Managing agility and productivity in the electronics industry
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Managing agility and productivity in the electronics industry

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Keywords

Electronics industry, Manufacturing systems, Enterprise zones, Resource management

Abstract

Managing the production and operations of a contemporary electronics manufacturing is challenging. Companies need to be proactive for uncertainties of the market in a productive way. This paper analyses the electronics manufacturing context and proposes the data system implementations based on context requirements. The general trends in electronics manufacturing are time-based competition, increasing product variety and new technologies. Cost structure changes are driving productivity. Price erosion is forcing flexible operations and fast inventory turn rates. The uncertainties in electronics manufacturing that need especial management are: volume – the change in demand and its effect on lead-time of order-fulfilment; product mix – managing product variety and lot sizing issues and product life cycles – changing products and production technologies. Managing and measuring these dimensions require wide implementation of ERP packages. In some cases, more advance planning tools such as product configurators and advanced planning systems are required.

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1. Introduction

Agile manufacturing is a concept describing maintaining good productivity under pressure of uncertainty. A useful definition of agility is "the capability of reacting to unpredictable market changes in a cost-effective way, simultaneously prospering from the uncertainty" as suggested by Gunasekaran (1998). Sometimes, we understand agility as a business concept for prospering from environmental instability. According to Vokurka and Fliedner (1998) agility is the ability to produce and market successfully a broad range of low cost, high quality products with short lead-times in varying lot sizes, which provide enhanced value to individual customers through customisation.

Constantly changing markets demand more differentiated products in lower volumes and within shorter delivery times. This is the case especially in industrial electronics. Another way to say this is to describe agility as "the ability to grow in a competitive market of continuous and unanticipated change, to respond quickly to rapidly changing markets driven by customer-based valuing of products and services" (Definition of agility – Youssef, 1992 in Kidd, 1994; Yusuf *et al.*, 1999). A manufacturing company being agile should not be only reactive for uncertainty but also proactive for unknown. According to the literature the following three are characteristics for agile manufacturing:

(1) Delivering value to customers (Anderson, 1997; Goldman *et al.*, 1995; Vokurka and Fliedner, 1998), especially in time-based measures (Youssef, 1992),
(2) Being ready for changes in terms of market and technologies (Goldman *et al.*, 1995),
(3) Prospering from the turbulent environment emerging (Goldman *et al.*, 1995).

Flexibility as a close concept to agility refers to the capability to adapt to a changing environment and is also related to the concept of elasticity. Sometimes these words are used as synonyms, but generally flexibility is connected to ability to manufacture in different conditions, while agility is business concept for overall company performance. Much attention has been paid to total productivity measurement as originally defined by Craig and Harris (1973). They argue that their measure shows the company as an entity and furthermore maximises the return of invested capital. Many modifications of this productivity framework have been suggested for different purposes. However, the idea of productivity as a ratio between outputs and inputs remains the same in most of the models. The number and nature of input components vary, some models make

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distinction between price change and productivity changes. Nevertheless the core is the same.

Productivity is a dynamic measure by nature. Productivity of a manufacturing company may differ by products produced and the technology used. Richardson and Gordon (1980) claim that companies need to utilise different performance measures at different stages of a product life cycle. In the first stage, the firm maximises the performance by concentrating on innovation, flexibility and responsiveness. Later on, a firm operates with growing capacity. Appropriate measures in this stage include capacity utilisation, growth, order backlogs, stock outs and lost sales. In the last phase, cost minimisation is important. Measures such as cost per unit, labour productivities, etc., are typically in use. Richardson and Gordon (1980) also claimed that as product life cycles decrease the importance shifts from productivity to measures related to innovation and flexibility. Thus, the understanding of appropriate measures in dynamic situations is essential.

This paper analyses what are the data system implications that may be derived from the market requirements and generally the electronics manufacturing context. The reminder of this paper is as follows. First, the market trends in electronics manufacturing are analysed.

2. Market trends in electronics manufacturing

The long term trends in manufacturing that are pointed out in this chapter are very common in many industries. The phenomenon behind is probably the production paradigm change from cost effectiveness and conformance quality to lead-time and flexibility issues. Many researchers have noticed this, (Dugay *et al.*, 1997; Jaikumar, 1986; Kenney and Florida, 1989; Roobek, 1987; Spina *et al.*, 1996). In the past, one of the most topic issues of mass production were the economies of scale – cost reduction by increasing the volume of production by using a highly specialised workforce divided by tasks. International markets of produced goods has caused new dynamic environment for companies operating with technology, i.e. electronics manufacturers.

Stalk and Hout (1990) claimed in their book "Competing Against Time. How Time-based Competition is Reshaping Global Markets," that timing is one of the most important productivity drivers of a contemporary company. This claim has been supported by many other authors, such as Spina *et al.* (1996) who found that time-based competition and uncertainty are typical of the new environment. The adopters of new business tools, such as time-based management and flexible manufacturing, were bigger companies, typically operating in industrial countries.

At the same time, the concept of strategic flexibility has changed the prevailed conception that company can be good at one thing at time, cost effectiveness, market niche selection or product design uniqueness. The new claim is that companies can have several high performances simultaneously (Spina *et al.*, 1996). The concept of it is sometimes referred to as strategic flexibility.

To summarize some general trends in contemporary manufacturing, three major issues are emerging. They are as follows.

