MANUFACTURING CHALLENGES OF THE 21ST CENTURY – AND A METHODOLOGY TO HANDLE THEM

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Abstract.
Based on a Norwegian trend study, this paper identifies driving forces and trends within manufacturing and logistics. Four general trends are identified: globalization, fragmentation of markets and individualization, increased focus on environmental and sustainable development, and the enabling Information and Communication Technology. Price, precision, and speed will remain major competitiveness determinants, but manufacturing companies will increasingly need to offer customized products and services. Success will increasingly require a new form of manufacturing systems that are flexible and responsive, and operated in collaboration with customers and suppliers. A methodology is introduced that provide a structural approach to meet the new challenges.

Key words: Trends, Operations Management, Manufacturing Systems Design

INTRODUCTION

The world is characterized by extensive changes. The times when companies could run their activities in stable environments are gone. Manufacturing companies find themselves, whether they like it or not, in a more global and changing reality.

To meet the emerging changes and the challenges that accompany them, manufacturing companies have to be aware of, act in accordance with, and influence the trends that may determine their future. This was the background for a trend study initiated by Næringslivets idefond, a development programme at the Norwegian University of Science and Technology (NTNU). The project aimed to identify driving forces and trends within manufacturing and logistics, and thereby provide a support for decision-makers in industry and academia (Strandhagen et. al. 1999).

This paper describes the major trends identified by the trend study, and how they put challenges on manufacturing companies that must be reflected in their operation management. Companies will find that improved performance is required, and that competitiveness may imply radical changes in manufacturing and logistics processes. The "Control Model methodology" is introduced as a structural approach to analyze manufacturing systems and implement the necessary changes.

GENERAL TRENDS

The major themes for Næringslivets idefond's trend study were trends within society and policy, individuals/consumers, and technology, and how these trends will impact future logistics and manufacturing. The trend study was carried out during the spring of 1999 by an interdisciplinary team of academics and professionals with background in logistics, production management, operation research, sociology and history. The trends outlined in this paper are the result of 50 interviews with Norwegian academics and professionals, each carefully selected to cover the major aspects of logistics and to ensure a sufficient broadness.

Four major trends were identified that point to a new competitive situation for manufacturing companies:

- Globalization
- Fragmentation of markets and individualization
- Increased focus on environmental and sustainable development
- The enabling information and communication technology (ICT)

These trends are not claimed to be universal. Our investigation is carried out in Norway, and the trends may be more valid in Europe than in other parts of the world. The next sections will outline the trends in more detail.

Globalization

Globalization means that the diverse fragments of the world melt together and are forced to relate to each other. This implies that geographical distance and national borders have lost much of original importance. Taste, communication, standards and even concepts are getting globalized, and the national control of the economy is declining. International competition is rapidly replacing national competition due to open markets with increased size, accessibility and homogeneity. The most central aspects of globalization for logistics are:

- Technology is becoming easier accessible everywhere. Easy access to technology allows rapid reproduction of products developed by others. The result is decreasing product lifecycles and a market situation that favors innovative companies.
- Deregulation and adjustment of trade regulations create global markets. Trade regulations and arrangements are leveraged from national control to trading blocks like the EC.
- Intensified global communication and worldwide movement patterns create a global cultural and consumption flow.
- Improved transport and communication infrastructures enable an increasing globalization of companies. Global companies produce components in the countries that are favorable regarding access to, and price on, workforce and knowledge at a given moment. The final production and customization are often executed near the markets.

The globalization of markets opens up for new competitors. Global companies can utilize the lowest factor inputs available to supply almost identical items to different countries. Globalization implies fiercer competition and requires new strategies for manufacturing and logistics. Today, local competition operates in global markets.

Fragmentation of markets and individualization

Companies are forced to compete in increasingly fragmented markets regarding price, quality, customization, and service. Many markets have traditionally appeared to be homogenous for the producer, even though customers' buying dispositions were fragmented. Low purchasing power and few product alternatives resulted in relatively stable market situations. This situation is now changing, and customers buying power is increasing due to two driving forces:

- *Economical growth*. The welfare in western countries is increasing, and most western people have more money to spend on consume, travels and entertainment. Customers are increasingly willing to pay extra for value-adding facilities like service, symbolic value and customization.
- *Globalization*. Improved transport and communication infrastructure, combined with available and flexible technology, creates fiercer competition and more surveyable markets. Customers can choose from an increasing range of products that are comparable regarding price and quality, and buy products that provide most personal value for them.

