CHALLENGES WITH SUPPLIER INVOLVEMENT IN PRODUCT DEVELOPMENT: A SUPPLIER'S PERSPECTIVE

Flankegård, Filip (1); Johansson, Glenn (1,2); Granlund, Anna (1)

1: School of Innovation, Design and Engineering, Mälardalen University, Sweden; 2: School of Engineering, Jönköping University, Sweden

ABSTRACT

Studies of supplier involvement in product development have revealed potential benefits including faster time to market, reduced cost and increased quality. However, existing literature has mainly focused on the customer's perspective on advantages, disadvantages and factors to be considered when involving suppliers in product development. This paper addresses the supplier's perspective by answering following research question: How do challenges that originate from involvement in customer's product development affect a supplier? The question is answered through a single case study at a supplier that develops and manufacture products primary used in capital goods. Thirteen challenges are identified, classified as being internal or external, and categorised into five areas: (A) Customer requirements, (B) Information exchange between customer and supplier, (C) Product variety management, (D) Design-manufacturing integration and (E) Processes and work instructions. The findings suggest that internal challenges need as much attention as external ones that originate from the customer. Also, an indication of when the challenges affect the supplier during product development is presented.

Keywords: Supplier integration, Case study, New product development, Integrated product development

Contact:
Flankegård, Filip Thomas
Mälardalen University
Division of Product Realisation
Sweden
filip.flankegard@mdh.se

Cite this article: Flankegård, F., Johansson, G., Granlund, A. (2019) 'Challenges with Supplier Involvement in Product Development: A Supplier's Perspective', in *Proceedings of the 22nd International Conference on Engineering Design (ICED19),* Delft, The Netherlands, 5-8 August 2019. DOI:10.1017/dsi.2019.224

1 INTRODUCTION

The harsh competition on the market drives companies to decrease time to market of new products and to minimise costs. In addition, products are becoming more complex by utilization of new technologies, and an increasingly change of market preferences has led to shorter product life cycles implying that companies' must be both efficient and innovative in the development of new products (Eisenhardt and Tabrizi, 1995). Therefore, new product development is crucial for the success and survival of companies (Brown and Eisenhardt, 1995, Wagner and Hoegl, 2006). In order to reduce time to market and to access knowledge, Original Equipment Manufacturers (OEMs) have come to involve suppliers in product development to various degrees, from consultation to full responsibility for designing a product (Ragatz *et al*., 2002, Wagner and Hoegl, 2006). OEMs do so for good reasons, since it has been indicated that involving suppliers support reduced time to market (Johnsen, 2009) and increase OEMs innovation potential (Un *et al*., 2010). Earlier research has discussed the advantages and disadvantages with supplier involvement in product development (Wagner and Hoegl, 2006, Koufteros *et al*., 2007, Johnsen, 2009) and factors to be considered when involving suppliers (Eggers *et al*., 2017, Rauniar *et al*., 2017). A great deal of previous research has focused on the customer's perspective and only a few on the supplier's perspective. This means that prior research poorly addresses the challenges that suppliers face when involved in OEMs product development projects.

Consequently, the objective of the study presented in this paper is to investigate challenges and how they affect the supplier, which leads to the research question for this paper: How do challenges that originate from involvement in customer's product development affect a supplier?

This paper first presents the frame of reference, including a brief overview of product development, product customisation and supplier involvement in product development literature. The next chapter describes the research method followed by a description of the case company. The fifth chapter presents identified challenges and finally the findings are discussed and conclusions drawn.

2 FRAME OF REFERENCE

2.1 Product development of capital goods

For capital intensive one of a kind products, commonly referred to as capital goods, e.g. an oil rig or a manufacturing system, the product development typically consists of the following phases: tendering, product design, procurement, manufacturing, commissioning and maintenance (Hobday, 1998, Hicks *et al*., 2000, Veldman and Alblas, 2012). Capital goods are commonly designed according to customer specific requirements stated at tendering. These specific requirements are usually fulfilled by modifying previously designed parts, which increases the design and process variety (Veldman and Alblas, 2012). However, in practice customer specific requirements are often incomplete, conflicting or unclear causing misunderstandings among actors involved in product design. It is also common that they change during the product design as knowledge about the design solution grows (Almefelt *et al*., 2006). Design activities may therefore not only take place during the product design phase, but also other phases of the product development due to necessary design changes identified during product tests or changed customer requirements, for example.

