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This is an accepted version of a paper published in *International Journal of Services Sciences*. This paper has been peer-reviewed but does not include the final publisher proof-corrections or journal pagination.

Citation for the published paper:

Bruch, J., Bellgran, M. (2012)

"Creating a competitive edge when designing production systems: facilitating the sharing of design information"

*International Journal of Services Sciences*, 4(3/4): 257-276

Access to the published version may require subscription.

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# Creating a competitive edge when designing production systems – facilitating the sharing of design information

## Abstract

When designing production systems, design information must be shared among functions at the manufacturing company and the external equipment supplier in order to integrate the various work activities. In this paper, factors facilitating the sharing of design information are analysed based on an in-depth case study of a supplier in the automotive industry. First, our findings show that the sharing of design information is promoted by formalisation. Second, informal coordination mechanisms are more crucial for internal integration between specialised functions than for external integration with the equipment supplier. Finally, our findings indicate that personal and language barriers appear more difficult to overcome than organisational bounds or geographical distance. Altogether, the findings provide strong evidence for the importance of sharing design information when designing more sophisticated production systems.

**Keywords:** Design information, information sharing, production system design process, integration, manufacturing industry

## 1. Introduction

As the competition in which manufacturing companies operate is increasing, it has been argued that the route to competitive advantage lies through the performance of the supply chain (Christopher and Towill, 2002). Lambert and Cooper (2000) identify product development and commercialization as one of the key supply chain processes. However, the success of many new products is highly related to the ability of integrating the development of production systems (Bellgran and Säfsten, 2010; Lambert and Cooper, 2000). Consequently, research into production system development is of high relevance to enhance the supply chain performance. Research in the production system design process is, however, seriously underexposed (Bellgran and Säfsten, 2010; Ruffini, Boer, and van Riemsdijk, 2000). The design of the production system supports manufacturing companies in their attempts to achieve faster time to market, smoother production ramp-up, enhanced customer acceptance of new products and/or a stronger proprietary position (Pisano, 1997). Further, competitiveness today is not solely based on the physical product, rather more and more customers buy an integrated package of products and services (Davies, Brady, and Hobday, 2006). For a detailed discussion about the importance of services in the manufacturing industry see for instance So and Sun (2010). However, many new services are dependent on the development of complex and novel operating capabilities (Hayes et al., 2005). For example the ability to introduce a product upgrade adjusted to the need of an individual customer or the manufacturing of spare parts is dependent on the manufacturing capabilities. Thus, in order to ensure low operational costs and the realisation of new products and services, a holistic perspective is necessary when designing the production system.

It has been stated in previous literature that the production system design process requires a holistic perspective and consequently a project team with members from different specialised functions (Love, 1996). That is, different functions need to be integrated when designing the production system in order to achieve a common purpose. The integration among different functions is crucial as it refers to “the process of achieving unity of effort among the various subsystems in the accomplishment of the organization’s task” (Lawrence and Lorsch, 1967,

p.4). Further, it is important to note that also external equipment suppliers need to be integrated when designing the production system, since they provide an important input in the design of the production equipment (Lager and Frishammar, 2010; Reichstein and Salter, 2006). Hence, it is not enough to focus on integration of internal functions involved in the production system design process, but there is also a need for external integration of equipment suppliers.

An integration process requires the processing of relevant and necessary information between functionally specialised departments (Frishammar and Hörte, 2005; Swink, Narasimhan, and Wang, 2007). Integration deficiencies often occur due to a lack or asymmetry of information or an inability to transfer the required information (Turkulainen, 2008). Or, to put it in the words of Moenaert and Souder (1990, p. 98), the sharing of information is “the major vehicle that allows individuals to become integrated”. However, despite the critical role of information, past research has not explicitly emphasised the role of design information when designing the production system. The purpose of the research presented in this paper is to analyse and discuss factors that facilitate the sharing of design information when designing production systems. In order to achieve the purpose of the research, one longitudinal case study of an industrialisation project in the automotive industry has been conducted.

As the area of the management of design information when designing the production system is fairly new in supply chain management literature, the paper starts by reviewing existing literature. Thereafter, the paper describes the research method employed, which is followed by a presentation of the data collected in the case study. Then the sharing of design information in the production system design process is analysed and discussed. Finally, conclusions are drawn and implications for further research are outlined.

## **2. Frame of reference**

### **2.1 The production system design process**

In this paper, the term production system refers to all activities and elements needed to transfer a set of inputs into products and services. To study the transformation process requires considering the totality of all subsystems and elements including the relationship between them and to their environment. Thus, the production system is defined as “an interacting combination at any level of complexity, of people, material, tools, machines, software facilities, and procedures designed to work together for some common purpose” (Chapanis, 1996). A general implication from this definition is the need to extend the activities of the production system design process beyond those of production equipment, plant layout and job design (Love, 1996). There is a need to ensure both an internal and an external fit in order to allow for high production performance (Ruffini, Boer, and van Riemsdijk, 2000). This means that decisions should not only be aligned properly (internal fit) but also consider the requirements placed by the environment (external fit), i.e. the production system has to provide the capacities and capabilities needed to win orders on the market. Consequently, the production system consists of many components that need to be integrated, and this is addressed by the production system design process, which refers to the conception and planning of the overall set of elements and events constituting the production system, together with the rules for their relationships in time and space (Chisholm, 1990).

