SAULI KARVONEN AND JAN HOLMSTRÖM

Operational Development Potential in Project Oriented Manufacturing Industries in Finland

ABSTRACT

The paper studies three important export industries in Finland; the manufacture of pulp and paper machines, the manufacture of steam boilers, and the manufacture of electric motors and transformers. The industries are all project oriented, i.e. suppliers of equipment to industrial investment projects. Typical for suppliers of industrial machinery and equipment is a strong focus on customer needs and a large proportion of customer specific products. First, the operational efficiency of the industries is analysed. Next, the means and methods to improve efficiency from an operations management perspective are discussed.

1. PRODUCTIVITY AND OPERATIONAL EFFICIENCY

It essential to understand that the measurements to use depend on the scope of interest when choosing from the wide range of available productivity measures. When studying social change

SAULI KARVONEN, M.Sc.(Eng) is a management consultant and managing director of SKA-Research Oy
• e-mail: smkarvon@lean.pp.fi
JAN HOLMSTRÖM received his PhD in Industrial Management at Helsinki University of Technology, where he now holds a Docentship in Supply Chain Management.
• e-mail: Jan.Holmstrom@hut.fi

labour productivity is an important factor to consider. Per capita productivity is useful to understand and explain changes in society (see e.g. Harrow). For example, the increase in labour productivity in agriculture provides a growing manufacturing industry with the labour it requires for growth. Similarly, increases in labour productivity in manufacturing supplies a growing service industry with personnel.

To understand changes in the efficiency of manufacturing establishments several factors must be included in the analysis. Total factor measures of productivity typically include human labour, energy, material, and capital (Hayes et al., 1986). In many industries standardisation of inputs and outputs is necessary because the price of inputs and outputs fluctuate dramatically. However, this is a non trivial task because of the complex relationships between factor prices and consumer demand in a competitive economy. Further discussion on the use of productive resources, preference relations of economic agents and market change can be found elsewhere (e.g. Debreu, 1996).

The concept of efficiency adopted in this paper is closely linked to profitability. Productive efficiency is defined as the least-cost combination for a given output (e.g. Dogramaci & Färe, 1988). Efficiency measurement of companies and industries can address either cost efficiency (i.e. minimise inputs for a given output) or value efficiency (i.e. to maximise the value on the market with given inputs). The focus in this study is on value efficiency. Value is assumed to reflect the desirability of output. In the study of competitive industries value takes predominance over output. The cost efficiency of the production process is irrelevant if output can not be sold.

The main inputs by an enterprise for producing value added are personnel and machines. Total personnel costs and costs of machinery and equipment are consequently factors that can be used to describe the value adding process. Thus, value added per costs offers an accessible venue to measure and analyse the efficiency of competitive industries.

Efficiency measures alone are not sufficient to understand the dynamics of industrial competitiveness. For example quality and organisation are also critical. The quality of products and the ability to purchase materials at a competitive price are difficult to quantify on an aggregate level. However, one relevant factor that can be quantified in terms of a statistical enquiry is logistical speed. Here, inventory commitment can be used as an indicator of the delivery process, i.e. to describe the speed that the industrial enterprises are able to respond to the markets.

In many industrialized countries inventory levels in manufacturing have been significantly reduced. In Finland total inventories decreased by one third between 1975 and 1991 in spite of a major increase in the volume of industrial production (Leinonen, 1994). A similar observation has been made in the UK. The explanation for this reduction has been sought in macroeconomic, managerial and technological changes (Black & Peters, 1994). In this paper focus will be on the operational practices of the firm.

The operational measures used in this study are defined as follows:

1. personnel efficiency = value added / (wages and supplements to wages of employees)
2. production investment efficiency = value added /(machine leases + the average investment in machinery and equipment over the last five years)
3. operational efficiency = value added/((wages and supplements to wages of employees) + (machine leases + the average investment in machinery and equipment over the last five years))
4. stock days = 365 * material stocks or finished goods inventory at the end of the year / procurement of materials or sales of goods during the year
5. Work in Process stock days = 365 * Work in Process inventory at the end of the year /(sales of goods during the year – 0.5 * value added)

Operational efficiency is defined as the ratio of value added to the costs of employing the necessary personnel and acquiring the necessary production machinery and equipment. To get an understanding of the competitive situation of an industry the operational efficiency of an industry should be studied over time. The operational efficiency measure is not affected by inflation, as the changes in the price of inputs are compensated by the changes in the price of outputs.

