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Design information for efficient equipment supplier/buyer integration

Abstract

Purpose – The purpose is to describe the underlying design information and success factors for production equipment acquisition in order to support the design of high-performance production systems.

Design/methodology/approach – The study employs an in-depth case study of an industrialization project together with a questionnaire of 25 equipment suppliers as a research strategy.

Findings – The study provides the reader with an insight into the role of design information when acquiring production equipment by addressing questions such as: What type of information is used? How do equipment suppliers obtain information? What factors facilitate a smooth production system acquisition?

Research limitations/implications – Limitations are primarily associated with the chosen research methodology, which requires further empirical studies to establish a generic value.

Practical implications – The implications are that manufacturing companies have to transfer various types of design information with respect to the content and kind of information. More attention has to be placed on what information is transferred to secure that equipment suppliers receive all the information needed to design and subsequently build the production equipment. To facilitate integration of equipment suppliers, manufacturing companies should appoint a contact person who can gather, understand and transform relevant design information.

Originality/value – External integration of equipment suppliers in production system design by means of design information is an area that has been rarely addressed in academia and industry.

Keywords – Production equipment acquisition, Manufacturing industry, Information, Production system design, Operations management

Paper type – Research paper.

1. Introduction

One key issue during production system development projects is the acquisition of production equipment, which often accounts for a fairly large share of costs in production system development projects. Skinner (1992) argues that the investment in new production equipment can increase both production performance such as reliability or dependability and financial performance such as margins or market share. Production equipment acquisition situations require inward technology transfer and thus provide an opportunity for bringing in new technology into the manufacturing process (Trott and Cordey-Hayes, 1996). In addition, the ability of designing production equipment that can be easily transferred and ramped up to high volume production is difficult to emulate by competitors and thus allows for competitive advantages (Hayes *et al.*, 2005).

However, the task of designing and building the production equipment or parts of it is rather complex and often involves collaboration between manufacturing companies and equipment suppliers. The design of production equipment is an iterative process requiring input from members of various functions with different backgrounds and roles. Holden and Konishi

(1996) conclude that the old model of technology transfer, i.e. import of technology, has to be replaced by more reciprocal collaboration including a more dynamic and interactive process of balancing internal R&D with that of strategic partners around the world. This is in line with Malik (2002), who argues that technology transfer should be a reciprocal iterative process. Consequently, it is of utmost importance to have good contacts and strong collaboration with equipment suppliers in order to explore new process development opportunities (Lager and Hörte, 2005).

Hence, there is a need for external integration during production system design, i.e. integration of work activities between organisations with formal boundaries (Pagell, 2004). An integration process requires the processing of relevant and necessary information between the parties involved (Koufteros *et al.*, 2002; Swink *et al.*, 2007). When design and building of production equipment is handed over to an equipment supplier, higher requirements are placed on the management of design information to secure that the equipment complies with technical and financial requirements of the manufacturing company. However, despite the fact that the integration of the equipment supplier is important (Bellgran, 1998) and consequently also the managing of design information between the manufacturing company and the equipment supplier, few studies have actually examined information processing between equipment suppliers and manufacturing companies.

The purpose of the paper is therefore to describe the underlying design information and success factors for production equipment acquisition in order to support the design of high-performance production systems. More specifically, the following questions are formulated:

- What type of design information is used for production equipment acquisition?
- How do equipment suppliers obtain the design information required?
- What factors contribute to an effective production equipment acquisition process?

2. Theoretical framework

Although production system design is deemed important for project performance, it seems difficult to achieve (cf. Bellgran and Säfsen, 2010; Duda, 2000). As Hayes *et al.* (2005, p.195) have noted that

“the development of new operating process technologies, however, has engendered far less excitement among academics and practitioners, let alone the public at large.”

However, the absence of support for the design of new process technologies increases the risk of installation and running-in problems and disturbances before start of production. Disturbances when installing new production equipment are often caused by new technology that has not been verified enough before being implemented. Probably most manufacturing companies have experienced this general problem.

