Flexibility Requirements in the Food Industry and How to meet them

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ABSTRACT

This paper discusses the emerging need for mass-customization, flexibility and responsiveness in the food industry, and argues that this can be achieved by utilizing concepts from lean production and socio-technological design. The rationale for this focus is found in the emerging market situation in Norway, characterized by:

- the market segments for high-volume foods with predictable demand is declining
- the market for low-volume innovative food with unpredictable demand is increasing
- fiercer international competition
- an increasing demand for private labels

Furthermore, it is found that Norwegian companies are using mass production principles and functional work-organization. This cannot fulfill the emerging requirements to flexibility and responsiveness in the market. A redesign of routines, layout, product design, control principles and information technology is necessary to meet the new challenges.

Keywords. Food industry status, Mass customization, Lean production, Socio-technical design

BACKGROUND

The importance of production and logistic performance for company competitiveness has increased during the last decade. Today, logistic performance and flexibility can be developed into major competitive advantages. The demand for standard products is declining, product life cycle becomes shorter, and customers continuously demand new products in which they can identify. The service content in products is increasing and customers now prefer companies that can customize products. Some companies (like Xerox) already offer “service with a product”, rather than “products with a service” (Strandhagen et al, 1999). At the same time customer focus on cost-efficiency and service levels has never been stronger. These trends generate a new market situation for many companies.

These trends are also valid for the food industry. The food market is no longer stable and predictable, and consumers are changing their consumption habits. According to Warde (1997) consumers no longer want what everybody else wants. They want special and personal food products that signalize their distinctiveness and individuality. The “schizophrenic consumer” is another term that seems to become valid. Customers can no longer be separated in distinct consumer categories like the urban consumer, the ecological consumer, the price-conscious consumer, the brand-oriented consumer, the international consumer or the traditional consumer, but do instead belong to a mix of such categories (Strandhagen et al, 1999). Furthermore, the demand for private labels from the supermarket chains increasing. Thus, the market segment for high-volume functional food with predictable demand is declining, while the market for low-volume innovative food with unpredictable demand is increasing. The emerging market situation requires more responsiveness and flexibility. However, enterprises in the food industry (at least in Norway) still cling to traditional mass-production principles, and the emerging requirements are seldom reflected in their production and logistic (P&L) systems.

One of the main advantages of the Norwegian food industry is the image and quality of its raw materials. Images of freshness, safety, nature and health are very strong and might be the most important selling point for the industry in the future. This is important as the Norwegian customs and trade barriers protecting the national food industry are now subject for deregulation and slowly removed. This will result in stronger international competition in the Norwegian food market. The survival in this new competitive market calls for the production of niche-products and utilization of Norway's image regarding raw materials. This will lead to stronger requirements for flexibility and efficiency in manufacturing operations.

In order to learn more about production and logistic performance in the Norwegian food industry, an extensive national survey was carried out in 1997/1998. A total number of 133 companies ranging from breweries, bakeries, fisheries, candy makers, soup producers, meat producers and more participated (Røstad et al. 1998). One of the main findings in the survey is that functional work-organization, low IT-support and use of traditional mass production principles characterize the food industry. Some of the most important indications of the food industry's gearing towards mass-production are found in the food industry's organization and its use of production and logistic control. It was found that the majority of the companies used a functional organization as shown in Figure 1.

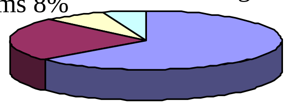

Figure 1: Organization of the production function (respondents=88)

Although it was found that functional oriented companies seemed to be in a good economical situation in today's market, findings in the survey pointed out that co-operation and communication across functions were bad and that there were problems regarding operations (e.g. improvement work, maintenance). Lack of communication was also found to be a problem for process-oriented organized companies, although the situation here seemed to be better regarding their operations[1].

One way to remedy lack of communication is the use of IT systems, but the IT support for production and logistic processes was found to be limited. Only 48 of 103 companies use an Material Planning Control (MPC)-system (commercial or customized), and only 16 of 48 companies use all modules related to manufacturing planning and control. The major reasons for not using all available modules are outlined in Table 1.

