Managers' Perception of Flexibility in Manufacturing - A Study in the Swedish Engineering Industry

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Managers' perceptions of flexibility in manufacturing: a study in the Swedish engineering industry

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Managers' perceptions of flexibility in manufacturing were investigated in a research case study conducted at six Swedish companies within the engineering industry. The goal of the study was to establish which factors managers considered to be important for manufacturing flexibility and how companies and managers perceived flexibility. The size of the company, the complexity of the products and the level of technology used in production were factors found to be important for issues concerning manufacturing flexibility. The findings have implications for both managers and researchers. Managers should be aware of the lack of conformity in the perception of flexibility within companies and its possible consequences. Gives researchers suggestions based on this study, for further research in manufacturing flexibility.

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Background

Since the early 1980s, working with flexibility in manufacturing has been of great concern. Flexibility can be an important competitive factor. Swamidass and Newell[1] have shown that there is a positive correlation between flexibility and the performance of a company. However, the flexibility concept has different meanings for different people and a large variety of flexibility aspects are discussed in the literature. In summary, flexibility is a multi-dimensional concept for which no one has been able to provide a set of valid measures, nor define it in an undisputable way.

Several authors[2,3] have pointed out that flexibility can be considered at different levels. Gerwin[2, p. 38] states that "at each level the domain of the flexibility concept may be different and alternative means of achieving flexibility will be available". Slack[3] uses four levels in a flexibility hierarchy: resources, system flexibilities, production performance and overall company competitiveness.

The domain of flexibility in the literature is often defined using a unique classification. The examples of different classifications are numerous. Chambers[4], for example, divides flexibility into eight classes: technical range, volume, volume mix, seasonality, delivery speed, set-up, set-up timing and quality flexibility. Other authors who have provided classifications are Brown *et al.*[5], Gerwin[2] and Slack[6].

Flexibility is dependent on the various resources in the production process. Gerwin[2] has identified labour and machines as important resources for flexibility. Slack[6] adds infrastructural resources. Many authors are predominated by flexibility in connection with machines, especially flexible automation (e.g. [4,7,8]).

Research involving managers' perception of flexibility is limited. However, Slack[3] has conducted research which is presented in the article "Flexibility as managers see it". The study, which was conducted from 1985-1986, shows that managers' perception of flexibility was partial rather than comprehensive. Managers often considered only one resource and one aspect of that resource and were unwilling to discuss connections between the resource and external flexibilities.

Slack's study also revealed that differences between functions existed. Managers from the supply side of the company tended to see flexibility as a solution for dependability problems. Manufacturing managers tended to stress flexibility in contributing to productivity while managers from the market side perceived flexibility as a way of solving problems in the availability of products. The study did not report on more specific findings about how different managers ranked flexibility factors. Some differences among companies were found. The flow principle of the companies appeared to be important for the resource characteristics mentioned by the managers. The jobbing/batch companies concentrated on "machine flexibility" while the process manufacturers concentrated on "labour flexibility".

In summary, while the previous literature provided some general insight into flexibility, only Slack[3] investigated factors relating to managers' perceptions of flexibility. Nobody has looked explicitly at the managers' perceptions of flexibility characteristics at the resource level or within the Swedish engineering industry.

Goal and definitions

This article reports on an empirical study in which the goal was to investigate:

1. How managers within the Swedish engineering industry perceive flexibility in manufacturing:
   - what the differences are between managers of different departments;
   - what the differences are between managers of different companies.
2. Which aspects of flexibility managers perceive as being the most important for manufacturing now and in the future.

The study was designed to assist both managers and researchers who are interested in gaining further knowledge about manufacturing flexibility. In order to use the flexibility concept without creating further confusion, this article will use a definition which makes a distinction between external and

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internal flexibility. External flexibility is flexibility in the relationship between the company and the context outside the company. A definition which divides external flexibility into four different classes[6] is used. Each class can be defined in terms of range and response. Range is defined as "the ability of the system to adopt different states" and response as "the ability of the system to move between states"[6, p. 26]. The eight different types of external flexibility possible are shown in Table I.

Internal flexibility consists of two levels[9], namely flexibility characteristics of the production system (henceforth called system characteristics) and flexibility characteristics of the resources (henceforth called resource characteristics). Flexibility characteristics are how a company, internally, can accommodate its production facilities in order to fulfil the demand for external flexibility. System characteristics are the inherent properties of the production system on an aggregated level. Examples of system characteristics are lead times and batch sizes. Resource characteristics are the inherent properties of the individual components of the production system. These components can be divided into three broad groups: machines, labour and infrastructure. Examples are set-up times, labour skills and the capacity of the internal transportation system. The resource characteristics decide how each resource can contribute to the performance of the production system. The relationship between the levels can be further illustrated by the the following example. Short set-up times and multiple skilled workers (resource characteristics) provide opportunities to produce in small batches (system characteristic). This can be a prerequisite of simultaneously manufacturing a wide range of products (external flexibility).