2.1 Design and development of production equipment

Already in the seventies, Abemathy and Wayne (1974) pointed out that vertical integration expands and specialisation in production equipment increases causing an increase in capital investments. As a result, there is a trend towards outsourcing the design and subsequent building of production equipment. Using the case of the process industry it has recently been shown that equipment suppliers play a key role during the different stages of the equipment's lifecycle due to the distinctive nature of the process technology (Lager and Frishammar, 2010; Rönnberg Sjödin and Eriksson, 2010). However, it is possible to find manufacturing companies with an internalisation strategy, i.e. companies that conduct a significant degree of activities related to the design and building of production equipment in-house (Yamamoto and

Bellgran, 2009). Consequently, the two choices should be considered as ends on a continuum. At the one end of the continuum, there are situations where the majority of activities is carried out by the manufacturing companies while at the other end of the continuum, the majority of activities is carried out by the equipment supplier. Between these two extremes of who performs the work, there are alternatives in which equipment suppliers and manufacturing companies cooperate in designing and building production equipment.

Companies applying an outsourcing strategy become dependent on the equipment suppliers' efforts to secure or improve the operating performance of the equipment (Lager and Frishammar, 2010). Further, even in situations where production equipment acquisition is completely outsourced to an equipment supplier, it seems necessary to maintain certain competencies also within the manufacturing company. Previous research point out that the trend towards outsourcing has made it even more essential to keep in mind the required in-house competences for system integration (e.g. Hobday *et al.*, 2005; Von Haartman and Bengtsson, 2009).

2.2 External integration

Utterback and Abernathy (1975) argue that the potential benefits of development of equipment are often marginal, while the payoff required to justify the cost is large. Therefore, equipment suppliers are sources of major innovations in process technology for which the incentives are greater and adopted by the larger user firms (Freeman, 1968; Hutcheson *et al.*, 1996; Reichstein and Salter, 2006). By access to new process technology, manufacturing companies can benefit from faster market introductions, lower development risks and improved productivity (Pisano, 1997). Therefore, to create a win-win situation is not only desirable but essential for both the equipment supplier and the manufacturing company in order to stay competitive in the future (Lager and Frishammar, 2010).

To be able to integrate the activities carried out by the equipment supplier into a smoothly functioning production equipment requires overcoming many barriers. Ro *et al.* (2008) point out competitive bidding, trust issues and poor coordination and communication as major relational barriers. Organisations that want to overcome barriers need to have employees facilitating technology transfer and to reward good technology-transfer behaviour (Jung, 1980). Leonard-Barton and Sinha (1993) identify in their study about technology transfer that above cost, quality and compatibility of the technology, also user involvement and the adoption by the developers and users of both the technical system itself and the workplace are important success factors. During the transfer of a technical system, equipment suppliers often encounter differences in the context, equipment, skill of the operator, etc., which often requires adjustments of the technology in the operating environment. This is true even if developers meet the specified requirements and original objectives.

2.3 The role of design information

In order to design and build production system equipment, equipment suppliers must have necessary and relevant information about the functions, capabilities and properties the equipment should meet, i.e. design information. Consequently, integration is approached as an information-processing phenomenon, where shortages occur due to a lack and asymmetry of information or an inability to process information (Frishammar and Hörte, 2005; Turkulainen, 2008).

Given the large amount of information to be exchanged, information may be classified into different types of information. Findings of information studies indicate that different types of information are appropriate for different purposes (e.g. Fjällström, 2007; Häckner, 1988; Zahay *et al.*, 2004). For example, Frishammar (2003) classifies information into hard

(quantified) and soft (qualitative) information and discovers that companies usually rely on a combination of both hard and soft information. Hard information regards numerical information that can easily be quantified and processed with the help of analytical models, whereas the soft information refers to images, visions, ideas and cognitive structures (Häckner, 1988). In addition, soft information may be characterised as broad, general and subjective as it concerns holistic images of reality and is linked to the individual person (Shrivastava, 1985).