In general, it can be concluded that early design decisions are much more significant than later production decisions due to their impact on the downstream business activities by being technically feasible or practically viable (Barton, Love, and Taylor, 2001). Thus, emphasis should be placed on the design process. However, many find it difficult to coordinate the production system design process and work in a structured and systematic way; see

discussions by Bellgran and Säfsten (2010) or Cochran et al. (2001/2002). One of the reasons for these difficulties is that the production system design process is multidisciplinary and thus requires the integration of several specialised functions. Since departments can include more than one function and also evolve over time, in this research the term function is used to denote responsibilities and work areas required to design the production system.

## 2.2 Integration in the production system design process

The need for integration can be derived from the dilemma of achieving unity or efforts among specialised functions (Lawrence and Lorsch, 1967). While specialisation aims at improving the productivity within an organisation (Mintzberg, 1983), it decreases the organisation's ability to combine skills to develop and to produce successful products and in the long run causes suffering (Griffin and Hauser, 1996). Therefore, companies have to pay attention to achieve integration among the different departments and functions involved in order to accomplish the designing of a high-performance production system. Earlier research classifies integration research into external and internal integration (e.g. Pagell, 2004). External integration refers to the need of integration of organisations with formal boundaries, while internal integration concerns the integration of various organisational units within one company. In the context of production system design process both types of integration are required; external integration is called for because of the need to include the equipment supplier, and internal integration of operational sub-functions is necessary since the production system design process is multidisciplinary as stated earlier.

It has been argued that a company's ability to effectively integrate cross-functional activities is based on the process of sharing information in order to identify and solve problems (Frishammar and Hörte, 2005; Moenaert and Souder, 1990; Turkulainen, 2008). In this paper the term design information is used to denote the information needed to carry out the necessary work activities when designing the production system. Although the transfer of information is essential, research by Ottum and Moore (1997) shows that the information collected by one function is not automatically shared with other functions. The diversity of functions implies a high degree of differentiation and interdepartmental differences causing problems in the sharing of information (Lawrence and Lorsch, 1986; Vandevelde and Van Dierdonck, 2003). Griffin and Hauser (1996) argue that subtle terminology difference between different functions may imply vastly different solutions. The terminology and technical language used can cause frustration when people with different expertise and skills share information (Vandevelde and Van Dierdonck, 2003). In general, it becomes more difficult to share information among people with different functions and backgrounds the more abstract the information is (Jacobs, 1996). For people with the same background and knowledge it is much easier to understand the shared information. Allen (1977) points out that the frequency of information sharing among people normally decreases in line with increased physical separation. Similar conclusions have been drawn by Mortensen and Hinds (2002), who argue that people working in dispersed teams are more likely to discard members who are distant. With an increase in distance, informal and face-to-face communication becomes inconvenient (Vandevelde and Van Dierdonck, 2003). Another example is that organisational bounds can hamper the transfer of information because of the lack of clarity, roles and responsibilities (Gupta, Raj, and Wilemon, 1987).

To sum up, this section has highlighted that although the sharing of design information is crucial to achieve external and internal integration when designing the production system, it is difficult to achieve an effective sharing of design information. In order to overcome these difficulties, appropriate coordination mechanisms need to be applied.

### 2.3 Coordination in the production system design process

Coordination can be defined as “all informal and formal mechanisms that establish and integrate the roles of project participants and it involves the timing and frequency of activities that are required to meet the product goals” (Olausson and Magnusson, 2011, p. 283). Thus the available coordination mechanisms can be divided into two groups: structural, formal mechanisms and other more informal, subtle mechanisms (Martinez and Jarillo, 1989). Expanding on Thompson (1967) and Adler (1995), Vandavelde and Van Dierdonck (2003) discuss four categories of formal coordination: (1) standards or rules, (2) plans and schedules, (3) formal mutual adjustments and (4) dedicated teams. In a study of the design-manufacturing interface in the UK automotive industry, Twigg (2002) found that those coordination mechanisms can also be applied when company bounds are crossed.

Formalisation concerns the degree to which rules or standard operating procedures are used to govern interaction between different functional areas (Ruekert and Walker Jr., 1987); they can contribute to a more effective sharing of design information. For example, it has been argued that an intangible and non-standardised content of the product development process hampers the sharing of information (Moenaert and Souder, 1990), while a stage-gate product development process with critical go/no-go decisions at various points provides procedures for improved information sharing (Cooper and Kleinschmidt, 1991; Griffin and Hauser, 1996). Informal coordination mechanisms, on the other hand, concern formless relations that cut across formal structures or informal communication supplementing formal (Martinez and Jarillo, 1989). One possibility would be to co-locate project members, which has been shown to be beneficial for a smooth information flow (Lakemond and Berggren, 2006).

Although the literature discussed above provides some indications on the importance of coordination mechanisms for the sharing of design information, it only provides limited advice on what factors are important when designing the production system. With our study we intend to identify factors important for the design of the production system, an area which has not been at the centre of attention in earlier research.

