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IDENTIFYING THE 'RIGHT' SUPPLIER FOR MODULE DEVELOPMENTS — A CROSS-INDUSTRIAL CASE ANALYSIS

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Relational view argues that buying companies should integrate supplier resources in new product development (NPD) projects to realise competitive advantages. Due to decoupling of modules and the associated opportunity to allocate development activities to upstream suppliers, modular product architectures are considered to be a driving factor for the integration of supplier resources. Module developments are associated with substantial investments, long-term orientation and risks across product families for the buying firm. Therefore, supplier integration for module development is highly critical. Regardless of the relevance, research has not yet analysed, which supplier competence are considered as antecedents for successful module developments with suppliers. To close the identified gap, this paper analysed case companies from the automotive, agriculture equipment and rail vehicle industry. Technical, organisational and relationship aspects are identified as critical success factors. The results contribute to theory by adding to relational view the finding that competences for successful collaborations differ in accordance to the level of interaction between suppliers and buying firms. Moreover, this study provides a model and an evaluation scheme that helps practitioners to allocate the best suitable development role to suppliers within module developments.

Keywords: Relational view; module development; supplier integration; supplier characteristics.

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We applied the sequence-determines-credit approach for the sequence of authors.

Introduction

Increasing customer demands drive product complexities, so that single firms can barely cope with the full spectrum of resources required for new product developments (NPD) (Corso *et al.*, 2001; Grant and Baden-Fuller, 2004). Based on resource-based view. (Eisenhardt and Schoonhoven, 1996), relational view argues that external resources can be rented to overcome those natural constraints (Dyer and Singh, 1998). Accordingly, previous research has observed that buying firms are incorporating external competences in order to realise competitive advantages (Bonaccorsi and Lipparini, 1994; Droege *et al.*, 2000; Howard and Squire, 2007; Jaakkola and Hakanen, 2013; Koufteros *et al.*, 2007). Modular product architecture is expected to aid the integration of supplier resources. The decoupled structure of modular product architectures enables outsourcing of development activities to suppliers, since decoupled modules have no interfering with other modules of the end product (Baldwin and Clark, 2003; Baldwin and von Hippel, 2011; Campagnolo and Camuffo, 2009; Howard and Squire, 2007; Nepal *et al.*, 2012; Sako and Murray, 1999). Accordingly, original equipment manufacturers (OEMs) increasingly use suppliers to perform development activities of supplementary modules, so that they can focus on core activities (Helander and Möller, 2008; Langlois and Robertson, 1992; Sako and Murray, 1999), which results in generally improved NPD performance (Das and Teng, 2000). The automotive and aircraft industry can be seen as examples, where modularisation of products has given buying firms the lead in product development, while a large share of the actual development work is delegated to suppliers (Frigant and Talbot, 2005; Gadde and Jellbo, 2002). Specialized technical knowledge, long-term experience and most of the time, cross-industrial familiarity with technologies allow suppliers to leverage knowledge and to develop specific modules and sub-systems faster, cheaper and with better performance (Koufteros *et al.*, 2007). As a result, the innovation level of the buying firms and the likelihood of developing commercially successful products increase significantly (Faems *et al.*, 2005; Rosell and Lakemond, 2012; von Hippel, 1988). Even though scholars agree on the relevance of supplier resources for innovation creation in supply chains, reviewing open innovation literature shows that the supplier perspective of competences is less intensively researched (Gassmann *et al.*, 2010; Roy *et al.*, 2004). There has been first conceptual and empirical work on supplier identification (Croom, 2001; Pulles *et al.*, 2014), however not for module suppliers.

Since results on supplier characteristics are limited in literature, we consider possible threats to find foregoing results for required supplier characteristics. Previous research has indicated that integrating suppliers in NPD projects is always associated with technical and performance risk (Handfield *et al.*, 1999).

Module suppliers, in particular, are exposed to both risk perspectives. The long-term orientation and impact across product families rises the importance and reliance on supplier input which increases both technical as well as performance risk for the buying firm (Giunipero and Eltantawy, 2004). Moreover, due to complexity and required investments, modules are most likely developed and sourced from a single supplier, which increases the dependency and relevance of module suppliers significantly. To find module suppliers with the 'right' resources, therefore, symbolises a critical success factor for companies. The analyses of three leading OEMs from different four wheel vehicle industries will be used to identify supplier competences for module developments. Thereby, this paper tries to answer the following research questions:

> Which supplier characteristics are critical for module developments with suppliers?
> How to integrate suppliers in module developments in accordance to their supplier characteristics?

In order to answer the introduced research questions, this paper gives a short literature review, which outlines the theoretical background of the topic. In the following, the paper will present the results of the three case studies to identify competence criteria for module suppliers. Based on the findings, a practical oriented model will be developed and provide guidance on how suppliers should be integrated in module development in accordance to their competences. Thereby, this paper adds to relational view as well as helps practitioners to prevent potential supplier risks.

Theoretical Background

Suppliers as module developing resource

A modular product structure represents a type of product architecture, which follows the idea that design and components are shared across different products and product families by introducing modules and platforms as well as part commonality (Halman *et al.*, 2003; Utterback and Meyer, 1993). The significant level of standardisation and flexibility enables companies to improve production and procurement performance by for instance leveraging technologies into new markets with reduced per-unit costs (Frattini *et al.*, 2014; Meyer and Mugge, 2001). The decoupling of modules enables efficient and effective outsourcing of development activities, so that external resources like suppliers can be integrated more easily (Baldwin and Clark, 2003; Baldwin and von Hippel, 2011; Nepal *et al.*, 2012; Sako and Murray, 1999). Consequently, a modular product architecture

enables the transfer of certain value-adding tasks to upstream suppliers (Doran *et al.*, 2007; Ford *et al.*, 2003). In accordance to. Wagner and Hoegl (2006), the interest of buying firms to integrate suppliers can differ between know-how projects and capacity projects:

- Know-how projects relate to high innovative products with firms intention to utilise the specialised technical knowledge of suppliers. Suppliers get, therefore, responsibility for more critical and comprehensive modules or systems.
- Capacity projects have the intention to compensate shortages of internal R&D resources or to increase firms R&D flexibility. Since the buying firm defines interfaces in regards to product and task, the involvement of suppliers is limited when it comes to time and scope.