The result is increased buying power and a pressure on companies to focus on certain market segments. Competitiveness requires customization of products and services based on knowledge of consumer dispositions and trends. Two main forces are influencing consumer dispositions - individualization and informalization – which tend to reduce the social embeddedness and normative regulation of the class structure that characterized earlier consumption behavior.

- *Individualization* means that people are less attached to social institutions and freer to choose their lifestyle, identity and consumer habits as individuals. What people have in common is their desire to maximize life quality. We are getting more concerned about our own wellbeing, and less loyal to others. Each individual has distinctive ideas and different approaches to how a good life should be lived.
- *Informalization* means that rigid, established and routinized patterns of consumption dissolve. People are free to consume and present themselves according to their own preferences, as moral, aesthetic, and social standards are relaxed.

However, there are counter-forces that create higher attachment and higher regulation by groups. A counter-force to individualization is that people create imagined communities in order to compensate for a lack of sense of belonging. Belonging is sought in the invention of traditions, and in regional or local identities. A counter-force to informalization is that people (e.g. young subcultures) use goods and services more extensively to express their distinction and belonging to social groups. Membership is recognized by shared taste in clothes, music, etc, and creates a high group regulation of consumption. Altogether, forces and counter-forces create four distinct and partly conflicting consumer trends as illustrated in figure 1.

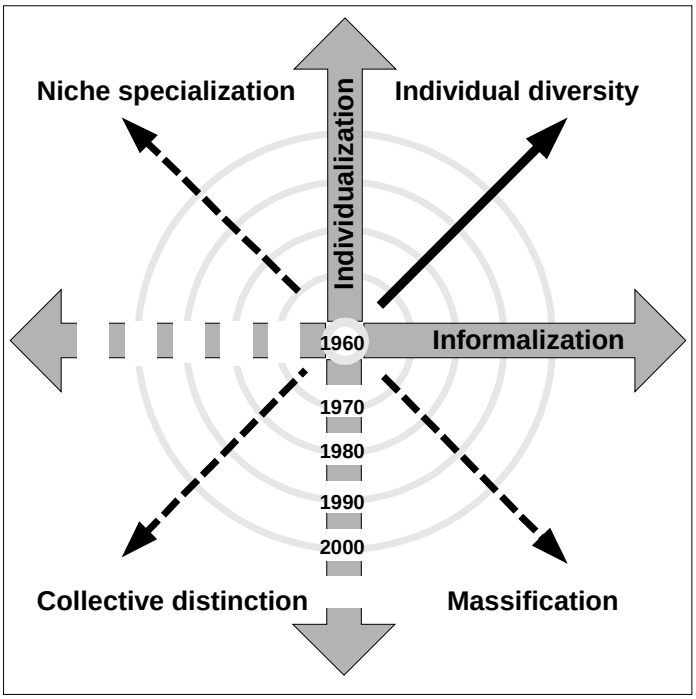

Figure 1 Consumer trends (adapted from (Warde, 1997))

Figure 1 shows forces and counter-forces that dissolute and transform the earlier class structuring of consumption. These forces have influenced consumer dispositions from the 1960s up until today, and have created four distinct and conflicting consumer trends:

- *Individual diversity* means that there is much greater diversity in consumer behavior, that rules are relaxed and individual preferences released from the constraints of group approval.
- *Niche specialization* means that there is a growing differentiation of distinctive lifestyles. People are disembedded from traditional networks, and create their identity through sharing lifestyles (and consume) with others. New, niche-groups or "neo-tribes" are created.
- *Massification* (or the McDonaldization of society) means that the passing of class differentiation and relaxed normative regulation leads to much greater uniformity in consumption. This trend opens up for global markets and sale of almost identical products in many different countries.
- *Collective distinction* means that the differentiation between social groups is increasing. National, regional, ethnic, and local identities are re-created and consumption is used to mark group belonging. Age, gender, education, interests, and social networks create different consumption practices.

