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COLLABORATIVE STRATEGIES FOR SUCCESSFUL PRODUCTION TECHNOLOGY DEVELOPMENT PROJECTS

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Abstract

Collaborative development between the user and the equipment supplier of production technology has an increasingly important effect in terms of generating innovative, sustainable, and unique production process ideas that can be easily ramped-up to high volume production. However, joint development of production technology is challenging and has received surprisingly limited attention. Against this background the objective of the paper is to explore collaborative challenges from the equipment suppliers and customers' perspectives in production technology development projects, and to suggest strategies for how these challenges can be addressed. Empirically the results are based on multiple case studies from two manufacturing companies in Sweden (i.e. users) and two equipment suppliers, ensuring that the perspectives of both the user and supplier sides in production technology development projects are considered. Our findings show that the identified collaboration challenges do not only relate to inter-organizational development activities but also to the companies' internal characteristics, i.e. the prerequisites for company collaboration. Internal characteristics have a clear impact on the ability to bridge the interface with the equipment supplier and thus to advance the collaboration in production technology development projects. Our findings underscore the importance of having intra and inter-organizational strategies to enhance the success related to collaboration in production technology development projects.

Keywords: production equipment design, inter-organizational collaboration, joint development, buyer-supplier integration, process development, manufacturing industry

Introduction

Manufacturing companies are increasingly turning their attention towards improving the process of designing production systems in order to gain competitive advantages. In production development studies, it has been argued that the greatest potential for realizing a high-performance production system is during the design of a new production system, while the management and control of an existing production system offers less potential (Bellgran and Säfsten, 2010; Bennett, 1986; Hayes *et al.*, 2005). The design of the production system takes place early in the development process and contributes to the creation of a system that is in line with the properties required for handling changing customer demands. Once the production system is in operation, the manufacturing company mainly controls problems related to the ongoing material processing activities, where the ability to make major changes is limited due to cost and time restrictions.

An important activity in the development of production systems is the design and building of production technology since it enables large changes to the production process, significant productivity improvements and industrial change (Pisano, 1997; Reichstein and Salter, 2006). However, developing production technology presents many challenges and changes in the technology will have an impact on multiple functions and activities (Bellgran and Säfsten, 2010; Pisano, 1997). The findings of Khazanchi *et al.* (2007) show that the development of new production technology is likely to also result in changes in, or the introduction of new elements into, the production process. The need to introduce new materials, different task specifications, or changes in the material and information flow can be the result of the introduction of new production technology (Gopalakrishnan *et al.*, 1999; Reichstein and Salter, 2006). Accordingly, the development of production processes requires systemic knowledge, i.e. a change or modification in the production technology will also affect the other subsystems within the overall production system (Gopalakrishnan *et al.*, 1999). In addition, changes in the production technology may also have an impact on other processes close by, such as product development, manufacturing strategy and operations strategy (Pisano, 1997). For example, to be able to frequently introduce new products to the market it is not sufficient to only be excellent in product development, but also requires superior production development capabilities (Bellgran and Säfsten, 2010; Turkulainen and Ketokivi, 2012). Consequently, the success of many new products is tightly related to the ability of integrating the development of new production technology. However Hayes *et al.* (2005, p.195) conclude that "the development of new operating process technologies has engendered far less excitement among academics and practitioners, let alone the public at large".

The development of production technology is often not considered among the core competencies of many manufacturing companies (Hamel and Prahalad, 1994; Hayes *et al.*, 2005) and as a result innovations in production technology are frequently generated from external sources, i.e. equipment suppliers (Bruch and Bellgran, 2014; Robertson *et al.*, 2012). Major parts of activities related to the development of production technology are outsourced to the equipment supplier who suggests suitable solutions based on a more or less detailed requirement specification (Säfsten, 2002). Therefore, collaborating with the equipment suppliers is of outmost importance for manufacturing companies. Similarly, the equipment supplier is also highly dependent on the collaboration with the manufacturing company. For equipment suppliers to learn and improve their own development capabilities, it is critical to gain knowledge and expertise about experiences, process data and optimizations done with the production equipment in the operation phase (Rönnberg Sjödin, 2013). However, despite

the need for collaboration, companies' processes and support are introspective and thus people are trained to think internally (Witzeman et al., 2006). Further, it has been noted that research is lacking concerning collaborative challenges for suppliers and customers in production technology development projects (Rönnberg Sjödin, 2013). Therefore, the objective of this paper is to explore collaborative challenges from the equipment suppliers and customers' perspectives in production technology development projects and to suggest strategies for how these challenges can be addressed.