Table 1: Major Reasons for not using all modules in MPC-systems (respondents=48)

Reason	**%**	**Reason**	**%**
Not adapted to needs	44%	Too little follow-up from management	12%
Lack of training in use	20%	Doesn't see the use	4%
Doesn't need all modules	20%		

As the table shows, most food processing companies find MPC-systems too unfit or inflexible for their needs, and thereby reject or only partly implement such systems. A major reason might be that commercial MPC-systems (Enterprise Resource Planning-systems) do not support the informal *ad hoc*–approach many Norwegian food companies use in production and

[1] The last two organization forms did not, due to the data-material's nature, yield interesting significant correlations.

logistic control. The production management principles of Norwegian food companies are outlined in Figure 2.

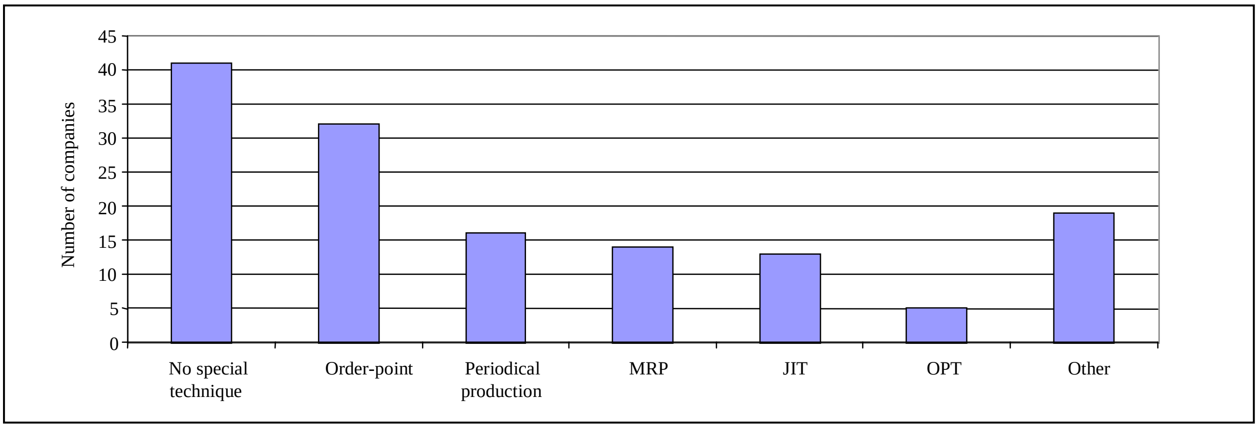

Figure 2: Principles used for manufacturing planning in the food processing industry of Norway

Many companies use no special technique for manufacturing management. This may be related to the size[2] and nature[3] of the Norwegian food processing companies, as they may be considered small by European terms. Companies are using order-point, periodical production and MRP (Material Requirement Planning). Few are using principles from JIT (Just-In-Time) or OPT (Optimized Production Technology[4]). Some of the companies are using more than one guiding principle. This, in addition to other findings in the survey, indicates that the Norwegian food industry is geared towards mass production.

From the findings in the survey, one might conclude that the guiding principles and organization used, are sufficient in today's market situation, but might not be so in the future. The argument of this paper is that mass-production principles are insufficient for competition in the growing market segments characterized by high demand variety, increasing product diversity and speed requirements. Food processing enterprises need to improve the flexibility of their P&L system, and this can be achieved by customizing a mix of principles from e.g. socio-technical design, lean production, and Enterprise Resource Planning (ERP) systems. These principles will be presented in this paper.

MASS PRODUCTION

According to Skorstad (1999), mass production is still the dominant production form in most industries. Mass production is characterized by centralized hierarchical control, scientific management and function oriented layout, and was developed by scholars like Fredrik Taylor (1911) at the beginning of the 20th century. Mass production focuses on productivity and capacity-utilization, presupposes detailed information and standard products with predictable demand, and was well-fit to meet the relatively stable market situation at that time. These principles are still applicable to certain markets segments. However, more dynamic markets segments often require a redesign of production and logistic processes. Fisher (1997) has created a framework to understand the connection between demand variety and the required system design (see Figure 3).

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[2] Total man labor years in the Norwegian food processing industry: Minimum=3; Average=99,8; Maximum=1203; Median=46.