Research methodology

Overall design

We considered two approaches in attempting to achieve the goal of the study, namely a case study approach which emphasized qualitative data and a sample survey which emphasized statistical inference. The survey technique is most appropriate when one wants to examine variables for which there are causal relations and clear measurements. Some measures of flexibility on the "machine level" are reported in the literature (e.g.[10]). These measures do not cover the scope of this study and can therefore not be used. The case study technique is best when studied objects are broad and complex, when the present state of knowledge does not allow causal questions or when the studied objects can not be studied outside the context in which they occur[11]. These conditions are true in the case of flexibility, therefore, a case study methodology was selected.

Sample

The study was conducted in the Swedish engineering industry. Since the population of companies is large, it was decided to use a convenience sample generated from industry contacts. The case selection was guided by a main rule: examine polar types[12]. The dimensions where we wanted to create polar cases were: the level of technology used in production; the size of the company; and the complexity of the products.

The level of technology used in production was selected because previous research indicates that technology itself affects the level of flexibility[7,13,14]. The experience of flexibility can also be expected to be higher in companies having advanced manufacturing technology (AMT). The size of the company was selected as a criterion because the level of

Table I
The range and response of the external flexibility classes

Flexibility	Range flexibility	Response flexibility
Product	The range of products which the company has the design, purchasing and manufacturing capability to produce	The time necessary to develop or modify the product and processes to the point where regular production can start
Mix	The range of products which the company can produce within a given time period	The time necessary to adjust the mix of products being manufactured
Volume	The absolute level of aggregated output which the company can achieve for a given product mix	The time taken to change the aggregated level of output
Delivery	The extent to which delivery dates can be brought forward	The time taken to reorganize the manufacturing system so as to replan for the new delivery date

Source:[6, p. 28]

formalization was expected to vary with the size. Managers of larger companies were also expected to have a more complex view of flexibility[3]. The complexity of the products was expected to influence the need for flexibility since the context is normally more complex when the products manufactured are complex.

Once a company had been classified into these three dimensions and identified as a candidate, the managers were contacted for participation in the project. Six companies were selected and we were granted interviews with managers from finance, marketing, production and product development in each company. These managers were selected because their departments affect and are affected by production flexibility (see Table II for a description of the companies).

Interview guideline

An interview guideline was designed for each department in order to cover the aspects of production flexibility. It contained questions in four main areas. The questions were open-ended in order to avoid the effects of leading questions. This also made it possible to follow a more complex line of reasoning than would have been possible with fixed questions.

The main areas where questions were asked are presented below. The questions in this section are presented in a somewhat condensed form compared to how they were presented to the respondents:

- *What are the constituencies of the company regarding, size, organization, flow principle, products, market and the level of technology in manufacturing?* Previous research[3] has shown that flexibility cannot be looked at out of context. In order to be able to compare answers from managers in different companies, we examined the specific context of the company where the managers worked. Factors that can be expected to affect the answers are primarily the size, organization, flow principle, products, market and the level of technology in manufacturing.
- *What does flexibility in manufacturing mean to you? What do you regard as characteristics of a flexible production section?* The conceptualization of flexibility differs between individuals[3]. Open-ended questions about the individual's understanding

Table II
The six companies in the study

Company	General description	Size	Products	Level of technology
A	35 employees. Manufactures industrial furnishings for workshops. Distributes the products via independent retailers. Has a rather informal organization. The level of automation in the workshop is low. The workshop contains, e.g. manually operated machines for sheet metal working and punching	Small	Simple	Low
B	1,300 employees. Manufactures equipment for internal transport in workshops and warehouses. Distributes the products via their own net of retailers. Uses manually operated machines, FMS-cells and industrial robots in their workshop	Large	Medium	High
C	200 employees. Manufactures cutting machines for the engineering industry. Distributes the products via independent retailers. The workshop is dominated by new, high performing CNC-machines. Company's experience of advanced manufacturing technology (AMT) is high	Medium	Complex	High
D	200 employees. Manufactures a simple component for producers of heavy vehicles, such as trucks and buses. Company D is a subcontractor. The workshop contains both a fixed line and and advanced FMS-cell	Medium	Simple	Medium
E	70 employees. Manufactures equipment for the meat-packing industry. Often works in project form and delivers whole systems. Deals directly with end-users. The products are usually customized and the work is mainly done manually	Small	Medium	Low
F	4,500 employees. Is a division of a large company within the transportation industry. Manufactures complex systems for vehicles. The only customer is the parent company. They have one of the most advanced workshops in Sweden with AGV's and FMS-cells	Large	Complex	High

of the concept of flexibility must be put forth. If the interviewer mentions any specific type of flexibility, there is an obvious risk of influencing the respondent, and thus affecting the credibility of the findings. Several authors[2,3] point out that there are different levels of flexibility in a company. Therefore, the question was asked both on a system level and on a resource level.