### 3. Research method

Given the lack of prior studies emphasising the sharing of design information when designing the production system, a single case study was conducted in order to gain deeper insights into the phenomenon studied. A case study can be defined as a research strategy that focuses on understanding the dynamics present within single settings (Eisenhardt, 1989). Choosing a case study made it possible to study the sharing of design information when designing the production system in its natural setting, enabling rich understanding of the studied phenomenon (Yin, 2009). However, it is important to note that the task of designing a production system is often carried out in a project. A project refers to a temporary endeavour undertaken to solve a unique task such as the design of the production system within a well-defined time frame, which should be guided by the company’s design process. Therefore, the industrialisation project, covering the design of the production system, was chosen as the unit of analysis.

The starting point for the study presented here was to identify a manufacturing company that placed high value on the process of designing production systems and that acquired the production equipment from an equipment supplier. The case is from a supplier in the automotive industry and the study followed an entire industrialisation project for a new product and included the acquisition of equipment from an external supplier. The company used the term industrialisation to refer to the process required to transfer a product design into production, thus including the design of production systems. The industrialisation project was

divided into several phases. Figure 1 illustrates the different phases of the industrialisation project, where each phase describes different work activities that need to be accomplished in the respective phase. The main data were collected in the phases 1 and 2 illustrated in Figure 1, which represent the production system design phases. However, during the remaining phases contact was maintained with the companies by mail and telephone to follow the progress and asking follow-up questions. Further, a final evaluation was made four months after start of production. Keeping contact with the company facilitated the investigation of the long-term effects of actions taken.

<<<< (Take in Figure 1) >>>>

Data collection was performed by observing events and actions at the company for 37 days between November 2009 and August 2011. Data were collected from multiple sources including observation, interviews and document studies (see Table 2). In addition, the research also benefited from informal conversations during the various visits at the company. During the data collection, a diary was kept where observations and impressions were recorded after each day at the company. The information recorded in the diary included also methodological aspects such as the persons met and the content and duration of the meetings.

The nature of the data collection changed as the research progressed. At the beginning of the case study the aim was to gain a basic understanding of the background, scope and status of the project. After the introduction, the research was more interactive and included observation and participation in the production system design process. For example, the project leader and production engineer received continuous feedback about the findings and progress of the study. Interviews were conducted with various stakeholders in order to identify and analyse the different perspectives that affected or were affected by the production system design process. During the final period, the research consisted mainly of reflections.

The analysis followed the guidelines provided by Miles and Huberman (1994), meaning that the data analysis followed three flows of activity: data reduction, data display and conclusion drawing/verification. Data reduction took place after each visit at the company by coding the material according to coordination mechanisms found in the theory. Thereafter, patterns were identified depending on mechanisms used for sharing of design information with external partners and among internal functions. The findings from the analysis were compared with the existing theory before conclusions were drawn.

**Table 1** Overview of the data collected during 37 days between November 2009 and August 2011

<b>Technique</b>	<b>No.</b>	<b>Duration (Minutes)</b>	<b>Types of primary data that were collected</b>
Passive observations:			
• New product development group	9	30-45	Status and progress of the new product development project, information sharing between the different functions
• Industrialisation group	11	30-90	Status and progress of the industrialisation project, coordination between logistics and production
• Equipment supplier	6	90-600	Technical equipment development, identification of information to be included in the technical specification
• Various meetings	11	30-180	Information about the product, working routines, project status
Participant observation:			
• Workshop	4	75-120	Manufacturing strategy, identification of order winners, order qualifiers and order losers

<ul style="list-style-type: none"> <li>• Lessons learned, feed-forward</li> <li>• Technical specification review</li> </ul>	5	60	Preliminary findings/propositions, continuous work
	5	40-60	Feedback, potential improvement
Face-to-face interviews	24	40-90	Roles, responsibilities, problems and requirements that should be included in the future system
Informal conversation	Daily		Wide range, e.g. opinions, status, ongoing activities
Documents	Full access		

#### 4. Empirical findings

The industrialisation project studied was part of a new product development project that was initiated in 2008 in cooperation with a customer and had a time frame of three years. To support the various work activities, the project was divided into three work packages: (1) product development, (2) industrialisation and (3) improvements after start of production. The case study targeted work package two, which started in November 2008 and included the design of the production system. The new product was highly complex in line with previous products on the same platform but could not be assembled in the existing production system.

The new product development (NPD) project followed a stage-gate process with critical go/no-go decision points and included members from different functions. Although production system design issues were considered in the stage-gate model, the model was created from a product perspective. As a result, the focus of gravity in the model was on product issues, while many important issues of the production system design process fell outside of the stage-gate model used. A formal process coordinating the work activities required in the industrialisation project separately from the NPD model was not available.

In general, the project was carried out under severe time pressure as the time plan for product design was not adhered to and the resources allocated for work package two were inadequate at the beginning. At the start of the NPD project it was mainly the production engineering manager who gave valuable input to work package one and worked with a production system concept. The production engineer manager had experience from several production system design projects and he had also been responsible for the design of the existing production system for the same product platform. From November 2009, i.e. after one and a half years, extra resources were allocated to work with work package two. One of the resources provided was the appointment of a separate industrialisation project manager responsible for the industrialisation of the product from concept until serial production.