Applying relational view to both interests, suppliers need relevant and complementary resources to add to development activities of the buying firm (Dyer and Singh, 1998). Supplier competences are of highest relevance for successful supplier integration in NPD projects (Handfield *et al.*, 1999). Specifically, module developments are seen as highly critical, since a modular product architecture combines a high level of complexity by containing technical, supply chain and service aspects (Novak and Eppinger, 2001; Salvador *et al.*, 2002). Thus, module suppliers need specialised resources (Doran *et al.*, 2007; Momme and Hvolby, 2002; Wolters, 2002). For example, modularisation brings high technical complexity (Handfield *et al.*, 1999; Wasti and Liker, 1997), which requires suppliers to have advanced development flexibility, module understanding and engineering competences (Oh and Rhee, 2010). Therefore, suppliers contributing to module development activities in NPD need to provide advanced capabilities, which extend the profile of a single component supplier (Monczka *et al.*, 2000; Wognum *et al.*, 2002). Two risk dimensions illustrate the need for sophisticated supplier competences in regards to module developments, namely (1) technical supplier risk and (2) supplier performance risk (Handfield *et al.*, 1999):

- Technical risk related to the extent to which a supplier is able to provide the desired technical functionality and performance (Handfield *et al.*, 1999). For example, a module can contain a significant number of parts and functionalities, which would need to be developed and managed by the module supplier.
- Performance risk is associated with the threat that suppliers are not capable of executing the assigned task, which would result in bad performance of the supply chain (Wagner and Bode, 2008). For example, suppliers could fail to adapt to technological or product design changes which could have detrimental effects on the customer's costs and competitiveness (Zsidisin and Ellram, 2003).

Both technical as well as performance risk become more crucial with increased importance and reliance on the supplier input (Giunipero and Eltantawy, 2004). Consequently, suitable module suppliers need to have a special profile of qualifications, which covers technical and performance capabilities.

Method and Sampling

To explore supplier competences for successful module development within its real-life context Yin (2013), we have chosen a multiple case analysis which is explicitly applicable for purchasing related research (Stuart *et al.*, 2002). Case analysis allows the focus on cause and effect relationships by asking for how and why (Yin, 2013), which enable us to capture the motivation as well as the perception of supplier competences. To ensure comparable results, we applied the replication logic, so that all cases are analysed in the same standardised manner (Yin, 2013).

Our unit of analysis is the OEM perspective. In all cases, central functions with global responsibilities, for example for a specific product group, were the point of analysis. We selected three leading OEMs from different four wheel vehicle industries namely automotive, agricultural equipment and rail vehicles. Even though product structures are similar, the case industries show significant differences in some general characteristics like production volumes and product life cycles. Therefore, the focus on four wheel vehicle industries allows a cross-industrial analysis with industry and product differences. Please find in Table 1 some key characteristics of the selected case companies.

To overcome common weaknesses of case analysis in form of external validity (Cook *et al.*, 1979; Kidder and Fine, 1987) and the threat of paradox sampling (Kaplan, 1964), we have selected our research sample based on two principles: theoretical sampling and criterion sampling. Following theoretical sampling, we have limited the sample to companies, which produce tangible products focusing on four wheel vehicle industries (Eisenhardt and Graebner, 2007). We concentrated on tangible products, since research has shown that 85% of companies acting in a producing industry involve suppliers in their product development projects (Roberts, 2001; Wagner, 2009). Moreover, previous research has reported a high level of modularity for four wheel vehicle industries (Gavioli, 2005; Mikkola, 2003; Pandremenos *et al.*, 2009). Taking both dimensions in to account, we acknowledged the four wheel vehicle industries as information rich cases.

Second, we have applied a criterion sampling approach, which increases the probability to select information-rich cases that highlight the issues under study, significantly (Patton, 2005). Thus, we considered multinational industry leaders

Table 1. Selected companies and their key characteristics.

Company label	Industry	Turnover category in m Euro[a]	Number of employees[a]	Ownership	HQ location
M1	Rail	5000–10000	>10,000	Publicly traded	Canada
M2	Agricultural machinery	5000–10000	>10,000	Publicly traded	North America
M3	Automotive	>10,000	>10,000	Publicly traded	Germany

Note: [a]The turnover and number of employees are given in categories to guarantee anonymity.

for each of the industries. We assume that industry leader have a reasonable firm size presenting a sufficient level of maturity, professionalism, market position and resources to successfully employ product platform architecture and supplier integration. We used the parameters of number of employees, revenue and market share as indication for industry leadership.

Data collection

Within the each case company, individual expert interviews were realised, so that the data could be gathered in a moderate way of openness and structure (Lamnek, 2002). Detailed instruments included face-to-face and telephone interviews in combination with archival data from the internet. All interviewees were employees with a significant level of involvement in NPD activities like product development engineers, which allowed a reliable overview of the analysed organisation. To represent the variety of perspectives relating to supplier integrations in module developments, 22 interviews were conducted at case companies. The selection of individual interviewees within the chosen case companies followed the approach of seeking 'intensity' (Miles and Huberman, 1994) which looks for intense but not necessarily extreme manifestations of the phenomenon under study (Marshall and Rossman, 2014). As the supplier selection involves many stakeholders and especially, engineering and purchasing within a buying company (Pearson and Ellram, 1995), it is advisable to include more than one business function in the target group of the proposed study (Sánchez-Rodríguez and Martínez-Lorente, 2004). Thus, this research included representatives from the purchasing and engineering function as interviewees. Table 2 illustrates the split of interviewees along the case companies as well as the functions.

Data for the study was collected through semi-structured (Rubin and Rubin, 2011) or standardised open-ended (Patton, 2005) interviews. Thereby respondents have the chance to express their comments and perceptions openly which can lead

Table 2. Selected companies, functions and list of interviews.

	Interviewees		
Company label	Purchasing	Engineering	Total
M1	2	14	16
M2	2	2	4
M3	1	1	2

to in-depth data and a 'thick description' (Geertz, 1973). The interview protocol consisted of six main sections and is primarily based on the assets of successful platform developments as proposed by Robertson and Ulrich (1998). The first section aimed at obtaining general information about the interviewee as well as his background. Sections 2–5 represent the four assets for successful platform developments namely process, component, knowledge and relationship (Robertson and Ulrich, 1998). Section 2 stands for process and investigates 'how' suppliers are integrated for module developments. Section 3 refers to component and looks at the product part designs as well as the fixtures and tools needed to make them. Section 4 signifies the knowledge about product technologies and design know-how. Section 5 stands for relationship which characterises relations among team members and as well as interfirm activities. Section 6 reflects on positive and negative experiences of the interviewee. Thereby, we aimed to identify key factors for successful supplier integrations. A shortened version of the interview protocol can be seen in Table A.1.

To ensure reliability and external validity, a second set of data was collected at a purchasing conference of a leading German automotive OEM, who is a direct competitor to case company M3. Thereby, a random sample as a second-independent source was collect to support the reliability of the case findings (Ellram, 1996). Conference participants were drawn from the OEM and suppliers of the OEM. In total, the input from 20 random participants could be compiled for this paper. Twelve responses originate from the OEM and eight from representatives of suppliers. Suppliers of the automotive industry often supply simultaneously to multiple automotive OEMs, which thereby give insights to the industry understanding. Moreover, due to similarity of components, automotive suppliers also work with other industries like agriculture equipment and rail vehicles. By this means, the group of participants can be considered to be independent but supplementary to the selected case company sample.

