Kuutti, K. 1994. Information Systems, Cooperative Work and Active Subjects: The Activity-Theoretical Perspective. University of Oulu, Department of Information Processing Science, Research Papers, Series A 23.

Köhler, C. & Schultz-Wild, R. 1985. Flexible Manufacturing Systems - Manpower Problems and Policies. Journal of Manufacturing Systems, Vol. 4, No. 2, pp. 135-146.

Laurila, J. 1995. Social Movements in Management. Making a Technological Leap in the Case of the Anjala Paper Mill. Helsinki: Helsinki School of Economics and Business Administration, Acta Universitatis Oeconomicae Helsingiensis, A 100.

Lay, G. 1990. Strategic Options for CIM Integration. In: Warner, M., Wobbe, W. & Brödner, P. (Eds.), New Technology and Manufacturing Management.

Strategic Choices for Flexible Production Systems. Chichester - New York - Brisbane - Toronto - Singapore: John Wiley & Sons. Pp. 125-144.

Lehner, F. 1991. Anthropocentric Production Systems: The European Response to Advanced Manufacturing and Globalization. Synthesis Report, CEC, FAST, APS Research Series, Vol. 4, June.

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. 3, August, pp. 248-266.

Leonard-Barton, D. 1992. The Factory as a Learning Laboratory. Sloan Management Review, Fall, pp. 23-38.

Lillrank, P. 1990. Laatumaa. Johdatus Japanin talouselämään laatujohtamisen näkökulmasta. Jyväskylä: Gaudeamus. (In Finnish.)

Lindberg, P. 1992. Management of Uncertainty in AMT Implementation: The Case of FMS. International Journal of Operations & Production Management, Vol. 12, Nos. 7/8, pp. 55-75.

Lundvall, B.-Å. 1988. Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G. & Soete, L. (Eds.), Technical Change and Economic Theory. London - New York: Pinter Publishers. Pp. 349-369.

Lundvall, B.-Å. 1992. Introduction. In: Lundvall, B-Å. (Ed.), National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning. London: Pinter Publishers. Pp. 1-19.

Lyytikäinen, K. 1984. Hammaspyöräverstas. Tampere: Tampereen teknillinen korkeakoulu, konetekniikan osasto, diplomityö. (In Finnish.)

MacKenzie, D. & Wajcman, J. 1987. Introductory Essay. In: MacKenzie, D. & Wajcman, J. (Eds.), The Social Shaping of Technology. Milton Keynes - Philadelphia: Open University Press.

March, J. & Simon, H.A. 1958. Organizations. New York - London - Sidney: John Wiley & Sons, Inc.

Mieskonen, J. 1989. Suomalainen FM-järjestelmä. Havaintoja kentältä ja vertailuja kansainväliseen aineistoon. Helsinki: SITRA, TES-program in Finland, nro 11. (In Finnish.)

Miettinen, R. 1993. Oppitunnista oppimistoimintaan. Tutkimus opetuksen ja opettajankoulutuksen kehittämisestä Suomen Liikemiesten Kauppaopistossa vuosina 1986-1991. Tampere: Gaudeamus. (In Finnish.)

Mortimer, J. (Ed.) 1984. The FMS Report. By Ingersoll Engineers. Berlin - Heidelberg - New York - Tokyo: IFS (Publications) Ltd., UK.

Mortimer, J. (Ed.) 1985. Integrated Manufacture. By Ingersoll Engineers. Berlin - Heidelberg - New York - Tokyo: IFS (Publications) Ltd., UK.

Nadler, G. & Robinson, G. 1987. Planning, Designing, and Implementing Advanced Manufacturing Technology. In: Wall, T.B., Clegg, C.W. & Kemp, N.J. (Eds.), The Human Side of Advanced Technology. Chichester - New York - Brisbane - Toronto -Singapore: John Wiley & Sons. Pp. 15-36.

Nelson, R.R. 1987. Understanding Technical Change as an Evolutionary Process. Amsterdam - New York - Oxford - Tokyo: North-Holland.

Nonaka, I. 1991. The Knowledge-Creating Company. Harvard Business Review, November-December, pp. 96-104.

Nonaka, I. & Takeuchi, H. 1995. The Knowledge-Creating Company. How Japanese Companies Create the Dynamics of Innovation. New York - London: Oxford University Press.

Nord, W.R. & Tucker, S. 1987. Implementing Routine and Radical Innovations. Lexington, Massachusetts - Toronto: Lexington Books.

Norros, L. 1991. Development of Operator´s Expertise in Implementing New Technologies: Constructing a Model in a Case Study on Flexible Manufacturing. In: Enander, A., Gustavsson, B., Karlsson, J.C. & Starrin, B. (Eds.), Work and Welfare. Papers from the Second Karlstad Symposium on Work. University of Karlstad, Research Report 91:7. Pp. 67-82.

Norros, L. 1996. System Disturbances as Springboard for Development of Operators´ Expertise. In: Engeström, Y. & Middleton, D. (Eds.), Cognition and Communication at Work. New York: Cambridge University Press. Pp. 159-176.

Norros, L., Toikka, K. & Hyötyläinen, R. 1988a. FMS:n käyttöönotto: tapaustutkimuksen tuloksia. Julkaisussa: Ranta, J. & Huuhtanen, P. (toim.), Informaatiotekniikka ja työympäristö. Osa III: Informaatiotekniikka metallituote- ja konepajateollisuudessa. Helsinki: Työsuojelurahasto, Julkaisuja n:o A3. Pp. 139-189. (In Finnish.)

Norros, L., Toikka, K. & Hyötyläinen, R. 1988b. FMS-Design from the Point of View of Implementation - Results of a Case Study. In: Preprints of the IFAC/IFIP/IEA/IFORS Conference on Man-Machine Systems, Oulu, Finland, June 14-16. Pp. 405-410.

