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Information management for materials supply systems design

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Information management for materials supply systems design

The aim of this paper is to categorize difficulties related to release and use of information for materials supply systems design during product development projects as well as specific approaches to deal with them. In the literature it has been argued that materials supply systems design should form one dimension of concurrent engineering and be coordinated with product and production systems design although little research on how to manage it is presented. The research presented in this paper is based on multiple sources of data, mainly gathered by means of three case studies conducted at two companies from the automotive industry. The difficulties are categorized in terms of whether or not they are related to a concurrent engineering context. The approaches are categorized with regard to whether or not they focus on difficulties related to a concurrent engineering context, and whether or not they focus on the materials supply systems designers and their work.

Keywords: materials supply; product development project; concurrent engineering; information management.

1 Introduction

Technology development and competition are very intense in many industries, and companies have much to gain from reaching the market with new technology and products ahead of their competitors. Therefore, companies try to shorten the product development time (Smith and Reinertsen 1998).

The increasing interest in shortening the time between concept and market for new products has highlighted the need for working with overlapping activities in product development projects (PDPs), i.e. concurrent engineering (CE). CE involves decisions being taken about, for example, the production system and the supply chain before the product is completely developed. In line with this, Thomke and Fujimoto (2000) advocate that, by shifting the identification and problem solving to the earlier phases of PDPs, development performance can be enhanced.

Fine (1998) advocates three dimensions of CE, namely product-, production systems- and supply chain design and is supported by Ellram *et al.* (2007). Fine (1998) explains that when companies do not treat supply chain design as an activity concurrent to product and production systems design, they often encounter problems at a later stage of product development, or with the product launch, logistical support, quality control, or production cost. Fine (1998) includes make or buy, sourcing, and contracting decisions as well as inventory, delivery, and information systems in supply chain design. Recently, there has also been an increasing emphasis in the literature on coordinating product-, production systems-, and supply chain design decisions and journals have published special issues on this subject (Hult and Swan 2003, Rungtusanatham and Forza 2005). In these special issues, the scope of supply chain design decisions is defined quite broadly and includes decisions ranging from supplier selection to management of distribution channels. Ellram *et al.* (2007) express some critique of the research related to three-dimensional CE, for example that the research is very deterministic and lacks empirical studies.

In this paper, the focus is on the materials supply system (MSS) and how to integrate the MSS design during PDPs. The MSS is the system that supplies materials from suppliers through the focal company's production system to industrial buyers. The MSS thus comprises materials flows between as well as within

plants and includes both physical flows and their planning and control. The focus is on MSS designers as users of the information produced by others involved in the PDP.

Despite the importance of integrating MSS design during PDPs, little research on how to manage it is presented in the literature. Product development performance and CE have been the subject of extensive research (see e.g. Clark and Fujimoto 1991, Wheelwright and Clark 1992, Krishnan *et al.* 1997, Yassine *et al.* 2008). Much of this literature treats the overlap within design engineering, between product design and production systems design at a general level as well as the overlap between product design and the development of tools for manufacturing or assembly of the product. However, the MSS design during PDPs is seldom discussed. Much of the recent emphasis on coordinating product-, production systems-, and supply chain design decisions focuses on one or a few specific questions at a time e.g. postponement structure (Su *et al.* 2005) and product architecture (Fixson 2005), but the coordination of decisions is not related to PDPs.

The information flow is essential in a CE context where related activities overlap, and preliminary and partial information has to be released and used as it emerges (Clark and Fujimoto 1991, Krishnan *et al.* 1997, Yassine and Braha 2003). Clausing (1994) states that one principle that leads to the major benefits of CE is the utilisation of all relevant information as early as possible. Accordingly, Yassine *et al.* (2008) argue that early release of preliminary information is of advantage to PDPs since it provides downstream activities with both a general sense of direction and an early feasibility check. In order to create opportunities to integrate MSS design at an early stage of PDPs, the release and use of information has to function well. However, as already discussed, hardly any CE literature could be found that focuses on difficulties related to MSS design during PDPs. Instead, the attention is on design engineering and production systems design. The aim of this paper is therefore to categorize difficulties related to release and use of information for MSS design during PDPs as well as specific approaches to deal with them.