2.2 Supplier involvement

Previous research has shown that supplier involvement increases competence and access to technology (Ragatz *et al*., 1997, Von Corswant and Tunälv, 2002, Un *et al*., 2010), innovation (Bahemia *et al*., 2017, Bao *et al*., 2017), resource flexibility (Wagner and Hoegl, 2006) and mitigates risks of an OEM in new product development (Handfield *et al*., 1999, Chiang and Wu, 2016).

However, involving suppliers is not a given way to success. Previous studies recognizes the involvement of suppliers in product development being a reason for increased cost (Littler *et al*., 1998), loss of know-how and competence (Wagner and Hoegl, 2006, Koufteros *et al*., 2007) and information leakage (Ragatz *et al*., 1997). An additional disadvantage mentioned in the literature is that the buyer gets locked in with the chosen technology and a supplier (Handfield *et al*., 1999).

There is a growing body of literature that recognizes these issues for an OEM and studies have revealed factors that need to be considered when selecting suppliers, but also contingency factors for a

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

successful outcome of the involvement. Examples of factors to bear in mind when selecting suppliers are suppliers' technological competence (Wagner and Hoegl, 2006) and managerial skills (Eggers *et al*., 2017). Examples of contingency factors for a successful outcome are information sharing (Zhang *et al*., 2017) and clear communication (Wynstra *et al*., 2001). Supplier involvement is also positively affected by similarity in culture and mind-set, aligned strategies, a shared purpose, standards for design rules and clear targets between the buyer and the supplier (Twigg, 2002, Schoenherr and Wagner, 2016, Rauniar *et al*., 2017).

Suppliers are entrusted with various degrees of responsibility for the product design. If the OEM consults the supplier on the design solution, e.g. about manufacturing issues, the supplier's responsibility is considered low. This is also called "white-box" involvement (Petersen *et al*., 2005). The customer and the supplier can have a shared responsibility, so called "grey-box" or the supplier can be entrusted being responsible for the design based on customer's product requirements, so called "black-box". Customers seeking for involving black-box suppliers should notice that project management capabilities are important (Eggers *et al*., 2017) and that the supplier actively seeks information (Karlsson *et al*., 1998). In circumstances of unpredictable demands, it calls the supplier to have engineering and modularisation capabilities (Oh and Rhee, 2010)

3 RESEARCH DESIGN

A case study approach was used to investigate challenges faced by a supplier when involved in customers' product development projects in its real-life context (Yin, 2009). Semi-structured interviews were used for data collection to allow an in-depth insight into the challenges through rich data (Brinkmann and Kvale, 2015). Eight interviews were conducted. Five with members of the company's management team representing product design, product management, quality, manufacturing and the purchasing/logistics department. Three interviews were conducted with personnel working with product support, sales and purchasing. The duration of the interviews were 30-48 minutes and each interview were conducted by two researchers. The interviews were recorded and transcribed resulting in 87 pages text. Seven of the interviews were done face-to-face and one was carried out as a phone interview. The transcripts were analysed through coding and category construction (Merriam and Tisdell, 2016). First key-words and phrases were noted when reading the transcripts, and then categorised into themes. Next, all quotes exemplifying the codes were copied to a spread sheet together with the key-words and phrases indicating different themes and the naming and categorisation of the challenges were developed. The categories were presented at a workshop with the management team and interview respondents at the studied company to receive feedback on the categories. In the final step of the analysis, the identified categories were related to a model of the product development process to allow for enhanced understanding of when they affect a supplier. See figure 1 for an overview. It should be noted that interviews were carried out in Swedish and quotes from interviews used in this paper have been translated to English by the authors.