Norros, L., Toikka, K. & Hyötyläinen. R. 1989. Constructing Skill Based FMS - Lessons for Design and Implementation. In: Preprints of IFAC/IFIP/IMACS Symposium on Skill Based Automated Production, November 15-17, 1989, Vienna, Austria. 6 p.

Odagiri, H. & Goto, A. 1993. The Japanese System of Innovation: Past, Present, and Future. In: Nelson, R.R. (Ed.), National Innovation Systems. A Comparative Analysis. New York - Oxford: Oxford University Press. Pp. 76-114.

Ollus, M., Lovio, R., Mieskonen, J., Vuorinen, P., Karko, J., Vuori, S. & Ylä-Anttila, P. 1990. Joustava tuotanto ja verkostotalous. Helsinki: SITRA nro 109. (In Finnish.)

Perez, C. 1986. Structural Changes and Assimilation of New Technologies in the Economic and Social System. In: Freeman, C. (Ed.), Design, Innovation and Long Cycles in Economic Development. New York: St. Martin´s Press. Pp. 27-47.

Pettigrew, A.M. 1990. Longitudinal Field Research on Change: Theory and Practice. Organization Science, Vol. 1, No. 3, August, pp. 267-292.

Polanyi, M. 1983. The Tacit Dimension. Gloucester, Mass: Peter Smith (published originally 1966).

Pollard, S. 1968. The Genesis of Modern Management. A Study of the Industrial Revolution in Great Britain. Harmondsworth: Penguin Books.

Ranta, J. & Tchijov, I. 1990. Economics and Success Factors of Flexible Manufacturing Systems: The Conventional Explanation Revisited. International Journal of Flexible Manufacturing Systems, 2, pp. 169-190.

Rasmussen, J. 1986. Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering. New York - Amsterdam -London - London: North-Holland.

Rembold, U., Blume, C. & Dillmann, R. 1985. Computer Integrated Manufacturing Technology and Systems. New York and Basel: Marcel Dekker.

Rogers, E. M. 1995. Diffusion of Innovations. New York - London - Toronto - Sydney - Tokyo - Singapore: The Free Press, Fourth Edition (first edition in 1962).

Rose, M. 1975. Industrial Behaviour. Bristol: Allen Lane.

Rosenberg, N. 1976. Perspectives on Technology. Cambridge: Cambridge University Press.

Rosenberg, N. 1985. Inside Black Box: Technology and Economics. Cambridge - London - New York - New Rochelle - Melbourne - Sydney: Cambridge University Press.

Rosenberg, N. & Steinmueller, W.E. 1988. Why are Americans Such Poor Imitators? AEA Papers and Proceedings, May, pp. 229-234.

Rosenbrock, H. 1981. Engineers and the Work That People Do. IEEE Control Systems Magazine, September, pp. 4-8.

Rosenbrock, H. (Ed.) 1989. Designing Human-Centred Technology. A Cross-Disciplinary Project in Computer-Aided Manufacturing. London - Berlin - Heidelberg - New York - Paris - Tokyo - Hong Kong: Springer-Verlag.

Rouse, W.B. 1991. Design for Success. A Human-Centered Approach to Designing Successful Products and Systems. New York - Chichester - Brisbane - Toronto - Singapore: John Wiley & Sons.

Rouse, W.B. & Cody, W. 1988. On the Design on Man-Machine Systems: Principles, Practices and Prospects. Automatica, Vol. 24, No. 2, pp. 227-238.

Räsänen, K. 1986. Tensions in Management. A Study of Managerial Work Processes and Firm Performance. Helsinki: Acta Academiae Oeconomicae Helsingiensis, Series A:25.

Sabherwal, R. & Robey, D. 1993. An Empirical Taxonomy of Implementation Processes Based on Sequences of Events in Information System Development. Organization Science, Vol 4, no. 4, November, pp. 548-576.

Sahal, D. 1981. Patterns of Technological Innovation. London - Amsterdam - Don Mills, Ontario - Sydney - Tokyo: Addison-Wesley Publishing Company.

Sandberg, T. 1982. Work Organization and Autonomous Groups. Uppsala: Liber Förlag.

Sayer, A. 1992. Method in Social Science. A Realistic Approach. Second Edition. London and New York: Routledge.

Senge, P. 1990. The Fifth Discipline. The Art and Practice of the Learning Organization. New York: Doubleday.

Senker, P. 1986. Towards the Automatic Factory? The Need for Training. Bedford -Berlin - Heidelberg - New York - Tokyo: IFS (Publications) Ltd and Springer-Verlag.

Seppälä, P., Tuominen, E. & Koskinen, P. 1986. Joustava valmistus Oy Tampella AB Tamrockin Myllypuron tehtailla. Informaatiotekniikka ja työympäristö -tutkimusohjelma, julkaisematon raportti. 29 p. + app. (In Finnish.)

Seppälä, P., Tuominen, E. & Koskinen, P. 1988a. Joustavien valmistusjärjestelmien käyttöönotto suomalaisissa konepajoissa. Julkaisussa: Ranta, J. & Huuhtanen, P. (toim.), Informaatiotekniikka ja työympäristö. Osa III: Informaatiotekniikka metallituote- ja konepajateollisuudessa. Helsinki: Työsuojelurahasto, Julkaisuja n:o A3. Pp. 29-66. (In Finnish.)

Seppälä, P., Tuominen, E. & Koskinen, P. 1988b. Uuden tuotanto-organisaation toteutus ja vaikutukset: tapausesimerkki. Julkaisussa: Ranta, J. & Huuhtanen, P. (toim.), Informaatiotekniikka ja työympäristö. Osa III: Informaatiotekniikka metallituote- ja konepajateollisuudessa. Helsinki: Työsuojelurahasto, Julkaisuja n:o A3. Pp. 101-138. (In Finnish.)

