Socio-technical redesign of logistic systems

Erlend Alfnes, Jan Ola Strandhagen

Department of Production and Quality Engineering
Norwegian University of Science and Technology (NTNU), and
SINTEF Industrial Management, Trondheim, Norway

Abstract

This paper develops the Control Model (CM) methodology for re-design of manufacturing companies and their logistic systems. The CM methodology aims to design logistic systems for mass customisation and focus on; products and market requirements, material flow, control areas, control principles, supplier- and customer-related processes, and information flow. The main design principles are;

- **to design control areas with decentralised control, and clearly defined responsibilities and rules.**
- **to design a layout that simplifies material flow and enable co-ordination.**
- **to apply differentiated control principles**
- **to replace or supplement centralised generation and collection of control-information by flow-orientated information.**

The design process involves analysis, design and implementation of a Control Model. An example from a Norwegian chair manufacturer illustrates the CM design principles.

Keywords**:** Re-design methodology, logistics, mass customisation.

Introduction

The importance of logistic performance for company competitiveness has increased during the last decade. Increasing product diversity, shorter product life cycles, and customers focus on cost-efficiency and delivery-performance has created a new market situation. The current situation requires logistic systems that satisfy customers' needs fast and cost-effective in uncertain and dynamic markets. Today, logistic performance and flexibility can be developed into major competitive advantages.

These new requirements are seldom reflected in traditional logistic systems. Traditionally, work-organisation and layout are divided into functional domains, and the planning is carried out by ERP/MRP[1]-systems. Such solutions are seldom good enough to ensure a competitive logistic system. ERP/MRP-systems require standardised and comprehensive calculations to provide plans for production and logistic control. The plans generated are based on prognoses and simplified assumptions like fixed lead times and batch sizes. This usually creates a mismatch between real situations and generated plans in production and logistic control. Moreover, the division of work-organisation into functional domains involves unnecessary internal and external interfaces that create complexity, uncertainty and rigidity in the logistic system. Such artificial barriers inhibit the performance necessary for a competitive supply of products. The same critique is

[1] Enterprise Resource Planning /Material Resource Planning

valid for functional divided layouts. A layout based on functional domains will often create complicated material flows and co-ordination problems.

In such logistic systems, competitiveness can be improved by a redesign that reduce internal uncertainty, and provide the speed and flexibility that is necessary to handle variations and market uncertainty. This paper describes how this can be achieved by a socio-technical design methodology developed at SINTEF/NTNU.

Socio-Technical System Design

Socio-Technical System Design (STDS) is an applied science for the integral redesign of manufacturing companies. The "socio-technical" concept reflects a focus on joint optimisation of technology and social systems, indicating that really effective systems only can be generated when technology and people are properly matched [1].

General description

Traditionally, socio-technical design has focused on the work-organisation in production systems, and the STDS approach has long traditions in Norway. Several socio-technical projects were carried out in the 60's and 70's under the label "the Norwegian Industrial Democracy project". The Norwegian Industrial Democracy project was directed by Einar Thorsrud and the Tavistock institute and aimed to democratise work through what was called the "socio-technical" reorganisation of work. Since then, STDS has been developed and established as a comprehensive approach to system design that meets the logistic requirements modern manufacturing companies has to cope with: i.e. speed and flexibility.

The socio-technical viewpoint can be summarised as follows. The majority of manufacturing companies still bears the characteristics of predominant division of labour: hierarchy, maximum break-down of tasks, narrow skills, external control and total specification. These principles do not meet the functional requirements of modern logistic systems. Competitive logistic systems require a structure that enables effective control and co-ordination of functionally differentiated processes. The core of socio-technical enquiry is therefore the analysis and identification of internal structural characteristics and market characteristics, which together determine the probability for disturbances and the flexibility to handle them. These characteristics are the basis for a new design, more capable to handle variation and provide stable supply.

Control Model design methodology

The Control Model (CM) design approach to socio-technical design is distinctly different from the earlier democratic goals, and is converted into a design tool for high-performance industrial production and logistics. CM design is developed at SINTEF/-NTNU, and was first described by Strandhagen and Skarlo in 1995 [2]. This design methodology is based on a mixture of techniques and methods from well-known control principles, and aims to develop companies' control of manufacturing and logistic processes into a competitive advantage. This is carried out trough an analysis of the logistic system, and a design and implementation of a Control Model. The Control Model is *a description of how logistic systems are organised and controlled*. It contains information about layout and material flows, and is used to communicate and explain how the real system should be re-designed.