2. ANALYSIS OF PAPER INDUSTRY MACHINERY AND EQUIPMENT SUPPLIERS

The manufacture of paper and pulp machines is studied together with the manufacture of steam boilers. This is because the investment in the paper and pulp industry is the primary business driver of both of these industries. Figure 1. shows the production investment efficiency of the studied industries. Figure 2 exhibits the total investment in production machinery and equipment and figure 3 shows the value added of the studied industries.

Based on these figures (1,2 and 3) the following observations are made:

1. The production investment efficiency in the manufacture of paper and pulp machines has decreased. The developments in the steam boiler industry is very similar to the developments in the paper and pulp machine industry.
2. The value added of both studied industries are highly variable. The variation is due to fluctuations in the conditions of the economy in general,but specifically due to

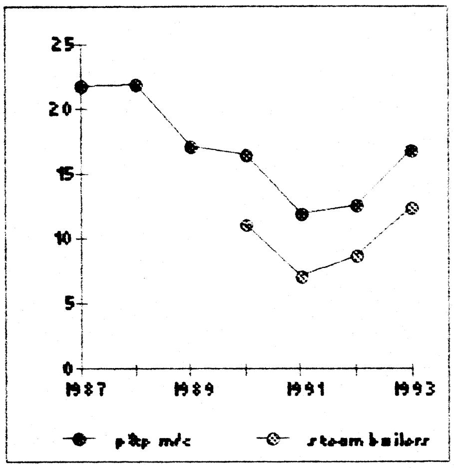

FIGURE 1: Production investment efficiency (p&p m/c = paper&pulp machines). (Statistics Finland 1995) (Statistics Finland 1994)

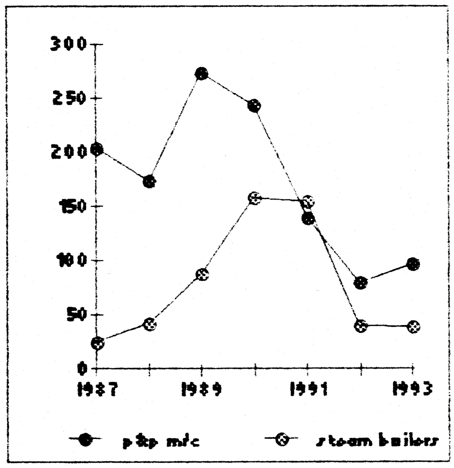

FIGURE 2: Total investments in production equipment/million FIM (Statistics Finland 1995) (Statistics Finland 1994)

the investment practices in the paper and pulp industry. The paper and pulp industry prefers to invest in new production capacity when demand its products are at its peak. Consequently, the demand for paper and pulp machinery drops sharply when the demand for the products of the paper and pulp industry declines.

3. The production investment efficiency of the paper and pulp machinery manufacturers drops by 24 per cent as the same time as the value added of the industry increases by almost 50 per cent between 1987 and 1990. The manufacturers of paper and pulp machines invest most heavily in new production equipment between 1989 and 1990. At the same time the value added of the industry peaks. The response to declining demand is to reduce investment in production equipment by about 40 per cent in 1991. Still, because of the high investment levels of previous years and 29 percent decline in value added the production investment efficiency falls to its lowest point in the period studied. All in all, the production investment efficiency falls by 45 percent between 1987 and 1991.
4. The production investment efficiency improves substantially in the period 1991–1993. In the manufacture of paper and pulp machines the production investment efficiency improves by about 40 per cent. In the manufacture of steam boilers and industrial piping the improvements is more than 70 per cent. The drivers for this improvement is a substantially increase value added and moderate level of investment in new production equipment.