Silverberg, G. 1990. Adoption and Diffusion of Technology as a Collective Evolutionary Process. In: Freeman, C. & Soete, L. (Eds.), New Explorations in the Economics of Technical Change. London - New York: Pinter Publishers. Pp. 177-192.

Sitkin, S.B. 1996. Learning Through Failure. The Strategy of Small Losses. In: Cohen, M.D. & Sprull, L.S. (Eds.), Organizational Learning. Thousand Oaks - London - New Delhi: Sage Publications. Pp. 541-577.

Slaughter, S. 1993. Innovation and Learning during Implementation: A Comparison of User and Manufacturer Innovations. Research Policy 22, pp. 81-95.

Small, M.H. & Yasin, M.M. 1997. Developing a Framework for the Effective Planning and Implementation of Advanced Manufacturing Technology. International Journal of Operation & Production Management, Vol. 17, No. 5, pp. 468-489.

Soete, L. 1987. Employment, Unemployment and Technical Change: A Review of the Economic Debate. In: Freeman, C. & Soete, L. (Eds.), Technical Change and Full Employment. Oxford - New York: Basil Blackwell. Pp. 22-35.

Sorge, A., Hartmann, G., Warner M. & Nicholas, I. 1985. Microelectronics and Manpower in Manufacturing. Applications of Computer Numerical Control in Great Britain and West Germany. Aldershot: Gower.

Spender, J.-C. 1996. Making Knowledge the Basis of a Dynamic Theory of the Firm. Strategic Management Journal, Vol. 17 (Winter-Special Issue), pp. 45-62.

Strauss, A. & Corbin, J. 1990. Basics of Qualitative Research. Grounded Theory Procedures and Techniques. Newbury Park - London - New Delhi: Sage Publications.

Tainio, R., Räsänen, K. & Santalainen, T. 1985. Suuryritykset ja niiden johtaminen Suomessa. Tampere: Weilin+Göös. (In Finnish.)

Taylor, F. 1913. The Principles of Scientific Management. New York - London: Harpers.

Thorsrud, E. 1980. The Changing Structure of Work Organisation. In: Kanawaty, G. (Ed.), Managing and Developing New Forms of Work Organisation. Geneva: International Labour Office, Management Development Series No. 16, pp. 3-31.

Tobin, D.R. 1998. The Knowledge-Enabled Organization. Moving from “Training” to Learning to Meet Business Goals. New York: AMACOM.

Toikka, K. 1987. Development of Work in FMS - Case Study on New Manpower Strategy. In: Brödner, P. (Ed.), Skill Based Automated Manufacturing. Oxford - New York - Beijing - Frankfurt - Sao Paulo - Sydney - Tokyo - Toronto: IFAC, Pergamon Press. Pp. 7-12.

Toikka, K., Norros, L. & Hyötyläinen, R. 1986. Development of Work in Flexible Manufacturing. Nordisk Pedagogik, Årg. 6, Nr. 1, pp. 16-24.

Toikka, K., Norros, L & Hyötyläinen, R. 1988. Kehittyvää työtä tutkimassa - metodologisia kysymyksiä. Julkaisussa: Ranta, J. & Huuhtanen, P. (toim.), Informaatiotekniikka ja työympäristö. Osa II: Vaikutusten tutkimisen metodiikka. Helsinki: Työsuojelurahasto, Julkaisuja n:o A2. Pp. 105-142. (In Finnish.)

Toikka, K., Hyötyläinen, R., Kuivanen, R. & Norros, L. 1990. Porakonetehtaan tutkimusprojektin työraportti. The Working Report of the Research Project in Case C. Technical Reseach Centre of Finland, Electrical Engineering and Automation Laboratory and Safety Engineering Laboratory 27.2.1990. 19 p. (Unpublished). (In Finnish.)

Toikka, K., Norros, L., Hyötyläinen, R. & Kuivanen, R. 1991a. Häiriönhallinta joustavassa valmistuksessa. Toinen painos. Tampere: Työsuojelurahasto, Julkaisuja n:o A14. (In Finnish.)

Toikka, K., Norros, L & Hyötyläinen, R., 1991b. Hard Road to CIM - Lessons from Constructing a Skill Based FMS. Technical Research Centre of Finland, VTT Automation, 70 p. (Unpublished Report.)

Toikka, K., Hyötyläinen, & Kuivanen, R. 1992. Porakonetehdas-projektin väliraportti. Intermediate Report in the Case C. Technical Research Centre of Finland, Electrical Engineering and Automation Laboratory and Safety Engineering Laboratory 12.2.1992, 39 pp. (Unpublished).(In Finnish.)

Toikka, K. & Kuivanen, R. 1993. Häiriöt kehitysmahdollisuutena. Tekniikan, organisaation ja työtavan kehitys joustavassa valmistusjärjestelmässä. Tampere: Tammer-Paino Oy. (In Finnish.)

Trist, E. 1981. The Evolution of Socio-Technical Systems. A Conceptual Framework and an Action Research Program. Ontario Quality of Working Life Centre. Issues in the Quality of Working Life, A Series of Occasional Papers, No. 2, June.

Tushman, M. & Nadler, D. 1986. Organizing for Innovation. California Management Review, Vol. XXVIII, No. 3, Spring, pp. 74-93.

Urabe, K. 1988. Innovation and the Japanese Management System. In: Urabe, K., Child, J. & Kagono, T. (Eds.), Innovation and Management: International Comparisons. Berlin and New York: Walter de Gruyter. Pp. 3-25.

Van de Ven, A.H. 1986. Central Problems in the Management of Innovation. Management Science, Vol. 32, No. 5, May, pp. 590-607.