Looking at the data collection, the following three steps were applied: First, participants were given a short presentation introducing the topic of supplier

integration for module developments. Second, a panel discussion between researchers and the audience was initiated addressing the questions mentioned in Table A.2. Third, during and after the discussion, participants documented their opinion on the topic in reference to the questions in a provided questionnaire. The addressed questions as outlined in Table A.2 were based on the theoretical foundation of supplier integration approaches (Petersen *et al.*, 2005) and assets for module developments (Robertson and Ulrich, 1998).

Data analysis

To analyse and transcribe the collected data, we applied a three step approach of data reduction, data display and conclusion drawing (Miles and Huberman, 1994).

First, data reduction started with the decision of research questions, initial research framework, cases selection and data collection methods. Within the decided setting, conducted interview transcripts as the main source of evidence were read several times to increase familiarity with the topic (Miles and Huberman, 1994). Next, coding of the transcribed interviews fostered the data reduction. The coding 'start list' (Miles and Huberman, 1994) encompasses the concepts which in our case were grounded on literature and theory (Araujo, 1995) in form of the relational view (Dyer and Singh, 1998) and the assets of successful platform developments (Robertson and Ulrich, 1998). To reduce and refine information, the coding process was repeated for two times.

Second, data was displayed with the attempt to draw conclusions from the 'clusters'. Accordingly, the coded data was transferred into a large 'thematic conceptual matrix' (Miles and Huberman, 1994). Within the matrix, cases can be contrasted and content can be divided by themes and their categories. As a result, interview statements could be 'clustered' under individual labels representing a specific theme or typology.

In the final step of data analysis, patterns of the utilisation and perceptions on supplier characteristics were detected. Thereby, the three dimensions of technical, organisational and relational factors could be identified as individual labels.

We analysed the responses from the purchasing conference by following a three step approach again (Miles and Huberman, 1994). First, we reduced data while defining a framework with areas of interest. Second, we checked the stated competences and grouped them in a matrix (Miles and Huberman, 1994). Third, we identified clusters representing key labels. Afterwards, we compared the identified categories with labels from the cases. In the next step, we evaluated the numerical result from the conference and calculated the average per competence. Thereby, we got an indication for each competence and could compare it with the outlined relevance from the cases.

Results

To ensure comparability between the three cases, we first checked the motivation to integrate suppliers of all case companies. The underlying motive can influence the way of acting with suppliers as described in the supplier integration model by Petersen *et al.* (2005). The model introduces four steps of interacting with suppliers, while each of the four steps comes with a different level of supplier involvement (Fig. 1).

The first step 'none' refers to no supplier integration. The supplier builds to print by bringing no value adding input with very limited development responsibility. 'White-box' integration stands for an informal integration of suppliers, when suppliers give advice on designs relating to limited responsibility. Grey-box integration describes a structured and formalised integration of suppliers for joint development activities. In this case, suppliers take an equal stage of development responsibility. Black-box integration assigns the highest development responsibility to suppliers. In this scenario, suppliers develop components individually in accordance to the specifications of the buyer.

Grey-box and black-box integration approaches address reasonable or major development responsibility to suppliers. In contrast, the other two integration steps symbolize limited supplier integration by leaving the main development responsibility to the buying firm. All cases mentioned in this paper apply grey-box and black-box integration, so that suppliers are integrated for value adding activities with high development responsibility. In accordance with the defined interests from Wagner and Hoegl (2006), case companies include suppliers to first rent detailed technical knowledge and second to reduce development complexity.

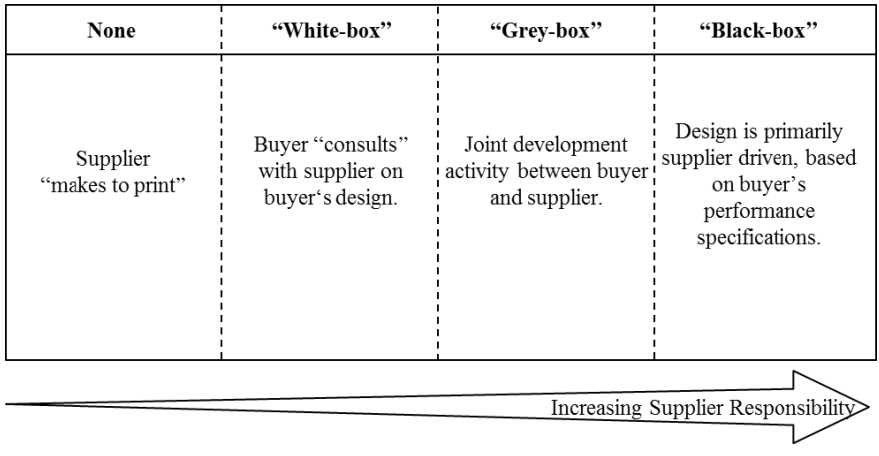

Fig. 1. Based on Petersen *et al.* (2005).

Thereby, technical and organisational factors as well as buyer–supplier relationship aspects show high relevance by driving successful module development with suppliers. Technical factors stand for the technical understanding of the suppliers. Organisational factors discuss operative and managerial aspects within the organisation of the supplier. Last but not least, the buyer–supplier relationship talks about soft and inter-personal aspects, which were highly emphasised by all case companies. Table A.3 provides an overview of key findings along the three identified dimensions.

Technical factors

Our results highlight that technical knowledge is a crucial aspect for module suppliers, since suppliers need to be able to develop the assigned part from a technical point of view. However, technical knowledge differs in accordance to the development responsibility of the supplier. In accordance to Petersen *et al.* (2005), results show difference of knowledge between joint development, grey-box integration, and self-contained developments by suppliers, black-box integration.

Looking at joint developments, suppliers are seen as technical experts, who bring specialised technical knowledge to the development project. Thus, a supplier should embody high expertise regarding the technology that is linked to the development. Especially for complex modules or new technologies, suppliers are expected to add special technical knowledge, whereas the OEM remains the system integrator. To give an example, one case company reported from a development project in which a module was developed representing a new, highly innovative technology. For both, the case company and the supplier, the technology was totally new. Thus, both parties had to work closely together, while learning from each other during the project. Due to the high complexity and the high investment level of money and resources, the case company needed a value adding partner, a technical expert, for the project. The case company pointed out that the level of detail and in-depth knowledge could only be provided by a supplier with specialised technical knowledge on the component level. The case company itself acted as a system integrator and ensured that the new development module fit the final end-product. Thus, the supplier and the case company acted in symposia together.