Figure 1. Research design.

4 THE STUDIED COMPANY

The studied company is a supplier that develops and manufacture products primary used in tough environments within pulp and paper mills, mining industry and waste water handling. The products represent a low monetary value in relation to the plants total investment but are necessary for the service of the application. Both standard and customised products designed to meet specific customer requirements are offered by the company. It is the customised products that have been of interest in this study. These customised products may differ from the standard range in various ways, i.e. geometrical measurements, characteristics of the media exposing the component and adherence to

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

customer standards for operating the products, which may require the use of components unique for the customer.
The company is in northern Europe and ships totally 20.000 products per year. The turn-over is about 20 million euro and approximately 90% of sales is exported globally. Past couple of years, the growth rate has been around 30% per year. The company has 80 employees, 30 white collar and 50 blue collar workers.
The company has full ownership and responsibility for the development of the customised products, which usually are included as parts in the plants. This entails that the engineering activities begin at tendering and are continued in product design and usually completed in the procurement and manufacturing phase. Engineering activities may also take place in the provisioning phase. Because of this, the product development process for the studied company is described as: tendering, product design, procurement, manufacturing and commissioning.
The studied company will hereafter be referred to as Company A.

5 FINDINGS

The analysis of the interviews revealed thirteen challenges. These have been categorized into five thematic challenge areas, which are: *(A) Customer requirements, (B) Information exchange between customer and supplier, (C) Product variety management, (D) Design-manufacturing integration, (E) Processes and work instructions*. The challenges and how they have been grouped into challenge areas are shown in table 1, together with quotes exemplifying the challenges. All challenges have also been classified whether they originate internally or externally. 'Internal' refers to challenges originating from the supplier's own organisation, while 'External' refers to challenges originating from customer or as a result of an OEM involving the supplier. The categories of challenges are numbered A to E and the challenges 1 to 13 in the table and following text.
Regarding *(A) customer requirements* it has been identified that the supplier confronts *(1) changing requirements* and various *(2) interpretations of customer's requirements*. The changes of the requirements may occur after a signed contract and can have a severe impact on the business case for Company A. The interpretation of the customer's requirements can be an issue of that different parties, i.e. resellers, other suppliers and the customer, have miscellaneous view about the meaning of the requirements, e.g. how a referred standard in the requirements shall be interpreted.
(B) Information exchange between customer and supplier is challenging for the supplier because information passes through intermediators and the meaning may be altered causing *(3) information distortion*. It has been found examples of that customers do not answer suppliers clarifying questions neither about quotation requests nor when it comes to claims. Due to short of time in the tendering phase and the importance to get orders sometimes leads to quotes are based on estimations (e.g. development lead times and price) rather than facts. *(4) Acquiring information* is a challenge. When it comes to communicating with the customers it may be difficult to understand each other due to differences in English skills. But also, different educational or occupational background can be a hinder, making *(5) comprehending the customer* a challenge.
(C) Product variety management is the third challenge area. The product variety makes it difficult to *(6) access information*, especially for the product designers. The product designers strive for reusing standard parts or previous designs but the comprehensive number of parts implies that identifying suitable parts takes too long time. It may even be quicker to design a new part. Since customised products are rather unique, they do not allow prototyping or pre-series and are produced in very low volumes, *(7) design verification* is a challenge resulting in that faults are detected in manufacturing. Due to time shortage, the product designers do not prioritise the fabrication of assembly drawings resulting in occasional manufacturing stops since manufacturing personnel do not know how to mount the parts together, indicating that *(8) Product assembly* is a challenge for manufacturing. The product variety results in that several components are manufactured in only a few copies of which several are purchased from sub-suppliers. Due to the low volumes, low monetary value and the pressure to get the components right in the first and only shipment makes *(9) finding sub-suppliers* a challenge.
Insufficient *(D) Design-manufacturing integration* is an issue since manufacturing and product design do not have agreed upon common guidelines that ensure an effective manufacturing of the products causing *(10) design for manufacturing* to be a challenge. Some sub-suppliers do also find the designed

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

components to be difficult to produce due to tight tolerances indicating that *(11) manufacturing involvement* is another challenge.