Achieving a holistic view required the sharing of information between several functions in the manufacturing company and with external partners. Figure 2 summarises the flow of information between the industrialisation project manager and production engineering manager with the internal and external functions involved in the design of the production system. It is important to note that the figure is schematic and includes only an indication of the information flow on a general level. However, it highlights the information dependency among the functions involved in the industrialisation project. That is, if design information was not adequately shared among the functions involved, it caused difficulties in carrying out the task at hand without avoiding suboptimisation.

<<<< (Take in Figure 2) >>>>

However, the results of the case study also showed that the sharing of design information with external partners and among internal functions differed to a large extent. In the following the differences are described.

#### 4.1 Information sharing with the external equipment supplier

The acquisition of production equipment as part of the industrialisation project included the hardware and software, and in the following 'production equipment' will refer to both. In the project studied, no production equipment could be re-used and thus all production equipment was newly designed.

*Standards or rules.* The design and building of the new production equipment normally involves external equipment suppliers, which has resulted in a considerable amount of standards and rules to be used when acquiring the production equipment. Figure 2 shows the standardised working procedure for selecting a production equipment supplier at the case study company. In each phase, sharing information between the equipment supplier and their customers was required. First, the request for quotation was sent to a number of potential equipment suppliers. The selection of potential suppliers was based on previous experience, timeline of the project, complexity, etc. In the second phase the equipment suppliers were invited to present their quotes at the manufacturing company. Thereafter, a technical and commercial evaluation of the quotes was made at the manufacturing company before one equipment supplier was selected for final negotiation. Finally a contract was created based on the technical solution and the financial details. Overall, it can be concluded that the equipment supplier selection follows a formalised process.

<<<< (Take in Figure 3) >>>>

In view of the numerous stakeholders involved in the acquisition of the production equipment as well as the tight schedule, the case study company focused on minimising misunderstandings and different interpretations between themselves and the equipment supplier. In order to make sure that experience was re-used and that the information was easily understandable, standard documents were applied. The company had continuously modified the existing documents and provided a comprehensive set of these to the equipment supplier. However, in order to avoid unnecessary discussions and conflicts, extra attention was paid to the technical language and content of the documents shared with the equipment supplier in the project studied.

*Plans and schedules.* To coordinate the work between the case study company and the equipment supplier, a time plan was created. The time plan included not only key dates to be kept in the project such as when the factory acceptance test or site acceptance test should be carried out but also several verification occasions, which should take place during the industrialisation project. The verification occasions were summarised in a verification plan, which included information about when and how the requirements specified in the request for quotation (RFQ) should be verified. Further, in the project studied a training plan regarding when the equipment supplier should train operators and maintenance staff was created.

*Formal mutual adjustments.* During the project progress, the cooperation with the equipment supplier had the character of a dialogue rather than a monologue. For example, the case study company placed requirements but did not present solutions to the equipment supplier. Rather, the equipment supplier was encouraged to find an effective solution to the problem. It was



mutually agreed on the next steps based on the production equipment options presented by the equipment supplier.

*Dedicated teams.* In the industrialisation project at the case study company, the core team consisted of five people, two people from the case study company and three people from the equipment supplier. These five people were present at each meeting. Other employees of the companies were invited to the meetings if the content related to their responsibilities. Both companies appointed also contact persons who should be notified of any issues and problems. The contact person appointed by the manufacturing company was a production engineering manager who was a member of the new product development project team and thus also had knowledge about the progress in the entire new product development project.

*Informal coordination mechanisms.* The equipment supplier was located in Sweden but in another city about 500 km away, which gave little opportunity for more informal, subtle mechanisms. However, appointing the production engineering manager as a contact person facilitated the communication with the equipment supplier. The appointed production engineer had experience from previous industrialisation projects and was the system designer of the assembly line used for the previous product generations. Thus the production engineering manager had a detailed understanding of the equipment supplier's issues. Further, the selected equipment supplier had great experience from working with companies in the automotive industry and was thus aware of particular issues relevant for this industry such as the demands for lean production and sustainability.

#### 4.2 Information sharing among internal functions

The production system was implemented in an already existing plant with available structures regarding many aspects of the production system such as material supply and work organisation.

*Standards or rules.* The company used a stage-gate model for the product development project. However, the model had been developed from the product perspective and thus did not focus on a structure for the production system design process. Instead the product development stage-gate model included elements of the production system design process that had to be completed at different gates. Consequently, the classification of work activities was made with regard to different functions such as production engineering, quality management or material supply and thus did not emphasise the importance of considering the totality of the production system. In addition, there was only limited documentation with regard to experiences from previous industrialisation projects.