(1) Competition in the markets is time-based. Right timing of new products in markets and competitive lead-time performance of order-fulfilment emphasise the success of any technology company. According to Mason-Jones and Towill (1999), pressure for progressive reduction in replenishment lead-times is independent of the market sector. Industries from food and consumer goods to chemicals and automotive all have significant improvements in order to attain fulfilment (Table I). It is obvious that if the cost level is appropriate and the product quality is satisfactory, the markets seek for fast delivery.

(2) Product variety is extending in many industries. Customers require wider selection of goods and inexpensive tailor-made solutions. Companies adopt new principles for late differentiation of goods. Products are built according to customer orders and sometimes there is a lot of selections to be made before the product is fully specified. Mass customisation is a good example of this kind of trend (Pine, 1993). Designing for manufacturing is a requirement for cost effective tailoring. A great variety of products cannot be stored in inventory and new approaches are required.

(3) Fast entrance rate of new technologies shortens product life cycles. Emerging new

Table I Examples on time competitiveness trend

Market sector	Lead times [days] 1987	1992	1997(estimation)
Food and beverages	5	4	3
Fast moving consumer goods	9	6	4
Petrochemicals	16	11	6
Automotive	28	20	12
Building materials	42	18	7

Source: Mason-Jones and Towill, 1999

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technologies drive the productivity and force users to adopt new solutions frequently. Life cycles of products have decreased from decades to months. Especially, fast developing industries like electronics is challenged by uncertainty of new and better product technology. In practice this means that the managers are required to maintain productivity in case where the product to be manufactured is changing several times every year.

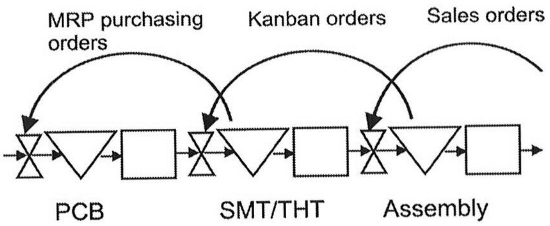
The productivity challenge is to maintain appropriate performance in this kind of dynamic environment. These trends show some important requirements for the manufacturing companies. For this reason, also manufacturing strategy research is waking up to understand the effects of different flexibility dimensions. According to Gerwin (1993) flexibility is a central tool in both defensive and proactive generic manufacturing strategies. According to Gerwin, the generic strategies include:
(1) adaptation,
(2) redefinition,
(3) banking, and
(4) reduction.

Any company should be able to know the required amount and type of flexibility in different situations. The value and cost for this ability should also be valued as outputs and inputs. (Gerwin, 1993; Jaikumar, 1986).

3. Cost structures and price dynamics

Value chain structure has changed in electronics manufacturing. The pressures from markets has driven companies to concentrate on core competency and outsource other functions. There has been an entrance of a new group of companies concentrating on manufacturing only. These companies are called as electronics contract manufacturers (EMS) and they do not have own product design or marketing departments, but perform well in manufacturing and logistics. Component manufacturing such as microchip production or printed circuit board producing is a separate world. Sometimes there is even distribution agents or special vendors between the component manufacturers and contract manufacturers. The chain of orders from sales to manufacturing, manufacturing to component purchasing is long but the response need in high. Figure 1 shows an example of a small industrial electronics supply chain consisting of three different companies. The sales orders are received by the brand name company that is using original equipment manufacturing (OEM). A contract manufacturer operating with surface mount technology and trough hole technology with full material responsibility does the manufacturing. PCB manufacturer supplies the chain with tailored boards.

Figure 1 Order mechanism of example electronics manufacturer supply chain



As the chains are getting longer, the proportion of purchases and materials are increasing in total cost. Typically, the share of purchased goods varies between 30 and 90 percent of total manufacturing costs. Labour and fixed capital costs present low percents and the focus is on the management of working capital and purchasing. In this kind of environment, the companies need to pay attention to delivery conditions and inventory control principles. Stock out costs would be very expensive and excess stock would increase the inventory level. Low inventory turn speed would affect inventory holding and working capital costs. This is a trade-off, which needs to be assessed in the changing market situations.

Taken the purchase intensive cost structure, price erosion is another effect eating the hard earned value added. Price erosion means a situation where decreasing price of the goods is a continuous trend. Price erosion is caused by fast development of manufacturing, the learning effect, in addition to competition in markets. Most of the mass produced goods are getting cheaper in the long run, but this is accelerated in high clock speed industries such as electronics manufacturing. To take a long term example, the US commodity index is today worth 20 per cent of it was 150 years back (1845-1999). Raw materials are cheaper than ever.

The pace of change is completely different in electronics. To take a modern day example, we could analyse some of the main components of personal computer. The most expensive components of any desktop computer are
(1) micro processor,
(2) mass media storage (hard-disk), and
(3) network communication interface.