The main idea in the CM methodology is to enable mass customisation. Customised products should be delivered as fast, precise and cost-efficient as possible. In order to enable mass customisation, the CM methodology provides the following major principles.

- Control areas are designed with clearly defined responsibilities and rules for customer/supplier relations between areas. Each control area has a clearly defined input/output.
- Layout and control areas are adapted to each other. The layout is designed to simplify material flow and enable co-ordination. Control areas often defines the responsibilities for specific manufacturing segments. The material flow between control areas should be one-way directed.
- Control principles are differentiated. Different control principles are chosen for different manufacturing segments, control areas and product groups.
- The information flow is simplified. Centralised generation and collection of control-information is replaced or supplemented by flow-orientated information. The information flow is supported by manual or computerised tools, which provide a quick insight in the demand and capacity situation for each control area.
- The design process involves analysis, design and implementation of a Control Model. The Control Model is developed through participation, manager commitment and knowledge creation.

A focus on time and value-adding activities is central to understand the CM methodology. The product supply process is carried out by suppliers, manufacturing units and distributors, and involves activities like production, assembly and transport. Such activities add value for a customer. However, value-adding activities often constitute a minor share of product throughput-time. An unnecessary long throughput-time is often created by delays in queues and stocks, and non-value-adding activities like:

- planning
- document handling
- quality inspections
- unnecessary handling and transport

The unnecessary long throughput-times create reduced liquidity, high costs and low delivery performance. This is the typical situation in manufacturing companies that still cling to traditional solutions for work organisation, layout and planning.

Traditional principles for design of work create jobs with a high degree of specialisation, and processes designed by these principles are characterised by an extensive number of separated activities. Many activities are superfluous and non-value adding, and do only contribute to delays and queues in the logistic system. Each activity represents a narrow area of responsibility that is separated from other activities by an interface. The extensive number of separated activities creates complex processes that are easily delayed and hard to co-ordinate. This is especially true in varying conditions. Variation as machine breakdowns, market fluctuations etc. often create delays in traditional logistic systems.

The problems are reinforced by a traditional layout. A functionally oriented layout give complex product routes where materials flow back and forth between functional segments. Furthermore, logistic systems are traditionally controlled by ERP/MRP systems. The ERP system executes material requirement planning that provide plans with fixed order sequence for complex and varying processes. These plans seldom match the actual situation and create extra delays. All together, traditional solutions may result in long throughput times, low flexibility and low productivity.

In such cases, there is a potential to improve performance and profitability through a redesign of the logistic system. The effect of a redesign project is illustrated in figure 1.

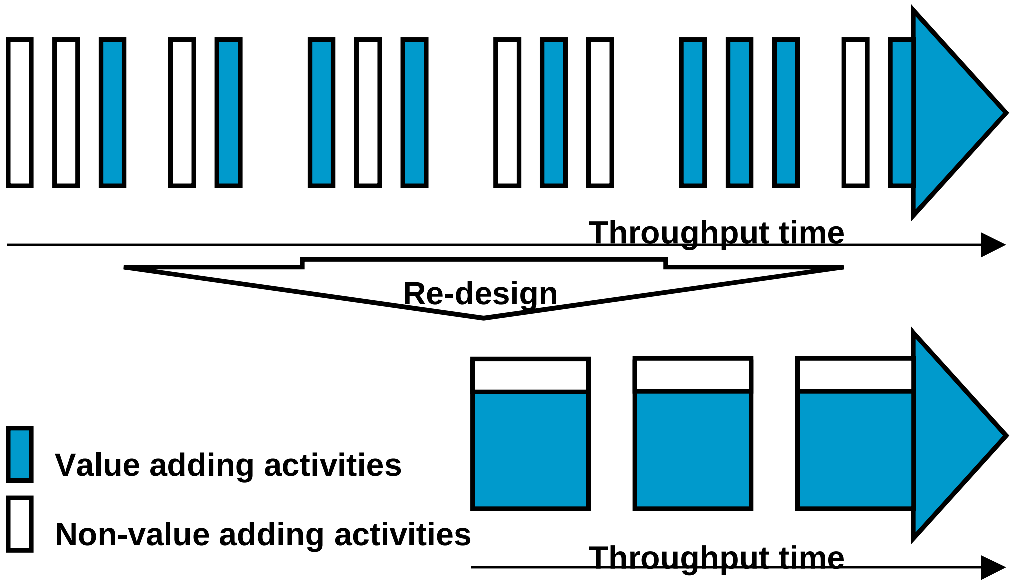

Figure 1: From functional to process/product orientated design

Figure 1 shows the activities and delays involved in a supply process. Grey boxes represent value-adding activities, non-value-adding activities are represented by white boxes, and delays in queues and stocks are represented by open spaces. The bottom of figure 1 illustrates a redesigned process where activities are integrated in three control areas. The new process mainly consists of value-adding activities. Non-value adding activities are eliminated or decentralised.