In general, information exchange can take place in a variety of ways including documents, meetings, conversations, etc. Applying formal documents during the process has two advantages. First, the author of the information is forced to structure the documents and ensure that important requirements will not be forgotten. Second, the receiver of information is provided with a concrete document. In general, written communication is more comprehensible than oral communication (Moenaert and Souder, 1996). This is, however, only valid if the information is written in a common, easily accessible language (Vandeveld and Van Dierdonck, 2003), and it depends on the type of information transferred (Daft and Lengel, 1986). Daft and Lengel (1986) conclude that if there is a need to process rich information, i.e. information that enables debate, clarification and enactment, a rich communication medium such as face-to-face or meetings is more appropriate. In contrast, a less rich communication medium such as documents is favourable for processing well-understood messages and standard data. Consequently, information can be transferred by personal sources via direct human contact or impersonal sources, which are written in nature (Daft *et al.*, 1988).

The processed information can reduce uncertainty, equivocality and ambiguity in organisations (Daft and Lengel, 1986; Kyriakopoulos and De Ruyter, 2004). However, for information to be useful, several information quality criteria have to be fulfilled, with dimensions such as understanding, completeness and accessibility (Lee *et al.*, 2002). Failure to realize deficiencies in the information quality may reduce perceived information utility, which is a prerequisite for information utilization. For example, slang and jargon filled language developed and used by one function show a tendency to improve the efficiency of intradepartmental information exchange but may hamper the flow of information between different functions (Lawrence and Lorsch, 1967; Tushman, 1977). Using the integration of R&D and marketing, Griffin and Hauser (1996) argue that already subtle differences in language imply vastly different solutions and determines whether a project is successful or not.

A common mean to overcome language differences is the use of a Gatekeeper. Gatekeepers can overcome barriers based on differences such as language, norms and values (Allen, 1977; Tushman and Scanlan, 1981) and can be described as key communicators (Davis and Wilkof, 1988), who are strongly linked to the internal and external organisation (Tushman and Katz, 1980; Tushman and Scanlan, 1981). Consequently, gatekeepers can provide a link between the organisation and its environment by collecting and translating relevant information. Another option would be to rely on more formal means deciding on the type of information that needs to be exchanged at different points in time or a standardization of the language used. For example, Liker *et al.* (1999) found that certain formal procedures such as design standards, design reviews and documentation supported to keep in-process design control, i.e. keeping product development projects within boundary conditions. Further, continuous interaction between project members is vital in development project (Lakemond and Berggren, 2006), particularly with regard for knowledge- and motivational-oriented information exchange (Van den Bulte and Moenaert, 1998).

To sum up, previous research provides convincing evidence about the importance of integrating external equipment suppliers into production development projects of manufacturing companies. Based on the literature review, some areas seem to be of particular importance:

- To benefit from equipment supplier integration manufacturing companies have to possess relevant in-house competences.
- Gatekeepers, formalization, coordination and continuous interaction are important means to overcome language and integration barriers.
- As different types of information are appropriate for different purposes, there is a need to transfer different types of information to the equipment supplier.
- Information can be obtained in different ways, which has consequences on the perceived usefulness of the provided information.
- Deficiencies in the information quality should be minimised in order to secure information utilization.

3. Research design

3.1 Case study research method

Due to the limited theoretical insights into the role of design information during production system acquisition, an exploratory case study approach was applied (Edmondson and McManus, 2007; Yin, 2009). The case study approach allows gathering rich and detailed data, which provides in-depth understanding of the phenomenon (Eisenhardt, 1989; Yin, 2009). The case study company is a global supplier in the automotive industry and the case study investigated on new product development project. The project can be divided into two parts: a product part and an industrialization part. The product part focused on the development of a manufacturable product, whereas the industrialization part was responsible for the design and installation of the production system required to assemble the product. The case study targeted the industrial part, which had the responsibility to design and develop an assembly line appropriate for volume production and included the acquisition of the production equipment. As on previous occasions, the design and subsequent building of production equipment was outsourced to an equipment supplier. The equipment supplier was located in Sweden but in another city about 500 km away.

The industrialization project started in November 2009 and ended in April 2011. The data for this paper were mainly collected between November 2009 and September 2010, but includes also a first follow-up with the manufacturing company four weeks after start of production. In order to observe events and actions in real-time, data has been collected under 36 days. During the research project, the nature of the data collection changed as the research progressed and can be divided into two overlapping periods.