Van de Ven, A.H. & Poole, M.S. 1990. Methods for Studying Innovation Development in the Minnesota Innovation Research Program. Organization Science, Vol. 1, no. 3, August, pp. 313-335.

Voss, C.A. 1988a. Implementation: A Key Issue in Manufacturing Technology: The Need for a Field of Study. Research Policy, Vol. 2, No. 17, pp. 55-63.

Voss, C.A. 1988b. Success and Failure in Advanced Manufacturing Technology. International Journal of Technology Management, Vol. 3, No. 3, pp. 285-297.

Vygotsky, L.S. 1978. Mind in Society. The Development of Higher Psychological Processes. Edited by Cole, M., John-Steiner V., Scribner, S. & Souberman, E. Cambridge, Massachusetts - London: Harvard University Press.

Westbrook, R. 1995. Action Research: A New Paradigm for Research in Production and Operations Management. International Journal of Operations & Production Management, pp. 6-20.

Winter, S.G. 1996. Organizing for Continuous Improvement. Evolutionary Theory Meets the Quality Revolution. In: Cohen, M.D. & Sproull, L.S. (Eds.), Organizational Learning. Thoudands Oaks - London - New Delhi: Sage Publications. Pp. 460-483.

Wobbe, W. 1992. What are Anthropocentric Production Systems? Why are They a Strategic Issue for Europe? CEC, FAST, Report EUR 13968 en.

Womack, J.P., Jones, D.T. & Roos, D. 1990. The Machine that Changed the World. New York: Rawson Associates.

Wright, G.H. von 1987. Tiede ja ihmisjärki. Keuruu: Otava. (In Finnish.)

Yin, J.Z. 1994. Managing Process Innovation through Incremental Improvements: Empirical Evidence in the Petroleum Refining Industry. Technological Forecasting and Social Change 47, pp. 265-276.

Yin, R.K. 1989. Case Study Research. Design and Methods. Newbery Park - London - New Delhi: SAGE Publications.

Yoshitomi, M. 1996. New Challenges for the Current Technology Paradigm in Japan. Paper presented at the OECD/Norwegian Ministry of Education Conference on Creativity, Innovation and Job Creation, on 11-12 January, 1996, Oslo, Norway.

Zuboff, S. 1988. In the Age of the Smart Machine. The Future of Work and Power. New York: Basic Books.

SUMMARY OF THE INTENSIVE CASE STUDIES

Table 1 presents the summary of the case studies, the development cycles in the companies, the research phases and activities connected to them and the research methods used. The *FMS-study* began in 1985 and was completed in 1992. Case study A covers the years 1985-89, case study B the years 1986-89 and case study C the years 1989-92.

The researchers *participated actively in and followed up intensively* the implementation process of the case systems. The case studies are based on the approach of *experimental development research* (see Sections 1.3 and 4.1). In cases A and C, the researchers participated actively in the implementation process to create and introduce *new methods, tools and organizational forms* in the user organization. In these cases, the researchers participated in the change processes in the companies almost on a weekly basis. Case studies A and C have been the main sources for this study. Instead, case study B was by its nature a *follow-up study* although new methods were applied for the observation of the users′ activity and the operation of the system. Case study B was aimed at producing comparative material especially for the results of case study A. Besides, systems A and C are large FM-systems whereas system B is a relatively small FMS.

RESEARCH PHASES AND ACTIVITIES

The *FMS-study* was started in the spring of 1985 and lasted to the end of 1992. It proceeded through *three main phases* during which the emphasis and focus of the study changed and developed. The results gained in the previous phase brought up new dilemmas and helped to focus the problem setting of the phase to follow. The long research process was also a learning process for the researchers. In the following the phases and their problem-setting are presented (see Table 1):

Table 1. Summary of the intensive case studies.

CASE	DEVELOPMENT CYCLE IN THE COMPANY	RESEARCH PHASES AND ACTIVITIES	METHODS
CASE A: Implementation of a large FMS	**Planning phase** Feasibility study 6/83- Technical design 6/84- Training of the users 2/85 - 3/86 **Implementation phase** 12/85 - 4/88 Cell by cell, stepwise Implementation of the central control system 11/87- **Beginning of "normal" use** 5/88-	**Basic analysis** 3/85- Theoretical analysis Planning analysis Change analysis **Experimentation** 10/85 - 11/87 Experimental system training **Follow-up** Follow-up of changes Disturbance control and development activity analysis 9/86 - 11/87 Intensive follow-up 5-6/89	Interviews, document and organizational analysis, tasks in training Training, simulation, safety analysis Interviews Log books in cells kept by the users, Follow-up of operation and user activity, interviews
CASE B: Implementation of a small FMS	**Planning phase** Feasibility study 83- Technical design 1/84- Training of the users **Implementation phase** 8/85 - 4/86 **The beginning of "normal" use** 5/88-	**Basic analysis** 4/86- Planning analysis Change analysis **Follow-up** Intensive follow-up 10/89 Feedback meeting 1/91	Interviews, document and organizational analysis Follow-up of operation and user activity, interviews
CASE C: Implementation of a large FMS	**Planning phase** First plans of a new factory 1/88- Investment decision 12/88 Technical design 1/89- Realization planning 10/90- Training of the users **Implementation phase** 6/91-	**Basic analysis** 9/89- Theoretical analysis Planning analysis Change analysis **Experimentation** 6/91 - 2/92 Disturbance log books Intensive follow-up 12/91 Development model 2/92 **Follow-up** 3-11/92 Log books, follow-up	Interviews, document and organizational analysis Development group, log books kept by the users, follow-up of operation and user activity, development model and report Log books, follow-up, interviews

(1) *The first phase of the intensive FMS-research* focused on the implementation process of large **system A**. The whole process, from the beginning of the planning to the starting of "normal" use, took about five years. The feasibility study began in June 1983 and the implementation was started in December 1985. The system was implemented stepwise, cell by cell, the central control system being implemented last, in November 1987. "Normal" operation of the system was achieved in May 1988.