In the redesigned process, activities are now longer separated and narrow areas of responsibility, but carried out in teams of multi-skilled and empowered workers. The decision-making and responsibility in a control area are decentralised to a team-leader. Each control area represents a clearly defined responsibility area, where a team has full responsibility for order fulfilment and utilisation of resources. Each control area is separated from the next by a delay, e.g. in the form of a buffer, that provides the necessary flexibility to co-ordinate processes in the most convenient sequence. The design principles necessary to obtain such processes are described in the next chapter.

Design principles

The CM methodology aims at creating robust, flexible and controllable logistic systems that enables mass customisation, and focuses on:

- products and market requirements
- material flow
- control areas
- control principles
- supplier and customer related processes
- information flow

These elements are merged to create logistic systems that handles uncertainty and variations in internal processes and customer demands, and are able to satisfy customers' needs as fast, cost-effective and precise as possible. The principles of the CM methodology are described below.

Products and market requirements
Different products and markets require different solutions and control principles. Products can be characterised by their:

- Sales volume and demand uncertainty
- Required delivery time and precision
- Degree of customisation
- Product complexity
- Product value and size

These product-characteristics and performance requirements influence solutions and control principles in a new design. For example:

- High volume products can be controlled different than low volume products, even for the same markets. The sales volume of products is also important for the design of a layout. Resources can be dedicated to high volume products, while low volume products require a combined flow on shared resources.
- Short delivery times require a high degree of product completion, and limits the possibility for engineering and production on order.
- The combination of short delivery times and customisation require modular products and assembly to order (mass customisation).

An important product characteristic for mass customisation is the identification of possible T-points in a product-structure. T-points enables modular products, and determines possible Customer Order Decoupling Points (CODP's) [3].

The examples above show just a few of the relations between products and possible solutions. The new logistic system is designed with focus on core products, and aims to control each category in a way that is suitable and in correspondence with company strategy.

Material flow
The robustness and flexibility of a logistic system depends on a product-oriented and flow-oriented layout. Traditional solutions focus on resource-utilisation, while the CM approach aims to:

- minimise handling and transport between different operations
- create a well-arranged and visible material flow that is easy to control
- group activities that are value-adding for a product

The design is carried out through Burbridge's material flow analysis and group technology [4]. Material flow is analysed and resources are grouped into segments that form clusters of operations with joint input and output channels.

Burbridge's method do not only create a simple material flow, the flexibility to handle process variation is also improved. Processes may interfere with each other or impede each other's due date. The grouping of functionally different resources in segments enables a more flexible order-sequence and better utilisation of resources. The flexibility can be further increased by a reduction of set-up times. The placement of buffers is also central. Buffers are placed between segments to provide the necessary delays for flexible co-ordination of processes.

Control areas

The work force is reorganised to handle dynamic and changing environments. Central for the design is to improve control through a unity of time, place and action. Unity in time, place and action is advocated because effective control relies on actual, complete information and judgement, and the best decisions are based on the decisionmaker's practical knowledge and insight in a specific situation.

The conventional hierarchy is therefor replaced by semi-autonomous control areas, which have clearly defined borders and responsibilities. Each control area defines a group of resources or a group of activities that are linked and can be separated from the rest of the system. The detail planning and decisionmaking is distributed to the leader of each control area, which manage the area in accordance to some clearly defined control principles. Effective co-ordination is ensured by manual or computerised tools, which provide a quick insight in the demand and capacity situation for each control area [5].

Control principles

Different control for material and information flow is dedicated to each control area. Research offers two main categories of principles, principles with material need in focus, and principles with resource-control in focus. The first category focuses on logistic systems controlled by:

- Finished goods stock level
- Production programmes as Manufacturing Resource Planning (MRPII)
- Kanban [6].
- Customer order

The second category of principles focus on resource-control:

- Bottleneck control and "drum-buffer-rope" [7].
- Load-oriented manufacturing control (BOP) [8].
- Cyclic production and product sequence dependency
- Capacity control and scheduling

Mass customisation requires diversified use of control principles, and the required control is determined by decoupling points, products and layout.