(E) Processes and work instructions is the final category of challenges. Some consider them to be an issue, while others think otherwise. Company A implemented a traditional stage-gate process some years ago and over the years, the company has tried to appoint full-time project managers, but for various reasons these initiatives have come to an end. Currently it is the product designers that also act as project managers. The interviews indicate that Company A manages to deliver the products to most of the customer's satisfaction, but it is not a smooth path and the interviewees impression is that it should be possible to shorten the lead time making *(12) project management* a challenge. The last identified challenge is *(13) adherence to work instructions*. Some interviews revealed that all work instructions are not known. In addition, some consider it easier to avoid the instructions.

The challenges categorized as *(A) Customer requirements* and *(B) Information Exchange between customer and supplier* are referred to as 'External' since these challenges are originated by the OEM or are a result of involvement between the OEM and Company A. The other challenges, *(C) Product variety management, (D) Design-manufacturing integration,* and *(E) Processes and work instructions* are referred to as 'Internal' as they originate within Company A's organisation.

Table 1. Challenges experienced by Company A when involved in an OEMs product development.

Thematic challenge areas	Challenges
(A) Customer requirements	(1) Changing requirements - External *"We have been very clear about what we have order acknowledged, according to which category (certificate). Then suddenly they claim to have a higher category."*
	(2) Interpretations of customer's requirements - External *"We have delivered three big projects and afterwards in all three projects, there have been discussions about "we wanted this instead", "yes, though you did not say that then"... even though you've been doing giant reviews and you've had a factory acceptance test, you do not agree on what customer wanted to have"; "You work with their (customers) subcontractors and they have a little different view on how customers specifications should be interpreted"; "the customer comes with very detailed specifications on material at washer level and we had not read the specifications properly enough, so it turned out that we had delivered washers with the wrong material".*
(B) Information exchange between customer and supplier	(3) Information distortion - External *"And sometimes, it's like playing the whispering game, what you say at one end will not be the same in the other end. Especially if you translate to another language, then it is easy to get it wrong"; "If you can contact someone who will have the product in the end, you will usually get the most correct answers."*
	(4) Acquiring information - External *"We have a questionnaire, where you fill in all the details we need, and when you send it out, as I did last week to a customer, we only get an answer on two out of twenty questions."; "In handling customer complaints it is difficult to get the information we need"*
	(5) Comprehending the customer - External *"it works well when you can talk directly to the engineering company, you often speak the same language"; "On the other hand, outside of Europe, the dialogue is difficult, because in Asia and in South America too, nobody speaks English there, so there's a language barrier"*
(C) Product variety management	(6) Access information - Internal *"We have a bad order for our drawings and documents... but it's not easy, if you search through 40 different folders in the explorer to find a particular item, it's usually faster to design a new one, even though we may have five hundred in stock"; "We need to standardize*

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

Thematic challenge areas	Challenges
Product variety management continued	*components, and in order to do that, we must get control of our different drawings to see what fits with what".*
	(7) Design verification - Internal *"We do it once, we never see it again, and we have no possibility of doing any prototype. It must work the first time."; "when you assemble the product, there are some missing parts and other parts interfere"*
	(8) Product assembly - Internal *"if you make seven new different combinations every day, you can't do seven new assembly instructions, because then we would need to hire fourteen more designers, who just sat and did mounting instructions"; "The assembly personnel doesn't know how to build the product, so he has to stop the production and ask someone "How does this work?" or to get hold of a designer and so on"*
	(9) Find sub-suppliers - Internal *"it is a matter of finding a supplier that can handle both the lead time requirement and get it first time right"; "is it an article that is not worth so much money, then the interest is not that great either"*
(D) Design-manufacturing integration	(10) Design for manufacturing - Internal *"We do not have common guide lines for design to ensure fit in production. No DFA, no DFM, no FMEA, that's our Achilles heel, I think"; "My theory is that we are far too functional. So we focus on our own function. We make a drawing, and on the drawing it looks very good"*
	(11) Manufacturing involvement - Internal *"We have definitely not involved the suppliers. We set measurements that suppliers can't meet."; "One example is that all of our foundries, we have ten-thirteen, all over the world, all have said that "we can't manufacture your products according to your drawings", and refer to a casting standard instead used in the industry"*
(E) Processes and work instructions	(12) Project management - Internal *"With the work we do, we have still managed, somehow, to meet the dead line. But maybe not in an optimal way."; "typical problems are that one is late, I would say that it takes time. Everything takes too long, but it is, as I said, that's my opinion."*
	(13) Adherence to work instructions - Internal *"it's good to take some shortcuts sometimes"; "unfortunately, we are bad at following our working instructions".*