At the beginning of the case study, documents were studied and the project meetings were attended (non-participatory). The aim was to gain a basic understanding of the background, scope and status of the project. After the introduction period, the research was more interactive and included interviews and participation in the industrialization process. Interviews were conducted with various stakeholders in order to represent different functions that are involved or affected by the industrialization project. In total, 26 interviews have been carried out ranging from 30 to 90 minutes. The different positions of the respondents included: vice president, project managers, department managers (production engineering, logistic, workshop and facility) program manager, marketing manager, engineers and

operators. Further, the industrialization project manager and the production engineer manager received continuous feedback about the findings and progress of the study. Preliminary findings were presented, which were among other things applied in the request for quotation, i.e. all information that was sent to equipment suppliers to receive a quote for the production equipment. Further, to acquire a good understanding about the interaction between the equipment supplier and the manufacturing company six meetings between the equipment supplier and the manufacturing company were attended (ranging from 90-600 minutes) and transferred documents were studied.

3.2 Questionnaire-based research method

Based on results from the case study and the literature review, a questionnaire was formulated in order to gather further information and enable confirmation of the case study findings. Beginning with exploratory fieldwork (case study), which leads to the development of a questionnaire, is an appropriate tool to expand the breadth and scope of the study (Miles and Huberman, 1994). The focus of the questionnaire was to investigate the design information that needs to be exchanged between equipment suppliers and manufacturing companies and to identify success factors facilitating production equipment acquisition. The random sample included 46 equipment suppliers. 28 respondents returned the questionnaire, of which three answers were invalid. The sample of companies included the design and development of both assembly and manufacturing equipment. Twenty companies represented equipment suppliers that provided both assembly and manufacturing equipment, four companies were specialised on assembly equipment and one company focused on manufacturing equipment.

The questionnaire contained 13 questions concerning design information characteristics as well as 19 potential success factors. The importance of the success factors was measured on a seven-point Likert scale. “1” indicated that the dimension was not at all important for the performance, i.e. disagree; “7” indicated that it was of crucial importance, i.e. strongly agree. The five intermediate values represented a sequence including the option “undecided”. The respondents could also choose the alternative “don’t know”. Further, the respondents were asked to rank the five most important factors and could state other success factors for a smooth production equipment acquisition, which were not included in the questionnaire. The questions concerning type of information were formulated to include answers about what and how, i.e. more detailed data about experiences/reflections of each individual company.

The respondents who answered the questionnaire had a median of 10.5 years of work experience in the company. Further, the majority of respondents had been working in sales and marketing (64 per cent). Other functions represented in the sample were project management, customer support, design and general management. The fact that the majority of respondents are working in sales and marketing may affect the answering concerning the ranking of relevance of different types of information compared to other functions and departments. However, most of these employees had a technical background and were also involved in the progress of the design and building of the production equipment.

3.3 Analysis

The case study analysis was conducted in an iterative way and followed the three activities suggested by Miles and Huberman (1994), i.e. data reduction, data display and conclusion drawing. Including a case study at the manufacturing company and a questionnaire answered by equipment suppliers, the study represents both perspectives, i.e. the customer and supplier of the production equipment acquisition are represented. The data from both the case study and the questionnaire were first analysed research question by research question from the perspective of the equipment supplier and from the perspective of the customer. Thereafter,

the results were compared with each other in order to analyse similarities and differences based on the two perspectives. All analyses are explanatory in nature.

4. Empirical findings

4.1 Type of information used for production equipment acquisition

In general, the 25 equipment suppliers that answered the questionnaire used a wide variety of information to accomplish their task of designing and building the production equipment. Table 1 summarises the type of information used by the equipment supplier ranked according to their relevance. The equipment suppliers quoted technical information about properties and functions of the production equipment as the most important type of information. The technical information should consider two aspects; general technical information (hydraulics, electric requirements etc.) and project specific technical information (tact time, expected length of life etc.).

Table 1. Type of information used by the equipment suppliers and ranked by relevance to the suppliers.