In case a supplier develops a module by himself, the technical understanding by the supplier should not be limited to the module itself. Due to multiple physical and functional interfaces with adjacent product parts, black-box module suppliers should have interface knowledge and architectural understanding. Thereby, module suppliers can ensure the fit of the module in the customers' end product. One case company described the occasion, when one of his black-box suppliers

approached another supplier of a related module to highlight potential problems and challenges related to the interface between both modules. Thereby, a problem relating to customers overall end-product was prevented. Architectural knowledge allows suppliers to obtain a system integrator role, so that the buying firm can allocate resources to core activities. Black-box projects were mentioned as not primarily innovation driven, but more capacity oriented, so that the case companies could focus on core elements. Therefore, suppliers for black-box integration need to act as a technical specialised and system integrator.

Organisational factors

In addition to technical characteristics, all cases emphasised the relevance of supplier attitudes relating to organisational competences, which represent firm characteristics and managerial competences.

Firm characteristics, namely financial stability and geographical proximity to the buying firm, were declared as necessities for successful developments by the cases. Due to the fact that module developments are associated with significant investments from both the buying and supplying firm, suppliers have to bring a robust level of financial stability. Otherwise, there is the threat that suppliers accept a module development, but cannot cope with the needed human and financial resources. If a supplier goes out of business within a module development, it causes significant trouble and costs for the OEM. The long-term orientation of module projects and the impact on various product families point toward the high criticality for buying firms.

Geographical proximity was stated as another crucial aspect with specific focus on grey-box collaboration. If a module is jointly developed with a supplier, presumably supplier representatives need to frequently interact with counterparts from the buying firm in person. Thus, geographical proximity of the supplier can be a critical factor, so that personal meetings can be easily arranged. Moreover, proximity implies a similar cultural background which can be another success factor for joint developments. When the supplier has to develop a module, self-contained proximity plays a subordinate role, as interaction between suppliers and buyers is less frequent.

Managerial aspects build the second dimension of organisational factors that appear to be enabling factors for suppliers to fulfil project targets like quality levels, in-time delivery and project deliverables. Managerial aspects can be broken down in engineering capabilities and procedures.

Module suppliers need engineering competences as well as sufficient and dedicated resources for product development projects. A supplier might have the technical understanding of a module, but the capability to develop a new

innovative technology is depending on the engineering capabilities of the supplier. Accordingly, suppliers need to be able to provide adequate degree of engineering support. For example, suppliers need engineers, who are proficient with the latest technologies who can respond quickly to technological changes. However, to transcribe the competences, suppliers need sufficient engineering resources that can be allocated to development projects. If the supplier embody great engineering abilities, but has limited number of people who can implement knowledge, the operative employment of engineering capabilities will be limited. For example, one case company mentioned that within one development project, two development engineers from his site were involved, whereas the supplier had 30 development engineers working on the project. The buying firm defined the interfaces and was safeguarding the development project, while the specialised supplier provided comprehensive technical knowledge to develop the high complex module. Thus, module suppliers need to have engineering resources from a technical and operational point of view.

As a substitute to competences available at the supplier, case companies report the case that module suppliers and especially black-box suppliers shift activities to their own supply base as pool of resources and expertise. Value creation by sub-suppliers, thereby, increases and resource availability at the first-tier supplier level rises. Nevertheless, first-tier suppliers need to manage the integration of upstream resources in form of *n*-tier suppliers.

To utilise internal as well as supply chain resources most efficiently, case companies highlighted the relevance of mature processes at the supplier. Special emphasis was indicated for NPD and quality management processes. From the case company understanding, the NPD process is supposed to facilitate cross-functional working like concurrent engineering in a systematic and structured way. Thereby, activities and principles are comparable and consistent, so that impulsive and non-systematic actions by suppliers are prevented. This allows case companies to integrate suppliers in their product development activities more easily, since activities and processes can be aligned. Moreover, case companies perceive quality processes as safeguards of a standard quality level by the suppliers. An example from one case company illustrates the relevance of processes with special emphasis on cross-functionality and quality. Within a NPD project of a complex module, the case company wanted to integrate a new supplier. Until this point, the case company had only one supplier, since the module had a significant complexity level and knowledge requirements. To increase competition, the case company has chosen to integrate a new supplier who had no previous relation to the company. During the development project, the case company requested parts for quality and geometry testing from the new supplier. The delivered components had bad quality, so that the parts were not applicable for testing purposes. The case

company investigated the cause of the bad quality and it turned out that the supplier had no dedicated quality manager as well as standardized process for quality testing within NPD projects. Due to the lack of cross-functionality and process existence, components were not previously checked by the supplier which caused the problems. As a result, the project costs increased and the project had difficulties to meet the anticipated time line.

Relationship factors

All cases highlighted that relationship factors are the third driving factor for successful module developments with suppliers, since people and the buyer–supplier relationship are considered as determining factors for successful execution of module development projects. In detail, trust to the supplier, proactivity by the supplier and willingness to adapt to customer needs by the supplier could be identified as key factors for success.

Trust to the supplier is referring to the belief of the buying firm that the supplier can successfully handle the addressed task. The aspect of trust was stressed, since case companies explained that suppliers tend to be overconfident in their abilities in order to make business. Therefore, it is sometimes a challenge to rely on suppliers, especially by taking in to account that a module development represents a high criticality and relevance for the buying firm. In consequence, buying firms have pinpointed to trust a supplier plays a critical role. Especially in regards to trust, the related people play a special factor. How well people relate to each other and interpret their role within the project was stated as potential differentiating factor.

Proactivity and willingness of adapting to customer needs are particularly relevant for module developments. To give an example, one of the case companies described a project, where the OEM and the supplier entered a development project for a totally new technology. The goal was to create a new technology which would have given both parties a competitive advantage. The case company reported that the supplier took a driving role within the project by showing proactively the will to reach the anticipated goal together with remarkable learning efforts by taking significant responsibilities. The supplier significantly identified himself with the project and considered the project relevant and critical for his own reputation and business. Consequently, the supplier showed great (http://dict.leo.org/-/search=initiative&searchLoc=0&resultOrder=basic&multiwordShowSingle=on) initiative, for instance, he suggested proactive improvement ideas to the buying firm. Moreover, the supplier offered access to his newest development activities and provided his best development resources to the project. The supplier made significant scarifies like taking development costs beyond agreements with

the intention to succeed with the development project. All in all, the supplier considered the project as his own and did a lot to ensure success.

In order to validate the findings from the case companies, we compared the responses from the case findings with findings collected at a purchasing conference of a global automotive OEM. The cross-checking of findings with responses from the separate purchasing conference indicate that major findings of the case companies are supported. The collected key words show a high similarity to the key findings from the cases. Moreover, looking at the numerical indication, all competences for module developments have a value above 3.5 out of 5, which underlines the relevance highlighted by the case companies. Table A.4 summarises the major findings from the conference participants. The cross-checking gives reason to belief that a replication of the case studies would create similar results, which supports the reliability of the case data (Ellram, 1996).