In the following, literature on CE and information management is presented, in order to provide a theoretical frame of reference. The methodology and case studies are then described before the results are presented and discussed.

2 Concurrent engineering and information management

The core of CE is parallel design, e.g. parallel design of a product and the production system or product sub systems (Koufteros *et al.* 2001). However, several researchers strongly underline the risk inherent in parallel design, since time-consuming iterations may subsequently occur if the overlapping product development process is not carefully managed (Krishnan *et al.* 1997, Loch and Terwiesch 1998). Haque (2003) describe several other problems in concurrent new product development, for example communication problems. Many studies stress the importance of information sharing for the management of an overlapping product development process (e.g. Clark and Fujimoto 1991, Wheelwright and Clark 1992).

Smith and Reinertsen (1998) discuss the difference in information transfer between projects with and without overlapping activities. In projects with no overlapping activities, the first activity accumulates information about a topic until this information is almost complete, after which it is transferred to the next activity. The second activity does not start until the first one has been completed. However, when activities overlap, the second activity starts before the first has been completed, and partial information is transferred in small batches as it develops. Thus, the information transferred is not complete and, consequently, there is a need for communication between the sender and receiver of partial information in order to resolve any questions which may have arisen (Smith and Reinertsen 1998).

Information management is a difficult task in a CE context, and several models have been developed to support it (e.g. Eppinger *et al.* 1994, Krishnan *et al.* 1997, Yassine *et al.* 2008). Eppinger *et al.* (1994) use a matrix to capture both the sequence of and the technical relationships among the design tasks to be performed so as to organise these tasks in product development. Krishnan *et al.* (1997) present a model-based

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3 framework, which identifies conditions where various types of overlapping are appropriate for a pair of
4 coupled activities. Yassine *et al.* (2008) develop a dynamic programming model and analyse different
5 situations that depend on the type of information exchanged; stationary versus dynamic information.
6 Somewhat different aspects of information management are discussed in Hauptman and Hirji (1996), Clark
7 and Fujimoto (1991) and Susman and Dean (1992), namely difficulties with release and use of information
8 associated with attitudes. The study presented in Hauptman and Hirji (1996) reveals a reluctance to use
9 incomplete and uncertain information as well as the difficulties encountered in attempting to do so. Clark and
10 Fujimoto (1991) argue that since engineers tend to be perfectionists, they are often reluctant to release work
11 that is incomplete. In addition, if design changes trigger accusations of laziness or incompetence, there will be
12 even less willingness to release information early (Clark and Fujimoto 1991). Susman and Dean (1992)
13 underline the importance of sharing preliminary information, acting upon it, and considering decisions as
14 preliminary until late in the project in order to increase problem solving flexibility during PDPs.

15
16 Terwiesch *et al.* (2002) bring to the fore the importance of understanding the fact that the nature of
17 information changes if it is released earlier than previously. If activities are overlapping, one cannot expect to
18 receive the same information as was received at a later stage when activities were performed sequentially.
19 Terwiesch *et al.* (2002) provide a definition of preliminary information in the form of two characteristics;
20 information precision and information stability. Information precision concerns accuracy, and measure of
21 precision is defined as a comparison between the range of communicated outcomes and the range of all
22 possible outcomes (for discrete sets), or by comparing the range of communicated outcomes to the distance of
23 the range from zero (for parameter intervals). Information stability is the likelihood that it will remain
24 unchanged for the remainder of the process. Technically, an accurate measure of stability is only possible
25 after potential changes have occurred, although the research presented in Terwiesch *et al.* (2002) suggests that
26 stability can be estimated on the basis of beliefs formed by experience.