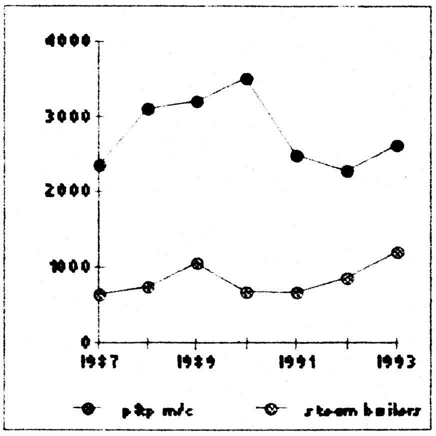

FIGURE 3: Value added/million FIM (Statistics Finland 1995) (Statistics Finland 1994)

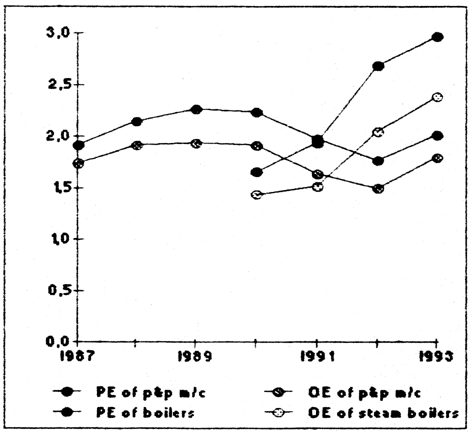

FIGURE 4. Personnel and operational efficiency in the period 1987–93. PE = personnel efficiency, OE = operational efficiency (Statistics Finland, 1995) (Statistics Finland, 1994).

5. The current moderate investment levels for production equipment indicates that a lesson was learned from the mistakes made in the boom years in the end of the 1980's. In the current situation with surging demand investments are better focused, and consequently a future decline in sales will not affect efficiency as drastically as was the case in the early 1990's.

Improved operating efficiency cannot primarily be based on investment in production equipment. High efficiency is a result of efficient operating practices, not having the most advanced production equipment available.

Figure 4 shows the personnel efficiency of the studied industries. The personnel efficiency of the paper and pulp machine industry is at its highest in 1989. From this high point the efficiency declines by 20 per cent until 1992. The combined effect of inefficient use of personnel and production equipment can be seen in the decline of the operational efficiency measure.

From 1992 the operational efficiency improves. The industry has had time to adapt to the fall in sales by reducing personnel costs and investment in new production equipment. The steam boiler industry experiences a similar dramatic decline in efficiency and strong recovery. The personnel efficiency in the steam boiler industry increases twofold during the period.

Figure 5 describes the development in the production investment and personnel efficiency in the electric motor and transformator industry between 1979–92. Until 1987 the personnel efficiency remains on a stable low level while the production investment efficiency de-

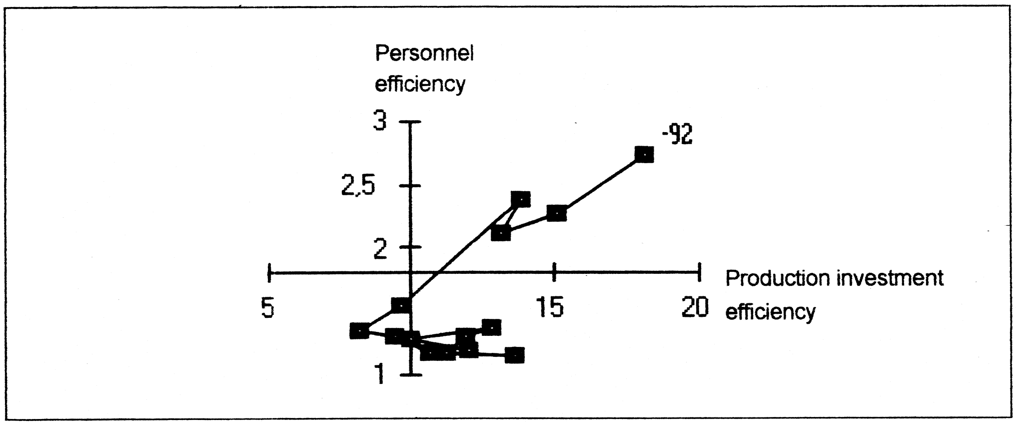

FIGURE 5. Production investment efficiency and personnel efficiency in the electric motor and transformator industry (Industry SIC79).

clines. This means that the increasing level of investment in production equipment does not lead to a more efficient utilization of personnel resources. In 1987 both the production investment efficiency and the personnel efficiency starts to improve. This dramatic turn around is explained by the fact that the industry acquired access to the international marketing channels after the acquisition of the largest Finnish enterprise by ABB. The value added of the industry could be quickly increased with better access to international markets.