During the industrialisation project studied more information was documented, which can be re-used in future projects. The industrialisation project manager initiated a white book, in which experiences and lessons learned were documented. Further, standard documents were introduced, such as a logistic setup document that described the logistic setup for the production system including the material flow from the supplier to the customer. This document can easily be re-used in future projects including calculations of costs for different alternatives. Another example is a procedure for handling engineering change order that was implemented. This document described a proceeding required to release or change the product design and implied that each affected function needed to approve the change of the product or indicate the follow-up costs of the changes as a basis for the decision making.

*Plans and schedules.* When the industrialisation project started, the schedules and deadlines available were the ones based on the gates of the product development model. However, the industrialisation project manager devoted a considerable amount of time to frontloading, i.e. planning and specifying work activities needed when designing the production system. For

example, information about how the components and material should be supplied to the production system was important for the detailed design of workstations. Therefore a deadline for packaging instructions was set in order to be able to consider these aspects in the design process. In addition, weekly industrialisation group meetings were implemented to ensure that no deadline was missed.

*Formal mutual adjustments.* The weekly industrialisation project meetings were a good basis to achieve formal mutual adjustments between all parties involved. At the meetings, critical issues were discussed. Based on the discussions the group agreed on joint problem solving activities and a prioritisation of the next steps was achieved.

*Dedicated teams.* Before the industrialisation project started in November 2009 no separate industrialisation project group was appointed. The functions working with the production system design were part of the new product development project. The appointed industrialisation project manager created however a cross-functional industrialisation team. Still, at the start of the industrialisation project the company did not allocate time for these employees to work with the industrialisation project; rather the employees were supposed to carry out the work activities related to the production system design in addition to their daily work activities. As the project was considered to be strategically important and had a tight schedule, resources were allocated to the industrialisation project later on. For example, one person worked full time with the design of the material supply system.

*Informal coordination mechanisms.* The fact that the case study company had not worked with formal coordination mechanisms in earlier industrialisation projects made the use of informal coordination mechanisms between the functions involved in the production system design process critical. A large amount of the relevant information was managed by direct interaction between the different functions and the exchange tended to be informal and ad hoc. Information was often acquired and shared when there was a need to complete the work activity. The discussions could take place in the corridor or by telephone and e-mail. Other opportunities for discussions between the industrialisation project members were for example during lunch or coffee breaks.

In addition, the industrialisation project manager was located close to the advanced engineering project manager, purchasers and product designers, which facilitated daily conversation about progress and changes. During the project, the industrialisation project manager also built a network of informal and personal contacts among other employees from different product areas of the company, i.e. he contacted other employees who he thought could contribute to the problem solving.

As resources were limited and the product design still uncertain, preliminary information needed to be used when designing the production system. The use of preliminary information made it impossible to plan for required rework later in the process. To minimise the need for rework and coordinate the various work activities, production engineering and material supply met on a daily basis.

#### 4.3 Overview of the differences in the sharing of design information

By focusing on the sharing of design information when designing the production system, this study has shown that such sharing differs depending on whether the information is shared with an external equipment supplier or between specialised functions within the manufacturing company. As Table 2 summarises, differences in the sharing of design information can be explained by the coordination mechanisms used.

**Table 2** Differences in the sharing of design information

	<b>Information sharing with the external equipment supplier</b>	<b>Information sharing among specialised functions</b>
Formal coordination mechanisms: <ul style="list-style-type: none"> <li>• Standards or rules</li> <li>• Plans and schedules</li> <li>• Formal mutual adjustment</li> <li>• Dedicated teams</li> </ul>	Standardised working process Comprehensive documentation  Time plan Verification plan  Frequent meetings Two-directional flow of information  Core team Appointment of contact persons	Starting point is the product development stage-gate model Shifting towards reusable documentation  Based on the product development stage-gate model Towards active working with front loading  Weekly meetings  Industrialisation project manager Loose cross-functional working team
Informal coordination mechanisms	Similarities in thinking and language Reasonable skill level	Close location Spontaneous discussions
Overall character	Highly formal, checklist-based	Informal and ad-hoc but changes were made to a more formal approach

## 5. Factors facilitating the sharing of design information

The empirical findings revealed critical factors that facilitated the sharing of design information in the industrialisation project studied covering the design of the production system. Table 3 summarises the identified factors.

**Table 3** Summary of the identified factors facilitating the sharing of design information

<b>Factor</b>	<b>How it contributes to the sharing of design information</b>
Cross-functionality in the design team	Cross-functionality implied that more functions were involved in the design process and thus design information was shared among the functions involved.
Structured production system design process	A structured process outlined design information that needed to be shared in the different phases to accomplish the work activities
Standardised documentation	The risk that the shared information was interpreted incorrectly and misunderstood was minimised by standardised documents.
Allocation of resources	Resources from various functions needed to be allocated to the industrialisation project in order to get people engaged in the design process and as a result share design information.
Separate industrialisation project manager	The project manager worked actively with frontloading and thus ensured that required design information was shared when needed and documented.
Timeline	The timeline indicated what design information needed to be shared at different points in time.
Co-location	Co-location allowed for more frequent design information sharing by spontaneous discussion.

The empirical findings showed that over time more and more functions were involved in the industrialisation project covering the design of the production system, i.e. the cross-

functionality in the design team increased and thus information from different functions was shared. The intention was to include design information from all functions that affected or were affected by the new production system. When the task of designing a production system is approached from a holistic perspective, the risk for suboptimisation that could cause problems in the total production system is reduced (Bellgran, 1998).