6 DISCUSSION

The identified challenges related to the *(A) Customer requirements* and *(B) Information exchange between customer and supplier* imply that vague requirements and extensive product specifications from customers may lead to misunderstandings for a supplier, which may result in delivery of products not conforming to requirements. In addition, changes in the requirements are to be expected in the design of complex products (c.f. Almefelt *et al*., 2006). The customer must communicate expectations clearly with the supplier to prevent diverging interpretations (Wynstra *et al*., 2001), state clear targets (Rauniar *et al*., 2017) and the supplier need to be active in obtaining information (Karlsson *et al*., 1998), which is linked with the challenges about *(B) Information exchange between customer and supplier*. There exists examples of how Company A has actively asked for information, but the response from customers being insufficient. A possible explanation for this could be that the customer and supplier have different views on the complexity of the product design task and therefore have different opinions about the necessity of information exchange. It is also conceivable that the customer does not understand what information is relevant to the supplier since it seems obvious for the customer.

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

The challenges connected to *(C) Product variety* has to some extent been discussed in previous research. It has been recognized that suppliers flexibility, product design and modularisation capabilities are crucial in order to manage future unpredictable requirements from the OEM customers (Oh and Rhee, 2010). The product variety has implications for meeting customer requirements, product design, process design and the supply chain and all these aspects should be considered when developing the product family (Jiao *et al*., 2007). In literature addressing customisation it has been acknowledged that modularisation can reduce the variety of products and provide the customer a greater range of end products with increased financial performance (Duray, 2002). Much research describes mass product customisation where products are assembled to order or configured to order by pre-designed modules, while Company A experiences that products may need to be modified or designed for specific customer projects, which is the common for low-volume engineer-to-order business (Veldman and Alblas, 2012). However literature provide few examples and case applications when suppliers develop unique products to be integrated in the customer's product (André and Elgh, 2018). Many products designed by the Company A are customer unique and verified by the customer order. This leads to unexpected stops in manufacturing.

The importance of *(D) Design-manufacturing integration* was acknowledged in the early research in the 1980s on supplier involvement in product development and an explanation of the success of the Japanese companies (Johnsen, 2009). Successful integration requires input from manufacturing, e.g. enabled by design for manufacturing tools (Twigg, 2002). Company A has not implemented tools common for design-manufacturing integration that are used to ensure ease of manufacturability resulting in products that sometimes are difficult to manufacture or assemble. This may be explained by the growth of the company, unawareness or inexperience of design-manufacturing tools. Regarding *(E) Processes and work instructions*, previous research has indicated that supplier's processes, especially those for product design and quality management to be important for the efficiency of supplier involvement. These processes are also important to enable alignment of activities between the customer and supplier. Important is also experiences of cross-functional work e.g. concurrent engineering (Eggers *et al*., 2017).

Eight of the thirteen identified challenges identified in this paper originate internally from the supplier's organisation. The interviews indicate that clear customer specifications and satisfactory information exchange are important, but the supplier's internal capabilities are at least equally essential for the outcome of the integration between customers and suppliers in product development.