Mass customisation often requires the abandon of traditional control principles as delivery from stock and material requirement planning. These principles require sale prognoses for each variant of final products, and are seldom suitable for the millions of possible variants that can characterise mass customisation.

Mass customisation implies to supply customised products composed by standard components. This requires the identification of T-points. T-points in a product-structure enables modular products, and determines possible decoupling points. The layout must be designed with buffers of standard components that allow variant explosion and assembly on order. Customer specific supply requires fast and flexible manufacturing that focus on due-dates rather than cost-efficiency. It is therefor favourable to postpone the customer decoupling point as close to product completion as possible. This can be enabled through a standardisation and modularization of products.

Manufacturing processes before a decoupling point are not time-critical in the same extent as customer specific processes. Their main responsibility is to ensure a buffer of standard components. Several projects have showed that Kanban control is effective for these processes. A Kanban system provides the visualisation of demand, clear responsibilities and customer/supplier rules that are necessary for decentralised control of processes. Other control principles, as cyclic production or bottleneck control, is only applied for resources that require special control, e.g. because of sequence dependency or capacity problems.

Supplier and customer related processes

Processes are integrated across company borders. The main principle is that operations only should be executed once, even across company borders. Personnel with similar or linked tasks are collocated in control areas or electronically integrated. This may include order fulfilment, invoicing, purchasing etc. Effective management of production- and purchasing-orders are based on agreed, product differentiated delivery arrangements and supported by lean, customised ICT tools.

Information flow

Effective control requires technical solutions, software and manual systems, that support the communication of information along processes. Centralised generation and collection of operative information (orders, confirmations, invoice, available capacity) is therefore replaced or supplemented with flow-orientated information tools.

These tools should be visual (like a Kanban) and provide a quick insight in the current demand and capacity situations. Lean, visual ICT tools are developed that:

- meet the requirements of a specific production and logistic environment
- enable effective communication and control
- are integrated with the company's existing ERP system.

Process

The point of departure for the CM methodology is that analysis, design, implementation and use should be considered as interwoven aspects of *logistic system development*. Every phase, from problem definition, to analysis, design and implementation of a Control Model, involve choices and knowledge-creation by stakeholders that influence the use of new designs.

Logistic system development is more than the analysis and synthesis of a "best" design by an expert. Interests and knowledge is embedded in every solution, and even thoroughly planned solutions will meet resistance, both from stakeholders and the existing infrastructure. The development of logistic systems is a political process that involves stakeholders with conflicting interests, and the conservative forces of economical, technological and organisational investments in the existing infrastructure. Logistic system development is also a knowledge creation-process, which relies on practitioners and designers experience and their ability to create new solutions.

The advantage of the CM design approach is that it acknowledges the interests and knowledge of the stakeholders, and provides conditions that facilitate negotiations and knowledge creation. Through a well-organised knowledge creation, sense making, and negotiation process, conceptual and operational knowledge can be shared and crystallised as good solutions. This design approach enhances the probability for good solutions that facilitate competent performance, and that are aligned to stakeholders' interests and the existing infrastructure.

The activities of a design project will be described in three stages, analysis, design and implementation. The activities involved in these stages are not necessarily carried out in a sequential order, e.g. will implementation activities often lead to new designs, but such a framework will nevertheless clarify the main process in a project.

Analysis.
The project starts with a mapping and analysis of the company and its environment. This preliminary analysis focuses on production and logistics performance and covers company strategies, market requirements, product categories, business processes, and material flow. It is based on available information, interviews and extracted information (e.g. corporate strategies) and is carried out in collaboration with practitioners. The result of this analysis is the designer's problem definitions and proposal for change areas. It will also propose objectives for improved performance or competitiveness. The second stage is to redefine and align project-objectives towards organisational intention in collaboration with managers. This process should ensure managers commitment to the project. The third stage is to identify relevant stakeholders and to invite them to join the design project. The fourth stage involves a brainstorming and sense-making process, where researchers and stake-holders collaboratively revise the designer analysis, and agree upon a description of the company situation. Based on the revised company analysis, researchers and stakeholders develop and prioritise further action programmes and analysis. Moreover, autonomous design-groups should be created. The design groups should consist of relevant practitioners and stakeholders.