[3] Excepting fish, Norwegian food processing companies have very little export (even out of their own county), and they are protected by national custom barriers and trade agreements. These are however being built down, so the expected increase in competition from foreign companies will probably make the food processing industry focus more on these aspects.

[4] OPT is described by Goldratt & Cox (1984).

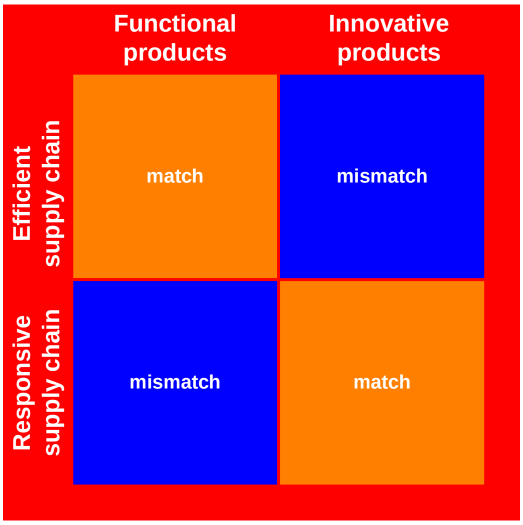

Figure 3: Matching supply chains with products (Fisher, 1997)

Functional products (with predictable demand, long lifetime, low contribution margin, low product variety, high degree of standardization) require physically efficient supply chains and mass production systems. Innovative products (with unpredictable demand, high product variety, short lifetime, high contribution margin, and high degree of customization) require responsive supply chains and flexibility.

Principles of mass production

Mass production emerged in a market situation were most goods had the characteristics of functional products, e.g. predictable demand and high degree of standardization, and is tuned towards resource utilization. The principles are (among others):

- All kind of variety is sought minimized, and all processes and activities are formalized.
- Discipline and accuracy are vital. Work is rulebased and follows a strictly hierarchical line of command. Activities must be carried out according to plans with fixed order sequence, and databases must always be updated.
- Planning and control are centralized and separated from value-adding activities. This principle creates jobs with a high degree of specialization and processes designed by these principles are characterized by an extensive number of separated activities, each representing a narrow area of responsibility.
- Resources (machines, equipment, personnel etc) are organized in functional domains.

Enterprises organized for mass production can run very efficiently in stable market situations. However, the mass production principles become problematic when demand variety increases, and many companies seek a technical fix to their problems by implementing ERP systems.

The support from Enterprise Resource Planning (ERP) systems

Enterprise Resource Planning systems are promoted as the new and modern approach to material planning and control. However, manufacturing resource planning (MRPII[5]) is still the planning engine in most (ERP) systems (Bartholomew, 1999). MRPII has been a well-known planning system in the last decades and base the calculation of stock- and production-levels on sales forecasts.

[5] Earlier versions were named Material Requirement Planning (MRP) systems

The principles of mass production are supported by, and embedded in, ERP/MRPII-systems. ERP-systems provide information about material flow, utilization of people and equipment, and future demand. This information aids managers in making decisions and control operations, and enables centralized hierarchical control. Moreover, the logic of ERP-systems is based on assumed future requirements for final products and presupposes that:

- Future requirements are known with a sufficient accuracy
- Production processes and Bill Of Materials (BOM) are known for every product
- All databases (stock levels, BOM, customer orders etc) are correct and updated
- Lead-times and lot-sizes are fixed (Andersen et al, 1998)

These presumptions represent a view on people, organization and control similar to the presumptions of mass production, and the use of ERP-systems requires that processes and activities are organized in line with mass production principles. The complex processes, combined with fixed lead-times, fixed lot-sizes and fixed order sequences, makes ERP-based P&L systems inflexible and hard to coordinate. Moreover, the dependency on accurate forecasts in such P&L systems is high, but as demand variety increases (e.g. due to higher degree of customization) it is likely that the demand variants and combinations would be too difficult to pre-define and forecast, especially when broken down to each product type. ERP-systems often introduce problems for production and logistics – including complex bills of materials, inefficient workflows, and unnecessary data collection. However, ERP-systems still can be applied to manage accounting, human resources and corporate-level planning (Bartholomew, 1999).