This is an illustration of how operational efficiency is not only dependent on efficient operating practices, but also on markets and products. With new marketing channels the industry sector gets new customers for which can be produced at no additional cost or investment. This increases the ratio of value added to costs.

The improved efficiency is not only a consequence of new markets. The steady improvement would not be possible without the simultaneous introduction of more efficient operating practices. A focus on investment driven improvements was replaced by operational practice driven improvement. This emphasises the efficient allocation of the current company resources, not acquiring new resources and replacing old production equipment.

3. OPERATIONAL SPEED

The reduction of lead times is an important enabler for finding the means and actions to effectivate industrial operations and reduce costs. The reduction lead times reduces working capital as well as makes it easier to allocate recourse according to customer demand.

The average lead times in an industry can be approximated by calculating the stock days

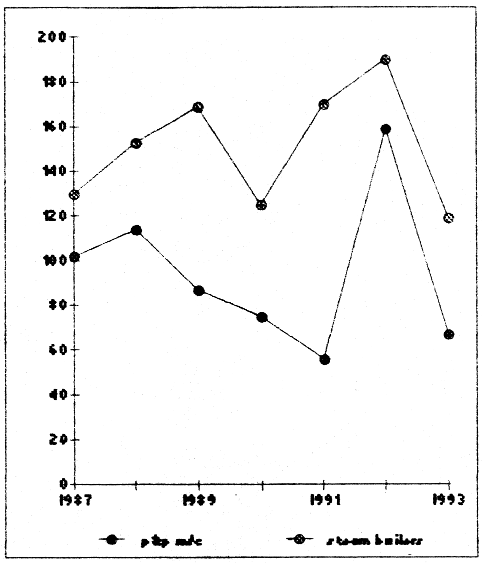

FIGURE 6. Work in Process stock days.

of the industry. Figure 6 shows that the production lead times in the paper and pulp machine industry (p&p m/c) have been substantially reduced between 1987 and 1991. The trend appears to be consistent, if the year 1992, which is exceptional because of the sudden reduction in output levels, is excluded. In 1992 the work-in-process (WIP) inventory doubles from the previous year. At the same time the value of deliveries falls by 18 per cent and the value added by 8 per cent. This is the reason why the WIP stock days suddenly increase almost threefold.

An important cause for the longer lead times is the economic recession, during which prices fall and the industry gets much few orders for green field installations. The incoming orders were to a much larger proportion orders to upgrade old plant. In this type of projects there is much less repetition and opportunity to efficient work process than in projects to deliver new machines. For example the opportunities to benefit from modular product design and standardization of components is limited in plant upgrade projects. This leads to problems with production planning and control and consequently longer lead times. The end of the recession and more orders for new paper and pulp machines is visible in 1993. The WIP stock days return to the level of 1991.

The average lead time in the steam boiler and industrial piping industry has not fallen during the studied period. Just like in the paper and pulp machine industry the highest WIP stock day value is from 1992. This is due to a 31 per cent increase in the WIP inventory and

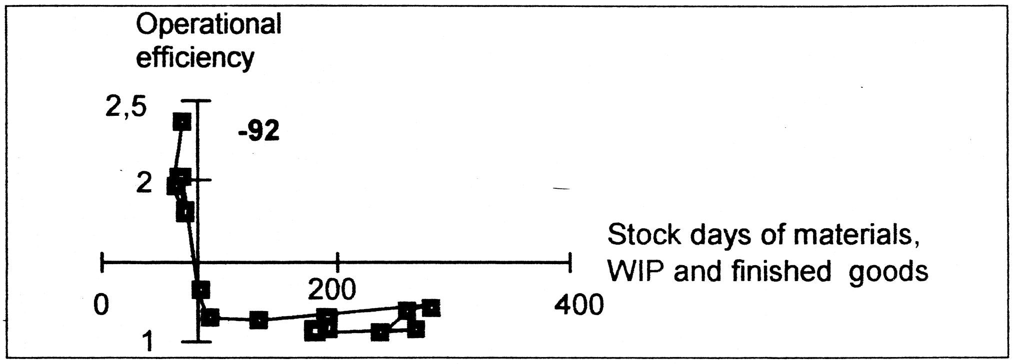

FIGURE 7. Manufacture of electric motors and transformators: Operational speed and efficiency 1979–92 (Industry SIC79).

only a 19 per cent increase in deliveries. In 1993 the WIP stock days are significantly reduced in this industry too.