- *How does the company treat flexibility issues in capital budgeting?* Within a company there can be expected to be a synopsis of the types of flexibility needed. One indicator of this can be how flexibility is treated in the capital budgeting process.
- *How do you think the need for flexibility in manufacturing will develop in the future? What are the driving forces for this development?* Several authors[14,15] predict an increasing demand for flexibility. The question refers to how managers interpret the situation and what their expectations for the future are. This is interesting since their actions are affected by their expectations. As a guideline for researchers, machine suppliers and managers, it would be of interest to investigate how managers view the future need for manufacturing flexibility.

Reliability

Data were collected primarily from telephone interviews (30-45 minutes), conducted by both authors using a conference telephone. This data collection method is likely to suffer from such problems as lack of recall and misunderstandings. These problems were, however, alleviated and the reliability of the data was safeguarded in several ways.

First, we selected cases that both authors knew from previous research (all companies except Company A). This allowed us to judge better the contextual factors of the cases. Second, both authors, independently, took notes during the interviews. Afterwards, each author made an independent transcript of the interview, which was later compared, discussed and modified. Finally, questions concerning contextual issues were asked to several respondents in the same company and their responses were compared later.

Data analysis

Five major steps in the analysis of the raw interview data were conducted. The first two constitute a within-case analysis, the last three a cross-case analysis[16].

The first step was to analyse each interview individually in order to establish the line of reasoning of the respondent. In doing this, 20 different variables were classified for further analysis. The second step was to analyse each company. This was done by comparing the four interviews from each company with each other and making a description of the companies constituencies. Ten different variables were classified for each company for further analysis.

The third step was to compare different companies with one another. This was done both in a qualitative way and by comparing the ten company variables statistically. The size of the sample did not allow any statistically significant conclusions. The statistical analysis was, however, most useful for the qualitative analysis. The fourth step was to analyse all managers, by department. The 20 variables classified for each person were arranged statistically as support for a deeper qualitative analysis. Finally, different departments were compared with each other using the same methods.

The various steps were not performed in sequence, on the contrary, it was an iterating process where we turned back and made conclusions as further insights into the cases and the flexibility concept were gained.

Description of the companies

The survey was conducted on six companies, selected according to the factors presented earlier. Table II contains a short description of each company. From the table, it can be stated that the cases vary in the three dimensions presented earlier and, therefore, fulfil the condition of being polar types.

Findings

Given the small sample, conclusions can not be regarded as general. The conclusions are based on qualitative analysis. In the following section, the findings are summarized and their implications discussed.

The importance of resources and the connections between different levels

A company has basically three different resources – labour, machines and infrastructure. The infrastructure is defined as all activities supporting production, e.g. production planning, purchasing, product design and logistics. Each resource has characteristics which decided in what way they will contribute to the overall production system. In the study, we have tried to map the resource characteristics perceived as most important for flexibility. We have also investigated how each resource characteristic is connected to the different flexibility types mentioned earlier.

The frequency order in which managers mentioned the resources was machines, labour and infrastructure. When asked the question "What is important for manufacturing flexibility?", 21 out of the 24 managers mentioned at least one machine factor as being important. Concepts such as flexible manufacturing systems (FMS) and CNC-machines were mentioned as examples of flexible machines. Differences were not found between managers in different companies in this respect. The importance of machines for flexibility and the possibilities they provided are underlined by several authors[14,15].

Nearly half of the managers mentioned labour as being important for achieving flexibility. This is a relatively high figure. One explanation can be that the study was conducted during a period of prosperity in Sweden, leading to a shortage of skilled workers, high levels of absenteeism and high employee turnover. At that time, labour was an important concern in industry. Two companies, E and F, mentioned labour more often than the other companies, however, for different reasons. Company E worked in a project form and sent their workers to the customers for installation of the purchased equipment. They were therefore heavily dependent on the skills of the workforce. Company F is a large company with a high level of production technology. They have suffered from labour problems, such as difficulties in hiring skilled workers to operate the advanced machines. Why was labour not equally as important to company B, which had the same company constituencies? There is no evidence that the problems were larger at F than at B. The reason why labour was mentioned more often at F could be that they are involved in the car manufacturing industry, where work organization and labour factors have been in focus. At this company problems were, therefore, recognized and managed.