THE EMERGING FLEXIBILITY REQUIREMENTS

Many companies experience that their system design no longer matches their market situation (Fisher, 1997). Market segments characterized by high demand variety, product diversification, and higher demand for customization are growing. At the same time the requirements for shorter delivery time and reduced costs are continuously getting stronger. In this kind of dynamic market situation, demand variety may become problematic, and more flexible P&L systems are required.

When demand variety becomes problematic

Burbidge (1961) has argued that there are basically two ways of meeting demand:

1) From varying the inventory levels (with fixed processes)
2) From varying the process rate (with fixed inventories)

In addition there is the possibility of doing both, which is a compromise that takes up some variations in stock levels and some in process rate.

To enable mass production, most companies prefer Burbidge’s way no.1. They de-couple production from demand and take up the variations by keeping final stocks. Stock-levels are varied in line with expected demand, and calculated from forecasts. This solution ensures stable processes and short delivery-times when forecasts are accurate and all products are stocked. However, the final stock becomes expensive and difficult to coordinate as demand variety and product diversity increases. It is also likely that forecasts become inaccurate when number of variants is increased and the time horizon is reduced. The use of Burbidge’s way no.1 in such situations often results in rush-orders, capacity overload and delays, especially in systems where many products are produced with the same resources.

Moreover, stock level variation, combined with the fixed (and long) lead-times of an ERP-system, may generate a “Forrester effect”. The Forrester effect coins situations where slight variations in end-customer-demand amplify when passed up a supply chain and cause high stocks and large fluctuations in factory orders (Forrester, 1958). The Forrester effect is mainly caused by a missing diversification between real demand information (end-customers order) and artificial demand information (inventory-orders generated to meet a supposed increasing demand), and will increase with increasing time delays. Burbidge (1987) has called this the “Law of Industrial Dynamics”:

> *“If demand for products is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer”.*

A simulation study of Towill, Naim & Wikner (1992) shows that there are three possible strategies to reduce the Forrester effect:

- To remove intermediate levels (as Forrester originally suggested)
- To integrate the information flow through the supply chain, so that end consumer demand is passed up the chain without distortion
- To reduce throughput-time so that time delays are minimized

These strategies are difficult to combine with traditional mass-production principles. However, P&L systems designed for flexibility often utilize these strategies.

An alternative approach

The functional division of work-organization in mass production involves unnecessary internal and external interfaces that create complexity, uncertainty and rigidity in the P&L system. Such artificial barriers inhibit the performance necessary for a competitive supply of products, and may facilitate the Forrester-effect. Moreover, hierarchical control, an extensive number of separated activities, and narrow areas of responsibility create systems that are inflexible and hard to coordinate (Dekker & Poutsma, 1999).

Burbidge’s way no. 2 (to keep fixed or predetermined inventories and vary the process rate), may not provide a better solution to demand variability. If stock levels are set high, fixed stocks will result in obsolescence, high stock levels and low service as demand variability increases. However, if stock levels are minimized and flexibility is maximized, Burbidge’s way no. 2 might be fruitful. Competitive P&L systems require a flexible structure that enables effective control and co-ordination of functionally differentiated processes. High demand variety requires volume flexibility, product mix flexibility (ability to produce a high number of models or variants) and new product flexibility (ability to rapidly introduce new products) (Suarez et al 1995).

Many companies (e.g. Toyota) utilize Burbidge’s way no. 2 with success. This is also the case in Norway. During the last decade, several Norwegian manufacturing companies has redesigned their P&L systems to minimize stock levels and maximize flexibility by the means of principles from e.g. socio-technical design and lean production. Most of them have radically changed their routines, layout, product design, control principles and information technology, and improved their performance (Strandhagen & Skarlo, 1995).