Figures 2 and 3 show the price trends of this kind of components. The data for these figures have been collected from Web-based component price watch service (source: mbnet.fi). *Y*-axis represents

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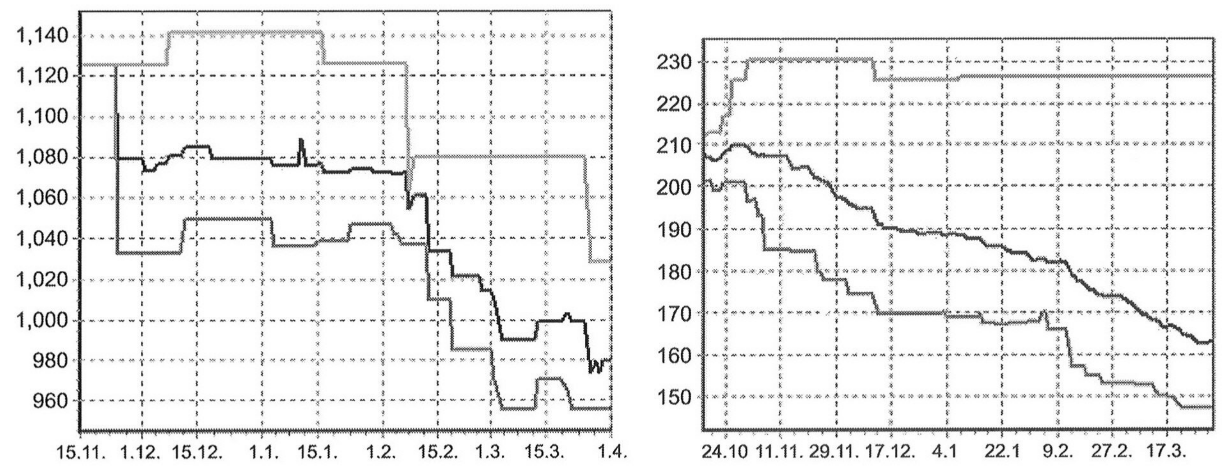
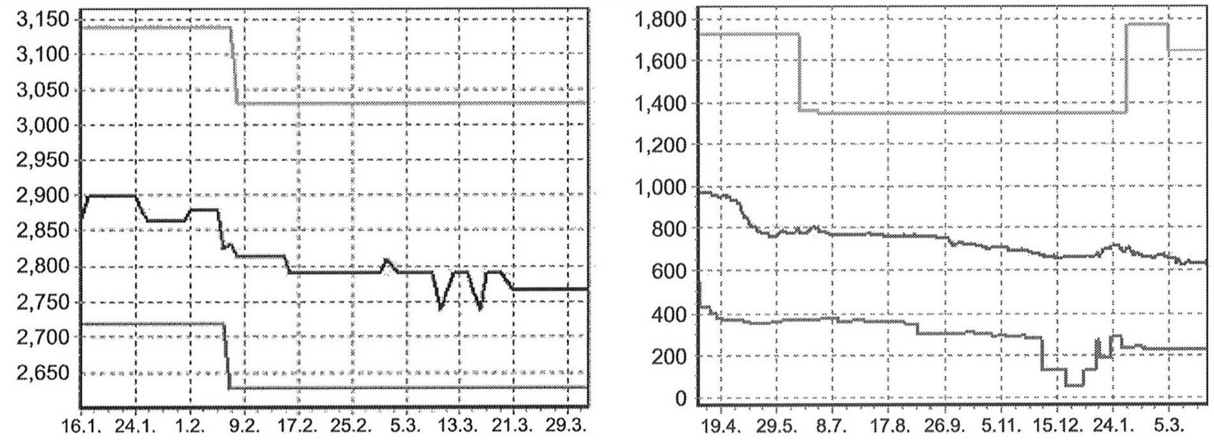
Figure 2 Price erosion of Quantum Atlas 10K III 80-pin (73 Gb) and Maxtor DiamondMax D740X (60 Gb)



Source: mbnet.fi

Figure 3 Price erosion 1,024 Mb, 100 MHz SDRAM and WLAN base station price erosion



Source: mbnet.fi

for price of the component in FIMs, *x*-axis is the time in dates. The upper trend line represents the most expensive market price for the product, the middle one the average and the lowest the cheapest price of the markets. All examples include several sales companies distributing the same component.

It is easy to consider how production managers would feel having this kind of components in stock for several months. Price conscious customer would probably not pay for the old technology a premium price. The enterprise management systems store item-pricing information in the inventory control systems or in a separated warehouse management system, which may be connected to an automated warehouse. The basis for tracing the impact of price erosion is derived from the bill-of-materials and purchase orders. Using LIFO principle in inventory management is very typical in order to support the high cycle time in inventories. In some cases market pricing is used. For example, standard components, such as memory chips, may be valued in stock markets. The management information system (MIS) may be connected to retrieve the latest pricing information for a item.

It is common knowledge in economics that the flexibility of production capacity has a direct impact on markets. There is a relationship between supply and demand called as price. Price is set where supply meets its demand. Higher demand versus supply ratio, the higher price. The concept of elasticity of supply has been used in economics to describe the ability of a manufacturer to operate in different demand levels. Supply elasticity is defined as a ratio between the percentage change in the quantity supplied and the percentage change in price. According to the elementary theory of price, "supply elasticity is a measure of degree of

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responsiveness of quantity supplied to changes in the commodity's own price" (Lipsey, 1980). The important elasticity factors in electronics industry are price elasticity and lead-time sensitivity of markets.