Consumption is heterogeneous, and the outlined trends are conflicting in many concerns. However, what can be valid for fashion industry may not apply for food industry, and McDonaldization may emerge in some market segments while the majority of the population tends towards greater consumer diversity. The "schizophrenic consumer" is a term that seems to become valid. Customers can no longer be separated in distinct consumer categories but do instead belong to different categories in different situations. Thus, the markets are becoming more dynamic and fragmented. Fiercer competitiveness and increased buying power require

close market surveillance and customer intimacy, together with manufacturing and logistics strategies that utilize customer knowledge to improve the company's market position.

Increased focus on environmental and sustainable development

Economical growth and globalization imply higher energy consumption, more pollution and more waste. However, public opinion is now aware of the environmental impact of products and manufacturing/logistics processes, and manufacturing companies are facing two major challenges:

- Consumers increasingly prefer green products
- Society put pressure on manufacturing companies through environmentally regulations and taxes.

As the ability to develop and operate environmentally friendly products and processes are becoming a competitive advantage, manufacturing companies are increasingly required to involve environmental considerations in their business strategies. Major strategic topics are:

- *Design for sustainable development.* Products are developed through an integrated design process, where environmental aspects are considered in all phases of a product lifecycle. The goal is environmentally friendly production and distribution, and refurbished and reused products. A great design challenge is the use of recyclable materials in new products, and to find application areas for recycled material. Today's garbage may become a future product.
- *Product lifecycle management*. Manufacturing companies take responsibility for their products' total lifecycle. Systems and structures are developed to handle the collection, and reuse/recycling of waste products. This will enforce a stronger integration of supply and recovery chains, and requires technology for tracking and tracing of products.

The enabling information and communication technology (ICT)

ICT has been utilized in manufacturing and logistics processes since the 1970s. However, the application areas for the technology have been limited. This situation has now changed dramatically, and we are facing two major shifts in the use of ICT:

- A shift towards www-integrated sets of integrated Enterprise Information Systems
- A shift towards global, mobile, multimedia communication and control.

These shifts are creating new opportunities for manufacturing companies. The new technology enables efficient execution of operations and communication. And even more important, new business areas are enabled by the new technology.

Enterprise Information Systems (EIS) have gone through an evolution regarding functionality, scope, technology and sophistication. The main changes is summarized by Wortman (2000) as:

1970 *Registration*. EIS were hardware systems covering one function. The systems were used for data collection and registration after the fact had happened

1980 *Automation.* EIS were based on databases and allowed transactions between different functions in a single site. The systems were used to automate existing processes.

1990 *ICT-enabling*. EIS were based on client servers, and enabled multi-site interaction and re-engineering of processes

2000 *E-business.* EIS will utilize integrated portal technology to enable E-business, i.e. the utilization of internett to create and operate new products and services in collaboration with other companies.

The growth in functionality, scope, technology and sophistication have enabled a shift towards EIS systems that integrate every site in a company, and that are integrated with a set of other EIS through internet. The latest technology makes integration a less painstaking process than in the past. This enables short-term collaboration (in temporary networks or supply chains) for rapid and cost efficient supply of products and services.

Moreover, technology for communication, tracking, and surveillance are becoming better, cheaper, smaller and more mobile. ICT is connecting the globe and dissolves barriers caused by geographical distance. People are now able to communicate across the world and to run remote applications through mobile multimedia stations. The new multimedia terminals provide communicative freedom and will soon allow you to operate your EIS independent of your position. The ICT also allows remote and mobile tracking, governance and control of manufacturing and logistics processes.

General trends summarized

The general trends described in the previous sections, create comprehensive changes in most industries and will influence the competitive situation of manufacturing companies. Fiercer competition, dynamic markets, new consumer habits, stronger environmental regulations, and new technological possibilities, enforce manufacturing companies to change. The new competitive situation requires the ability to handle a continuously changing business environment, where markets consist of rapidly changing niches. Price, precision, and speed will still be major competitiveness determinants, but competition for manufacturing companies will increasingly require offerings with more customization and more service. This will be the topic for the next section.

PRODUCT TRENDS

The new market situation will increasingly put pressure on manufacturing companies to improve their performance and business relationships. Increasing buyer power and market fragmentation will require more customization and more service. Standard products still constitute a major share of many markets, but the demand for classical standard products are declining. The major product trends identified by the trend study are illustrated in figure 2.