Frame Of Reference

Production technology development

A 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, p. 22). Thus, the production system consists not only of the production technology, but also of humans who operate the production technology and who need to be organized and communicate information within the production system (Bennett, 1986; Cochran *et al.*, 2001-2002). Although changes in the organizational processes affect the productivity, this paper focuses on the development and implementation of new production technologies since changes in the technology allow for larger changes to the production process (Pisano, 1997) leading to enhanced operational performance.

The development of production technology is often discussed in terms of production system or process development projects[1]. These projects emphasise how work is done (Utterback and Abernathy, 1975) and are usually driven by the desire to improve the production capabilities. Lager (2002) noticed that production system development projects are primarily related to internal production objectives and thus directed towards internal customers at the company, in contrast to external customers in product development projects. Consequently, production system development projects are often initiated to accomplish reductions in production costs, higher production yields, increased production volumes or improved product quality (Bellgran and Säfsten, 2010; Lager, 2002). Production system development can be described as "deliberate and systematic development related mainly to production objectives, implying the introduction of new elements into the production process with the purpose of creating or improving methods of production" (Kurkkio *et al.*, 2011, p. 491).

This definition implies that production system development is based on conscious and planned organizational attempts aiming at changing or modifying the production system to improve operational performance. Manufacturing companies that work with production system development are advised to use a structured and systematic development process. A standardized process is one enabler for successful performance of development projects and helps to ensure that development objectives are fulfilled (Lu and Botha, 2006). One way to ensure a structured and systematic development process is to apply a similar procedure to the stage gate concept, involving a formalized cross functional development process in which a team completes a series activities to move the project along (Bellgran and Säfsten, 2010).

[1] In this article, production system development and process development are treated as synonyms.

The development of production systems can be a major key for competitiveness for manufacturing companies as the knowledge relevant for creating the details are difficult to observe and imitate by competitors (Hayes *et al.*, 2005). However, due to the systematic nature of the production system, i.e. where changes in one part of the production system can also affect other parts makes production system development a challenging for many companies. As a result, the development of production technology may involve adjustments that extend well beyond the piece of equipment that is the initial focus (Robertson *et al.*, 2012). Thus, one of the major challenges is to develop production technology that fits into the existing production systems (Robertson *et al.*, 2009).

User supplier collaboration

Since production technology is often developed by equipment suppliers rather than being made in-house by the manufacturing company using it, a conclusion is that collaboration between the user (the manufacturing company) and the supplier (of machines and production equipment) is required to accomplish reliable production technology with superior operating performance. To have a good network and strong collaboration with equipment suppliers is of utmost importance in production technology development projects (Abd Rahman *et al.*, 2009; Lager and Frishammar, 2010). For example, the ability to achieve higher installation performance is increased when users and equipment suppliers develop stronger relationships in the earlier phases of the development project (Abd Rahman *et al.*, 2009). Many of the problems that arise from not having a structured early equipment management programme such as: start-up period repairs, inspection, adjustments, and initial lubrication and cleaning (Nakajima, 1988), can be mitigated if there is horizontal communication with the equipment supplier.

Despite the potential from a managerial perspective, executing a collaborative production technology development process with a user-supplier approach is still challenging. Multiple explanations for the difficulties in the collaboration between the manufacturing company and the equipment supplier can be found. First, integrative development work of production technology can be considered as a type of open innovation, i.e. external knowledge and technology is shared with external actors in the development process (Rönnberg Sjödin, 2013). However, the study of Enkel *et al.* (2009) shows that loss of knowledge, higher coordination costs, loss of control and higher complexity are mentioned as frequent risks connected with open innovation activities. Thus, by working together with an equipment supplier, a manufacturing company faces the potential risk that knowledge about core production processes is transferred to competitors via the equipment suppliers (Lager and Frishammar, 2010).

Second, collaboration with the equipment supplier is usually carried out over several stages of the lifecycle of the production technology, where different stages imply different challenges and opportunities (Rönnberg Sjödin, 2013). As a result, collaboration between the user and the equipment supplier is required over a considerable amount of time and the strategies that facilitate collaboration need to be adjusted according to the distinct challenges of each phase.