Oversupply and little demand cause sinking prices. An example of this is the memory manufactures case. RAM chips are used as a working memory in most computers. The technology is very difficult to manufacture and for this reason there are only very few RAM chip producers in the world. The demand is naturally very high. Technology in memory chips is developing in quantum leaps, which forces the products in great price erosion. Companies introduce new models, capable of handling bigger amounts of memory every now and then. New technology replaces old generation and products are highly standardized for use. To sum this up: production capacity of RAM chips is rather limited even globally and the prices are very sensitive to technology changes. Computer manufacturers have experienced this kind of drastic change in the past, for instance after earthquakes in Japan, customers overreacted in their purchase orders. Everybody wanted to get some safety stock because it took a long time to rebuild the manufacturing capacity. An increase in sales price was obvious and was corrected after a long time when all inventories were back on their normal level.

The very same thing is also emerging on semiconductors in generally. According to Dr Grove of Intel Corporation the supply and demand have been in equilibrium for 35 min in a 10 years period. The challenge of manufacturers is to be ready for the uncertainties. Towill (1991) says that this conclusion has effects on resource utilisation planning in the supply chain.

4. Product volumes and lead-time

According to Gunasekaran (1998) an agile manufacturer can be described with four characteristics: customer enriching pricing strategies; co-operation, which enhances competitiveness; managing organizational changes and uncertainty; investments that emphasise people and information. As suggested earlier, managing lead-times is important for two reasons. First, the customers are expecting for fast delivery of even tailored products. Secondly, the other companies in the chain are not willing to carry excess inventory for better sales availability. Price erosion forces production planning to move goods fast in the chain and keep stock only for inexpensive components and raw materials.

Figure 4 shows an example of time analysis for an industrial electronics product. The bars indicate how long orders spend time in different stages of production. The unit of measurement is in days. Each bar is divided into waiting part (left hand side), where orders are waiting to be processed and the right hand side, which is showing the actual processing time. The total order fulfilment time is component of queue in production, order batching (lot sizes in manufacturing and transportation) and actual processing time. The complete turn time for the whole chain would be approximately 90 days. In practice, the inventories feed next stages between the manufacturing phases. Capacity requirements planning for a chain like this requires real time information. Available-to-promise numbers for the customer may require calculation of the whole supply network and automatic bottleneck search.

It is a traditional cost accounting principle that capacity utilisation level is connected to unit cost of goods produced. The utilisation of capacity determines the lead-time for order-fulfilment. But good lead-time may be of value too. Kumar and Motwani (1995) concluded that time related performance leads through better product availability and more efficient production towards better profitability. Stalk (1988) proposed that responsiveness is so crucial a priority for customers that in the future factories will move closer to the markets. There has been this kind of movement in sight. Increasing consumer electronics markets in Asia have forced companies to move manufacturing near end-users. Of course, this is not only for cheaper labour costs or better understanding of markets but also due to delivery performance.

Lot sizing decisions is probably the most important issue in lead-time manufacturing. There are several lot sizes that should be taken into account, for example: manufacturing lot size, ordering lot size, set-up lot size and transportation lot size. To consider the relationship between lot sizes and capacity utilisation and their effect on lead-time, we can use queuing theory for demonstration[1]. Figure 5 shows that the waiting time is plotted as a function of lot size, which is increasing on the x-axis. There are time curves for utilisation of 0.40, 0.20 and 0.80, which also gives the idea of the behaviour in the cases of different demand levels. The figure shows that lead-time is very sensitive to lot sizes especially with high utilisation. Combination of big lot sizes and high capacity utilisation result long lead-times, which may affect customer satisfaction and force to price competition. The same result can be demonstrated easily with production simulation programmes or by seeing the practices of companies. According to Burgess (1998) cost is not where the major improvement takes place, but rather in the

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Figure 4 Time analysis of an electronics manufacturing supply chain