27
28 Terwiesch *et al.* (2002) suggest the following two alternative coordination strategies for exchanging
29 preliminary information in CE; iterative coordination strategy and set-based coordination strategy. The
30 iterative coordination strategy emphasises the importance of communicating information in a way that is very
31 precise. Downstream activities can then proceed with operational information, but at the risk of having to
32 iterate and redo part of the work should modifications occur. The set-based coordination strategy emphasises
33 the need to communicate the information in an extremely stable way. Based on the information, resources can
34 then be committed by downstream activities without running the risk of having to redo some or all of the
35 work. However, since the precision of the information is in some cases too low, it may be impossible to
36 continue downstream activities (i.e. starvation) or it may prove necessary to duplicate the work (i.e. redundant
37 work). Terwiesch *et al.* (2002) recommend that an organisation should apply both coordination strategies
38 within a single development project and choose one of them for each individual situation. This choice is
39 driven by the cost of rework relative to the cost of duplication and starvation.

40
41 The information aspect of CE is also discussed in Oehlmann *et al.* (1997), where it is emphasised that CE
42 increases the use of incomplete and potentially inconsistent information and also strongly influences the use
43 of new information and communication technologies. Oehlmann *et al.* (1997) present a methodology, which
44 they term formal interaction analysis, aimed at optimising the availability of information and in which the
45 following quality dimensions of information are listed: completeness, reliability, accessibility, legal aspects,
46 reusability, and compatibility. However, many other dimensions of information quality are presented in the
47 literature. Lee *et al.* (2002) present 15 dimensions of information quality that are empirically derived as
48 important to information consumers. The information quality dimensions are: Free-of-error, Concise
49 representation, Completeness, Consistent representation, Appropriate amount, Relevancy, Understandability,
50 Interpretability, Objectivity, Timeliness, Security, Believability, Accessibility, Ease of operation, and
51 Reputation.

3 Methodology

The research presented in this paper is based on multiple sources of data, mainly gathered by means of three single qualitative case studies (case study A, B and C) conducted at two companies from the automotive industry; two studies at an end producer (Company 1) and one study at a first tier supplier (Company 2). The case studies and data collection are described in more detail in the next section. The research attempts to capture a rather wide and in some respects new problem area. Single case studies made it possible to investigate MSS design in detail, parts of it in real time, as well as the interplay between those designing the MSS and the other actors involved in a PDP. Since companies seldom have formal processes, routines or methods for MSS design, it is essential that detailed questions are verbally explained during interviews so as to ensure that they have been correctly understood by the interviewee.

The case studies were conducted at companies in the automotive industry. Much that has been written on PDPs and CE has built on automotive industry research. The automotive industry is a natural candidate for research on CE, since its PDPs combine novelty with complexity and CE is widely used (Terwiesch *et al.* 2002). The criteria for selecting the two companies for the three main studies were to a large extent their interest in the research area, the fact that they employed a CE approach and tried to shorten product development times and thus overlapped product development activities, that they recognised the importance of integrating MSS design during PDPs. Finally, they placed a high value on the performance of the MSS as a means of preventing production disturbances.

The companies' interest in the research area of MSS design during PDPs was most likely related to their situation. The competition in the automotive industry is intense and product life cycles have shortened dramatically over recent decades. However, this also applies to other industries such as the computer sector. What makes the automotive industry especially interesting for this research area are the complex flows of physically large components and products. The selection of an end producer for the first case studies was natural, since in the automotive industry, the products, and thereby the PDPs and MSSs, become more complex and require more resources further down the supply chain, which makes them interesting to study. The difficulties encountered during the MSS design at the end producer should cover a large spectrum due to the complexity involved. Nevertheless, by continuing the research with a case study at a first tier system supplier, the context could be further broadened by incorporating the supplier perspective.

This paper does not report the results from each study separately but the results presented in this paper are a further analysis of the results gained through the studies conducted. Results from the case studies are presented in Johansson and Medbo (2004), Johansson and Johansson (2004), and Johansson *et al.* (2006). Johansson and Medbo (2004) describe the use of product data and information systems in the design of an MSS in a PDP. This description is further structured in Johansson and Johansson (2004) by means of information quality dimensions and improved by the addition of an increased amount of empirical data. Johansson and Johansson (2004) also discuss how PDM systems can improve information quality. In Johansson *et al.* (2006) the focus is broadened to incorporate sourcing, production, and market data as well as product data, and the paper also discusses how preliminary data can be used in the MSS design process.