The economic benefit of reduced lead times in the studied industries is substantial already from a pure working capital point of view. In the studied period the average WIP inventory of the industry is 1,4 billion Finnish marks (FIM). A one third reduction in lead times frees more than 400 million FIM working capital. Additionally, the reduction would also reduce yearly operating costs by 120 million (the cost of capital, labour, facilities and damage is estimated as 30% of the inventory value).

However, the benefit of reduced lead times is much greater than the benefit of reduced working capital alone(Hayes and Clark, 1986). A lead time reduction has a direct positive effects on productivity. Faster throughput and delivery makes it simpler to allocate resources for value adding activities and to eliminate waste (Holmström, 1995). A faster operation also improves the possibilities to manage demand distortions in the supply chain. In the fast operation a shift in demand is immediately evident and can be managed directly through the order book. There is no need to anticipate demand in parts production and procurement of materials.

The developments in the electric motor and transformator industry supports this view. Figure 7 shows how the operational speed was substantially improved for many years. Only when the operation was able to operate with quick response to customer need did the efficiency of resource allocation improve. The operational speed measure is obtained by summing up the stock days of materials, work in process and finished goods.

4. WAYS OF IMPROVING OPERATIONAL EFFICIENCY

4.1 Theoretical base: analysing the operational activity chains

By analyzing the operational activity chains it is possible to identify the activities that cause costs and delays. From the activity chains the activities that do not add value to the product are separated. The non-value adding activities can be eliminated and the remaining activities can be performed faster by reducing waiting times and delays (Turney, 1991).

The LOGI-analysis emphasizes a time based analysis of logistical activity chains (Luhtala et. al, 1994). Based on activity chain analyses in a dozen make-to-order manufacturing enterprises it was concluded that the most unnecessary delays occur in the interfaces enterprises and operating units. Problems concerning project management also accumulate in the interfaces. The interfaces where problems occur in make-to-order production are:

- customer/sales organization
- sales organization/product design
- product design/manufacturing
- manufacturing/transportation
- transportation/installation

For instance, the time buffer between product design and manufacturing is usually a sign of lacking confidence between the project co-ordinator and the subcontractors. It is also important to consider risk in addition time and cost when analysing activity chains. Activity based risk assessment means that the required know how and necessary resources needed to perform an activity is determined. For example, the special know how needed to perform a task on the critical path could mean that the whole project is delayed if the one individual that has the necessary skills becomes unavailable.

4.2 Cases of improvements of operational efficiency

When the redundant time buffers have been removed the activity sequence can be optimized and paralleled. In one make-to-order activity chain where the interdependencies between installation and testing was analyzed it was found that concurrency was the only way lead times could be substantially reduced. To perform installation and testing concurrently it was necessary that the engineering designing power supply agreed on the power supply design in advance with the person responsible for the installation on the field. By taking installation requirements into account in advance the installation and testing phase could be reduced by four weeks. This means freeing 100 million FIM in working capital four weeks earlier in each case the new work practice of clearing installation requirements in advance is used. The cost reduction is about 2 million FIM per installation.

A major improvement potential is associated with the application of group technology (Burbidge, 1989). Production facilities were commonly streamlined with the introduction of production cells and focused factories in the 1980's. Group technology is not very well suited to plan new production systems, its greatest benefits are realized when the goal is systematically redesigning existing production systems. The tooling analysis, J.L. Burbidge calls his technique for reducing set up times and the number of different tools used, has proven effective in make-to-order manufacture companies (Karvonen and Holmström, 1996) (Karvonen et. al, 1997). Another effective group technology technique in the make-to-order industry is the line analysis. This is an useful method because the optimal material flow and routing changes constantly on the shop floor with the introduction of new products and new variations old products. Based on the line analysis it is possible to relocate work stations and keep the flow of materials fast and uninterrupted.