Design
The identified change areas are analysed in detail by design-groups. Based on the detailed analysis, a new preliminary model should developed through collaborative design. This may include the specification of layout, control areas, control principles, product range, processes and supportive ICT –tools. The most important action at this phase is to enable active participation and knowledge creation in the design process. This includes to train practitioners in logistics, control principles and design methods, and to let practitioners experience the future through simulation games and work place visits.

Implementation
Iterative design is a keyword at this stage. New designs and information tools are developed in more detail by design-groups and implemented stepwise. The solutions are not complete, and are implemented stepwise to allow learning and habituation. This allows a broader participation and makes it possible to change the course on the way. New solutions are tested in practice, and the gained experience is the input for new design solutions.

Applicability and results

The CM methodology enables customised mass production. The goal of customised mass production is to deliver customised products to a "mass production" price. This is achieved by postponing the customer order decoupling point (CODP) as long as possible, while the customer experiences the product as specially customised to him. By standardisation and modularization of products, the proper application of T-points and a controllable logistic system, it is possible to produce and stock larger quanta of components with a minimum of risk, because the components are integrated in many products.

The applicability and principles of the CM methodology is here demonstrated by a illustrative example from a Norwegian chair manufacturer. The example is chosen because the chair it self is relatively simple, this makes it easier to understand the main principles of the CM methodology. The chair manufacturer produce order specific chairs, competing on the European chair market, but their location creates a competitive disadvantage. The factory is located at Røros, more than thousand km from their main markets, while the European competitors are located in or near the European markets. This was the point of departure for a redesign project, that aimed "to move the chair manufacturer to Europe", i.e. to develop production and logistics processes that could compete or beat their competitors' delivery time and precision.

A analysis of the logistic system showed that the situation was characterised by a large stock of final goods, a high share of work-in-progress, long delivery times and low delivery precision. The actual numbers are presented in figure 2. The unsatisfactory situation was caused by several conditions. The factory was based on a make to stock production and was managed by a MRP system. This kind of control made it difficult to cope with the variety in demand and the variety of configurations (more than 2 Million possible variants) that is necessary to produce customised chairs. The plans generated by the MRP system seldom matched the actual sale. This lead to many express-orders that disturbed the plans and created co-ordination problems. The co-ordination problems were reinforced by a functional layout and work organisation that created complex processes. Materials flew back and forth between engineering, welding, varnishing, sub-assembly, sewing, gluing, assembly, packaging and stocks, as illustrated on the left side of figure 2. Complex processes combined with mismatching plans created unintentional stockings and long throughput times. Measurement of some components showed a average throughput time of 45 days!

A new Control Model was designed and implemented. The new Control Model includes a new layout, new control areas, new control principles and is supported by a ICT-tool.

A new and flow oriented layout was designed where:

- Most materials are supplied just-in-time and flow continuously through engineering, welding and varnishing into the first buffer.
- Subassembly is carried out in two parallel segments, dedicated to high and low volume products. Components are taken from the first buffer, transformed into subassemblies and stored in the second buffer.
- Assembly of final chairs is carried out in three parallel segments, dedicated to different chair types. Sub-assemblies are taken from the second buffer, assembled into customer-specific chairs, and loaded on trucks every 24 hour.

A new and decentralised work organisation was designed where activities and responsibilities are grouped in 11 control areas.

- Control area no. 1 is responsible for production of steel parts that are standard components in most chairs. The steel part supply is controlled by prognoses.
- Control area no. 2 + 3 are responsible for engineering, welding and varnishing of steel components. The steel component supply is controlled by Kanban.

- Control area no. 4 and 5 are responsible for high-volume and low-volume sub-assemblies respectively, and are controlled by Kanban.
- Control area no. 6 is responsible for gluing and sewing of seats, and produce on order.
- Control area no. 7, 8 and 9 is responsible for assembly of final chairs, and produce on order.
- Control area no. 10 is responsible for packaging and shipment of finished goods.
- Control area no. 0 is responsible for administrative activities as order acceptance and purchasing. This activities are supported by a ICT-tool that provide a visual overview of real time capacity situation, and supplier/customer agreements that ensure fixed and product-specific delivery times.