The findings illustrated that the use of a structured production design process supported the sharing of design information. The structured design process gave advice on what design information was required for the different work activities. Further, it was easier to achieve clarity about roles and responsibilities, which is needed to identify sources of relevant and necessary design information. Consequently, in line with the results of Cooper and Kleinschmidt (1991), it is argued that a structured process such as a stage-gate process with critical go/no-go decisions provides procedures for improved information handling.

Apart from the documents that were important for the purchasing of production equipment from the equipment supplier, there was a lack of documentation that concerned the design of the production system at the beginning of the industrialisation project. However, to provide an opportunity to learn from the experiences gained in the industrialisation project studied, more and more design information was documented. The documented design information was also useful for follow-ups later in the project and minimised the risk for ad hoc decisions. However, it is important to note that an intangible and non-standardised content of the design process hampers the sharing of information (Moenaert and Souder, 1990), which makes standardisation of the terminology used and the document structure important for an effective sharing of design information. Thus, effort was devoted to creating standard terminology in order to ensure that the shared design information was understandable by other functions.

The findings indicate that the sharing of design information between specialised functions was facilitated by organising the design of the production system in a separate industrialisation project with dedicated resources. This is in line with the reasoning presented by Love (1996) arguing that a process of designing a production system is organisationally complex requiring a project team with members from different specialised functions. Project teams facilitate the sharing of information across functional boundaries (Lawrence and Lorsch, 1967). For example, after resources were allocated at the case study company, the people had time to participate in project meetings, which were an important means to share design information among the functions.

Due to the very strict timeline for product launch and the delays in the new product development project, the company appointed an industrialisation project manager. The findings from the case study show that the industrialisation project manager had a major impact on the sharing of design information between specialised functions. He devoted much time to ensuring that relevant design information was available at the required point in time. It has been argued that a successful project requires a knowledgeable project manager who can devote sufficient time to plan, manage and monitor the project (Mabert, Muth, and Schmenner, 1992). Further, a project manager encourages information sharing and provides formal reporting procedures (Griffin and Hauser, 1996).

Finally, in the industrialisation project studied there was a timeline for the design activities. The different functions involved in the production system design process required different design information at different points in time. Therefore it was important to have deadlines that indicated when certain activities needed to be accomplished in order to minimise the risk for delays and rework. Further by having fixed deadlines the functions also knew what design information needed to be presented at different points in time to ensure that decisions could be reached.

## 6. Discussion

The study sheds light on some limitations of previous studies on sharing information across organisational boundaries and within the organisation when designing production systems. The limited integration between the functionally specialised departments involved in the production system design process highlights that solely physical proximity and organisational affiliation does not guarantee a smooth sharing of design information among specialised functions. Rather, the findings show that only when the case study company started to use formal methods was the sharing of information between the specialised functions improved. The importance of formalisation for the sharing of design information has been highlighted by prior research (Griffin and Hauser, 1996; Vandeveld and Van Dierdonck, 2003). However, what the research presented in this paper adds is an investigation into the more specific details of sharing design information when designing the production system. Although the identified factors seem to state the obvious, to achieve sharing of information requires a considerable amount of resources and efforts, an important first step in an area that has received only limited attention. For example, it was the first time that the design of the production system was not considered a subactivity of the product development project, and thus the industrialisation project received the attention and awareness required. The changes made in the industrialisation project studied led to the following benefits:

- No essential design information was left out, which reduced the risk of installation and running-in problems and disturbances before start of production.
- The project manager got an overview of what aspects needed to be handled by the project organisation and what was addressed by the existing organisation.
- A stronger commitment to the proposed solution was achieved as information was continuously exchanged between all parties involved in the design process.
- Decisions were taken in a cross-disciplinary fashion and all deadlines were met.
- The experiences can be re-used in future production system design projects.

The study also demonstrates that the demand for internal integration is not easily satisfied and requires also informal coordination mechanisms. The need for informal and ad-hoc sharing of design information facilitated a mutual understanding between the functionally specialised departments. The ability to understand each other's needs might be limited between the specialised functions involved in the production system design process due to different backgrounds and training. Therefore, personal communication provides a good opportunity for enactment and clarification to achieve mutual understanding, which is critical to overcome those barriers. Thus it can be assumed in line with the results of Griffin and Hauser (1996) that collaboration also enhances project success.