Discussion

Within this study, we follow relational view and argue that suppliers need relevant resources to add value to activities of the buying firm (Dyer and Singh, 1998). Assuming a nested modular product architecture representing a product architecture that consists of modules that, by themselves, can be further broken down in to components, the contribution of each supplier can differ accordingly (von Hippel, 1988). As a result, if a company wants to allocate the development of a supplementary module, like an engine, to a supplier, the supplying firm would need sufficient technical and managerial capabilities to execute the development. Otherwise, the anticipated module would cause problems in the end-system resulting in low NPD project performance for the buying firm (Zsidisin and Ellram, 2003). To identify critical supplier competences for module developments, we follow the concept of relational rents (Dyer and Singh, 1998). To evaluate potential drivers for relational rents in regards to module developments, the findings of the case studies are discussed along three determinants of relations rents.

Supplier characteristics are the primary focus of this study. Therefore, relation-specific assets are excluded from the analysis as those do not represent primarily, supplier-related aspects. For example, the volume of interfirm transactions is significantly influenced by buying firms. We, therefore, excluded relational specific assets from our perspective of analysis. In consequence, knowledge sharing routines, complementary resources and effective governance illustrates the level of discussion:

- Knowledge sharing routines related to absorptive capacity of the supplier, as well as the transparency and consistency of information exchange.

- Complementary resources stand for resources like competence and knowledge that is complement to the desire of the other relationship partner.
- Effective governance talks about enforcement mechanisms within the relationship.

In the following, specific competences related to module suppliers are discussed along the three determinants of relational rents.

Knowledge sharing routines

Module development requires suppliers to potentially coordinate simultaneous development tasks related to higher responsibility and work load (von Hippel, 1990). Accordingly, failure risk and complexity increases, since different components have to be integrated in to one final module (Olausson and Berggren, 2010; Tatikonda and Rosenthal, 2000). To ensure successful coordination of components, a module supplier should have stable and consistent processes in place (Eppinger and Chitkara, 2006; Henderson and Clark, 1990). In detail, module suppliers have to either deal with development responsibilities solely by their own or suppliers can share development activities with its supply base. In case, the whole module is developed with in-house resources of the supplier, module suppliers need next to technical competences also a process landscape which is capable to cope with related complexity. Therefore, suppliers need a reasonable management concept throughout the whole process chain including project and quality management processes. From the conducted case studies we learn that the NPD process is supposed to facilitate cross-functional working like concurrent engineering in a systematic and structured way. Thereby activities and principles are comparable and consistent, so that impulsive and non-systematic actions by suppliers are prevented. Thus, project management skills represent an essential capability for complex NPD projects (Schiele, 2010; Schiele *et al.*, 2008). Especially, black-box suppliers are considered to have mature processes by the case companies. To lead a module development such as a global module development, is a complex activity which becomes more challenging with every new stakeholder (Eppinger and Chitkara, 2006). Therefore, module suppliers, especially black-box suppliers, should have strong project management capabilities to manage and monitor the project in terms of milestones, technical work quality and cost. Case companies indicated quality processes as safeguard to ensure standard quality level by the suppliers. Accordingly, certified quality management is a suitable method for designing complex products (Clark and Fujimoto, 1991). Following quality management, suppliers can satisfy customer by ensuring quality at each stage of the product development process with less time in development,

fewer start-up problems and lower start-up costs (Akao and Mazur, 2003). Pekovic and Galia (2009) argue that a company in a manufacturing industry should scout for suppliers with mature quality management systems.

Case companies outlined that module suppliers and especially black-box suppliers can shift activities to their own supply base as pool of resources and expertise. In this case, the module supplier has to coordinate development activities of his supply base during the NPD process (Sanchez and Mahoney, 1996; Ulrich, 1995). Module suppliers, therefore, need a supplier management approach which comes with supplier selection and supplier development processes as well as procedures for early integration of suppliers. All cases highlight that both grey-box and black-box developments are associated with higher process complexity for module suppliers, but due to the higher responsibility and higher complexity, black-box suppliers have a higher urgency for process maturity. In general, module suppliers should have the following competences:

- NPD process,
- Quality management process,
- Sub-supplier integration process.

Complementary resources

Modular product architecture enables the decentralisation of product development activities (Sanchez and Mahoney, 1996; Ulrich, 1995), so that companies can delegate a large share of the actual development work to suppliers (Frigant and Talbot, 2005; Gadde and Jellbo, 2002). In accordance, suppliers can take a coordinating role within the development of modules, which can mean responsibility for the development process and coordination across involved subsystem developers (Pittaway *et al.*, 2004; Prencipe, 2003). The complexity of modules, however, requires a sophisticated technical understanding by suppliers that can be divided in component knowledge and architectural understanding (Henderson and Clark, 1990; Takeishi, 2002). Looking at the results, case companies apply a similar distinction of knowledge, which underlines the relevance of component and architectural knowledge within supplier and buyer collaborations. Component knowledge relates to design and manufacturing of single components or modules (e.g., the fuel tank) for the final product of the buying firm (e.g., an automobile). Architectural knowledge, on the other hand, stands for the capability to integrate, manage and manufacture tasks beyond the module level. Architectural knowledge is a specific aspect for module suppliers, since mainly in modular product designs different subsystems are linked together in a well-functioning end-system (Henderson and Clark, 1990). Thus, understanding and developing physical and

functional interfaces between modules build a distinctive characteristic of module suppliers.

Cases have shown that the component and architectural knowledge potentially differs in accordance to the integration approach. Black-box suppliers need a technical understanding around their module, since the module has to fit the final product of the buying firm. Due to multiple physical and functional interfaces with adjacent product parts, general interface understanding represents a key success factor for black-box suppliers. All in all, potential module supplier should bring the following competence in regards to complementary resources:

- Component knowledge,
- Architectural knowledge.

Effective governance

Modular product architectures are associated with vertical and horizontal inter-organisational relationships with special emphasis on interaction patterns within NPD projects (Campagnolo and Camuffo, 2009; Henderson and Clark, 1990; Muffatto, 1999). For example, modularisation requires a certain level of collaboration in order to reduce interface constraints. This suggests that successful outsourcing involves cooperative buyer–supplier relations (Jacobs *et al.*, 2007). To overcome potential barriers between supplier and buying firm, Ragatz *et al.* (1997) suggest a broad concept called relationship structure, which considers risk/reward sharing agreements and joint agreement on performance measurements. To ensure consistent and effective collaboration, both parties should be willing to enter such agreements. Interviewed companies have strongly indicated that suppliers need to be willing to invest resources on an equal level ideally in form of a preferred customer status (Schiele, 2012; Schiele *et al.*, 2012). Cases indicated that mutual agreements can set boundaries for collaboration, but communication between parties fosters successful operationalisation in NPD. Frequent and operative communication with the NPD team of the buying firm can be a critical factor in order to exchange and align knowledge (Swink, 1999; Wasti and Liker, 1997). For example, to solve potential interface constraints, a team problem solving approach with functional specialists from all stakeholders can be an appropriate approach (van de Ven *et al.*, 1976).