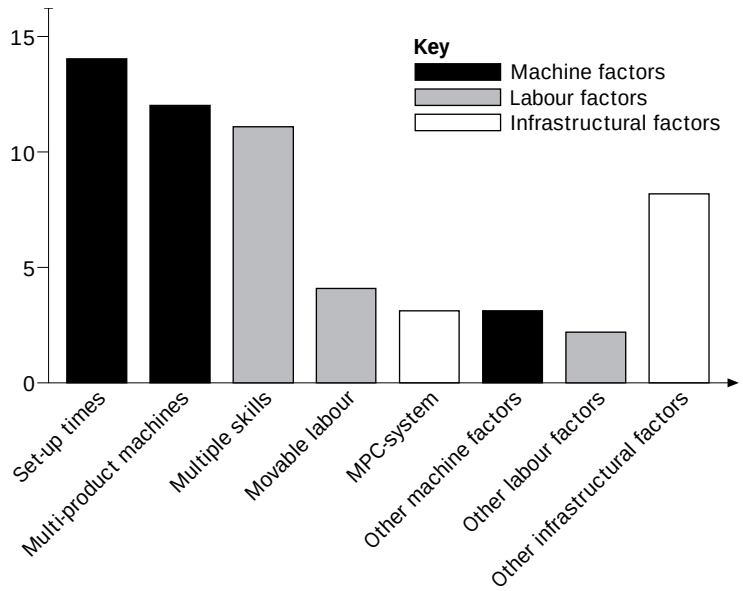
One-third of the managers mentioned infrastructural issues as being important for flexibility. The planning system was the most frequently mentioned infrastructural factor. The speed of product design changes and the possibility to handle rush orders were also viewed as important variables in achieving flexibility. There were no significant differences between companies; however, there were indications that the higher the product complexity the stronger the emphasis on infrastructure.

The resources have different characteristics. The number of respondents that mentioned different resource characteristics are presented in Figure 1. A discussion of connections between system characteristics and external flexibilities is made in the following section.

The most mentioned resource characteristic for achieving flexibility in production was set-up times. Previous research has found small batch sizes to be important for the economic benefits of FMS[14]. A prerequisite for small batch sizes are short set-up times. During the last decade JIT and the use of capital in companies has been in focus. Short set-up times have frequently been discussed in connection with this, which can be an explanation for the focus on this factor. The company in the study that emphasized set-up times the least was Company E. This can be explained by the fact that they worked in a project form and did not use advanced machines.

The main flexibility goal, with short set-up times, was to increase delivery range flexibility. Most companies pointed out market pressure for fast delivery and product customization as an important reason for short set-up times. On a system level, short set-up times make it possible to produce in small batch sizes, which can give short lead times and, externally, a high delivery range flexibility. It was also pointed out that short set-up times are often a prerequisite for volume response and mix response flexibility. Ranta *et al.*[14] state that "a small batch size is usually also connected to productivity growth and lead time reduction". Chambers[4] points out that short set-up times often are intended to reduce cost. Other possible benefits are gains in capacity. Our study does not show what the main reason is for emphasizing set-up times.

Figure 1
The most mentioned resource characteristics for achieving flexibility in manufacturing



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Multi-product machines were claimed to give high product range and product response flexibility. Eleven out of 24 respondents mentioned multi-product machines. Multi-product machines were aimed primarily at increasing product range and product response flexibility. Product response flexibility means being able to respond to customer demands for product specific variants. The need for this seems to have increased during the last decade. Product range flexibility, the ability to produce totally different products, was regarded by smaller companies as being the most important. They viewed it as a method for finding alternative products and acting as subcontractors in different industries. Larger companies viewed multi-product machines more as a means for achieving volume response and mix response flexibility since they make it possible to change the flow of products in different sections of the job shop.

Multiple skilled labour was regarded as being important for volume flexibility, both in range and response. "Labour flexibility" can be divided into two different parts, functional and numerical flexibility[17]. Functional flexibility "embraces the crossing of occupational boundaries, multi-skilling and a willingness to adjust to production demands". Numerical flexibility "enables a firm to adjust labour force levels rapidly"[17, summary]. The Swedish employment laws prohibit, to a high degree, numerical flexibility. Therefore the companies used, to some extent, multi-skilled labour to gain volume range flexibility.

If a worker is multi-skilled it will be possible to move him/her between different production sections. The objectives are twofold. The most important one is to gain volume flexibility, both in range and response. Slack[18] points out manpower policies as being important for volume flexibility. He does mention multiple skills, but focuses on hire-and-fire and overtime. The second objective is to reduce the sensitivity to disturbances, such as machine break-downs and absenteeism. Another mentioned labour characteristic was the possibility to vary the work week between, for instance, 36 and 43 hours. This would provide a better opportunity to meet customer demands and to produce just-in-time. The desire to vary the work week indicated a need for numerical flexibility as defined by Pollert[17]. This was, however, not possible in Sweden at the time.

The manufacturing planning and control (MPC) system was regarded as being important for delivery flexibility, both in range and response. The most important flexibility feature of the MPC system was stated as being the simplicity of the system and its possibilities to handle rush orders. Company D had recently invested in a MRPII-based system in order to achieve these benefits. It is important to note that a company must look at the whole administrative chain because "delivery speed flexibility" is dependent on "all procedures in processing orders from their receipt to final delivery"[4, p. 9]. It can be noted that companies with more complex products mentioned the MPC system more often than others.

In order to see which factors concerned managers the most, we sorted out the single characteristic that each manager found to be the most important for achieving manufacturing flexibility (Figure 2).