<i>Type of information</i>	<i>Quoted (%)</i>
Technical information – information about general technical requirements and project specific technical requirements	96 %
Product information – information about the products that are going to be manufactured in the new production equipment	80 %
Objective information – information about the needs and wants	64 %
Project information – information about timing, scope, terms of purchase, etc.	56 %
Context information – information about the specific background and context of the actual production equipment acquisition project	48 %
Financial information – information about the investment budget	28 %*
Verification information – information about how and when to verify stated requirements	8 %

*Note: Financial information was not a proposed type of information in the questionnaire, but quoted by seven equipment suppliers as a relevant type of information. Thus, the relevance could have been different, when financial information would have been included as a proposed alternative.

The empirical findings from the case study company showed that a lot of effort was put on collecting and documenting general and project specific technical information in a requirement specification. This was in contrast with previous projects where the technical information mainly concerned the general technical requirements. The verification information (summarised in a verification plan) was an important type of information used by the case study company. It was used to outline when and how the fulfilment of the specified requirements and the progress of the design and development of the production equipment should be followed up and assessed.

Further, the results of the questionnaire indicated that the equipment suppliers preferred to use quantitative information rather than qualitative as illustrated in Figure 1. The figure shows the proportion of quantitative information of the total information exchanged. For example, an equipment supplier who indicated a proportion of 80 per cent quantitative information needed 20 per cent information of qualitative character to carry out the necessary work activities. The equipment suppliers tended to rely heavily on quantitative information (median 70 per cent) compared to qualitative information. However, the provided information should be a

combination of quantitative and qualitative information. The results from the questionnaire were in line with the industrialization project at the case study company. Here, the information transferred to the equipment supplier could be characterised as mostly being quantitative rather than qualitative.

[Take in Figure 1. The proportion of quantitative information used by equipment suppliers in relation to the total information.]

4.2 Equipment suppliers ways of obtaining required design information

The results of the questionnaire indicate that the equipment suppliers usually obtained information from their customers, i.e. the manufacturing companies sent the information identified as relevant to the equipment suppliers, see Figure 2. In total, 21 out of 25 equipment suppliers stated that 50 per cent or more of the needed information was provided on the initiative of the customer. For the whole sample, however, the median was 50 per cent, i.e. the customers did just provide half or more of the information needed by the equipment suppliers. The equipment suppliers pointed out that information about the investment budget and the context often was insufficient. For example, the information provided lacked details about on-going manufacturing and about the processes taken place before and after the actual manufacturing process targeted for the purchased equipment. When relevant information was missing, project participants from the equipment suppliers had to seek additional information themselves from the customer. Missing information was obtained by direct contact with the customer, preferably via an appointed contact person of the customer. Usually telephone or e-mail communication was used to obtain the missing information, sometimes followed up by visiting the customer.

[Take in Figure 2. The proportion of information needed by equipment suppliers that was obtained from the manufacturing company without requests.]

The findings of the case study illustrated that the information provided by the case study company was not sufficient for the work of the equipment supplier. To get additional information, the equipment supplier contacted the case study company and visited the shop floor during meetings at the case study company. When visiting the shop floor the equipment supplier studied the assembly line for the previous product generation and the location for the new assembly line. An interesting approach of the manufacturing company was that they did not provide any information to the machine suppliers about the available equipment budget. The primary rationale for not providing this type of information was that the manufacturing company as a customer did not want to put financial limitations that could restrict the supplier's development of conceptual and technical solutions and hence restrain the innovativeness.

Despite the fact that the equipment suppliers had to look for additional information, the results of the questionnaire show that not all information obtained from the customer was considered relevant. The aspect concerning the relevance of the obtained information was visualized in the questionnaire when the equipment suppliers explicitly indicated the proportion of relevance of the obtained information, i.e. the percentage of the transferred information they needed to fulfil their work activities, see Figure 3. The results indicated that the majority of the transferred information was considered relevant for the equipment suppliers (median 80 per cent). However, only six equipment suppliers stated that the provided information was completely relevant, i.e. to a 100 per cent.

[Take in Figure 3. Relevance of the information transferred to the equipment supplier.]