The case companies have indicated that geographic proximity can be a key point that allows frequent in person meetings. Thereby, communication and operationalisation is fostered which can help to successfully collaborate in joint developments. Such as being member of the same regional industry cluster can help to engage in collaborative activities (Steinle and Schiele, 2008). For

black-box developments of suppliers, case companies indicated that mutual agreements have to be formulated at the beginning of the project. However, after the beginning, frequent meetings and geographic proximity are less relevant. Effective communication is not only key between the supplier and the buyer; also internally, suppliers should apply cross-functional collaboration. For example, best practice firms in NPD performance explicitly support their people and drive team communication (Barczak *et al.*, 2009). Consequently, module suppliers should have communications settings across functional boundaries like cross-functional development teams. Case companies mentioned that concurrent engineering in a systematic and structured way presents curial competences, which is the result of a collaborative internal working style at the supplier. Based on the previous observations, we argue that module suppliers should be evaluated along the following criteria in regards to people and relationship resources:

- Resource allocation,
- Preferred customer status,
- Geographical proximity,
- Internal cross-functional collaboration.

Conclusion

In reference to the formulated research questions, this paper identified supplier characteristics for module developments and developed a framework for supplier roles in module developments. Based on the identified gap in literature that supplier characteristics of collaborations is less intensively researched (Gassmann *et al.*, 2010; Roy *et al.*, 2004), this study fills the gap by recognizing supplier characteristics and providing supplier roles for buyer–supplier collaborations. In detail, the analysis identified significant theoretical and practical implications. On the theoretical site, understanding of relational view could be further expanded. Looking at the practical contribution, this study provides practitioners with a model and evaluation scheme helps to find the best interaction pattern for each supplier.

Theoretical implications

First, this paper contributes to relational view by focusing on successful operationalisation of relation rents between suppliers and buyers for module developments. As described by relational view, companies rent resources from suppliers in order to create competitive advantages. Likewise, we learn from literature that

modular product architecture foster those relational rents between buying firms and suppliers. However, the kind of competences needed by suppliers in order to be a valuable and interesting source of rentable resource within a modular architecture was not field of research yet. Thus, this study is the first that identifies supplier characteristics for module developments with suppliers. In detail, the paper implies that suppliers need mature processes for NPD, quality and sub-supplier integration. Moreover, technical competence especially component and architectural knowledge as well as collaborative working style are also considered to be crucial along the dimensions of knowledge sharing routines, complementary resource and effective governance (Dyer and Singh, 1998).

Second, this study adds to relational view by illustrating that different interaction levels between suppliers and buyers require different levels of supplier characteristics. In detail complementary resource, knowledge sharing routines and effective governance differ in relation to possible roles of module suppliers. Based on the integration model of Petersen *et al.* (2005), this study identified that joint collaboration, grey-box integrations, have different implications for suppliers, than a self-contained black-box development by suppliers. In detail, grey-box suppliers need to bring component knowledge, whereas architectural knowledge can be limited. In contrast, black-box suppliers should offer both knowledge types. Similarly, mature processes in regards to project, quality management and sub-supplier management are considered to be more relevant for black-box suppliers. Considering the introduced supplier risks from Handfield *et al.* (1999), risks levels and associated supplier competences differ in relation to the supplier integration approach. Findings imply that buying firms need to differentiate and define the role of a supplier first by then looking for a suitable supplier. In consequence, relational view was further developed, as it was shown that resources differ in relation to the integration pattern between suppliers and buyers.

Based on the finding that different supplier interaction levels require different supplier characteristics in order to prevent supplier risks, four possible supplier roles for successful supplier collaborations could be formulated. Following Handfield *et al.* (1999), we claim that a grey-box or black-box integration can have either know-how focus or capacity emphasis. Accordingly, our findings underline that the main types of supplier integrations projects are technical or capacity-oriented as described by Wagner and Hoegl (2006). Bringing the two projects types, the two integration approaches and the identified supplier characteristics together, four possible roles of module suppliers can be identified namely (1) basic provider, (2) project lead, (3) technical expert and (4) technical managing lead. The competence level of suppliers is split in accordance to the two risk dimensions namely, technical and performance risk (Handfield *et al.*, 1999). Thereby the model provides a systematic approach to match the project type with available

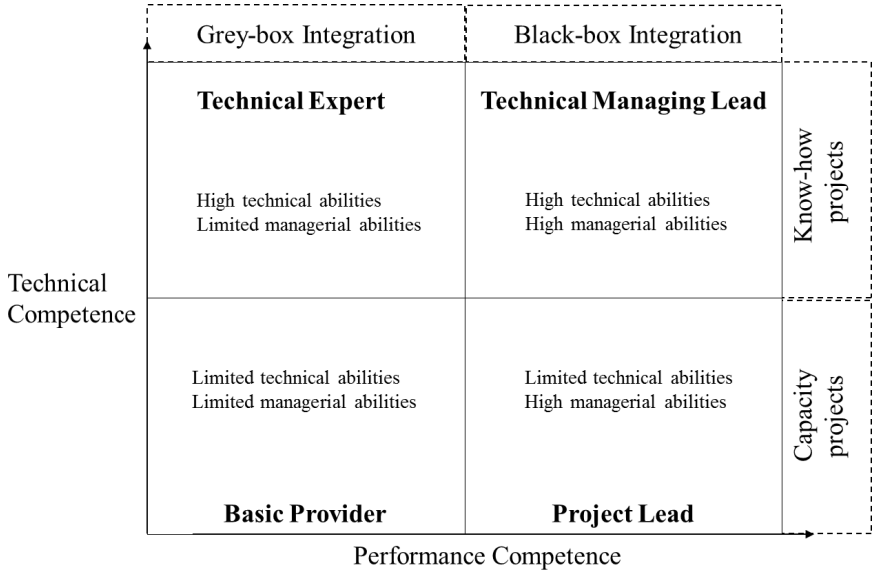

Fig. 2. Supplier roles for module developments (own illustration).

supplier characteristics by providing an answer on which supplier integration approach fits best which supplier. Figure 2 illustrates the model in detail.