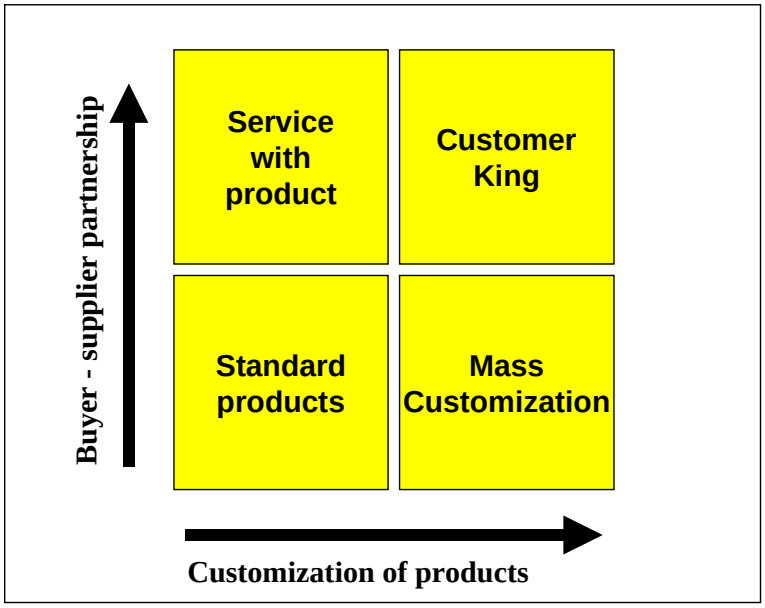

Figure 2 Product trends

Figure 2 shows two major product trends, customization of products and buyer-supplier partnership. Mass production of standard products are no longer sufficient, competitiveness requires three supplementing types of offerings:

- *Mass Customization*. Competition for manufacturing companies will increasingly require greater product variety and customer focus. The challenge is therefore to achieve mass customization – the production and distribution of customized goods on a mass basis. Mass customization implies cost-efficient and responsive manufacturing of a variety of products that provide unique value to customers.
- *Service with a product*. There will be a shift from products with a service to service with a product. The physical share in offerings is shrinking. Companies are achieving a competitive advantage by supplementing customized services to standard products. For example: Xerox's business idea is not to sell photocopiers, but to provide copies that satisfy the customer. Service with a product requires a close buyer – supplier relationship and integration of processes.
- *Customer King*. There is a shift from many deliveries from single suppliers, to complete product and service packages provided by one powerful supplier. Such suppliers are "Customer Kings" which utilize their customer knowledge to offer total system deliveries that are customized to the buyer. Customers only have to relate to one partner that takes total responsibility for products and services (maintenance, upgrading, replacement, recycling etc) through the entire system life cycle. This type of offering requires that the principal supplier develops and controls dynamic networks of sub-suppliers that are responsive to a specific customer's needs.

Success will increasingly require a new form of manufacturing systems that work closely with networks of suppliers and customers to develop customized products and services. This requires a shift from focus on internal efficiency, towards an approach that improves operations in the context of the total business. A methodology to carry out such a shift is the Control Model (CM) Methodology. The next section describes the concepts underlying the CM methodology.

THE CONTROL MODEL (CM) METHODOLOGY

The CM methodology is a structured approach to improve production and logistic performance by implementing modern manufacturing principles. CM design was developed at SINTEF/-NTNU, and is described by Quistgaard et al (1989), Strandhagen&Skarlo (1995) and Alfnes&Strandhagen (2000). The methodology acknowledges that competitiveness increasingly relies on the ability to provide customized products and services in collaboration with customers and suppliers, and aims to develop companies' control of production and logistic processes into a competitive advantage. The CM approach involves an analysis of the extended enterprise, and the design and implementation of a Control Model. The Control Model is a description of how enterprises are organized and controlled. The CM consists of text, figures and charts, and is used to communicate and explain how the extended enterprise should be re-designed. The CM methodology provides a customized design based on a mix of known principles and methods from manufacturing strategies like Lean Production (see e.g. (Monden, 1998)) and Agile Manufacturing (see e.g. (Kidd, 1994)).