Another aspect of obtaining information is the preferred communication media for different types of information. Figure 4 summarises the results of the questionnaire. For reasons of simplicity and clarity, the figure separates only three different types of information. However, fact-based information provided specifications with direct relevance for the production equipment and acquisition process and thus consisted of technical, product, project management, financial and verification information. The results showed that electronic documents dominated for the processing of both fact-based information and contextual information, while the information about the needs and wants, i.e. the objective was preferably obtained at meetings or study visits.

[Take in Figure 4. Communication media preferred by the equipment suppliers and in relation to type of information processed.]

The results of the questionnaire were similar to what the findings of the case study indicated, i.e. what communication media the case study company preferably used to transfer information to the equipment supplier. In the case study, fact-based information was processed by means of documents, drawings and the product prototype. Further, during meetings between the case study company and the equipment supplier the three types of information illustrated in Figure 4 are transferred. In between the meetings, technical and product information was processed by means of telephone and e-mails including electronic documents.

4.3 Identified success factors for an effective production equipment acquisition process

The factors identified by the equipment suppliers in the questionnaire as being the most important to achieve an effective production system acquisition process are summarised in Table 2. The equipment suppliers stated that the manufacturing companies should carefully select a skilled contact person for effective collaboration. The possibility to openly discuss alternative solutions with the customer was considered very important by the equipment suppliers. The equipment suppliers pointed out that the interaction with the equipment supplier should be characterised by responsiveness and honesty.

Table 2. The four most important factors contributing to an effective production equipment acquisition process as identified by 25 equipment suppliers in the questionnaire.

<i>Factor</i>	<i>No. of respondents that ranked factor as</i>			
	<i>of crucial importance</i>	<i>important to a large extent</i>	<i>most important factor*</i>	<i>one of the five most important factors*</i>
Appointed contact person	13	9	8	18
Clear/formal hand-over	9	9	3	8
Continuous communication	6	16	5	17
Common objective	5	16	5	15

* Note: The equipment suppliers were asked to choose and rank the five most important factors out of 19 stated factors. The respondents ranked the most important factor with 1, the second most important factor with 2, etc.

The project studied at the case study company also highlights the need to appoint a skilled contact person. Already before sending out the request for quotation to the machine suppliers, the production engineering manager was appointed as the contact person for the equipment supplier. He was a member of the project team and was the system designer of the company's existing assembly line used for the previous product generation. The findings of the case

study also support the need for formalization and continuous interaction during the production acquisition process. The acquisition project followed a formalized process in which the case study company had mapped out different steps or activities that the equipment suppliers had to complete at various points in the process. The activities undertaken in each stage incorporated the transfer of new information from both sides. Further, in order to improve the understandability of the transferred information, standards concerning the documentation had been created.

4.4 Summary of the empirical findings

Transferring necessary and relevant design information between manufacturing company and equipment suppliers is important for the collaborative development of production equipment. The empirical findings are summarised in Table 3. Table 3 illustrates the conclusions that can be drawn based on the questionnaire and case study for each research question posed in the introduction.

Table 3. Summary of the empirical findings in relation to the three research questions.

<i>Research question</i>	<i>Main findings</i>
Research question 1: What type of information is used for production equipment acquisition?	<ul style="list-style-type: none"> • Different types of information need to be transferred to the equipment supplier including technical, product, project management, financial, verification, contextual and objective information • The information transferred needs to be a combination of qualitative and quantitative information, but the main part is of quantitative character
Research question 2: How do equipment suppliers obtain the information needed?	<ul style="list-style-type: none"> • Equipment suppliers should obtain the relevant and necessary design information from the manufacturing company • There are differences in the perception of what is relevant and necessary information between the equipment suppliers and their customers • The use of documents is preferred for fact-based and contextual information, while personal sources should be used for transferring information about the objective, i.e. the needs and wants
Research question 3: What factors contribute to an effective production equipment acquisition process?	<ul style="list-style-type: none"> • A contact person with good technological knowledge should be applied • The acquisition process needs to have formal mechanisms for achieving coordination and in-process design control such as documentation, standardisation and design reviews • The two parties need to agree on a common objective of the production acquisition process

5. Discussion

The type of information transferred to the equipment supplier during the production system acquisition process extends far beyond transferring technical information. Although technical information is the primary type of information required by the equipment suppliers, the manufacturing company, i.e. the customer has to provide information of different types. For example, the transferred information also has to include a detailed description of the context to enable people to place the information in its context. Since information has no intrinsic value; instead, the value depends upon the context and the user. Therefore, the transferred information has to be embedded in a meaningful context for the equipment supplier, which requires for example also a description of the shop floor environment where the equipment will be located.