Performance competence represents the orientation of one axis of the model looking at the performance risk. In association with Handfield *et al.* (1999), we argue that high managerial or performance competences point toward a low performance risk level of potential module suppliers. In other words, with mature processes, strong business knowledge as well as good people and relationships resources, the supplier can most likely perform self-contained module development activities from a managerial perceptive. Therefore, we argue that supplier's ability to handle module development tasks is indicated by the performance competence. Consequently, buying firms should use the performance indicator to determine the scope of supplier responsibility. To give an example, a supplier with a low managerial score will not be able to successfully develop a module, since the company lacks the required process maturity level. Aiming for successful operationalisation of relational view, buying firms should exactly know which activities the supplier can perform and which not. It has to be mentioned that we assume that a supplier who is evaluated for modular development activities, anyway is a well performing supplier. Therefore, low performance competences are not associated with low operational performance, but imply lower entrusting of activities by the buying firm. This means, in case a modules supplier shows lower performance competences, the buying firm should take an approach with higher control and responsibility for itself, a so called joint development or grey-box

integration (Clark and Fujimoto, 1991; Petersen *et al.*, 2005). In contrast, a module supplier with high performance competences will most likely have the toolkit to work in a self-contained or autarkic setting with an autonomous 'black-box' role. For that reason, buying firms should check the project management expertise of suppliers. For example, having an experienced project manager on the supplier selection team could help to access the project management proficiencies of suppliers.

Technical competence stands for the second axis of the model and represents technical knowledge of a supplier. The technical knowledge includes component and architectural knowledge of the supplier. In accordance to technical risks described by Handfield *et al.* (1999), suppliers with limited technical understanding will have difficulties to execute development activities associated with complex components. Technical competences, therefore, characterise the second fundamental supplier characteristic, when it comes to project goals and integration approaches.

Practical implications

Along the theoretical contributions, also practical contributions can be drawn from the findings of this study. On one hand, interaction patterns between suppliers and buyers could be conveyed from the potential roles of suppliers. On the other hand, based on the findings, an evaluation scheme is proposed that helps practitioners to make better sourcing decision for module developments.

First, the formulated supplier roles exemplify four interaction patterns for buying firms. Below, the four patterns are described in more detail:

(1) Suppliers falling in the category basic providers are considered to have limited resources in regards to technical and managerial competences. Nevertheless, buying firms can integrate those suppliers for clearly defined tasks and products with a simplified structure. An example would be a module with industry standards which need to be produced in an effective and cost efficient manner. As described by a case company, one supplier had significant more engineers working on the project in comparison to the buying firm. Thereby, the buying company could use supplier resources for his aims. In accordance, buying firms can use basic providers as a source of resources, when capacity shortages need to be compensated.
(2) Project lead suppliers have a clear strength in managerial aspects, which make them a valid partner for buying firms within NPD projects. However, due to limitations of technical capabilities, suppliers operating as a project lead are more capacity oriented. Buying firms can allocate simple or supplementary

module to the suppliers in order to reduce development and coordination complexity and to finally expose in-house resources. Since technical competences are limited, project leads take a more consulting or project lead-oriented role. Nevertheless, due to the managerial competences, OEMs can allocate components with limited need for technical expertise as a black-box development to project lead suppliers.

(3) Technical experts are high potential tech-firms, which have a lack of managerial competences. An example could be a traditional family-owned business with significant technical potential, but simultaneously organisational weaknesses. Complex and innovative technologies can be addressed by the supplier, but buying firms would need to assist with supporting activities like project management skills. Due to the weaknesses, the buying firm will need to apply a joint development in order to support and assist the supplier.

(4) Technical managing lead represents a full capable module supplier who can execute developments in form of black-box developments. Technical and managerial resources are available and buying firms can use those organisations in order to create innovative products which can results in competitive advantages as described by relation view.

Second, in addition to describing potential interaction pattern with suppliers, this paper provides practitioners with guidance how to classify suppliers to the most suitable development role for the supplier. Thereby, this study helps practitioners to make better sourcing decisions for module developments.

First buying firms should use the proposed criteria of module suppliers to assess potential module suppliers. Figure 3 shows a possible evaluation scheme that uses

Category	Capability	Competence Level
Knowledge sharing routines	New product development process	◔
	Quality management process	◔
	Sub-supplier integration process	◔
Complementary resources	Component knowledge	●
	Architectural knowledge	◔
Effective governance	Resource allocation	◔
	Preferred customer status	◔
	Geographical proximity	◔
	Internal cross-functional collaboration	◔

○ 0 ◔ 1 ◐ 2 ◔ 3 ● 4

Fig. 3. Example of evaluation scheme (own illustration).

supplier capabilities, which were identified within this study, as evaluation parameter. For each capability, the buying firm can assess the competence level of a supplier on a scale from zero (very low) to four (very high). Thereby, managers from buying firms can get an overview of relevant supplier capabilities for module developing. In the given example, supplier A shows high knowledge sharing routines, high component knowledge and high governance structures. Only architectural knowledge is resented with a limited competence level.

Second, the buying OEM can use the assessment of each supplier capability to identify the best suited role for suppliers. Performance competence represented by one axis of the supplier model for module developments considers mature knowledge sharing routines like process and effective governance like people and relationships to ensure a good performance by module suppliers. In accordance, we take the average of knowledge sharing routines and effective governance to determine the performance competence level of potential module suppliers. Following the given example, supplier A has an average score of three for both knowledge sharing routines and effective governance. As a result, the supplier has a total score of three for performance competences.

The second axis stands for technical competence and is supposed to represent the technical knowledge of a supplier. Since, technical knowledge for module developments includes component and architectural knowledge, the technical competence level is the average of component and architectural knowledge. Referring to the example, supplier A has an average of 2.5 for the technical competence.

By using the same scale (0–4) on the axis of the supplier role model, the results of the evaluation scheme can be used to illustrate the best role of a supplier. Thereby buying firms can get a visual indication which role a supplier can potentially best fulfil. Taking on the previous example, Fig. 4 demonstrates that supplier A shows potential to be a black-box supplier by contributing to knowledge driven projects. However, due to the limited architectural knowledge, the buying firm should consider if supplier A is capable to develop a module with a high number of interfaces by himself.

With the proposed supplier roles and the related evaluation scheme, this paper provides buying firms a tool to assess a supplier and to understand the most suitable interaction pattern with the supplier. As a result, buying firms can match the supplier role with their own requirements to make better sourcing decision for module developments.