Somewhat unexpectedly, despite physical distance and organisational boundaries, the sharing of design information with the external equipment supplier was less troublesome than the sharing of design information among functions within the manufacturing company. Therefore, the findings of the industrialisation project studied challenge previous research suggesting that geographical distance and organisational boundaries have a negative impact on the quality of the design process (e.g. Allen, 1977; Vandeveld and Van Dierdonck, 2003). A first plausible explanation for these findings is that formalisation is a primary facilitating factor to eliminate integration barriers (e.g. Adler, 1995; Twigg, 2002). A second plausible explanation for a high degree of integration between the equipment supplier and the manufacturing company is that the main contact person at the manufacturing company is the production engineering manager. He has the same background and training as the representatives of the equipment

supplier and thus has an understanding of the needs and work approach of the equipment supplier. As Vandeveld and Van Dierdonck (2003) suggest, the empathy of the designer, i.e. a person who explicitly thinks about the needs of other functions and who is able to recognise the difference between the company's own world and that of the partners, can overcome integration barriers. Another factor that might explain the differences in how the design information was managed is the degree of newness and the associated costs. Production equipment is often extremely costly and involves a high degree of newness, which requires project members to be as detailed as possible to minimise the risk of costly rework. The design information that is handled among functions within the manufacturing company relates partly to the already existing organisation. As a result, the costs of poor management of design information among functions are not transparent and are thus difficult to estimate. Further, the utilisation of sophisticated information technology can contribute to overcome integration barriers by neutralising them. Finally, a reason why the managing of design information with the external supplier was less troublesome could have been greater dependency, i.e. the risk of losing the order.

Another interesting aspect of the empirical findings was that service engineers and the production engineer or the industrialisation project manager did not share information about the planned service offers when designing the production system (see Figure 2). Thus, although the case study company identified customer service as an important order winner in the future and prior research has emphasised the relation between the ability to provide services and the operational capabilities of the production system, service information was not considered when designing the production system. However, as early design decisions provide the foundation for operational capabilities (Bennett, 1986), field engineers should work with the production system design engineers to ensure that serviceability is considered in the early design of the production system.

## **7. Conclusions and future research**

The purpose of the research presented in this paper was to analyse and discuss factors that facilitate the sharing of design information when designing production systems. Since such sharing has received little attention, we contribute with new knowledge by studying managerial actions that promote the sharing of information across organisations and within organisations and thus facilitate integration. In sum, our results show that the sharing of design information is promoted by a formal approach and that it is indefensible to ignore the need for formalisation also for the sharing of design information among functionally specialised functions within the manufacturing company. Furthermore, the results imply that integration barriers based on physical distance and organisational bounds seem to play a minor role when designing production systems, while language and personal differences were major sources of integration barriers. Thus, the findings of the study challenge previous research that geographical distance and organisational bounds are barriers to integration (Allen, 1977; Vandeveld and Van Dierdonck, 2003). The question then arises if geographical distance and organisational bounds reinforce personal and language barriers, i.e. personal and language barriers are more difficult to overcome in dispersed settings.

The findings provide important insights that should contribute to an improved process of designing the production system. Project managers should strive for formal methods, structures and processes that promote the interfunctional exchange of design information within the manufacturing company. The implementation of organisational devices such as what information must be exchanged between different functions at what point in time can stimulate the sharing of design information between the different functions involved. However, it is important to note that formalisation is only beneficial when it contributes to a

comprehensive and leaner process. Further, it is also clear that the coordination mechanisms available have to be chosen carefully in industrialisation projects combining formal and informal coordination possibilities.

As in all research, it is important to acknowledge the limitations. The conclusions are based on a single case study of an industrialisation project and thus further research emphasising the sharing of design information in the production system design process is required. Future research should include both studies of ongoing design projects and already completed design projects as well as survey studies in order to verify the findings of the current research. It would also be of interest to study the potential of a production system design stage-gate process with critical go/no-go decisions at various points. Prior research has emphasised that a stage-gate process provides procedures for improved information sharing (Cooper and Kleinschmidt, 1991; Griffin and Hauser, 1996), but this research had a product perspective. In addition, it would be interesting to study the service information required when designing production systems. This would contribute to an improved understanding of how the production system design process can play an important role in creating new service offerings to the customers.