Multiple skilled labour, set-up times and multi-product machines, in this order, were the resource characteristics managers regarded as most important for achieving flexibility in manufacturing. The variety of factors regarded as most important points out that the view of flexibility is strongly contingent on individuals and context. The study was carried out during a period of prosperity, which led to a shortage of skilled workers. This partly explains the concern for labour factors. A trend towards just-in-time, combined with a focus on work-in-progress (WIP), partly explain the concern about set-up times. Regardless of these circumstances, we can state that multiple skilled labour, short set-up times and multi-product machines were important resource characteristics for achieving flexibility.

In Table III, some of the connections between resource characteristics, system characteristics and external flexibilities are reported. Various managers mentioned different connections and had different logic in

Figure 2
The resource characteristic regarded as being the most important by managers

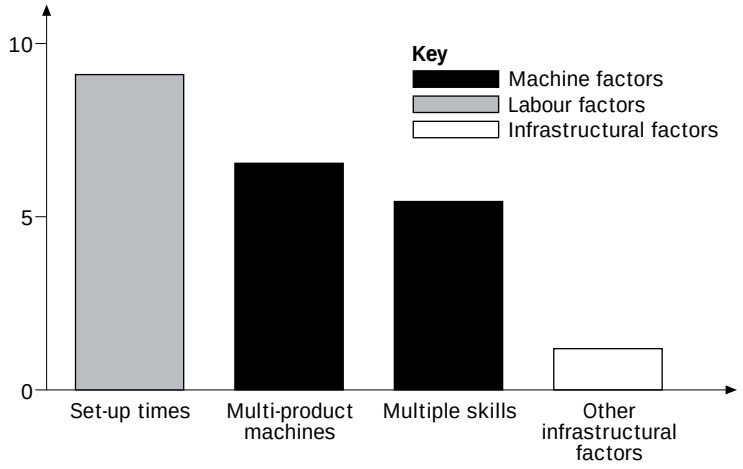

Table III
Resource characteristics mentioned as being important for different types of external flexibility

Flexibility	Range flexibility	Response flexibility
Product	Multi-product machines Multiple skilled labour	*Set-up times*[a] *Costs of fixtures*[b] Multi-product machines Multiple skilled labour Product design in modules Fast reactions within the infrastructure[c]
Mix		Set-up times Multi-product machines
Volume	*Multiple skilled labour*[d] Flexible work week Transferable labour Over-capacity *Standard machines*[g]	*Set-up times*[e] *Multiple skilled labour*[f] Flexible work week Over-capacity Supplier relations Alternative flow-ways
Delivery	MPC-systems Possibility to handle rush orders Set-up times	MPC system Set-up times Multi-product machines

Notes:
[a] The manager said that it is faster to introduce new products if you have short set-up times. The logic is not clear from this answer. The set-up times are probably, in most cases, much shorter than the time needed for product development
[b] The respondent said cost, but the leadtime for new fixtures could be more important
[c] The respondent included the MPC system and product development in the word infrastructure
[d] Multiple skilled labour was said to promote high utilization of the machinery, which gives high capacity. The relevance of this factor can vary between different contexts, depending on the kind of machinery used
[e] Short set-up times promote throughput and therefore, in practice, the ability to react to changes in the market demand
[f] Multiple skilled labour gives a better "flow" in the production, making it easier to control, therefore, it is easier to change the production rate
[g] The respondent stated that "Standard machines have shorter delivery times, which makes it easier to build new capacity quickly"

achieving flexibility. It should be noted that the table shows how *managers* viewed the flexibility connections. Some of the factors mentioned are not clearly understood. In some cases this can be explained by the context of the company while in other cases, it is due to the manager's inadequate perception of flexibility. The factors that are not self-explanatory are commented on in the notes.

Slack[18] made a similar listing of factors for flexibility from a theoretical point of view. In our study, managers assigned more characteristics to volume and product flexibility than Slack's theoretical listing. This can be interpreted as a special concern for these two aspects of flexibility by the managers.

Company-related differences

All the companies are in the engineering industry. The small sample and the numerous variables make it hard to isolate findings with high credibility. In spite of these difficulties, we feel the evidence to be reasonably strong for the following findings:

- *Managers of larger companies tended to have a more complex view of flexibility than managers of smaller companies.* The cases reveal that only Company F explicitly discussed labelled types of flexibility. The reason can be that they are in the car manufacturing industry and have high external demands on performance. They might therefore have worked more with concepts such as human resource management, JIT and total quality management during the last few years. This could have created an awareness of problems and possibilities for using different concepts, e.g. flexibility. Seven, out of the eight managers of small companies in the study (A and F), had a low level of complexity in their reasoning. An explanation can be that managers in larger companies have a higher and more general competence, education and experience than managers in smaller companies. Furthermore, smaller companies, in themselves,

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are more flexible, which can mean that the managers of these companies do not perceive the lack of flexibility as strongly as managers in larger, less flexible companies.