Moreover, the results of the empirical studies show that equipment suppliers need a combination of quantitative and qualitative information (Frishammar, 2003; Häckner, 1988), although both the equipment suppliers and their customers prefer the transfer of quantitative information. One reason is that quantified information facilitates the handling and processing of large amounts of information compared to qualitative information. Quantitative information such as performance specifications on tact time or availability is fundamental when designing production equipment for a new production system. Further, since it is quantitative it is also easy to verify that the stated requirements are fulfilled. A possible reason why manufacturing companies need to provide quantitative and qualitative information is the underlying nature of the type of information. Different types of information are transferred for different purposes (Fjällström, 2007; Zahay *et al.*, 2004), which underscores that some types of information are transferred to enable clarification, while other information types seek answers to explicit questions. By using only quantitative information, it might be difficult for the equipment suppliers to set the information in its context. Further, to increase the understanding of the information, it was found that the different types of information should be transferred by different communication media, which is also mentioned by Daft and Lengel (1986).

The empirical data shows that the equipment supplier and the manufacturing perceive the relevance of information differently. For example, the results from the questionnaire revealed that verification information summarised in a verification plan was of minor relevance to the equipment suppliers, while the case study company regarded it as important information. A potential reason for the contradictory relevance is that the equipment suppliers test the equipment by themselves during the development process, while for the manufacturing company the plan is an important guiding or control document. Further, although the equipment suppliers do not identify the verification plan as an important type of information, it can facilitate continuous communication and interaction during the project. This is vital for the manufacturing company in order to integrate the activities carried out by the equipment supplier as discussed by Lakemond and Berggren (2006) or Ro *et al.* (2008).

The differences in the amount of information provided by the manufacturing company and the information required by the equipment supplier indicate that the transferred information has to be based on a holistic perspective. However, the empirical findings indicate that the information required by the equipment suppliers to make a quote is seldom based on a holistic perspective. For example, several equipment suppliers stated that information about the entire process flow of the product to be manufactured or information of how material and components should be supplied to the workstations were missing. A potential reason is that the customer, i.e. the manufacturing company does not always consider the fact that the equipment supplier only has a limited insight into the organisation of the manufacturing company. This implies that it is easy to become blind to the shortcomings of one's own company and thus have difficulties in judging the relevance of information to the equipment supplier. Further, this type of information is more complex and not as easy describable as for example information of a quantitative character.

The challenge of providing the right amount of information from buyer to equipment supplier is reflected by the fact that equipment suppliers perceive that some information obtained is not relevant for their work activities. Manufacturing companies must find a trade-off between transferring too much or too little information. If too much information is provided, there is a risk that equipment suppliers will overlook important information. Further, by providing too much information, separating important from unimportant information becomes the responsibility of the equipment supplier and information might be misunderstood causing frustration and possibly a need for rework. Collecting irrelevant information also becomes a

time consuming and costly activity at the manufacturing company. Thus, not all-available information should be transferred automatically; rather equipment suppliers have to purposefully choose the required design information that is going to be transferred.

Further, the results propose that the information transfer between organisations with formal boundaries can contribute to deficiencies in the information quality. Since the information quality determines utilization of information, it can have major implication on the work of the equipment supplier. For example, when information is not accessible the frequency of usage will decrease (Frishammar, 2003; Sawyerr *et al.*, 2000). Thus, if the equipment suppliers obtain too little information, they have to seek additional information, which can be very time consuming. Figure 5 illustrates information quality deficiencies and its consequences for the equipment supplier that originates from the collaboration between two separate companies. The figure exemplifies information quality deficiencies based on observations in the case study. As can be seen, the information quality of the transferred information is crucial in order to avoid frustration, confusion and time-consuming activities at the equipment supplier.