Third, the results of Abd Rahman *et al.* (2009) illustrate also that the suitable collaboration strategies need to be selected based on the specific characteristics of the production technology. Different production technology development projects have different degrees of

novelty for both the user and the supplier (Bruch and Bellgran, 2014) and thus imply different degrees of uncertainty, complexity, customization, etc.

Fourth, the manufacturing company and the equipment supplier may have different perspectives on the project, i.e. the generation of production equipment may be considered as either product development or production process development depending on the parties concerned (Hutcheson *et al.*, 1995; Lager and Frishammar, 2010). From the manufacturing company's perspective this kind of development is normally considered as process development, while the equipment supplier regards this as a product development activity. Therefore, a critical aspect in ensuring successful collaboration between users and suppliers when generating ideas is to develop a common objective to be accomplished in the production system design project, i.e. there needs to be a common understanding about the application of the production equipment (Bruch and Bellgran, 2012).

Research Methodology

The empirical data presented have been collected as part of a research project which aims at developing an integrated production equipment design methodology to be used by users and equipment suppliers in order to increase creativity and innovation resulting in new solutions for sustainable and competitive production equipment. A multiple case study was conducted with two equipment suppliers and two manufacturing companies in Sweden, i.e. the users of the production technology. The manufacturing companies did not develop any production technology internally, which made collaboration with the equipment supplier critical. The case setting is particularly interesting as it includes both manufacturing companies and equipment suppliers, which provided the possibility to explore not only the perspective of the users, but also how equipment suppliers experience collaboration with their customers. The majority of earlier research has been on the user perspective, while the perspective of the equipment supplier in production technology development has received less attention among academics.

Given the lack of studies focusing on collaboration challenges in production technology development projects the case study approach was considered the most suitable method. The case study method provides the possibility to gather a rich set of data from actual practice in order to facilitate the understanding of the phenomenon studied (Voss *et al.*, 2002). Thus, the cases allowed for a more holistic and contextual assessment of the complex activities that constitute collaborative development of production technology. Furthermore, a case study strategy contributes to new insights of the phenomenon studied.

Data for the study were collected primarily through in-depth interviews at the four case companies. Interviews are essential sources of case study evidence and can be focused directly on the research topic (Yin, 2009). The interviews were semi-structured and guided by a list of questions covering different issues in joint development projects of production technology. Conducting semi-structured interviews allowed follow up questions to be asked in order to clarify understanding and discussion of critical issues. In total, 30 semi-structured interviews with 33 respondents were undertaken ranging in duration between 60-120 minutes. Two thirds of the interviews were conducted at the manufacturing companies, which was partly motivated by the fact that at the customer side usually more people are involved in this kind of projects. The respondents were selected both from the operational and strategic levels to avoid bias in the data collection as well as to include diverse perspectives. All respondents

had been continuously involved in production technology development projects and they were carefully selected together with key informants at the case study companies. The respondents had different roles in production technology development projects and came from a range of functions within the companies. As such, there were differences in their background and knowledge, years of training, experience, etc. and thus contributed with diverse perspectives. The aim was to gain a two company perspective of collaboration and the experience made.

When collecting case data, the focus was on identifying and analysing challenges and opportunities with user-supplier collaboration during production technology development projects. The data set was validated by asking several persons at both the manufacturing companies and the equipment suppliers. In cases when differences were found in the answers of the respondents, these were followed up by discussions with several people. The data collected by interviews was complemented by document studies of projects documents and processes of the companies. In addition, most of the interviews were conducted by two of the authors in order to facilitate investigator triangulation.

Empirical Findings

The perspective of the users of production technology

To study collaborative practises in production technology projects from the user perspective two manufacturing companies were selected, henceforth referred to as Company A and Company B. Both companies needed to develop frequently new production technology and the development of production technology was usually carried out in collaboration with equipment suppliers. Hence, the companies had long experience of collaborating with equipment suppliers and thus had established processes, routines and standards for how to proceed with production technology projects. The projects followed a form of stage-gate process with critical go/no go decision points, i.e. a formal process coordinating the work activities required in the production technology development projects. However, the process was not followed in all types of projects and many important issues fell outside of the used stage-gate model.