In those papers, difficulties related to release and use of information for MSS design during PDPs are described and specific approaches to deal with the difficulties are discussed. However, the focuses of the papers differ, two of the papers focus only on product data, and all approaches discussed in the papers are not explicitly connected to specific difficulties in a structured manner. Moreover, the research presented in this and the earlier papers aim at integrating the MSS design at an early stage of PDPs and designing the MSS in parallel with the product and the production system. Interestingly, however, is that many of the difficulties found associated with the release and use of information are not directly related to a CE context. The difficulties are more generally related to MSS design during PDPs, irrespective of whether a CE approach is applied or the MSS design is carried out as a final step after the design of the product and the production

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system. In the further analysis of the empirical data presented in the present paper, the difficulties described in the earlier papers are thus analysed and categorized in terms of whether or not they are related to a CE context. The approaches to deal with the difficulties discussed in the earlier papers are here analysed and categorized with regard to whether or not they focus on difficulties related to a CE context, and whether or not they focus on the MSS designers and their work. This further analysis and categorization will provide a thorough and coherent description. The understanding and application of the approaches when dealing with difficulties will thereby be enhanced.

4 Case studies

4.1 Case study A

During case study A, the MSS design in PDPs at Company 1 was studied by investigating what departments, or roles, were involved, what issues were dealt with and what difficulties were encountered in the design of the MSS. The case study concentrated on the design of the MSS for one of the company's assembly plants, where the products were assembled on a single, paced mix-model line. Next to the assembly area was a large storage area with an automatic storage and retrieval system. The focus of the study was on the external materials flows from the suppliers to the assembly plant and the internal materials flows to the assembly stations. The materials supply involved large and complex flows of materials from many suppliers, which required a great deal of resources in terms of manpower, equipment, and space.

Data collection was performed over a five-month period from multiple sources, including interviews, various internal company documents and direct observations at relevant meetings. The interviews were the main data collection method. The documents and direct observations were used to verify the content of the interviews and provide details of design issues dealt with by the MSS designers. The interviews were conducted with staff responsible for MSS design in PDPs. In total, 15 MSS designers were interviewed, 11 on one occasion and 4 on two occasions.

4.2 Case study B

Case study B investigated the use of product data and information systems in the MSS design during a PDP and was also conducted at Company 1. The chosen case concerned a common question in MSS design, namely whether or not to outsource a process for the sequencing of materials that need to be displayed in sequence at the assembly stations, including the decision regarding a suitable outsourcing partner. Such decisions influence many parts of the MSS besides the actual workstations for sequencing, for example, packaging design, external transportation, internal transportation, storage, and planning and control.

There were three MSS designers involved in the outsourcing decision process studied. They were interviewed separately on three occasions, and one of them was interviewed a fourth time in order to make the data collection complete. The time between the main interview occasions was about six months. A design engineer responsible for the development of the components studied was interviewed once. Data were also collected from several documents, which included calculations made for comparison purposes, and information systems. In addition, one meeting was attended at which the outsourcing alternatives were discussed by the MSS designers and the purchasers who dealt with the suppliers involved. Between the second and the third round of interviews with the MSS designers the type of information systems used at the company for registering product data were examined.

4.3 Case study C

Case study C was conducted at Company 2 and studied large parts of the MSS design during a PDP in real time as well as the interplay between those designing the MSS and the other actors involved in the PDP. Case study C can be described as consisting of two parts. The first investigated requirements on an MSS design process to be used during PDPs. The second part dealt with performance assessment of MSSs at an early stage of PDPs and how this could be carried out despite the fact that many of the input data were preliminary. The case study focused on one PDP, in which a new product was developed to replace an existing product in one specific car model. The materials flows for the product involved repacking many components into smaller boxes before feeding them to the assembly stations, after which the final products were repacked before dispatch to a separate unit for sequencing. At the sequencing unit, the product was sequenced together with similar final products destined for different product models and variants at the customer's plant.