Focus

Manufacturing companies should take a broader view than to only consider what occurs within the factory, and see their operations as part of a value chain[i]. Browne et. al (1995) term the broader view the "extended enterprise". Browne et al (1995) are pointing out that the ability of manufacturing companies to compete and succeed may increasingly depend upon its understanding of and its integration with its surroundings. These notions are by no means new. The dynamic effects of changes on systems (such as supply chains) and the need to integrate have been well understood since the work of Forrester (1958). For the purpose of the CM-methodology, the extended enterprise is defined as a conceptual business unit or system that consist of a manufacturing company who collaborate closely with customers and supplier in

such a way as to maximize the returns to each partner. The extended enterprise does not necessarily comprise the entire value chain, but a group of companies within it.

Design principles

The CM-methodology seeks to analyze the future market situation and identify market requirements for products and performance. Requirements for customization, service, delivery time, cost efficiency etc will determine the manufacturing strategy and the design of the extended enterprise. The major principles for the CM-design are:

- *Time compression*. A major cause for poor performance is the unnecessarily long throughputtimes that characterize many manufacturing enterprises. Time compression is a major enabler for the cost efficiency, responsiveness and flexibility that is necessary to provide customized products and services in dynamic markets.
- *Integration of processes and information sharing*. Effective and agile control requires software and manual systems that support supplier-customer integration through the inter-change of commercial and technical information.
- *Flexible and flow-oriented production*. Agile supply and mass customization requires a flexible production-system and a multi-skilled and team-based workforce. Equipment is developed by lean principles like setup-time reduction, manufacturing segmentation and flow-orientation to allow small-lot production by real demand. Workers are organized in control areas with decentralized control, and clearly defined responsibilities and rules.
- *Strategic positioning of buffers and differentiated control*. The Customers Order Decoupling Point (CODP) (Browne, 1996) is a stocking point that separates the part of the enterprise where manufacturing control is based on customer orders from the part that is based on planning and level control. Supply of customized products to a “mass production” price is achieved by postponing the CODP as long as possible, while the customer experiences the product as specially customized to him.

These principles are utilized in the design of a customer-specific Control Model, which is developed through participation and manager commitment.

Design process

A CM design process typically includes analysis, design, and implementation, and is carried out in line with socio-technical principles of participation and co-operation (se e.g. (Ehn, 1992)).

- *Analysis*. The analysis focuses on production and logistics performance and covers company strategies, market requirements, product categories, business processes, and material flows. It is based on available information, interviews, and extracted information (e.g. corporate strategies) and is carried out in collaboration with customers and suppliers. The result of this analysis is problem definitions and proposal for change areas. Project objectives are defined and aligned towards company strategy in collaboration with managers.
- *Modeling and design*. The modeling and design process tries to enable active participation and knowledge creation. Different stakeholders should be allowed to tell their version of the company situation and their view of the underlying causes for insufficient competitiveness. Based on a revised company analysis, researchers and stakeholders develop and prioritize further action programs and analysis. Business processes are thereafter modeled and redesigned in detail. The new enterprise model may include the specification of layout, control areas, control principles, product range, processes, and supportive ICT tools.
- *Implementation*. A new enterprise model is developed and implemented stepwise. The solutions are not complete, and are implemented stepwise to allow learning, changes and habituation.

During the last decade, more than twenty manufacturing companies have developed their processes by the means of the CM methodology. Most of them have radically improved their manufacturing and logistic performance.

CONCLUSION

The trends identified by our trend study shows that a new market situation is emerging for manufacturing companies. Globalization of tastes, communication, and markets and at the same time rising separatism, individualization and decentralization pose challenges to manufacturing companies. The new market situation requires that we view customers as belonging to several market segments and treat them as individuals. Further, environmental requirement forwards new conditions for competition and makes sustainable development and product lifecycles increasingly important in manufacturing strategies. Meeting this calls for dramatic changes in processes, information and performance, changes that can be enabled by the Control Model methodology.

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[i] The concept of value chain was popularized by Porter (1985), and did originally denote a series of activities through witch materials moves as it is transformed from low-value raw material to a high-value product within one company. The value chain is now a common term for the whole process of supplying goods and services to end-consumers, and denotes value-adding activities in chains of companies.

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