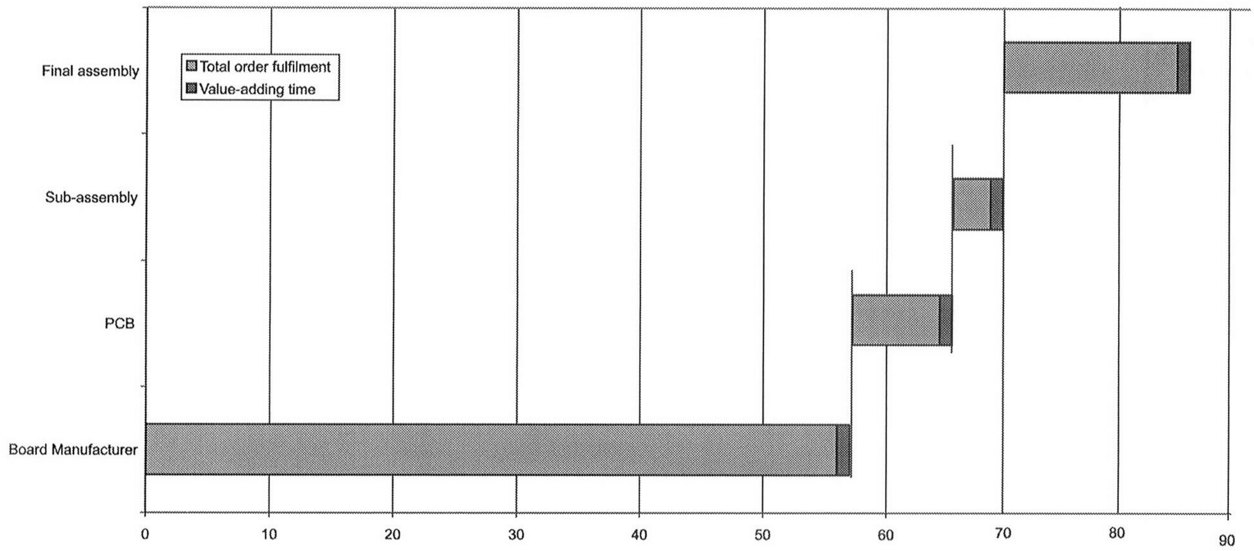
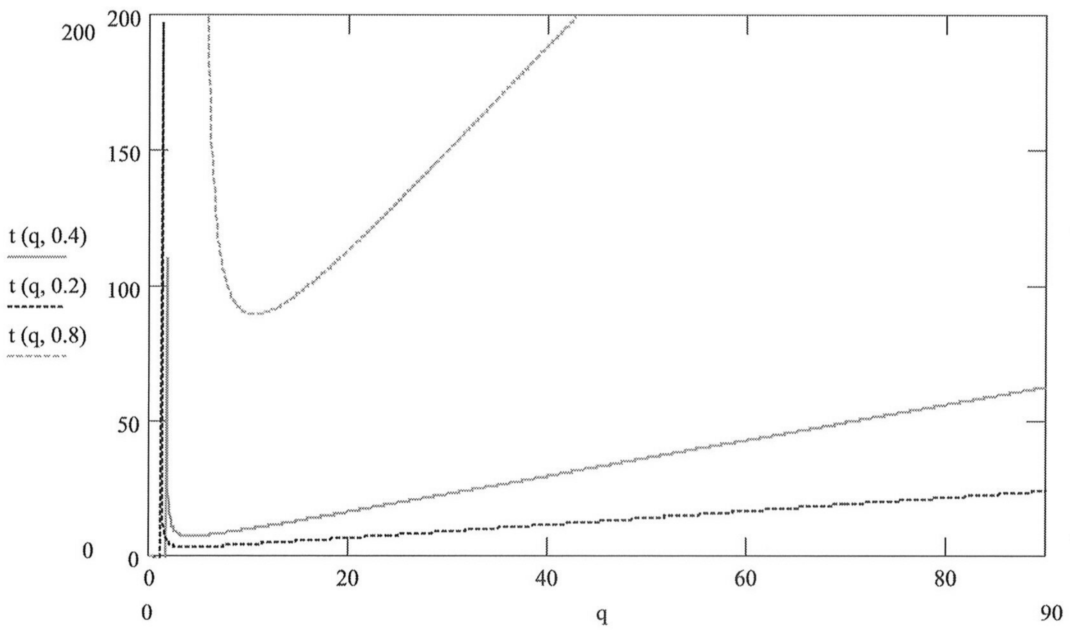


Figure 5 Order fulfilment lead-time: effects of lot sizing decision with the utilisation parameters of 0.4, 0.2 and 0.8



resulting reduced cycle times. In other words: capacity has time value. If the markets are willing to pay for short lead-time, the business-based profit optimum is completely different from the cost minimising solution. The use of buffering inventories is more difficult today because of great product variety and fast technological changes.

Lot sizing decisions are made in MRP-II calculation. As a basis in together with the bill-of-materials, lot sizing for the orders and production, should be defined and updated frequently. Products move from novel to mature very fast and lot sizing should be in accordance. New ERP features such as an automated ABC analysis helps this procedure, which may involve with thousands of items.

Lead-times and utilisation are connected to perceived value and cost of manufacturing. Small lot sizes and low utilisation may cause poor cost performance but on the other hand. If customers are willing to pay for the ability to react, the company profits from that. An agile enterprise is thus "capable of operating profitably in a competitive environment of continually, and unpredictably, changing customer opportunities" (Goldman *et al.*, 1995). Thus, agility is strategically connected to the competitive ability of the company.

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Increasing product variety is caused by tightening international competition, which drives companies to produce a more extensive variety of goods within a shorter time (Da Silveira, 1998; Fisher and Ittner, 1999; Frey, 1994; Lee and Tang, 1997). Traditional production systems have problems in generating accurate sales forecasts for products and maintaining inventory and service levels within uncertainty (Lee and Tang, 1997). According to long-standing opinion, large product variety combined with low volume causes bigger unit costs due to complexity that drives the overhead costs up (Hayes and Wheelwright in source Kekre and Srinivasan, 1990).

Managing product variety is connected to lot sizing and especially set-up issues. Fast set-up process enables cost-effective changeover. Kekre and Srinivasan (1990) show with empirical data that large product variety may lead to greater market share and for this reason the inventories or immediate costs will not necessarily rise. The explanation for this is the use of advanced manufacturing techniques, such as group technology, flexible manufacturing, setup-time reduction and just-in-time practices (Burbidge, 1996a and b). Management of variety is not only production issue, but a challenge for sales as well. Several sales automation tools have been presented for sales of complex products. These kinds of expert systems are called usually sales configurators (Metaxiotis and Psarras, 2003). Sales configurators input customer requirements of a product and as a result generate a manufacturing specification including sometimes BOM, assembly instructions, etc. The output for the customer may be a technical speciation and offer for a quote or order confirmation. Configurable products are also supported by some ERP software, but currently it is common that this requires external software.