The PDP was studied for a period of one year and the company was visited on average one day per week, with more frequent visits during the initial part of the study, about 50 days in total. Data were collected from multiple sources including interviews, information systems, various internal company documents, and direct observations of products, components, packaging, workstations, storage facilities, etc. as well as at relevant meetings. The interviews were conducted with people responsible for designing and operating the MSS as well as industrial engineers, purchasers, design engineers, and marketers. While some of the interviews were arranged in advance, many of them were informal in nature, for example in the form of a few questions after a meeting. The meetings attended were mainly project meetings, such as the weekly cross-functional project meetings and full day workshops concerning the design of the production system.

5 Results

The difficulties related to release and use of information for MSS design during PDPs and specific approaches to deal with the difficulties will now be described and categorized.

5.1 Difficulties with information management

As previously mentioned, although the research presented in this paper has a CE approach several of the difficulties found are not directly related to a CE context. The difficulties will now be categorized in terms of whether or not they are related to a CE context.

The difficulties found that are *related to a CE context* are mainly due to the fact that dependent activities are performed in parallel, which influences the completeness, timeliness, and interpretability of the information¹. These difficulties are, for example:

- that the information required for an activity may not have been produced or is only preliminary, which influences the completeness of the information.
- that releasing and using preliminary information may not always be natural to everyone involved in a project. Thus, producers and users of information wait until it is final before they release and use it, which influences the timeliness.
- that preliminary information may change to a greater or lesser degree early or late in the projects. It is thus difficult to estimate to what extent preliminary information can be used for the design of the MSS, i.e. it is difficult to estimate the status of the information, which influences the interpretability.

¹ The consequences of the difficulties to the information quality are described by means of the dimensions from Lee, Y. W., Strong, D. M., Kahn, B. K. and Wang, R. Y., AIMQ: A methodology for information quality assessment. *Information and Management*, 2002, **40**, 133-146.

The difficulties found that are *more generally related to MSS design during PDPs* are irrespective of whether dependent activities are performed in sequence or in parallel and concern accessibility, understandability, and relevancy. These difficulties are, for example:

- that the MSS designers do not know where to find the information required or who to ask for information, which influences the accessibility.
- that the information may not be available in any information system; thus the MSS designers have to trust personal communication in order to obtain it, which influences the accessibility. Personal communication is essential for dealing with outstanding questions etc., but if it is the only information source, there is a risk that the search for data becomes time-consuming and results in incomplete and even contradictory data.
- that even if the information is available in an information system, some information systems, such as CAD systems, are usually only used by design engineers, and MSS designers often find them impossible to use, due to lack of appropriate training. This influences the accessibility of the information.
- that the information required is of a kind that is a question of judgement and thus cannot be found in any document or information system, which influences the accessibility. Examples of this are whether or not a component is identifiable or liable to theft, which influences how the component should be displayed at a work station and how it should be stored.
- that many of the product data required for MSS design can be found in drawings. However, MSS designers often find the drawings very difficult to read and understand, which influences the understandability of the information found in drawings. This results in that the information management process becomes very time consuming and some product data actually available in the drawings cannot be used.
- that the available information have been produced for another purpose and is thus not adapted to the MSS design, which influences the relevancy of the information. For example, it may be possible to find information regarding the surface material of the component, i.e. the material on the surface, in contact with the environment. However, it may be impossible for the MSS designers to determine how sensitive this material is, thereby making it difficult to decide how the component should be packed and handled.
- that the MSS designers may be unable to state what information they need, which influences the relevancy of the information they receive.

Considering the fact that the research had a CE focus, it is remarkable how obvious the difficulties were that are more generally related to MSS design during PDPs irrespective of whether a CE approach is applied or not. Moreover, it is important to bear in mind that the difficulties that are not directly related to a CE context nevertheless have to be dealt with in order to use a CE approach, as they will probably increase if the latter is applied, due to the uncertainty of preliminary information.

5.2 Approaches for improved information management

Several complementing approaches are required in order to deal with the difficulties related to the release and use of information described in the preceding section. The difficulties found that are related to a CE context concern the completeness, timeliness, and interpretability of the information. Completeness and timeliness involve that information is preliminary and thereby difficult to use but also that information is missing due to that it has not yet been produced or that the producer of the information has not yet released it. Three approaches can be used to deal with completeness and timeliness deficiencies: *indicators, standards, and scenarios*.