After a production technology development project was formally approved by the management, a project manager was appointed. The competence of the project managers differed at the studied companies. At Company A the project manager had a background from production engineering, while at Company B project managers had various backgrounds and experiences. Company B also regularly used external resources as project managers, which caused problems due to several reasons such as lack of process or company specific knowledge. Both user-companies aimed at having a cross-functional team in production technology development projects. The project manager was responsible for securing resources. This was accomplished by requesting the required resource from the department manager of the respective function. A drawback with this was that not always the most suitable resources were assigned to projects. Further, the projects were carried out over a considerable amount of time, so it was difficult to accomplish continuity in the projects because resources were replaced during the progress of the project. Another issue was that it was generally deemed important to have skilled people involved, which have a holistic perspective. For example, at Company A the benefit of having an experienced purchaser with knowledge about production was frequently mentioned since it avoided a pure focus on costs when selecting the equipment supplier.

Many problems experienced in the production technology development projects were related to management. Strategies related to investments, production technology development and collaboration were either unclear or decisions made were not well established in the organizations. At Company B a preferred supplier strategy was chosen, but how the suppliers were selected was not transparent and the final selection of the preferred suppliers resulted in suppliers being selected that were not judged as most suitable by the people involved in the production technology development projects.

The point when equipment suppliers became involved in the production technology development projects depended on the degree of complexity and novelty. In general, several equipment suppliers were involved in the early stages of the development process when different concepts were generated to uphold some degree of competition. But also after a formal purchasing decision was taken, several suppliers could be involved in the project. When new production technology is developed it might be necessary to work with several suppliers as different competences might be required.

For the users of new production technology, one critical challenge during development projects is the communication with the suppliers. Failure to communicate effectively can have severe consequences, such as suppliers that do not understand the context or misinterpreted the project goal. Equipment suppliers need to understand how the production technology should fit into the user's production process which means that a common vision needs to be established. Moreover, organizational and physical dispersion can cause problems in collaboration as interaction mechanisms such as meetings, workshops and teambuilding activities can be more difficult to accomplish. Due to organisational differences, it is important to have an open communication where problems should be communicated as early as possible and suppliers should not give a false impression of the situation.

The perspective of the suppliers of production technology

In order to study collaborative practises in production technology projects from the supplier perspective two equipment suppliers were selected, henceforth referred to as Company C and Company D. Company D used their own development process visualized as a stage-gate process consisting of two parts: sales and project execution. At Company C no formal development process was implemented, rather the production technology development process was based on a non-articulated process following several stages and stages. However, the company actively worked to formalize and standardise their processes. Although the suppliers had an own process, it should be noted that the development of the production technology was mainly determined by the time plan and process of the customers.

Due to the high uncertainty at the beginning of the production technology projects, i.e. before a formal purchasing decision at the user was taken, the equipment suppliers assigned only limited resources to the projects. Increasingly more resources were then allocated when a formal decision was taken. Further, depending on how the suppliers were organized, not all people involved in the early phases before a formal decision was taken were subsequently involved in the project execution. For example, in Company D the sales department was responsible for the contact with the customer until a formal decision was taken, but was not then a formal partner in the project group. Accordingly, the transfer of information from sales to the project group was critical to ensure that no information was lost. To minimise the risk

of information loss, the planned project manager for the execution should also be involved in the sales part.

When a formal purchasing decision is taken a project leader and a cross functional project team is assigned. The project managers were often not only responsible for project management issues but were also active in generating solutions. The project managers had a technical background and limited training in project management skills. One risk was that project managers focused on to bring the technical solution to perfection and missed economical and project management issues. The studied equipment suppliers did not provide any standard solutions and each projects involved had a high degree of customization, i.e. no project was similar to a previous one. Therefore, it was important to have skilled people in the projects that could transfer solutions from earlier projects to new problems.

The equipment suppliers preferred to work with customers that they had previously worked with successfully. Having the possibility to work again with the same customer could save time and costs since the equipment suppliers had built up an understanding of the context and the customer demands. Further, rules and standard documents such as the technical requirement specifications are understood. However, once the production technology was installed, the equipment suppliers did not have clear strategies for how to follow-up with the user, nor did they evaluate the production technology when it was in operation. Accordingly, the ability to learn and gain knowledge about the production technology in the operation phase was limited.