THE SOCIO-TECHNICAL APPROACH

Socio-Technical System Design (STSD) has been developed and established as a comprehensive approach to system design that meets the logistic requirements modern manufacturing companies have to cope with: i.e. speed and flexibility. (Dekker & Poutsma, 1999). The “socio-technical” concept reflects a focus on joint optimization of technology and social systems indicating that really effective systems only can be generated when technology and people are properly matched (Herbst, 1977). Central for the STSD is:

- A focus on participation in work. Effective control relies on actual, complete information and judgement. The best decisions are based on the decisionmakers practical knowledge and insight in a specific situation
- Semi-autonomous groups/worker teams. In a socio-technical system, activities are no longer separated into narrow areas of responsibility. Teams of multi-skilled and empowered workers replace the conventional hierarchy (Taylor & Felten 1993).
- A focus on participation in design. Technology (tools, information, machines, procedures etc) should be designed for competent worker performance, rather than automation. This requires an extensive worker participation in design (Ehn, 1992).
- An emphasis on 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 P&L systems that are capable to handle variation and provide stable supply.

LEAN PRODUCTION

An emerging and related approach is "*lean production*". During the last decade several enterprises have achieved flexibility and increased competitiveness by implementing the "lean" or "just-in-time" principles developed at Toyota (Raabe, 1999). Even though the "Toyota Production System" originally was developed for car production, the major principles frequently associated with lean production are not specifically automotive specific. They include time compression and reduction of inventories, product oriented layout, the pulling of production by demand, and product standardization and modularization (Raabe, 1999).

Principles of lean production

Skorstad (1999) summarizes the logic behind lean production in Figure 4.

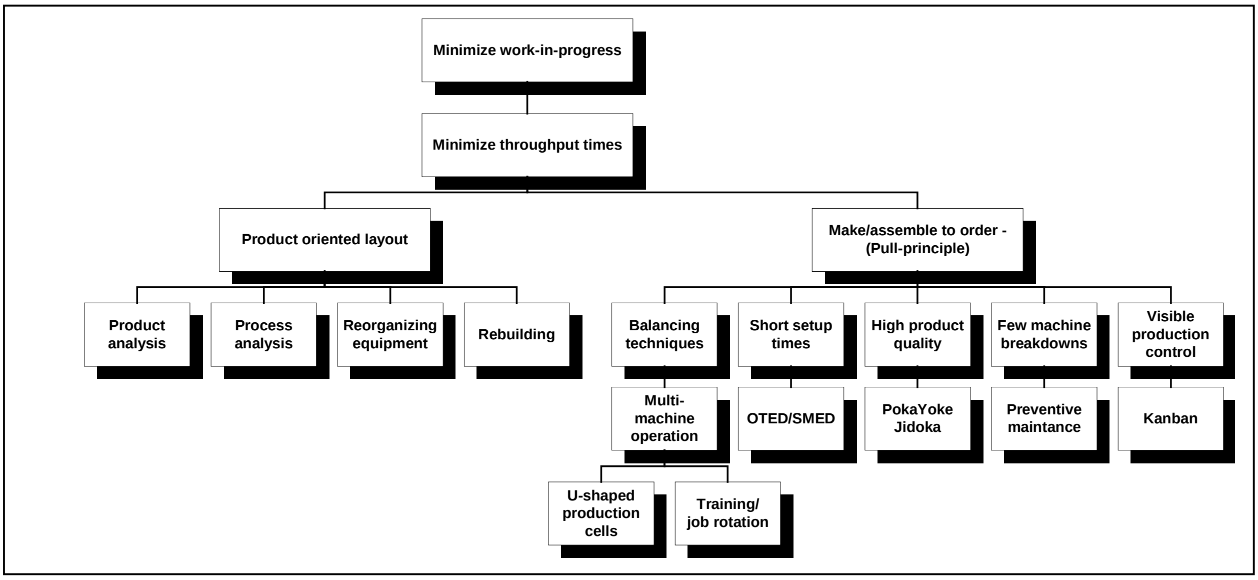

Figure 4: The logic behind lean production (Skorstad, 1999)

The two main principles in lean production are "the pull principle" and product-oriented layout (Skorstad, 1999). The *pull principle* means that production is pulled through the factory by real demand. The pull principle is opposite to "the push principle", which often is utilized in mass production. The push principle means that production is pushed through the factory to meet expected demand calculated from forecasts (Andersen, 1998). The pull principle ensures supply based on real demand, and will to a large extent eliminate the Forrester effect. However, certain requirements are necessary to enable the pull principle.