5. Product life cycles

One of the important trends in electronics manufacturing is that the technological life cycles have shortened, because the companies invest heavily in product development. Sometimes the drastic changes occur in big leaps changing the whole industry structure. Christensen (1997) calls these as patterns of evolution, which means cumulative changes in the attributes of individual new models that are introduced. According to Christensen the patterns of evolution are phases of:
(1) functionality development,
(2) reliability improvement and
(3) and finally, shifting to price competition.

Products have life cycles in manufacturing, but the patterns of evolution are connected to technologies. Sometimes these are very connected to each other and the concepts are used mixed. Oiwng to production system variations and a strong learning curve effect, it is extremely difficult to use standard costs from a cost accounting point of view (Frey, 1994). Fast changing technologies represent a crucial problem for electronics manufacturing companies.

From production planning and control point of view, the stages of product life cycle of a products include three major stages:
(1) ramp-up,
(2) maturity, and
(3) ramp-down.

The ramp-up stage is challenging to manage; typically the slow demand starts to increase vigorously in some stage. The pattern follows an *s*-shape curve, but the uncertainty remains with the timing and the final volume. In the beginning the quality issues of new product are on focus, but very soon the emphasis will be on keeping the volume up. Sometimes these issues are referred as ramp-up to quality and ramp-up to quantity, respectively. Figure 6 shows an example of this kind of demand pattern.

All products will reach their maturity point. Sometimes the maturity of demand will be a very short time and new introduced product replaces old ones very fast. There is a great difference between product life cycles of products. For instance, industrial electronics product such as automation control module, may be produced with only minor modification for 10-20 years. On the other hand, consumer electronics such as DVD players, personal computers or mobile phones may have life cycles of months. For example, a life cycle of mobile phone is about 11-24 months, while a laptop computer could be in production for 2-3 months only (Figure 7).

The last stage of product demand is ramp-down. Sometimes the demand decreases naturally,

Figure 6 Ramp up to quantity of a product

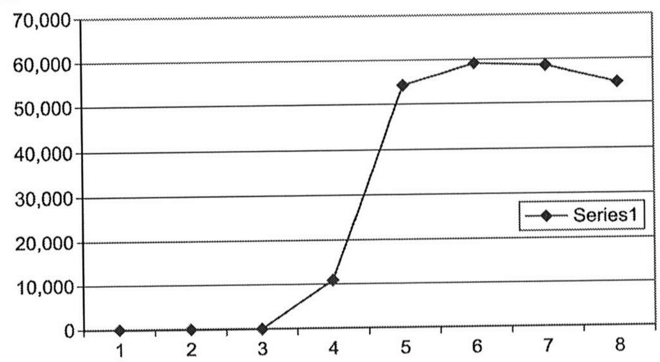

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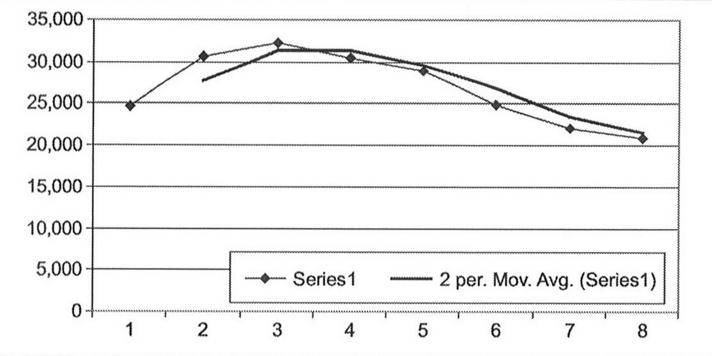
Figure 7 Example of mature product demand

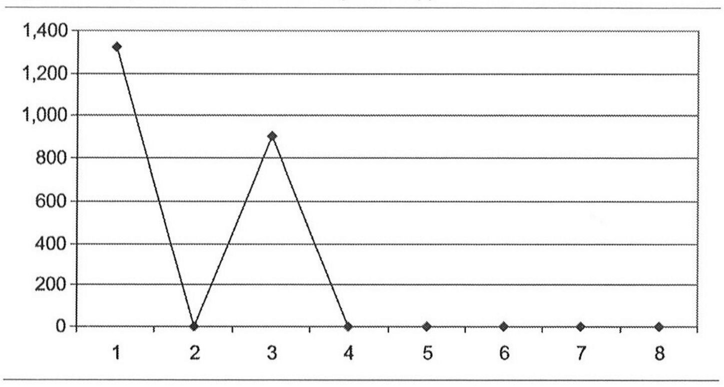


but in many cases the decision is made well before actual changes in demand. While designing a new product, a ramp-down schedule is planned for a competing product. If the life cycle of the product has been long, the ramp-down may be lumpy. Some distributors may fill up the inventory for spare part needs or cheap dumping price may actually increase the demand of the product. Figure 8 shows such a situation.

Managing products in different stages is supported by product data management (PDM) systems, which originally were tools for designers to keep record of design changes and documents. Modern PDM systems may create cost structures and BOMs automatically for the ERP systems. State-of-the-art ERP systems also have properties which support managing the life cycle. The features supported may include managing revision trees and change history of BOM.