The challenges affect the supplier differently during the product development, see figure 2. The externally originated challenges, categorised *(A) Customer requirements* and *(B) Information exchange between customer and supplier*, seem to affect the supplier in the tendering, product design and in the provisioning phases. This is exemplified by that the design engineers needs to have a dialogue about the product requirements in tendering and product design phases. But also by the customer being dissatisfied in the provisioning phase since the product does not meet customer's expectations resulting in corrective actions due to unclear requirements at the tendering and product design phases.

The internally originated challenges related to the thematic challenge areas *(C) Product variety management, (D) Design-manufacturing integration* and *(E) Processes and work instructions* are associated with activities during the phases of product design, procurement and manufacturing. This implies that these phases are the ones primarily affect by the challenges. Moreover, challenges related to *(E) Processes and work instructions* also appears in tendering phase. The variety of existing components is a challenge for product designers in product design and manufacturing phases since there is no system support for identifying if a component exist that might fulfil customer unique requirements. It is a challenge for sourcing to find suppliers interested of these low value orders in the procurement phase and components not being designed for manufacturing leads to challenge's in manufacturing phase. The challenges with processes and work instructions exists from tendering to the manufacturing phase. Even if the projects are delivered on time, they could run more smoothly with higher attention through all project phases.

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

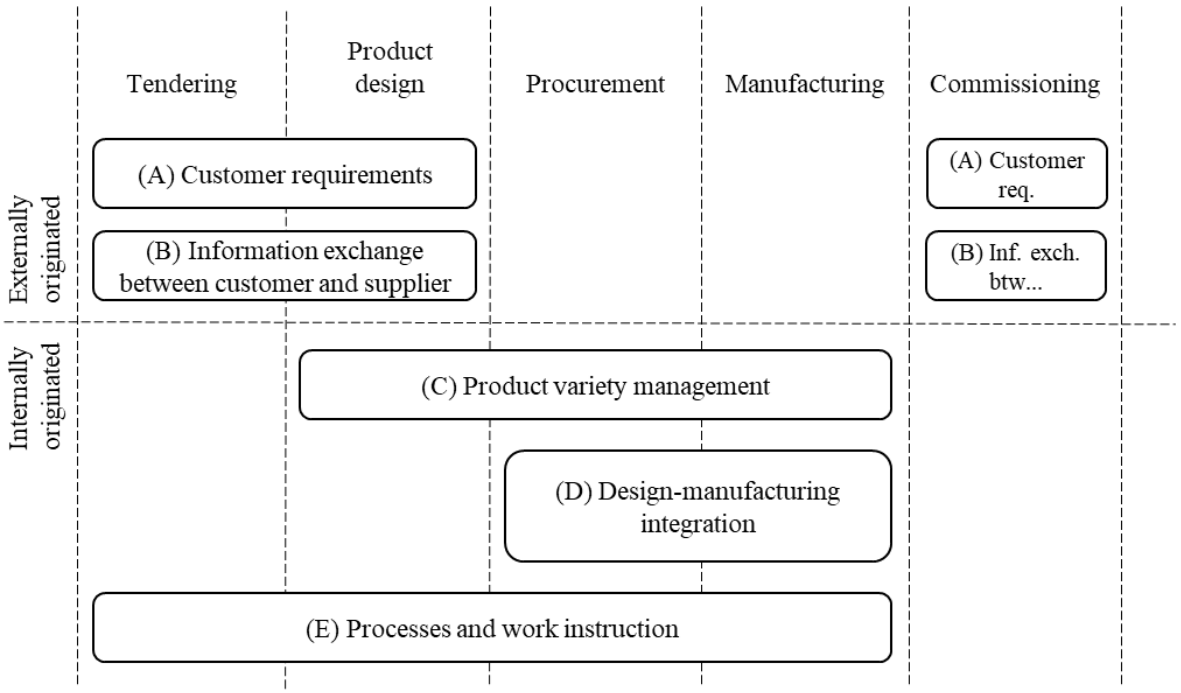

Figure 2. Challenges mapped in the product development.