- Supply on real demand require that Work in Progress (WIP) and throughput times are minimized to ensure responsiveness. Short throughput times are enabled through small batch sizes. Hence, set-up times are reduced to maintain productivity and efficient use of equipment. Techniques like OTED "One-Touch Exchange of Die" or SMED "Single digit-Minute Exchange of Die" are applied.
- Demand-variation in volume and product mix is handled by variation in processes. Balancing techniques like multi-machine operation, U-shaped production-cells and training of multi-skilled operators ensures the required process variations.
- The reduction of stocks, combined with a minimization of throughput times makes the P&L system vulnerable, so zero defects and stable equipment is a necessity in such systems. Techniques like Poka Yoke (a fail safe/equipment improvement process) and Jidoka (automatic halt of production if defects occur) aim at achieving zero defects. Preventive maintenance is applied to avoid machine breakdowns.
- Simple, visible, flow-oriented order systems (Kanban) are applied to only make what is needed – in the smallest possible quantities. A Kanban system might be viewed as a refined version of "Burbidge's way no. 2", and constitute a effective and flexible compromise between Burbidge's two ways. Kanban systems are simple pull-based systems where cards are circulated between workstations. Buffer levels are varied to meet the demand immediately, but most demand variation has to be handled by varying processes. The system principles are:
  - Supply is based on real demand. Products can only be produced up to a predetermined maximum level.
  - The demand of different products is visible. This enables workers to plan efficient order-sequences and to vary the Kanban stock-levels in order to meet demand variations
  - Maximum levels of products (stocks + WIP) is continuously minimized

The second major principle is a *product-oriented layout*, which means that functionally different resources are dedicated to one product or a product-family. The resources are organized in flow-oriented product lines, which provides shorter throughput times, and a simple and visible material flow. In many food-processing enterprises, this principle is already fulfilled. Another related principle is product standardization and modularization. A P&L system becomes harder to co-ordinate as product variety is increasing. A standardization and modularization of products can enable a more simple and controllable material flow and provide shorter lead times.

Integration of processes across company borders

The lean principles outlined above have an internal focus. However, strong coordination between a manufacturing company and its suppliers and customers is important for lean production. It is considered difficult, if not impossible, for a company to get lean in isolation (Womack, 1990). Direct deliveries from external suppliers contribute to time compression and a reduction of duplicate inventories. In addition, lowered inventories, limitation of batch sizes, and frequent changeovers demand fast and frequent deliveries from outside suppliers. When inventories are lowered or removed, the quality of incoming parts is crucial for continuous production. Mutual quality improvement and trust make quality inspections on incoming parts superfluous (Raabe, 1999). Processes are integrated, and operations are only executed once, even across company borders.

The sharing of information, e.g. about end-consumer demand and capacity situation, is enabling effective coordination of resources between customer and supplier. The information sharing can be executed in Quick Response (QR) or Efficient Consumer Response (ERC) systems. The approach of synchronizing and shortening lead times throughout the chain, combined with continuos, fast feedback of real sales information, are central in QR / ECR. The basis of QR / ECR is to allow real point-of-sale (POS) data from the stores to be distributed back up the chain to producers. Really efficient lean production is possible when real demand information and short lead times enable a synchronization of customer- and supplier-operations.

Responsiveness

An emerging development of the lean production mindset that claims to address the needs of market responsive processes is the concepts of "agility" and "mass customization". *Agility* may be defined as the ability of an organization to thrive in a constant changing, unpredictable business environment (Christopher et al, 1999). In agile production, the focus is turned towards time-competition, and the major principles are:

- Enriching the customer
- Co-operating to enhance competitiveness
- Mastering change and uncertainty
- Leveraging people and information (Christopher et al, 1999)

Mass customization is to supply low-cost, high-quality, customized goods and services (Pine II et al, 1993). The key to effective mass customization is to compose a variety of products by standard modules. This requires the identification of T-points in product-structures that enable modular products and variant explosion (Alfnes & Strandhagen, 1999). Moreover, customer-specific supply requires fast and flexible (agile) manufacturing that focus on due-dates rather than cost-efficiency. Non-customer-specific manufacturing processes on the other hand, are not in the same extent time-critical. It is therefore favorable to postpone the customer order decoupling point (Browne, 1996) as close to product completion as possible.