According to Iansiti and West (1997) the average product life cycles have shrunk by 25 per cent in the 1980s in the semiconductor industry. von Braun (1990) of German Siemens AG reported some empirical evidence for this. According to his studies declining life cycles are accompanied by increasing sales. From a production technology point of view, this presents some challenges. Rajagopalan *et al.* (1998) have studied the relationship between capacity additions and technological uncertainty. They conclude in their analysis that the optimal capacity acquisition, destroying and replacing sequence is in proportion with demand increase. Life cycle uncertainty is presently one of the most interesting research areas in the technology management field.

Figure 8 Ramp down of a product may be lumpy



6. Measuring agility and productivity

Management data systems include data mining tools, which create an user interface for collecting and analysing data from different sources. This is a requirement for managing the agility in electronics manufacturing as well. The data are stored in several systems; however, the management of a company need to get a quick overview of current situation and the past. A measurement framework to support managerial decision is needed for assessing the current, required and maximum levels of agility. A great deal of literature deals with making the distinction between those flexibility dimensions that are related to demand, and those which enable the flexibility dimension.
The electronics manufacturers' top priorities are related to product lead-time and pricing issues. For this reason, agility/flexibility should be valued against lead-time and cost. These attributes are connected to three uncertainty dimensions, which are typical for the electronics manufacturing:

- volume flexibility – the ability to change throughput in terms of response and range;
- product mix flexibility – the ability to change products in production in terms of response and range; and
- life cycle flexibility – the production ability to change the expected life cycle of a product.

For the customers these dimensions are visible properties of agility, the dimensions of externally uncertain market requirements. This definition is compatible with those presented earlier in the literature (Gunasekaran, 1998; Vokurka and Fliedner, 1998) and allows the possibility for us to use the framework of flexibility research. The difference between agility and flexibility is thus time-related. Agility can refer to any flexibility dimension, while flexibility refers either to range or response.

According to Vokurka and Fliedner (1998) agility is the capability to react to change in a dimension beyond flexibility. Flexibility refers to company's ability to adjust from one operation to another. Agility, however, can refer to any dimension of flexibility. The key difference according to Vokurka and Fliedner is the ability to react to non-predictable changes in markets. Swink and Hegarty (1998) stress the difference

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between manufacturing outcomes and manufacturing means. The definition for general flexibility is proposed as follows. Flexibility is the ratio between change in the first parameter and corresponding change in the second parameter. In economic analysis, the second parameter is cost. Each of these dimensions have two components, they are:

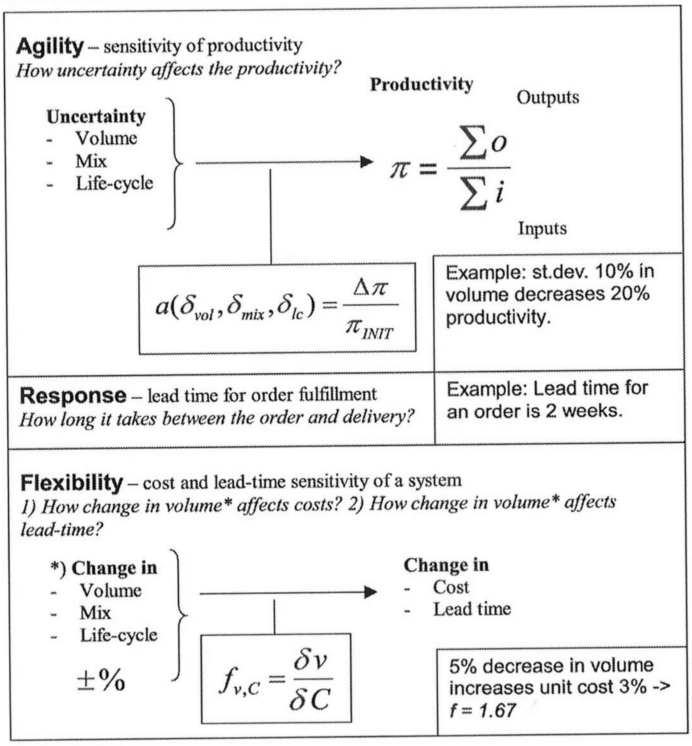
(1) time – the responsiveness aspect stands for fast reaction times in supply chain and production rate; and
(2) cost dimension – the ability to change cost effectively in terms of volume, mix and life cycle (Pal and Saleh, 1993).

The agility of a manufacturing system is considered to be a derivative of these generic dimensions. The practical aspects, used in this model, are volume flexibility; mix flexibility and life cycle flexibility. See Figure 9 for details of measurement.

Flexibility is connected to cost performance in uncertain environments, agility may refer to cost efficiency or the value creating side. According to the definition here, the major difference between agility and flexibility is the level of concern. We claim that flexibility is always connected to the cost aspect and the concept of agility refers to sensitivity of the productivity of a firm. Agility is a business measure, which is assessed against the productivity of a company, whilst flexibility may be analysed against market parameters such as cost or lead-time sensitivity. In other words, the agility of the company is the sensitivity of the productivity, whilst changing the uncertainty parameters of volume, product mix, or product life cycle.