7 CONCLUSION

The study presented in this paper adopted the perspective from a supplier involved in OEMs product development, a perspective largely overlooked in previous research. This paper set out to answer the research question: How do challenges that originate from involvement in customer's product development affect a supplier? Thirteen challenges were identified that affect the supplier and those were categorised into five challenge areas whereof two were externally originated and three internally originated. The findings suggest that internally originating challenges need as much attention as those originating from the customer. Therefore, internal supplier capabilities must be focused upon and developed to deal with the challenges. The findings also indicate when in the product development the challenges affect the supplier.

The insights about when the challenges need to be addressed, improves possibilities for practitioners mitigating the risks when the challenges arise, e.g. by taking actions to avoid resource bottlenecks in later phases.

A limitation of this study is that it includes a single case company, making the generalisability of these findings limited. Further research should be undertaken to identify whether the challenges identified are relevant for a broader set of suppliers and to determine whether the challenges are linked. It would also be worthwhile to study how supplier's performance are influenced by the challenges and how they should be managed when involved in product development.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions from all the interviewees involved in the study. Financial support was provided by the Knowledge Foundation and is also greatly appreciated. This research was also a part of the XPRES framework at Mälardalen University. The constructive feedback from the anonymous reviewers is much appreciated.

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

REFERENCES

Almefelt, L., Berglund, F., Nilsson, P. and Malmqvist, J. (2006), "Requirements management in practice: findings from an empirical study in the automotive industry", *Research in Engineering Design*, Vol. 17 No. 3, pp. 113–134. http://dx.doi.org/10.1007/s00163-006-0023-5

André, S. and Elgh, F. (2018), "Modeling of transdisciplinary engineering assets using the design platform approach for improved customization ability", *Advanced Engineering Informatics*, Vol. 38, pp. 277–290. http://dx.doi.org/10.1016/j.aei.2018.07.006

Bahemia, H., Squire, B. and Cousins, P. (2017), "A multi-dimensional approach for managing open innovation in NPD", *International Journal of Operations & Production Management*, Vol. 37 No. 10, pp. 1366–1385. http://dx.doi.org/10.1108/ijopm-07-2015-0415

Bao, Y., Li, Y., Pang, C., Bao, Y. and Yi, X. (2017), "Do resource differences between manufacturers and suppliers help or hinder product innovation of manufacturers? The moderating role of trust and contracts", *Industrial Marketing Management*, Vol. 64, pp. 79–90. http://dx.doi.org/10.1016/j.indmarman.2017.02.004

Brinkmann, S. and Kvale, S. (2015), *Interviews: Learning the craft of qualitative research interviewing*, Sage Publications, Thousand Oaks.

Brown, S. L. and Eisenhardt, K. M. (1995), "Product Development: Past Research, Present Findings, and Future Directions", *The Academy of Management Review*, Vol. 20 No. 2, pp. 343–378. http://dx.doi.org/10.2307/258850

Chiang, I. R. and Wu, S. J. H. (2016), "Supplier Involvement and Contract Design During New Product Development", *Ieee Transactions on Engineering Management*, Vol. 63 No. 2, pp. 248–258. http://dx.doi.org/10.1109/tem.2016.2518960

Duray, R. (2002), "Mass customization origins: mass or custom manufacturing?", *International Journal of Operations & Production Management*, Vol. 22 No. 3, pp. 314–328. http://dx.doi.org/doi:10.1108/01443570210417614

Eggers, J. E., Hofman, E., Schiele, H. and Holschbach, E. (2017), "Identifying the 'right' supplier for module developments-a cross-industrial case analysis", *International Journal of Innovation Management*, Vol. 21 No. 3, p. 1750026. http://dx.doi.org/10.1142/S1363919617500268

Eisenhardt, K. M. and Tabrizi, B. N. (1995), "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry", *Administrative Science Quarterly*, Vol. 40 No. 1, pp. 84–110. http://dx.doi.org/10.2307/2393701