Case study A is based on the approach of *experimental development research*. In case A, forming of new practices was attempted consciously through experimental activity. However, the experimental development activity was restricted mainly to *system training* in which the design issues of the system were also included. The systematic *follow-up of disturbances, problems and development measures* was organized *through log books kept by the users* during the implementation phase of the system. The long time study activity of system A forms the basis of this study.

Table 1 presents the main phases and activities of case study A together with the change process of the case system. The case study began in the spring 1985 and continued until the summer of 1989, lasting over four years. The study material covers the entire period. The *field work* of the case study was divided into two phases. The first phase lasted from the spring of 1985 to the end of 1987. During 1988 only two research visits were made to the plant. The second phase started in January 1989 and lasted half a year. The research phases, methods and study material are presented in more detail in Appendix 2.

In the first phase of the intensive FMS-research, in *case study A* the first problem concerned the question of what kind of a *way of working* the mastering of the FMS demanded from the users. The second problem was the question of *how a well functioning FMS would have to be designed and planned* (Norros et al. 1988a and b).

(2) *The second phase of the FMS-research* began in the beginning of 1989, case study A continued and the analysis of system B was started. Based on the results of the first phase, special attention was paid to *disturbances and problems* in the "normal" operation of the systems and to *disturbance control* as well as *development activity* of the users and the user organization (see Toikka et al. 1991a).

Systems A and B belonged to different companies. *System A* was studied in that phase for half a year, beginning from January 1989, as presented above. Case **system B** was included in the study in the autumn of 1989. The analysis results of system B were aimed at acting as *comparative material* for case A.

Case study B was by its nature a *follow-up research* but in the study new kinds of observation methods were used for examining the real use activity of the system, among others the operation of the system as well as the activity of the users were observed minute by minute during two shifts with the same method as in the case of system A.

System B is a relatively small FM-system and already four years in the autumn of 1989 had passed from its implementation. The feasibility study of system B began in 1983 and the technical design in the beginning of 1984. The implementation of the system started in the summer of 1985. It is at this time that the system can be seen to have reached a stable state of activity. The case study concerning system B ended in January 1990. The change process of case B and the main phases of the case study are presented in Table 1. The research phases, methods and study material are presented in more detail in Appendix 2.

(3) *The third phase of the FMS-research* focused on the implementation process of **system C**. As a part of the realization of a new factory a relatively large FM-system was implemented. The planning phase took about 2,5 years. The implementation of system C began in June 1991. The implementation turned out to be a slow and difficult process which was still continuing at eighteen months after the beginning of the implementation, when the case study ended.

Case study C is based on the approach of *experimental development research*. Creation of new practices for the organization was tried by the research activities. In case C, the researchers were able to participate actively in the implementation process in its different phases. In the planning phase, the *assessment of the planning situation* with recommendations for development efforts to the organization were made. The systematic *follow-up of disturbances, problems and development measures through log books kept by the users* was organized from the beginning of the implementation of the system. *Disturbance data was analyzed* and processed during the implementation phase. Correspondingly, the *analysis of problems and development needs* of the system with proposals for development measures were made in the case study. The organization had difficulties in forming common development programs. *New methods and tools for development activity* were formed and tried out in the organization.

The goal of case study C was to produce knowledge on the need and opportunity for *systematic develoment activity* (see Toikka & Kuivanen 1993). Case study C was a central case for the conclusions of this study.
The main phases of case study C together with the change process of case C are presented in Table 1. The research phases, methods and study material are presented in more detail in Appendix 2.

RESEARCH PHASES, METHODS AND STUDY MATERIAL IN THE INTENSIVE CASE STUDIES

The *FMS-research* was started in the spring of 1985 and lasted to the end of 1992. The object of the three case studies (cases A - C) was the implementation process of FMS (Flexible Manufacturing System). Case study A covered the years 1985 - 89, case study B the years 1986 - 89 and case study C the years 1989 - 92. Case studies A and C were the main sources in this study, based on the approach of experimental development research. Case study B was by its nature a follow-up study, aimed at producing comparative material especially for the results of case study A. In the following the research phases, methods and study material in the case studies are presented.

Case Study A

The reseach on case A started by **basic analysis**, beginning in March 1985 (see Table 1 in Appendix 1). First, a *theoretical analysis* of the implementation issues of the FMS was made, based on the literature and studies on the subject. The result was the basic hypothesis on a new way of working and planning. Second, the *planning process and designs* of system A were analyzed. Third, the *change process* and the users´ orientation were studied. Material of the planning process, the designs and the change process was acquired through the following methods:

- interviews of the production manager, the department chief, the main designer of the system, a planner of the central control system, and two supevisors; the interviews were repeated several times during the study;
- interviews of all six workers becoming the users of the system in October 1985;
- document analysis concerning the planning process, designs, and change;
- organizational and job analysis concerning the organization of the plant and the jobs of the supervisors and workers in the old production.

In addition, information of these questions was collected during the system training given by the researchers, especially through the tasks performed and the models produced.

Implementation of the first cells of system A was started in December 1985. In this connection, the **experimentation phase** was started as *experimental system training*, the first training session held in October 1985 and the last one in November 1987, nine training sessions in all. The methods used were training, simulations of the system and its control, and safety analysis of the system. The preparation of the training sessions and the tasks and simulations done in them were registered carefully, with detailed descriptions and models as well as recorded tapes of the sessions.