- *Managers of companies producing more complex products mentioned infrastructure as being important for flexibility more often than managers of companies producing simpler products.* The infrastructural factor most often mentioned in the study was the MPC system. The two companies producing simple products did not mention any infrastructural factor as being important for flexibility. The explanation is that more complex products give a more complex planning environment[19].
- *Companies using a higher level of technology in production experienced a higher need for flexibility than did companies using a lower level of technology.* This finding requires further research since we experienced problems in measuring the need for flexibility. A hypothesis is that workshops using a high level of technology are, in themselves, more inflexible than workshops using a low level of technology. Therefore, companies using a high level of technology perceive a higher need for flexibility. It is hard to tell which is the chicken and which is the egg. The size of the company is another variable that can influence the result.

Managers' perceptions

The survey reveals that there are substantial differences between how managers perceive flexibility. The reasons for this are probably numerous – education, experience, the positioning of the company, manager's responsibilities, and so on. The case studies, which are based on interviews with various managers from finance, marketing, production and product development, reveal some findings.

Most of the managers had a low complexity in their perception of flexibility. Fifteen of the managers had a low complexity in their perception of flexibility. Five had medium and four had a high complexity. Low complexity means that managers mentioned characteristics of one resource and the line of reasoning was on one or two levels as defined previously, or they mentioned two resources but their reasoning was restricted to one level. High complexity is defined as respondents who mention characteristics of at least two resources and their reasoning extends over three levels. Medium complexity is between these two. In previous research, Slack[3] also found managers conceptualization to be low. He further states that managers' tended to limit their view to one resource type, e.g. labour or machine. In our study, 11 out of the 24 managers were limited to one resource. Since Slack does not present any statistical data, it is hard to determine if we have found a higher recognition of different resources. As presented earlier, the highest complexity of perceptions were found in large companies.

The managers were most concerned with response flexibility. Response flexibility was mentioned three times as often as range flexibility. Mix response flexibility was the single most mentioned flexibility type. This reflects a concern for the ability to respond to changes in the demand patterns of the market. The need is emphasized in companies that have adopted just-in-time. Delivery response flexibility was mentioned less often than other types of response flexibility. The range dimension of delivery flexibility was perceived as more important than the response dimension. Regarding range flexibility, managers were most concerned with product range and delivery range flexibility. Smaller companies were more concerned than larger, with product range flexibility. This can be explained by the fact that they experienced a higher level of uncertainty concerning future products. They, therefore, expressed a desire to be able to produce totally different products than from those produced at present. Response flexibility is directed more at operative matters than range flexibility, which is directed at handling long-term uncertainties. A conclusion is that managers are more concerned with the immediate problems of flexibility than with long term, more strategic, flexibility problems.

The managers believed in an increased need for flexibility in the future. Most of the managers believed in an increased demand for flexibility in the future (18 out of 24). Five said that it depended on which industry and only one believed that the demand for flexibility would not increase in the future. The resource characteristics believed to increase the most in importance were labour skills and set-up times. We also found indications that the ability to produce other products will be increasingly important in the future.

Noori[15] states that trends that increase the need for flexibility are shorter product life cycles, fragmented markets, demand uncertainty, etc. In our study, we found that uncertainties and fragmented markets were of more concern to managers than shorter product life cycles. The main driving force behind the increased demand for flexibility was believed to be the sharpened competition in the future. The EC and the stronger competition it brings, was mentioned by many

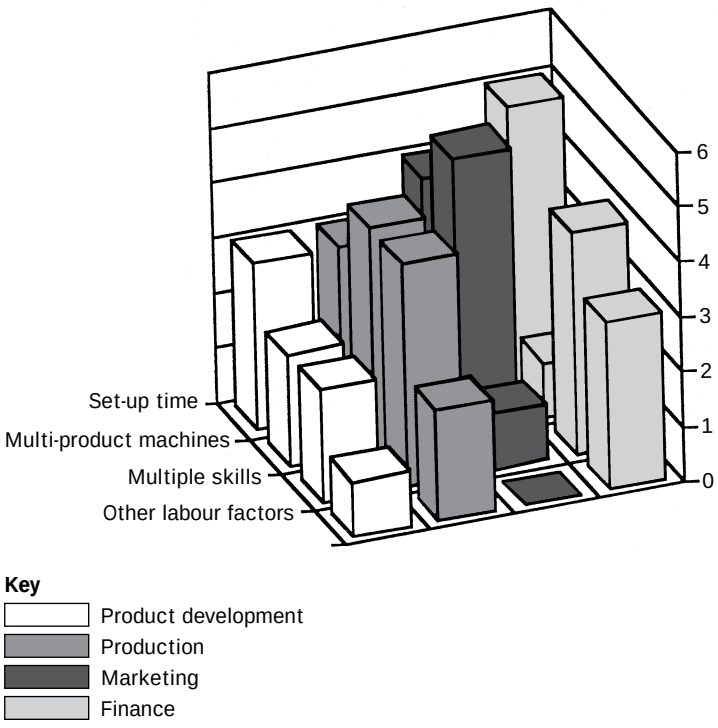
managers as being the most important reason for the expected increase in flexibility need.