[Take in Figure 5. Information quality deficiencies and its consequences due to separate organisations of the equipment supplier and their customers.]

To a background where equipment suppliers play a key role in designing and building the production equipment, it seems justified to elaborate on what factors contribute to the overcoming of integration barriers. From the empirical studies, it can be concluded that a clear success factor for the collaboration concerns the manufacturing company's appointment of a skilled contact person that bridges the exchange of relevant information and communication between buyer and supplier. Thus, the contact person can be seen as a so-called gatekeeper, because he/she opens the gate or barrier raised by the organisational boundaries (Allen, 1977; Tushman and Scanlan, 1981). However, it is important to point out that, as the success of the production acquisition process is partly dependent on the contact person, the success depends on the skill and engagement of that person. This poses a great challenge for the manufacturing company to have the required in-house competence.

Finally, the empirical findings underscore the importance of formal processes that can contribute to the coordination of the work activities, which is also mentioned by Ro *et al.* (2008) and Liker *et al.* (1999). As both parties have different needs and interests, the process should be characterised by transparency, clear decision-making responsibilities and contain performance measures. The use of formal documents and structured processes with identified milestones may reduce procrastination caused by problems into which the other party does not have any insight. Another aspect that may highlight the importance of formal documents is the requirements placed on the author of written information. The use of formal documents requires writing in a common and easily understandable language, which increases the understandability of information (Vandeveld and Van Dierdonck, 2003).

6. Conclusions

The presented research contributes with new knowledge by describing the underlying design information and success factors for production system acquisition. Information types relevant for the production equipment acquisition process have been identified and categorized into three categories: fact-based, contextual and objective information. In order to realize the benefits of collaboration with an equipment supplier, it is important that manufacturing companies have a holistic perspective when collecting relevant and necessary design information to be transferred to the equipment supplier. Judging which design information is relevant or not for the equipment supplier appears to be especially challenging for the manufacturing company. As such, we highlight the fact that transferring all available

information is not always the most suitable option. However, one has to be aware that by separating important from unimportant information at the manufacturing company, there is a risk that the equipment supplier might not obtain all information needed. Therefore, the information transferred should be cautiously tailored to the specific needs of the equipment suppliers. Furthermore, we have found that it is beneficial to organise the collaboration in a formal process and to appoint a skilled contact person.

The implications of the research are that the lack of ability to manage design information has severe consequences on the performance of the production equipment acquisition. The management of design information is crucial for both the manufacturing company and the equipment supplier. The consequence of underestimating managing information will be a poor production system causing significant problems, disturbances and delays, which have major implications on the productivity and profitability. It also implies that equipment suppliers have to spend more time than estimated at the manufacturing company solving problems and disturbances, which requires additional resources and generates unexpected costs. Further, these problems and disturbances might have negative consequences for future collaborations. In order to reduce these risks, project managers are encouraged to create a formalised collaboration that facilitates the coordination between both sides. The process should include critical gates that are located at various points in the process and incorporate frequent meetings with the project members. These meetings facilitate the exchange of rich information that allows the project members to define problems and resolve conflicts. In addition, successful production equipment acquisition also requires a focus on the in-house competencies at the manufacturing company. Our empirical findings revealed that successful collaboration with equipment suppliers requires the ability to gather, understand and transfer information as well as to discuss and give meaningful feedback and input to proposed solutions or problems that arise and thus requires skilled and engaged employees.

With regard to future research, we identify two areas. First, innovation in production processes and technology becomes increasingly important and can imply competitive advantages for the manufacturing company. Due to the large amount of costs and risks associated with production process and technology innovations, collaborative development of equipment supplier and manufacturing industries could be one solution. Thus, understanding the impact of an effective management of information on production process and technology innovation capabilities is a critical issue that needs to be investigated. Second, it would be useful to investigate the impact of the contact person and the members of the project team on the project performance. The present study's result point to the importance of the people involved but understanding how the project team at both the equipment supplier and the manufacturing company affect the acquisition process needs to be enhanced. Hence, further research is required in order to achieve the best possible production equipment and thus contribute to the profitability of the manufacturing company.

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