A critical aspect in the collaboration was the attitude of the customers towards the equipment suppliers. Despite the fact that the majority of work in several phases of the production technology development process is carried out by the supplier, they remained highly dependent on the customers. In some cases, the suppliers experienced difficulties obtaining access to the relevant and necessary information. It could also be hard for the customer to understand the needs, requirements and work approach of the equipment supplier and to recognize inter-organizational differences. Instead of being open-minded to the equipment suppliers, customers were negatively prejudiced and had no confidence in the suppliers' capabilities, which made it difficult to work together.

Equipment suppliers want to be considered as partners and both sides of the partnership should be responsible for ensuring the success of the production technology development project, i.e. the equipment supplier cannot be solely responsible. As a consequence, customers should show a high interest and commitment as well as a willingness to solve problems together. Further, in a partnership the risk of either side losing core competences and knowledge should be minimized. However, the suppliers in the study had experience of their solutions being transferred to competitors so that they could adjust their tenders and quotations. If the customer is not deemed to be trustworthy, there is reluctance towards open information sharing. In addition, the studied suppliers experienced a trend that the expectations of the customers regarding the readiness of the conceptual solution before making a formal decision had increased. As a result the suppliers were forced to put more resources and effort into preparing a quotation, while at the same time almost no customer was prepared to pay for the efforts made.

Analysis and Discussion

Challenges in production technology development projects

The findings reveal that collaboration in production technology development projects is necessary, but at the same time challenging both for the suppliers of the equipment and the users. The challenges identified are divided in two categories: intra-organizational challenges and inter-organizational challenges see Table 1. The challenges identified from the interviews connected with intra-organizational category were: competences, project organization and management and strategies. The challenges identified from the interviews connected with inter-organizational issues were: complexity, technological novelty, uncertainty, organizational and physical dispersion, and trust.

Table 1. Summary of the identified collaboration challenges between users and equipment suppliers in production technology development projects.

Intra-organizational challenges
Resources – Lack of skilled human resources, limited commitment
Project organization – Deficiencies in the development process, lack of clear standards and rules, lack of engagement/interest of management, poor selection of resources
Strategies – Unclear strategies regarding collaboration, production technology development and investments
Inter-organizational challenges
Complexity – Difficulties in coordinating different actors, large number of different technologies and competences, dependency between components and partners
Technological novelty – Immature production technology
Uncertainty – Late changes, late involvement of equipment suppliers, deficiencies in the information sharing
Organizational and physical dispersion – Lack of holistic view and common vision, deficiencies in culture and language, poor accessibility, poor meeting frequency
Trust – Lack of understanding for the needs and work of the partner, negatively prejudiced and limited confidence in each other capabilities, poor communication

Before engaging in collaboration, the users and equipment suppliers describe a need to create internal prerequisites at the organizations. Most of the respondents identified challenges related to company's internal characteristics, i.e. they were looking for improvements in the own organization to provide better prerequisites to bridge the interface to the partner and thus to advance the collaboration in production technology development projects. The importance of resources, project organization and strategies has received considerable support in the literature about production system development projects (Bellgran and Säfsten, 2010; Lu and Botha, 2006). However, despite its critical nature, there has been only limited attention on the intra-organizational prerequisites in previous literature on user-supplier collaboration in production technology development projects. Focus has been on the challenges related to the direct interaction between users and equipment suppliers. Our findings suggest that these intra-organizational challenges need to be handled sufficiently within each organization in order for the collaboration to be successful.

While the intra-organizational challenges are similar for the user and the equipment supplier, the inter-organizational challenges originate from the differences between the user and the supplier. Collaboration seems to be particularly challenging in the pre-study phase, i.e. before a formal purchasing decision is taken. Only on rare occasions are suppliers engaged as consultants during this stage and thus are remunerated for their efforts and costs. Accordingly, there often exists some degree of mistrust and the equipment suppliers avoid sharing all information. The findings are line with the reasoning presented by Lager and Frishammar (2010) arguing that equipment suppliers fear the risk of losing core knowledge before a formal purchasing decision is made.

After a formal decision is taken, collaboration between the user and supplier in production technology development projects becomes easier. However, there are still major challenges that need to be overcome to enable sufficient collaboration. In line with earlier research (e.g. Abd Rahman *et al.*, 2009; Bruch and Bellgran, 2012) efforts should be made to reduce the challenges related to complexity, technical novelty and uncertainty. However, the findings also show that organizational and physical dispersion deserves particular attention, an area which so far has been neglected in previous research in collaborative production technology development.