In the study of system A, **follow-up** was going on continuously. The i*nterviews* of the management, the planners and the users produced information for the follow-up of the system implementation and of the activity of different persons. The implementation of the system proceeding stepwise was systematically followed up during 15 months (September 1986 - November 1987). During that period the main focus was on the analysis of *disturbance control and development activity*. The methods used during that period were as follows:

- Interviews: The leader of the system was interviewed five times. All six users were interviewed in June 1986;
- Log books: Log books were set up in four cells, of which only three were in full operation at that time, and on the loading and unloading station. The users recorded daily the normal production events, the problems, the occurred disturbances and the experiment and development activities (see Toikka et al. 1991a, Appendix 1);
- Follow-up visits: The researchers´ visits numbered 19 and took place in general every two to three weeks. During the visits, the researchers observed the use situation of the system, discussed that with the users and went through the records made after the previous visit together with the users. The researchers also drew up a report immediately on the basis of the visits.

In *the last phase of the follow-up,* the researchers *observed intensively* the operation of system A and the activity of the users in May 1989, when the system as a whole had been in "normal" operation for one year (see Norros et al. 1989; Toikka et al. 1991a). The observation was carried out on two days during which minute by minute registrations of the production flow and the users´ activities in the three shifts were taken. The researchers filled in two forms in the case of each disturbance (see Toikka et al. 1991a, Appendix 2). Disturbance was defined as the state or activity of the system which deviated from the planned or aimed one (Toikka et al. 1991a, 8). The causes for a disturbance as well as its effect on production, materials and work safety were assessed. In addition, the use activity with regard to the disturbances and disturbance control were examined and assessed according to the dimensions of the diagnosis, co-operation, measure planning, and further development activities. After the observation, the users were interviewed, with the aim to discuss the users´ developmental expertise and contribution to the system development during “normal” operation of the system.

Case Study B

The study on system B started by a **basic analysis** (see Table 1 in Appendix 1). In April 1986 the researchers interviewed the production manager of the plant. The *interview* concerned the planning and implementation of system B. As a part of the study concerning the implementation process of seven Finnish FM-systems Seppälä et al. (1988a) also examined system B. During this examination the work report concerning system B was made in 1986 (Seppälä et al. 1986). System B was also one of the targets in the investigation of Finnish FM-systems where material was collected from the autumn of 1987 to the spring of 1989 (Mieskonen 1989).

In case study B information was collected in the autumn of 1989 by *interviews*. First the production manager of the plant and the manager of the product shop were interviewed. The reseachers interviewed separately the supervisor who also answered for system B.

The **follow-up** phase began after that. The operation of system B and the activity of the users were observed minute by minute through *intensive observation* during two shifts which operated manned, the night shift being unmanned (see Toikka et al. 1991a). All disturbances that occurred in that period were registered and a disturbance follow-up form was filled in the case of each disturbance (see Toikka et al. 1991a, Appendix 2; the same form was used as in case A). The form included information of the disturbance identification, reasons for the disturbance and its impacts, and the user activities. The data of the disturbance was complemented during the observation by discussing with the users. All activities of the users were also registered during the observation period. About a month after the intensive observation the researchers made a *group interview* with the users. The researchers discussed the results of the intensive observation with the users and asked them to assess the results. The *summary report* on the study made by the researchers was discussed in the *feedback meeting* arranged in the plant in January 1990 (Toikka et al. 1990).

Case Study C

Case study C began by a **basic analysis** (see Table 1 in Appendix 1). The situation of the planning of system C was studied and evaluated the first time in the autumn of 1989 as a part of the study of system B, because systems B and C were located in the same company. At that time the decision on the acquisition of machines for system C had not yet been made. The situation of the planning was considered especially from the viewpoint of how big the change from old FMS B to new system C would be and how well this was realized in the planning. The researchers made development proposals concerning the planning and its organization, and the implementation of system C. *The situation analysis of the planning* and the development proposals were discussed in January 1990 in a *feedback session* in the plant - when the technical design of the new factory as well as of system C had continued for a year. The result of the feedback session was presented to the plant as a *work report* (Toikka et al. 1990; see also Toikka et al. 1991a, Appendix 4).

The next time the researchers returned to the analysis of system C in the FMS-research was in April 1991, when the installation of the machines of the system was started. The planner answering for the manufacturing system and technology of the new factory was interviewed in April 1991 and the product shop manager in June 1991.

The whole *field phase* of the study concerning *the implementation of system C* was divided into two stages (see Toikka & Kuivanen 1993). The first stage covered a period of eight months (June 1991 - February 1992) and the second phase ten months (March - November 1992). The aim of the *first phase* was to bring *new methods and tools* for the development work of the organization. In the *second phase* the researchers *followed up* in what form and to what extent the organization adopted new tools and procedures for its development work and what the results were.

The first phase was an **experimental** one. The phase began by forming a *development group* for helping the organization in the development work. The group consisted of the product shop manager, the planner for the manufacturing system and technology, two methods designers, all eight users, the shop steward and three researchers (see Toikka and Kuivanen 1993). The group met three times. In the *first meeting* in June 1991 it was decided that the log books would be introduced. There were four separate *log books* in the system. The users marked down in the log books disturbances and their time and duration, what was done for eliminating the disturbance and the development proposal and who marked down the entry (see about the form of the log book, Toikka and Kuivanen 1993, Appendix 2). Disturbance data were collected in the log books for 16 months (June 1991 - September 1992).

The researchers made *follow-up visits* to the factory, during which the disturbance entries in the log books were discussed together with the users. At the same time, the researchers made *structured interviews* on the disturbances with the users. The aim was to get more information on the disturbances and to evaluate the disturbance orientation of the users. Therefore, the answers of the users were coded into a form where different matters were assessed: observation, diagnosis, measure planning, disturbance control, and further starting (see about the form, Toikka et al. 1991a, Appendix 2). A report was made directly after every visit. The follow-up visits totalled 11, all of which were made before the end of 1991. All in all, the structured form was filled for 51 disturbances (see Toikka & Kuivanen 1993, Appendix 1).