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3 Preliminary information can be used as an indicator of the final information when this is sufficient for the
4 design process. One example is when preliminary product data are employed to determine type of packaging
5 and quantity in each package. Even if the product data are slightly altered, type of packaging and quantity in
6 each package may not be influenced at all or only to a minor extent.
7

8 When information is missing, standards can be used when the difference between the information required
9 for the design process and the standards is likely to be negligible. One example is when transportation data for
10 existing suppliers are used as standards for new suppliers located close to existing suppliers.

11 Scenarios can be used to take different alternatives into account for data that are crucial to the calculations
12 but not decided or fixed. One example is when the suppliers have not yet been decided and there are several
13 possible suppliers. Different scenarios will then reveal the outcome of the alternative paths.
14

15 Indicators and standards can be used when applying what Terwiesch *et al.* (2002) call an iterative
16 coordination strategy since the information is very precise but modifications may occur. If modifications
17 occur, iterations of the design work are necessary. When applying a set-based coordination strategy
18 (Terwiesch *et al.* 2002), scenarios can be used to continue the design work, although redundant work is
19 necessary since scenarios involve that several alternatives are used in the design work before the final
20 decision has been taken regarding which alternative to use.
21

22 In order to improve the interpretability of the information, *categorization of data* could be used. If the
23 current status of the information is not provided, including indications of how much it may change, it will be
24 less useful than if the MSS designer is in a position to determine to what extent the information can be used.
25 In this case the producers of the information required for the MSS design have to assist by assessing and
26 categorizing the data so as to make clear to the user how preliminary the information is, i.e. inform the user of
27 the information precision and information stability. This approach is also discussed in Terwiesch *et al.* (2002).
28 In one company studied, the status of the data connected to a component is registered as valid for (1)
29 Component development, (2) Tool development, (3) Purchasing, and (4) Production. This gives information
30 about how much the product data may change and thereby for what type of decisions the data may be used.
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32 The difficulties found that are more generally related to MSS design during PDPs concern accessibility,
33 understandability, and relevancy. In order to improve the accessibility, it is important that the greatest possible
34 amount of information required can be accessed from one *information system*. The information system used
35 should be easily accessible for all parties concerned and adjusted in order to facilitate MSS designers' work,
36 e.g. with the help of interfaces adapted to meet their requirements. Users who are unfamiliar with CAD
37 systems are able to view product designs and other related information with the help of viewing tools, for
38 example in PDM systems (Product data management systems). The information systems should also support
39 the registration of data categories discussed above. Moreover, by means of such information systems,
40 preliminary information can be released at an early stage and the users concerned can be notified and retrieve
41 the data, which can increase timeliness. In addition, the users can be notified about changes in the data.
42 Information systems can thus be used to deal also with difficulties related to a CE context.
43

44 There is a major potential in improving information quality by means of suitable information systems.
45 However, more is required than merely introducing an information system since they cannot perform any
46 miracles with information that is irrelevant or difficult to understand. Instead, it is essential that MSS
47 designers are able to specify what information they need and in what form, for example how the data should
48 be coded and presented. The competence of MSS designers has been touched upon when describing
49 difficulties related to the release and use of information, for example that some information systems are
50 difficult for MSS designers to use, that drawings are difficult to read and understand, and that MSS designers
51 may be unable to state what information they require. Education is a natural part of *improving MSS designers'*
52 *qualifications* as well as their ability to access models and tools to assist their work. It is also important that
53 they are able to demonstrate that the information produced and delivered to them is useful for the PDP as a
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whole and not solely for MSS design. This could result in efforts to improve the quality of the information required for MSS design.

It can be concluded that categorization of data as well as indicators, standards, and scenarios can assist in coping with difficulties related to a CE context, while improvement of MSS designers' qualifications can be used to address the difficulties related to MSS design during PDPs, irrespective of whether a CE approach is applied. Information systems can be used to deal with difficulties whether related to a CE context or not.

The approaches can also be discussed in terms of whether or not they focus on the MSS designers and their work. Indicators, standards, and scenarios and improvement of MSS designers' qualifications are approaches that focus on MSS designers and their work, while categorization of data relates to the work of the information producer. Information systems are an approach that should be addressed at company level. Figure 1 summarizes the categorization.