Agile and mass customization are viewed as philosophies of their own. However, their application still relies heavily on the lean principles outlined in Figure 4.

GETTING FLEXIBLE

To improve their performance, leading companies in the Norwegian food industry hold the implementation of lean principles as a possible strategy (Rasch 1999). However, many of the lean concepts and techniques are not directly transferable to the food industry, as food products have characteristics that may constrain the use of lean principles. Some of the factors that can make a direct transfer of flexible principles problematic are outlined below.

Production in the food industry is not purely discrete (as e.g. in the car-industry), but range from discrete to process (continuos) production or involves a combination of these production forms. Moreover, food is organic and food is vulnerable. This plays a crucial role in the design of production and logistics processes. Major aspects are:

- Raw materials (e.g. cereals, vegetables, pigs) need to grow before they can be supplied. This may imply seasonal fluctuations and/or long production time for raw materials.
- Weather conditions, diseases etc. may cause large variations in raw-material quality and supply situations (e.g. strawberries)
- Food products and raw-materials are perishable, this implies limited storage time. However, for some products storing is a step in the production process.
- The quality of some ingredients are rapidly declining during and after processing (heating, melting, boiling etc). This limits the possibility for delays/buffers between production steps, and may imply continuous production in process lines.
- Rough handling, temperature variations or contamination can damage food.

These aspects may have implications for several of the flexible principles outlined in this paper.

- In pure discrete production, flexibility and responsiveness can be achieved through frequent changeovers at each work-station. However, continuos elements in the food industry provide extra challenges in the strive for flexibility. For some food product categories, changeovers result in material losses, and new products may require the changeover of an entire process-line. In addition can the danger for contamination require a fixed product sequence, or a thorough cleaning of equipment between products. In such cases is the application of techniques like SMED or OTED hard. However, striving for reduced set-up times and minimum waste still can increase the flexibility of such P&L systems. Furthermore, short throughput times are a necessity for most perishable food, but responsiveness and reliability can be further be improved by lean balancing techniques and e.g. Poka Yoke, and preventive maintenance.
- Just-in-time deliveries are constrained by variations in product quality and supply situation (e.g. for fish). Such uncertain supply situations require extra flexibility. One can not base production on reliable just-in-time deliveries, but has to use raw materials when they are available and have the sufficient quality. On the other hand, some raw materials (e.g. meat) have long production times and require that orders are made in advance. Still, striving for reliable just-in-time supply will improve the production situation in many food companies.
- Another obvious difficulty is seen for the use of Kanban cards. In the food industry, products are often pushed through process lines where every step then is dedicated to one specific product-type. Product-mix flexibility is only achieved through cyclic changeovers and often requires that all steps are set up for a new product. Kanban cards are unsuitable in such environments. However, process lines often are segments in an entire production process, and Kanban principles (supply on real demand, visible demand etc) might be more suitable for ordering between segments, (e.g. in the co-ordination of packaging and internal final stocks, or in combination with QR).

To summarize, an adaptation of lean principles makes them applicable in the food industry. However, a single focus on lean production might be insufficient in order to achieve flexibility and responsiveness. Getting flexible requires a redesign based on a customized mix of principles from socio-technical design, lean production and other approaches like e.g. the Theory of Constrains (Goldratt & Cox, 1984), or load-oriented manufacturing control (Wiendahl, 1995). The implementation and adaptation of such principles have already been successful in other industries, and many of the fundamental ideas behind the concepts and techniques outlined in this paper may lead to radical improvements in the food industry.

CONCLUSION

The Norwegian food industry will be facing serious challenges when protective customs barriers are removed and foreign competitors are able to enter the Norwegian market. This will lead to fierce competition. One possible way of surviving and staying competitive is to develop and nurture the positive image and characteristics of Norwegian raw-materials. Furthermore, to produce mass-customized niche-products, and fulfill demands from customers requiring more than standard-products. Such a focus requires a high degree of flexibility and responsiveness. However, the Norwegian food industry is still geared towards mass production with functional work-organization, low IT-support in production and logistics processes and traditional mass production principles. Thus, Norwegian food processing companies will probably have a clear disadvantage in the expected new market situation. A redesign of routines, layout, product design, control principles and information technology is necessary to meet the new challenges.

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