The *second meeting* of the development group was held in October 1991. The researchers made an *analysis* of the material of the log books and showed how that material could be used as a means for systematic development of the system.

All eight users of system C were *interviewed* in November 1991. Also the product shop manager and both methods designers were interviewed together in November 1991. The interviews were conducted as a thematic interview. The themes contained the following points: the development phase of the FMS; activity of the users; tasks of the users, co-operation between the users and other personnel, disturbances and problems, disturbance control and development activity, tasks, and the wage system.

The operation of the system and the activity of the users were *observed intensively* minute by minute during two shifts in December 1991. The method applied was the same as in cases A and B. The researchers *discussed* the result of the intensive observation with the users in January 1992.

In January 1992, the planner for the manufacturing system and technology, the planner answering for the central control of system C and both methods designers were *interviewed*. The main point was the tasks of each one and the implementation situation of the system.

The *third meeting* of the development group was held in February 1992. The researchers presented the *summary report* on the problems and development needs of the system and the organization. Also the proposal for *the model of tools and organizational practices for development activity* was made (Toikka et al. 1992).

The **follow-up** began in March 1992. After the third meeting of the development group the product shop manager called a *cell meeting*, in which the users of system C, both methods designers, the product shop manager and the production manager participated. All in all, seven cell meetings were held during the follow-up phase of the study (in March - November 1992). The representatives of the assembly took part in the second meeting, when the production control and parts assembly were considered. An expert of the vendor was present in the last cell meeting, in which the disturbances and problems of the central control were addressed. The researchers *followed up* the last four cell meetings. The researchers made a summary *report* of the disturbances for the seventh meeting.

The end *interviews* were made in the autumn of 1992. The users of system C were interviewed together in November 1992. Also the product shop manager and both methods designers were interviewed in November 1992. The themes of the interviews contained the following topics: markets and the production situation; the development phase of system C; the organization of the support functions and their relations to the users; the tasks and division of labour of the users; the skills of the users; disturbances and problems; disturbance conrol and development activity; the way of working of the users; and the wage system.

APPENDIX 3

PROBLEMS IN SYSTEM C IN THE IMPLEMENTATION PHASE

PROBLEM	DESCRIPTION
1. Shortcomings in the central control system	Problems among others in the transfer of information and programs and in the control of some devices.
2. Variation of pressure in the cutting liquid system	This increased the need for control on the machines and caused breakage of cutting tools.
3. Problems in the feed of the cutting liquid	The machining centers stopped due to a low feed of cutting liquid in special M 50-machining operation.
4. Problems in tool change in one machining center	There were continuous problems in the tools changing system resulting in a lot of troubleshooting.
5. Ending of guide lubrication oil	This caused some stoppages of the machining centers.
6. Problems in jigs	There were problems in the solid structure of the jigs for certain products produced in the machining centers.
7. Shortcomings of hoist devices	That increased exertion and stress for the users.
8. Difficulties in fixing workpieces into pallets	There were different fastening screws in the pallet, which demanded the use of several tools and slowed down work.
9. Difficulties in manual drilling	The users manually drilled certain parts, focusing difficult.
10. Shortage of manual sharp edge removal places	The places were decreased from the plan, which caused backlog due to the increase in the production.
11. Problems in transport of workpieces	The transport cage for the parts washing machine was too big for the space, which resulted in the users having to carry parts.
12. Problems in loading parts to the transport cage	The sides of the transport cage were too high, which caused exertion for the users.
13. Shortage of tools for the machining centers	The shortage caused problems in flexibility, methods design, programming, assembly and control of tools
14.Sharp edge removal robot unused	This increased the need for manual removal, which caused time and ergonomic problems.
15. Slowness in implementing the gantry robot for the lathe	Programming and design of the grippers was a great effort. That formed an obstacle for automatic operation.
16. Drawing program unused	It was possible to draw descriptions of the presetting and the work phases by the tools management system.
17. Time control of the cutting tools unused	Automatic control could not be used, because the length of the operation time was not defined in the machining centers.

Please turn over

Appendix 3 continues

PROBLEM	DESCRIPTION
18. Measure checking for bits unused in the machining centers	This concerned programs for the machining centers. Checking is a precondition for automatic operation.
19. Simulation characteristics unused	There were possibilities for program checking by simulation in the machining centers but they were unused.
20. Lack of the probe for parts measurement in the lathe	The probe was a necessary precondition for unmanned operation in the lathe.
21. Individual ways of working	Lack of systematic methods caused failures and made automatic operation difficult.
22. Disappearance of use data and knowledge	There were problems especially in the transfer of knowledge between the different shifts.
23. Changing of the filter for the cutting liquid system	Stoppage of the filter had caused failures in the machining centers when the liquid flow had stopped.
24. Errors in compensating values in the machining centers	Changing of values when repairing programs from the users´ memory caused risk situations and even damages.
25. Disorder of tools	Tools were brought from many quarters, which was a cause for the disorder of tools, toolholders, and cutters.
26. Lack of file of tools and their settings	There was no file of the tools, which was an obstacle for the use of the automatic tools management system.
27. Shortcomings in the disturbance data	There were shortcomings in the disturbance control advice in the log books.
28. Need for working instructions	There was a need for working instructions and comments on the use of tools for systematic working.
29. Further training needed by the users	The users desired further training in the control system, disturbance control and programming.
30.Obsolete wage system	The old system had a negative effect on the users´ work motivation, group spirit and motivation for training.
31. Problems in the flow of information	There were "holes" in the organization preventing systematic flow of information in the use organization.
32. Confusion with work planning in the system	There was no systematic program but impulses for the production came from many sources to the users.
33. Problems in organization of the support functions	There was confusion in the supervision of work and in the responsibilities of the different support persons.
34. Disconnection of knowledge of problems	Knowledge of problems and development needs was scattered in different persons without common goals.