Strategies for improved user-supplier collaboration

The empirical findings summarised in Table 1 identified several challenges that made collaboration between the user and the equipment supplier difficult. Based on the identified challenges, collaborative activities are suggested for how these challenges can be addressed in production technology development projects, see Figure 1. Equipment suppliers and the users of the production technology can use these strategies to develop appropriate practices to improve collaboration.

The empirical findings demonstrate how users and equipment suppliers could provide better prerequisites. Before engaging in user-supplier collaboration in production technology development projects both partners need to recognize the importance of working with internal organizational capabilities to overcome collaboration challenges. Without having resources, processes and strategies in place, the potential to draw benefits of collaboration will be difficult as the partners need to focus on handling internal issues instead of being able to work productively. Further, one has to be aware that both parties have different needs and interests in production technology development projects. Accordingly, collaborative strategies are required that aim at minimising the risk for misunderstandings and confusion between the user and the supplier. Thus, collaborative strategies between the two parties should be established and agreed before collaboration starts if the goal is to utilize its potential for gaining competitive advantages in production technology development projects.

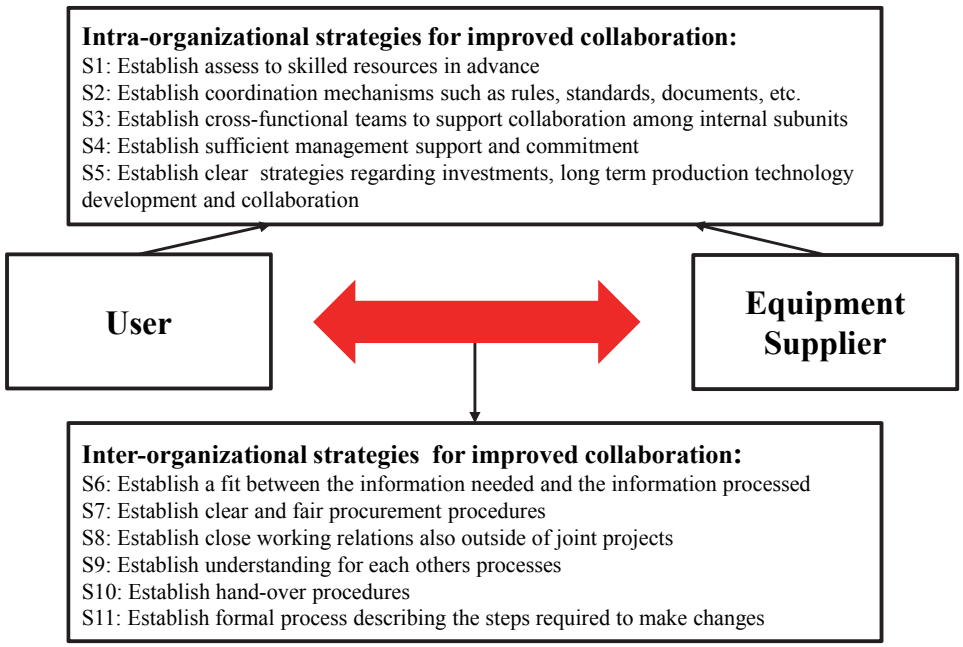

Figure 1. Strategies for improved user-supplier collaboration in production technology development projects.

Conclusion

Literature on production technology development projects has highlighted the need for further guidance on how to facilitate collaboration between equipment suppliers and customers. As several studies demonstrate, good collaboration between equipment suppliers and customers results in better production technology and thus can contribute to superior production capabilities. Drawing upon empirical studies at equipment suppliers and users, this paper provides in-depth insight into the challenges that make collaboration between equipment suppliers and users difficult. Further, the paper adds to existing body of knowledge by suggesting strategies of how these challenges can be addressed. The strategies provide managers at equipment suppliers and users with guidelines to reduce the risks related to collaboration in production technology development projects.

In line with earlier research (e.g. Rönnberg Sjödin, 2013), these findings indicate that collaboration challenges between the user and the equipment supplier depend on the different stages of the product life cycle. The collaboration activities carried out in each phase are of varying character with distinct problems that need to be solved. As a result, future research should further explore collaboration challenges in each phase, and examine in greater detail collaboration strategies that are adjusted to each phase. A further question is how the relative strength between suppliers and customers is distributed and how this affects collaboration. It may be necessary to adjust the collaboration strategies depending on the size of the user in relation to the size of the equipment supplier.

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