The managers experienced a lack of quantitative measures for flexibility. All the companies claimed that flexibility was taken into consideration in the capital budgeting process. When investing in machines, managers looked mainly at two resource characteristics for flexibility – set-up times and multi-product capabilities of the machines. At the system level, managers were interested in how the machines affected the lead time. Managers wanted to quantify the benefits of flexibility, but stated that they lacked proper methods for doing this. Some managers also wanted, and tried, to measure the benefits of flexibility in the continuous running of the workshop. The most used quantitative measures that, to some extent, were considered to measure the flexibility benefits were: levels of work-in progress; utilization of machinery.

Apart from the quantitative measures mentioned above, most companies claimed that they made strategic assessments and looked at qualitative aspects of flexibility. It is not possible from this study to draw conclusions concerning how and to what extent these consideration were taken into account.

It can also be noted that many of the respondents were dissatisfied with the routines currently used for capital budgeting. This was expressed especially in companies that used pay-back as an evaluation technique. Some managers felt a need for other methods for evaluating investments which take more factors (not only flexibility factors but also, e.g. throughput time) into consideration.

Figure 3
The most common resource characteristics presented by functions



Position-related differences

In Figure 3, the most interesting resource characteristics mentioned by the various managers are presented. The logical connections between the system characteristics and external flexibilities made by the managers are also discussed.

In summary, we can conclude that all the managers strongly emphasized set-up times. However, they had different perceptions of what could be achieved with short set-up times. The other factors they focused on were characterized by the areas they worked in.

The finance managers focused on set-up times and labour characteristics for achieving flexibility. The emphasis on short set-up times was related to the need for market responsiveness. The finance managers' view of flexibility was market oriented. Slack[3] does not mention finance managers in his study but he states that marketing managers see flexibility as a solution to problems of availability. Our findings indicate that finance managers have similar views of flexibility. Some finance managers mentioned implicitly or explicitly short set-up times as a means of lowering WIP-levels. Labour factors were often mentioned by finance managers. Also, labour factors were related to market response. The most mentioned features of labour factors were to gain volume flexibility, range and response. One explanation for the awareness among finance managers of the importance of labour characteristics is that they, at least in the smaller companies, were in close connect with the labour function of the companies.

The finance managers were not concerned with multi-product machines. Only one finance manager mentioned multi-product machines as being important for flexibility. The finance manager of Company E was very uncertain as to which products the company would be producing in the future. He viewed the possibility to produce new products as a way to secure long-term survival and to level out the volume by subcontracting in different industries.

The marketing managers focused on set-up times and multi-product machines. We found that marketing managers often mentioned set-up times in connection with delivery range flexibility. This means that the

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marketing managers saw this factor as a way to increase responsiveness to market demands. This is, as mentioned earlier, supported by previous research[3]. They also saw multi-product machines from a market perspective and as a way of offering customer specific products.

The marketing managers were not concerned with labour as a means of obtaining flexibility. What managers did not mention is as interesting as what they did mention. Only one out of six marketing managers mentioned labour as an important characteristic for flexibility. The manager who mentioned this was the marketing manager of Company F where a flexibility strategy had been discussed and formulated within the company. The conclusion is that marketing managers were more concerned with external flexibility than with characteristics at the resource level.

Production managers were most concerned with labour characteristics, multi-product machines and set-up times, that order. Significant for production managers as a group, was that they mentioned a greater variety of resource characteristics. As individuals, they had the same tendency to focus on one resource as did other managers. As opposed to marketing and finance managers, the production managers looked primarily at flexibility as a means to increase internal effectiveness. The production managers discussed resource characteristics connected to system characteristics more often than external flexibility.

Managers in product development did not focus on any specific resource characteristic, but their reasoning was directed at increasing the product flexibility. As did production managers, product development managers mentioned many different resource characteristics. The common theme was that they stressed the responsiveness to product design modifications. The companies that had a high degree of uncertainty concerning the market and the products (primarily A and E), stressed the possibility to produce entirely new types of products, that is product range flexibility. The companies working on a stable highly competitive market (primarily B and F), stressed the possibility to produce new variants of the existing products, that is product response flexibility.

The complexity of the flexibility perceptions did not differ between departments. From this study, we could not detect any differences in the complexity of the flexibility perception of different managers.

Concluding comments

When this study was begun, our research questions were developed from findings of previous studies and the following beliefs:

- Flexibility is a complex concept with many aspects.
- Managers have different perceptions of flexibility.
- The perception of flexibility differs between companies.
- The perception of flexibility differs between departments.

In general, the findings concerning the importance of different resources and the relationship between resource characteristics, system characteristics and external flexibility were similar to those predicted by previous researchers, although some novel findings were noted. The most important findings are summarized and discussed further in the next section. Following this discussion we give some implications for managers and researchers arising from this study.