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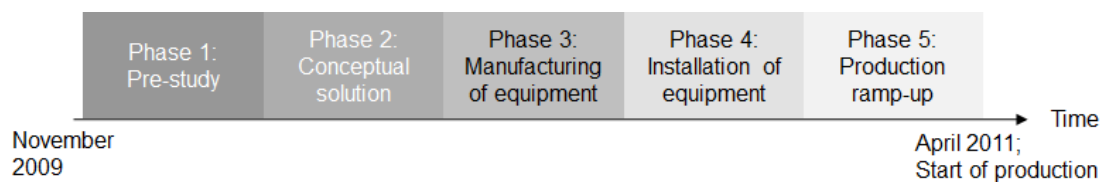
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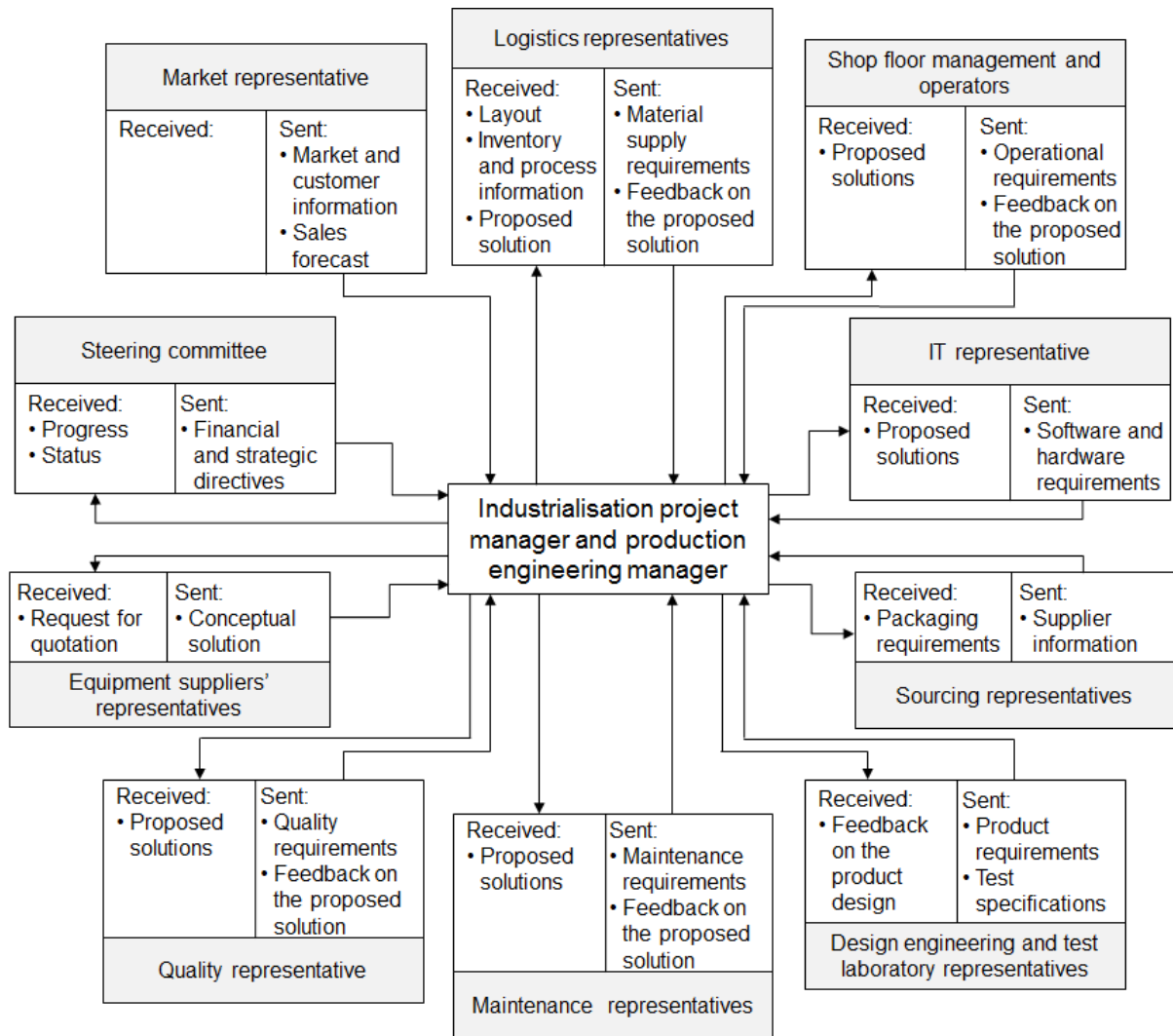


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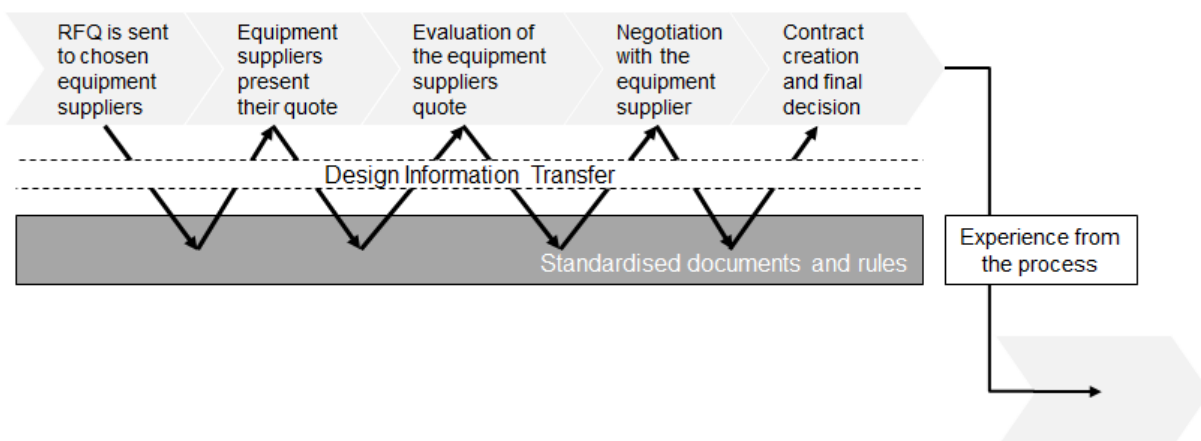
## Figures



**Figure 1** Time line of the industrialisation project studied.



**Figure 2** Design information received from and sent to the industrialisation project manager and production engineering manager when designing the preproduction system.



**Figure 3** Standardised working procedure for selecting a production equipment supplier.