((((((((((((((((((((Take in Figure 1))))))))))))))))))

Figure 1 supports the view that the responsibility for improving the information management in MSS design during PDPs does not solely rest with the MSS designers but they have to take their part of the responsibility. However, those producing the information required for the MSS design as well as the company as a whole have to contribute.

6 Conclusions and discussion

In this paper, difficulties related to release and use of information for MSS design during PDPs and specific approaches for dealing with them are described and categorized so as to provide a thorough and coherent description, thereby improving understanding of the various approaches and facilitating their application. The difficulties are categorized in terms of whether or not they are related to a CE context. The approaches are categorized with regard to whether or not they focus on difficulties related to a CE context, and whether or not they focus on the MSS designers and their work.

The categorizations highlight the fact that several of the difficulties experienced by the MSS designers are not related to a CE context with overlapping activities but are more generally related to release and use of information between different departments. They also emphasise that the responsibility for improving information management rests with both the MSS designers and those who produce the information required for the MSS design as well as with the company as a whole. The MSS designers are in this paper regarded as the users of information. However, they are also producers of information used by other MSS designers or by other parties involved in a PDP, such as design engineers, industrial engineers, purchasers, and marketers, which means that they may have to, for example, categorize preliminary information in order to facilitate its use.

The approaches for dealing with the difficulties associated with release and use of information are: categorization of data, indicators, standards, and scenarios, improvement of MSS designers' qualifications, and information systems. These approaches complement each other. Thus, the choice is not which approach to select but rather where to start. Many companies today do not work concurrently with the MSS design during PDPs. In order to start integrating the MSS design at an early stage of PDPs, it may be wise to first address the non-CE related difficulties.

The present research complements the rapidly growing literature on CE by emphasising the importance of integrating MSS design at an early stage of PDPs so as to utilise the information produced and provide feedback. This integration not only ensures the performance of the MSS but also increases product development performance, due to the improved possibilities to influence product design, production systems

design, and sourcing and market issues, thus avoiding sub optimisation, the need to rework, and quality deficiencies.

The research has been carried out in collaboration with companies. While qualitative case studies with on-site observations provided the opportunity to discover new phenomena in MSS design during PDPs, they nevertheless raise the issue of generalisability. The research has concentrated on companies engaged in mass production within the Manufacturing Industry, developing relatively complex and assembled products and employing a CE approach in order to shorten product development times and increase quality and productivity. There is no reason to believe that the approaches to improving release and use of information are not applicable in other types of companies. It is also believed that several of the results presented in this paper can also be applied to the broader area of production systems design during PDPs due to the similarity between the two, for example regarding status and qualifications of MSS designers and industrial engineers as well as the present lack of suitability of companies' information systems for use during MSS and production systems design (Medbo 1999). The status of employees belonging to different functions is discussed in Susman and Dean (1992) where it is pointed out that design engineers have a higher status than industrial engineers. Without wishing to overstate this fact, MSS designers and industrial engineers work under the same conditions; a fact that has to be addressed during PDPs.

Further research and development is required in order to support the implementation of the approaches to deal with difficulties related to release and use of information. This research covers a broad area, from competence issues related to MSS designers to adjustment of information systems, and would benefit from interdisciplinary studies. In addition, research on work organisation, focusing on cross-functional teams and the MSS designers' role and tasks in these teams, could be carried out in order to complement the research discussed in this paper and would contribute to optimising the use of information management approaches. It would also be interesting to further analyse the use of information systems versus personal communication during a PDP in order to support the release and use of information during PDPs. These aspects are also related to cross-functional teams, since such teams are implemented for the purpose of improving integration and communication.

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	Focus on difficulties related to a CE context	Focus is NOT on difficulties related to a CE context
Focus on the MSS designers and their work	Indicators, standards, and scenarios	Improvement of MSS designers' qualifications
Focus is NOT on the MSS designers and their work	Categorization of data Information systems	Information systems

Figure 1: Categorization of approaches for dealing with difficulties related to the release and use of information for MSS design during PDPs.

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