Summary of findings

The importance of resources and the connections between different levels. The study shows that machines, labour and infrastructure is the order in which managers mentioned the resources.

Set-up time was mentioned frequently and regarded as one of the three most important resource characteristics for flexibility in production. We cannot, in the study, detect any evidence that would decrease the importance of this factor. The respondents in the study considered set-up times to be important for a number of different types of external flexibility.

Multiple skilled workers were regarded as one of the three most important resource characteristics for flexibility in production. Given the low number of articles published concerning labour in connection with flexibility compared to the high number published concerning machinery in connection with flexibility, this is notable. Our conclusions are supported by previous research[2]. From a theoretical point of view, Gerwin outlined the labour characteristics important for flexibility and concludes, "In general the critical workforce characteristic is multi-skilling…"[2, p. 47].

Multi-product machines were also considered important for achieving flexibility. This was due to the need for product flexibility, both in range and response. Whether the range or the response dimension were perceived as the most important, was dependent on the size of the company.

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Company-related differences. Differences were found among the studied companies that can be assigned to the context of the companies. Complexity in the context, e.g. size, products or level of technology emphasized the need for flexibility experienced by the managers. Complexity can promote rigidity. The companies with a complex context were more concerned with flexibility. Smaller companies, or those with simple products, did not see flexibility as a problem since they, in themselves, were flexible. The following tendencies could be found in the study:

- The higher the level of technology in production, the higher the perceived need of flexibility in the company.
- The larger the company, the more complex the managers' view of flexibility.
- The more complex the products, the more important the infrastructure of the company.

Given the influence of the context, one can conclude that flexibility means different things in different contexts and that the meaning is likely to change with time. It is therefore hard to imagine that a complete classification of flexibility, valid in all contexts, can be defined. This has often been the goal of previous research. It can be expected that it is more viable to create a contingent frame for handling flexibility in a company.

Managers' perceptions. The perception of flexibility was partial rather than comprehensive. Only in one company did the managers discuss explicitly the handling of flexibility. Compared to Slack[3], we found that half of the managers recognized two or more resources as being important for flexibility. He states that most managers only recognized one resource as being important for flexibility. The study also showed that managers were more concerned with response flexibility than with range flexibility.

The need for flexibility in the future is expected to increase. The consequence of this is that it will become increasingly important for companies to have methods and routines for handling flexibility. If not, companies risk choosing a false level of flexibility, thereby, loosing their competitiveness. In the future, it may also be necessary to use flexibility in a proactive way instead of a reactive way in order to gain competitive advantage.

Position-related differences. Managers of different departments focused on different aspects of flexibility. In Table IV the most prominent findings are summarized.

The different concerns are interesting in that they pin-point the lack of conformity within companies. This suggests that the available flexibility is not used efficiently, or that necessary flexibility is not obtained since different managers strive in opposite directions.

Implications

The study has highlighted the fact that the awareness and ability to handle flexibility issues in companies is rather low and that the differences in perception between managers is high. The implication for managers is the need to compose a flexibility strategy in order to avoid sub-optimization and to gain competitive strength. These issues must be discussed and integrated with the overall business plan, in the same way that companies create, e.g. marketing strategies. The following three areas of research are suggested:

(1) For researchers, the implication is that more research is required. The study showed that managers in different companies had different perceptions of flexibility and also experienced different needs for flexibility. The study also showed that the external flexibility type which a certain resource characteristic gives can be

Table IV
The flexibility concerns of different managers

Function	Focused on	Were not concerned with
Finance managers	Set-up times[a] Labour characteristics[a]	Product flexibility[b]
Marketing managers	Set-up times[a] Multi-product machines[a]	Labour characteristics[a]
Production managers	Labour characteristics[a] Multi-product machines[a] Set-up times	
Product development managers	Product flexibility[b]	Labour characteristics[a]

Notes:
[a] Resource characteristic
[b] Flexibility type

different for different contexts. The size of the sample in this study did not allow more examples of possible connections. If companies are to obtain advantages from flexibility, researchers should provide guidelines for achieving certain types of flexibility in different contexts.

- *Research issue 1. How are resource characteristics, system characteristics and external flexibility types interconnected, and what is the influence of different contextual factors?*

(2) Managers experienced difficulties in quantifying the benefits of flexibility. The inability to measure flexibility can make the managers unwilling to discuss explicitly the advantages that can be gained. Therefore, they might omit investments which are profitable and/or strategically important. A first step would be to collect further data on the benefits of flexibility in different contexts.

- *Research issue 2. To collect reliable data for quantifying the benefits of flexibility.*

(3) Discrepancies between how different managers within a company perceived flexibility were found. Managers also saw different types of benefits from flexibility. Companies therefore need methods and methodologies for working with flexibility in order to focus their managers in the same direction.

- *Research issue 3. To develop methods and methodologies for supporting the work with flexibility concepts in companies.*

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