Published by

Series title, number and report code of publication

VTT Publications 337
VTT–PUBS–337

Author(s)
Hyötyläinen, Raimo

Title

Implementation of technical change as organizational problem-solving process

Management and user activities

Abstract

During the last two decades the growing innovation and management research has paid attention to the aspects of technical change. However, there are differing assumptions about the nature of the process of change. According to the innovation design dilemma two categories of innovation related to technical change have been identified, technical and organizational innovation. It has been become evident that there is a growing need to unite these two types of innovation into a common approach.

The focus of the study is the planning and implementation process of technical change in the user organization. The aim is to find out what kinds of planning and implementation models, methods and organizational forms can further innovative and organizational problem-solving activity in the implementation process of technical systems, which is contributing to the success of this process.

The study is based on long term and intensive development and research activity concerning the implementation process of three Flexible Manufacturing Systems in two companies. The FMS-study began in 1985 and was completed in 1992. Through the developmental approach based on experimental development research, the study was able to specify in great detail the progress of the implementation process in the cases. Attention was paid to social activity of the implementation process. The issue is how and by whom new techno-organizational solutions are finally brought about and carried out inside the user organization. New training, planning, organization and development methods were introduced and experimented with in the intensive cases, which created a rich and real picture of development potentials of the organization.

The analysis of the case study results showed that the implementation process of technical change consisted of a series of problem-solving and development steps taken by the user organization and its actors. This was a controversial, complex and long process in which the management, planners, support persons and users with different interests and ways of acting designed and constructed, mainly in a step by step way, the concrete technical and organizational characteristics of the “activity system”. This was performed by solving planned and unanticipated problems that emerged during the definition of the innovation problem and goal setting, planning phase, implementation phase and operation phase.

The system model of the implementation process of technical change was created based on the analysis and evaluation of the case study results. The model presents in great detail the connections and relations between the results of the implementation process in the cases and the management´s and users´ ways of acting with their many dependencies and interactions.

According to the system model of the implementation process, the most important factors from the point of view of the success or failure of the results are the following elements: viewpoint on the nature of change; design concept; and organizational patterns. The relations of these elements are described by the development model of the implementation process of technical change. The development model is further specified and presented as a solution to the innovation design dilemma.

The case study results proved that the organizational patterns carried the most central role in explaining the results of the implementation process. They determined the quality of the problem-solving process in the planning process, implementation phase and “normal” operation phase through which the results were gained. In the cases, the roles of support persons and users, the users´ way of working, actions of the management, co-operation patterns and the use of systematic methods were the factors which contributed mostly to successful results.

In the study, three planning and implementation models (techno-centric model, user-centered model, and lean production model) were chosen as the organizational patterns by which the organizational practices of the cases were studied. Comparative analysis of the activities of the management and users showed that the ways of acting in the cases were characterized mainly by the “techno-centric” and “user-centered” models. However, some features could be seen as practices in accordance with the “lean production” model.

The case studies demonstrated that the adoption of new kinds of planning and implementation practices was a controversial process. The planning and implementation process can be seen to form an “experimental field” where the difficulties, set-backs and good results experienced may act as a ground for learning and seeking new planning practices, implementation models and management approaches.

Keywords
technical change, technical progress, innovations, FMS, problem solving

Activity unit
VTT Automation, Industrial Automation, Otakaari 7 B, P.O.Box 1301, FIN–02044 VTT, Finland

ISBN
951–38–5216–4 (soft back ed.); 951–38–6687–4 (URL: http://www.inf.vtt.fi/pdf)

Date	Language	Pages	Price
February 1998	English	238 p. + app. 12 p.	E

Commissioned by
The Finnish Work Environment Fund; Antti and Jenny Wihuri Foundation

Series title and ISSN	Sold by
VTT Publications 1235–0621 (soft back ed.) 1455–0849 (URL: http://www.inf.vtt.fi/pdf)	VTT Information Service P.O.Box 1000, FI–02044 VTT, Finland Phone internat. +358 20 722 4404 Fax +358 20 722 4374

This is a study on the implementation process of technical change and on the innovation design dilemma. According to the innovation design dilemma two categories of innovation related to technical change have been identified, technical and organizational innovation. However, they have mostly been studied separately within the domains of innovation theory and organization theory, respectively.

In the study, the innovation design dilemma is considered to concern the planning and implementation process of technical change. The innovation design dilemma is determined in a new way. The three factors and their dimensions of the innovation design dilemma are differentiated. This opens the way to combine the two types of innovation into a common approach.

The system model of the implementation process of technical change is created and specified based on the analysis of the results of the implementation process in three cases. According to the system model, the most important factors from the point of view of success or failure of the results of the implementation process are the following elements: the viewpoint on the nature of change, the design concept and the organizational patterns. The relations of these elements are described by a development model of the implementation process of technical change. The development model is further specified and presented as a solution to the innovation design dilemma.

Tätä julkaisua myy

VTT TIETOPALVELU
PL 2000
02044 VTT
Puh. (09) 456 4404
Faksi (09) 456 4374

Denna publikation säljs av

VTT INFORMATIONSTJÄNST
PB 2000
02044 VTT
Tel. (09) 456 4404
Fax (09) 456 4374

This publication is available from

VTT INFORMATION SERVICE
P.O.Box 2000
FIN-02044 VTT, Finland
Phone internat. + 358 9 456 4404
Fax + 358 9 456 4374

UDK 65.01:65.011.8
ISBN 951-38-5216-4 (soft back ed.)
ISSN 1235-0621 (soft back ed.)

ISBN 951-38-6687-4 (URL: http://www.vtt.fi/inf/pdf/)
ISSN 1455-0849 (URL: http://www.vtt.fi/inf/pdf/)