Considering the supplier site, this study provides guidance which capabilities suppliers need to get focus on in order to get more development responsibility from their customers within module developments. To increase attractiveness, potential module suppliers should advance their knowledge sharing routines,

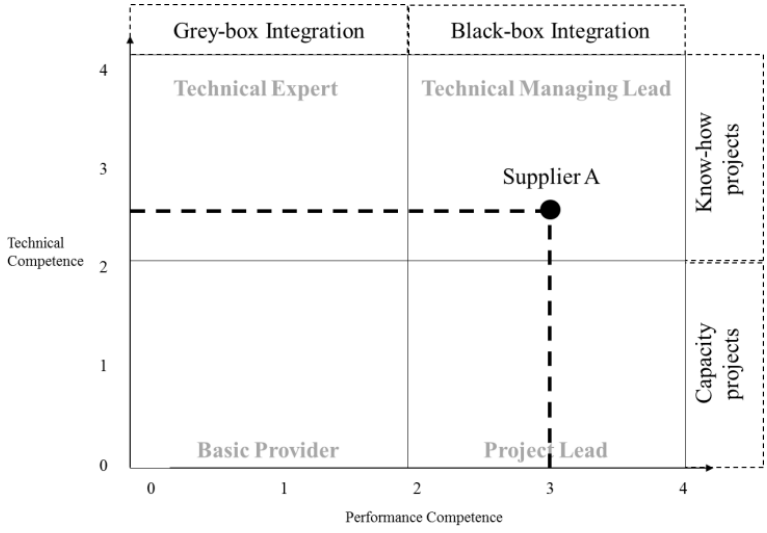

Fig. 4. Supplier scoring and supplier role (own illustration).

complementary resources and effective governance structures. By this means, suppliers might receive more development responsibility from customers.

Limitations and future research

There are limitations to the findings and conclusions of this study. First, we limited ourselves to three case companies from four wheel vehicle industries. While our theoretical sampling approach aid generalisability (Rosenthal and Rosnow, 1991), our findings may have limited applicability to other industries or service types. Second, while we study the buying site, we excluded the supplier perspective on the topic. Scholars of buyer–supplier relationships have acknowledged that a lack of dyadic responses is a limitation of research (Monczka *et al.*, 1995; O'Toole and Donaldson, 2002). Therefore, this study might have a limited scope as the supplier perspective was excluded.

Based on the presented result, we would like to show some opportunities for future research. First, future research could apply an empirical analysis approach to investigate, if identified supplier characteristics differ in relation to the integration approaches of grey-box and black-box. Second, other industries could be included in future qualitative analysis. Thereby, potential industry or product-related difference could be acknowledged. Third, the inclusion of suppliers would create a dyadic research methodology that would further advance the understanding of driving forces for buyer–supplier collaborations.

Appendix A

Table A.1. Interview protocol (shortened version).

Section	Question module	Examples of questions
1	Introduction and personal information	• What is your current position within your company? • How long do you occupy this position already? • How many years of work experience do you have in total? • Which function do you relate to? • . . .
2	Process	• Can you please describe how you involve suppliers in product development activities? • Can you please describe how you involve suppliers in the development of modules/platforms? • . . ..
3	Component	• Why are you integrating suppliers on modular product structures? • Can you please explain on which areas of the modular product architecture you integrate suppliers? • Can you please explain how you manage interfaces between modules in regards to supplier integration? • . . .
4	Knowledge	• What kind of skills and competences do suppliers need to be involved in your company as co-developer? • What kind of skills and competences do suppliers need to be involved in your company as module/system developer? • How do you deal with risk of reliance, e.g., if a supplier takes a system development role which so that the supplier knows more than you? • . . .
5	Relationship	• Can you please explain why and under which circumstances you apply co-development (grey-box development) with a supplier? • Can you please explain why and under which circumstances you apply main development (black-box development) by supplier? • . . .
6	Experience	• What is your experience concerning success factors of supplier taking the leading position of a module or system development? • Why has a system development by a supplier failed? • . . .

Table A.2. Guide for discussion and questions to be answered by participants.

Section	Question module	Question
1	Supplier integration approaches	What competences does a supplier need to develop a module in collaboration with an OEM? What competences does a supplier need to develop a module independently from the OEM?
2	Assets for module developments	Please indicate your opinion about the following statements on a scale from 1 (strongly disagree) to 5 (strongly agree): In general suppliers involved in module development need... ... component competence (e.g., knowledge about design, material, specifications). ... mature processes (e.g., NPD and quality processes). ... knowledge capacities (e.g., sufficient engineering capabilities). ... interconnected people and relationships (e.g., internal collaboration preferred relationship).
3	General information	What kind of business are you working for? (OEM or supplier) What is your position at your company?

Table A.3. Main findings per case.

Perspective	Major findings
Technical factors	• Suppliers need technical expertise on components, since complexity of products cannot be reflected by internal resources (*M*1, *M*2, *M*3). • Particularly suppliers for close collaborations are supposed to be technical specialists for their component/module (*M*1, *M*2, *M*3). • Black-box suppliers ideally understand component as well as interfaces and main concepts of adjacent components to ensure architectural fit (*M*1, *M*3).
Organisational factors	• Suppliers need the ability to interact along the supply chain (down and up-stream) (*M*1, *M*2, *M*3). • Organisational structure (e.g., key account, cross-functional team) and internal collaboration across functions is essential for project stability and compliance (*M*1, *M*2, *M*3). • Supplier should show resource capacity to ensure product development, quality and manufacturability (*M*1, *M*3). • Process maturity aids quality and project stability (*M*1, *M*2, *M*3). • Suppliers should embody NPD project management proficiency with process and structure (cross-functional team) especially for black-box developments (*M*1, *M*2, *M*3).

Table A.3. (*Continued*)

Perspective	Major findings
	• Suppliers have a duty to have supplier management expertise with *n*-tier suppliers (*M*1, *M*3).
Relationship factors	• Supplier needs to be willing to invest and share profits (royalty) for joint activities (*M*1, *M*2, *M*3). • Willingness to share capabilities and ideas openly are key prerequisite for close collaborations with suppliers (*M*1, *M*2, *M*3). • Trust and commitment for long-term partnerships with and by suppliers are critical for module developments (*M*2, *M*3). • Geographical proximity to supplier helps to meet in person and to collaborate closely (*M*2, *M*3). • People are key factor, since everything can be checked but people need to execute (*M*2, *M*3). • Suppliers with highest development responsibility should show learning attitude and proactivity like communication of threats, alignment on interfaces with other suppliers or providing ideas for final end-product (M1, M3).

Table A.4. Main findings from conference participants.

Section	Question module	Key findings
1	Supplier integration approaches	Supplier competences for joint development between supplier and buyer: • Technical knowledge, • Technical competence (Module competence), • Willingness to share, • Process and project competence. Supplier competences for independent development by supplier: • Full product knowledge (product design), • Technical knowledge, • Resource capacity, • Sub-supplier management competence.
2	Assets for module developments	• Component 4.5 • Processes 4.1 • Knowledge 3.6 • Interconnected people 4.1.

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