The total productivity of a company in our aspect is the ratio between created outputs, and the used inputs, measured as units of money. This approach makes it easier to compare different creators of value, such as labour, purchases, capital, etc. (Craig and Harris, 1973; Davis, 1955; Singh *et al.*, 2000). According to our definition, agility may include not only aspects of flexibility related to each dimension but also issues related to the reconfigurability of a system. In practice this kind of action may refer to more than one flexibility dimension at the same time. The proposed measure for agility may be theoretical and probably it is not very useful actually to calculate a practical value for this, but it connects the measures of flexibility and agility to a larger theoretical framework, namely productivity measurement. In any case, agility as presented is a short-term measure, which is suitable for system comparisons rather than actual systematic and operational performance measure.

Figure 9 Measurement of agility, flexibility and productivity requires data collection from several data systems



7. Are agility and productivity controversial?

There has been some discussion on the relationship between productivity and flexibility. Gustavsson (1984) proposed that dependence between flexibility and productivity is partly misleading. Gustavsson claimed that when flexibility is increasing, the productivity should decrease. According to the definition taken here, this is inconsistent. There might be some trade-off between flexibility and efficiency, but productivity depends on both.

Good efficiency may be productive in the short term, but in the case of product changes, the efficiency will be lost if the flexibility is low. To take an example, this kind of situation may occur when inflexible automation cannot cope with model changes. Great flexibility is not productive if manufacturing is very repetitive and unchangeable. The behaviour suggested by Gustavsson may be true in some cases, but it depends on other parameters as well. Capacity utilisation is one of these in addition to flexibility and efficiency. The mechanism of efficiency, flexibility and productivity is shown in detail in Figure 10.

Miller (1984) showed that profitability is the sum of two components: productivity and price

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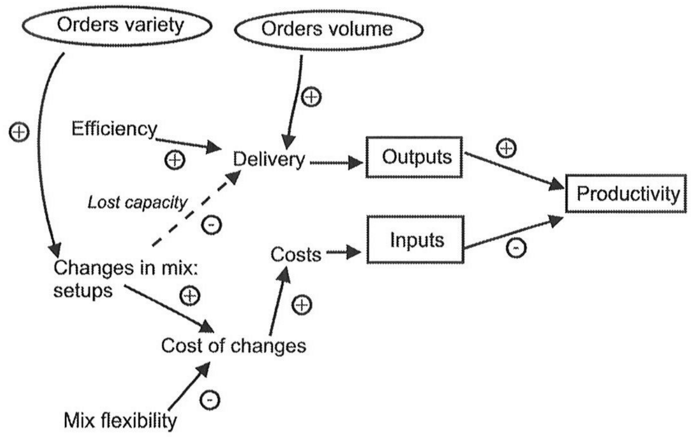
Figure 10 Efficiency and flexibility are independent components in productivity



recovery. The proposed agility framework is compatible with this thinking as well. Agility can be seen as the capability to make a profit by keeping productivity level high in a changing environment. Volume levels and product mix may fluctuate and life cycles change.

8. Conclusions and managerial implications

Vertical integration has been used widely in electronics manufacturing. Outsourcing the manufacturing is a typical way to cope with capacity changes. Different companies design the products and technologies than actually make the products. The vertical integration decision is made based on business competencies, but also includes risk sharing. From customer point of view, this structure helps companies to become more flexible in terms of costs. Contracts are made for a given period of time and for a certain product family or product type. Prices are updated on regular basis, depending on price erosion and the nature of markets, e.g. technological changes. The risk of volatility is decreasing for customers, because in terms of cost accounting, manufacturing has changed from long term investments to a unit based sales price. At the same time, contract manufacturers enjoy greater volumes and revenues from shared risks.

The recognition of special features of electronics manufacturing helps implementing the data system for a production plant. The decision makers should acknowledge these specific parameters. The implications may not be very radical from MIS point of view. However, it may be very different compared to some other – not so fast changing – businesses. For example, very often unused capacity is used as a synonym for non-productive capacity (for instance, Klammer, 1996). This conclusion is justified by traditional cost accounting – the better the utilisation, the lower are manufacturing costs. However, if you add the capability of buffering and dynamics between supply and demand into the consideration, the utilisation's effect on lead-time and profitability cannot be overlooked. When delivery performance is an important competitive factor, traditional unit cost minimisation policy would not show the optimal solution (Lockamy, 2003).

The examples given suggest paying attention to the uncertain parameters. In practice, this means: first, managing the price dynamics may require a more sophisticated inventory management system that a standard package. The products are price sensitive and for this reason the financial aspect is important. A clear connection to financial systems such as general ledger is a must. Secondly, management of variety is connected to continuous updating of lot sizes in ERP from the production side, and for the sales, in many cases as product configurator is needed. A clear process in adding a product or selling a mass customized product should be allowed by the information system. Thirdly, the tools should have features that support life cycle management. Products do change during their life. In addition to these, the overall MIS should support integration. Integration may be needed for interchange of purchase or product data between the customers, suppliers and authorities. The other important integration aspect is the management information integration. Despite the wide use of ERP packages, in challenging environments, what the electronics manufacturing represents, all required features may not be present in a single software package. When the MIS supports a company wide perspective it is possible to measure the agility and productivity and ultimately manage it.

Note

1 *Details.* According to Karmarkar (1993) the waiting time is as follows assuming a M/M/1 system, which uses batching a single product: $t(q,u) = 1 + qu/1 - u - (1/q)$. The lot size q and u are the utilisation parameters.

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