A particular problem in the project-oriented make-to-order manufacturing industry is the constantly changing schedules and plans in the implementation phase. The design is usually started without complete information. This means that the specifications are frequently updated throughout the design of the product. The product design changes become critical when they affect CAD-files that have been used as the basis for procurement and parts manufacture. In this case materials and components which are not according to the specification start to be purchased and produced. The same product design may affect several subcontractors. It is beneficial if the production system is product oriented rather than process oriented in order for the engineering change to reach the location where it must be acknowledge in the production process. If the production process of the subcontractor is product oriented it is possible for product design to inform the shop floor directly about product specification changes (Hameri and Karvonen, 1994). This makes the type of production system a very important criteria in the selection of subcontractors the make-to-order manufacture.

4.3 The project management systems of the next generation

Business process reengineering usually involves the radical change of work processes with the help of information technology (Hammer, 1993). McKinsey's recent information systems study indicates the greatest potential for information technology lies in product development and sales (Kempis and Ringbeck, 1998). Especially that is an important point in project management as the highest cost and profit relevance is in the sales phase and at the beginning of engineering. Due to the customer driven nature of make-to-order projects there will always be engineering changes. The effects of engineering changes should in the future be minimized by introducing standard work practices to deal with engineering changes.

Fast standard work practices to cope with engineering changes can be supported by with information technology. The next generation of project management software transfers all change information reports to a special change database (Törmä et. al 1995). When the change information report is transferred to the resources under the change it is automatically transferred also to the change database, so eliminating manually formulated reports (Karvonen, 1998). For instance, sales can focus on the contract negotiation with the help of the change analyses to prevent the design changes during the procurement phase.

The next generation of project management software are based on linking product structure with the activity networks of the projects (Törmä and Syrjänen, 1995). The requirement for the use of such systems is that the activities and products of the company is accurately modelled. It is however clear from research in the make-to-order manufacturing industry that many firms do not know their own processes in adequately detail (Luhtala et. al, 1994).

As it was pointed out previously, the streamlining of processes requires analysis, the elimination of non value added activities and development of remaining activities . This way the activity chains and product structures are simplified step by step. In this situation the products and the links the project tasks can be modelled in sufficient detail to enable the effective application of information technology. The pioneers in this effort will probably acquire competitive advantage through shorter lead times, lower costs and better customer service.

CONCLUSIONS

The strength of the efficiency measure of this study is in its explicit nature, thereby enabling conclusions pertaining to business strategy. This is in strong contrast to classical productivity measures. Labour efficiency based productivity measurement focuses on a physical variable, such as kg/capita. The link to profitability is only implied. The strength of the efficiency measure of this study is in its explicit nature, thereby enabling conclusions pertaining to business strategy. The idea of applying a net value based productivity measure is not new. For example Simula (1983) and Hörnell (1992) have at least proposed the application of such measurements. Hörnell considers value added measurement as the sole basis for productivity, although he applies the hourly based, more conventional analysis of value created.

In the project oriented make-to-order industry the potential for improved operational efficiency and speed is in changing the operational and management practices. The methods and techniques developed under the headings of JIT, lean production and business process reengineering are primarily based on experiences in the repetitive manufacturing environment. The application in the make-to-order industry requires particular adaptations and co-operation between organizational units.

The traditional paradigm of mass production argues that improved productivity is achieved by increasing volumes and economies of scale. Consequently, improved productivity contributes to unemployment if growth cannot be achieved. The alternative to this industrial strategy is to focus on the efficiency of resource allocation and strive to give customers better service, more variety, and sophistication. This could also be described as minimizing waste in providing value to the customer.

However, variety and efficiency are difficult to achieve simultaneously. Results from the analysis of the Profit Impact of Market Strategy – study (Buzzel & Gale, 1987) indicate that customization of products in general has a negative effect on profitability. This is supported by a study of the UK metal component manufacturing industry where make to order production was found to have a unfavourable impact on profitability (Hamblin & Nugent, 1991).

External factors are more difficult to affect. The studied industries are all more or less dependent on the investment behaviour of the paper and pulp industry. These investments are mainly made when the demand for the forest industry product peaks. This investment behaviour is explained by the high capital requirements for investments in production equipment. However, more attention should however be given to fact that early investment gives the firm the opportunity to better capitalize on high price levels. For the manufacturers of equipment the situation has again picked up with the change of the economic cycle in Europe and North America. ■

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