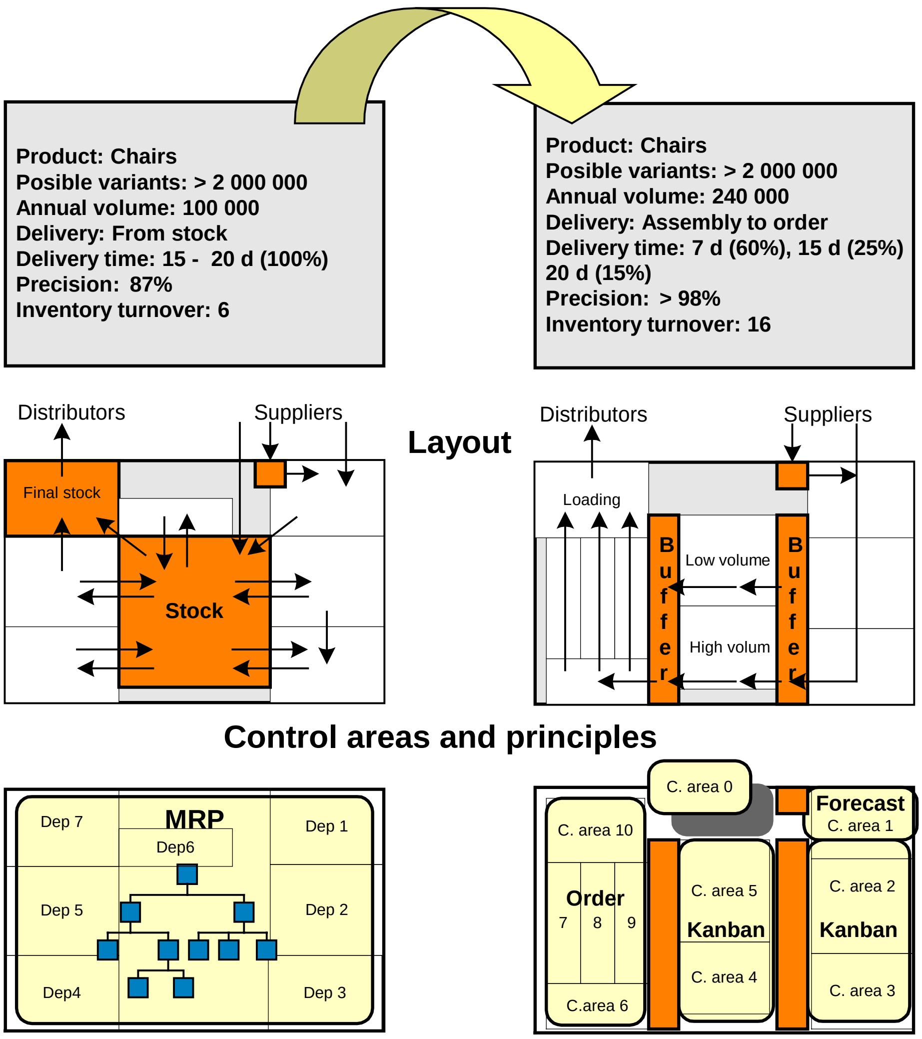

Figure 2. Redesign of a chair manufacturer

Central for the new design is the customer order decoupling point. The buffer of subassemblies is a decoupling point for customer orders. Every activity after this decoupling point is controlled by a customer order. The activities before this decoupling point is controlled by buffer levels or prognoses. The redesigned resulted in major improvements for the chair manufacturer, as presented to the right in figure 2.

Conclusion

During the last decade, more than twenty manufacturing companies have developed their logistics processes by the means of this methodology. Most of them have radically changed their routines, layout, product design, control principles and information technology, and improved their logistic performance [1]. The experience from these cases is that the CM methodology is effective for creating flexible and competitive logistic systems.

References

[1] Herbst P. *Alternativer til hierarkier* Oslo: Tanum-Norli, 1977.

[2] Strandhagen JO, Skarlo T. *A manufacturing Business Process Reenginering Method: Design and Redesign of a Production Control Model.* SINTEF report STF30 S95003, 1995.

[3] Browne J, Harren J, Shivan J. *Production Management Systems. An integrated perspective.* Harlow: Adison-Wesly publishing company, 1996.

[4] Burbridge JL. *Group technology in the engineering industry* London: Mechanical engineering publications Ltd, 1979.

[5] Andersen B, Strandhagen JO, Haavardtun LJ. *Material- og produksjonsstyring* Oslo: Cappelen Akademiske Forlag, 1998

[6] Monden Y. *The Toyota Production System.* Atlanta: Institute of Industrial Engineers, 1983.

[7] Goldratt M, Cox J. *The Goal: Excellence in manufacturing* Croton-on-Hudson: North River Press John Wiley, 1984.

[8] Wiendahl HP. *Load-oriented manufacturing control.* Berlin: Springer,1995.