Handfield, R. B., Ragatz, G. L., Petersen, K. J. and Monczka, R. M. (1999), "Involving suppliers in new product development", *California Management Review*, Vol. 42 No. 1, pp. 59–82. https://doi.org/10.2307/41166019

Hicks, C., McGovern, T. and Earl, C. F. (2000), "Supply chain management: A strategic issue in engineer to order manufacturing", *International Journal of Production Economics*, Vol. 65 No. 2, pp. 179–190. http://dx.doi.org/10.1016/S0925-5273(99)00026-2

Hobday, M. (1998), "Product complexity, innovation and industrial organisation", *Research Policy*, Vol. 26 No. 6, pp. 689–710. http://dx.doi.org/10.1016/s0048-7333(97)00044-9

Jiao, J., Simpson, T. W. and Siddique, Z. (2007), "Product family design and platform-based product development: a state-of-the-art review", *Journal of Intelligent Manufacturing*, Vol. 18 No. 1, pp. 5–29. http://dx.doi.org/10.1007/s10845-007-0003-2

Johnsen, T. E. (2009), "Supplier involvement in new product development and innovation: Taking stock and looking to the future", *Journal of Purchasing and Supply Management*, Vol. 15 No. 3, pp. 187–197. http://dx.doi.org/10.1016/j.pursup.2009.03.008

Karlsson, C., Nellore, R. and Soderquist, K. (1998), "Black box engineering: Redefining the role of product specifications", *Journal of Product Innovation Management*, Vol. 15 No. 6, pp. 534–549. http://dx.doi.org/10.1016/s0737-6782(98)00029-0

Koufteros, X. A., Cheng, T. C. E. and Kee-Hung, L. (2007), ""Black-box" and "gray-box" supplier integration in product development: Antecedents, consequences and the moderating role of firm size", *Journal of Operations Management*, Vol. 25 No. 4, pp. 847–870. https://doi.org/10.1016/j.jom.2006.10.009

Littler, D., Leverick, F. and Wilson, D. (1998), "Collaboration in new technology based product markets", *Int. J. of Technology Management*, Vol. 15, pp. 139–159. http://dx.doi.org/10.1504/IJTM.1998.002600

Merriam, S. B. and Tisdell, E. J. (2016), *Qualitative Research: A guide to design and implementation*, Jossey-Bass, San Francisco.

Oh, J. and Rhee, S. K. (2010), "Influences of supplier capabilities and collaboration in new car development on competitive advantage of carmakers", *Management Decision*, Vol. 48 No. 5, pp. 756–774. http://dx.doi.org/10.1108/00251741011043911

Petersen, K. J., Handfield, R. B. and Ragatz, G. L. (2005), "Supplier integration into new product development: coordinating product, process and supply chain design", *Journal of Operations Management*, Vol. 23 No. 3–4, pp. 371–388. http://dx.doi.org/10.1016/j.jom.2004.07.009

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press

Ragatz, G. L., Handfield, R. B. and Petersen, K. J. (2002), "Benefits associated with supplier integration into new product development under conditions of technology uncertainty", *Journal of Business Research*, Vol. 55 No. 5, pp. 389–400. http://dx.doi.org/10.1016/s0148-2963(00)00158-2
Ragatz, G. L., Handfield, R. B. and Scannell, T. V. (1997), "Success Factors for Integrating Suppliers into New Product Development", *Journal of Product Innovation Management*, Vol. 14 No. 3, pp. 190–202. http://dx.doi.org/10.1111/1540-5885.1430190
Rauniar, R., Rawski, G. and Hudson, D. (2017), "Antecedents and Consequences of IPPD Effectiveness", *International Journal of Innovation Management*, Vol. 21 No. 7, p. 1750059. http://dx.doi.org/10.1142/S1363919617500591
Schoenherr, T. and Wagner, S. M. (2016), "Supplier involvement in the fuzzy front end of new product development: An investigation of homophily, benevolence and market turbulence", *International Journal of Production Economics*, Vol. 180, pp. 101–113. http://dx.doi.org/10.1016/j.ijpe.2016.06.027
Twigg, D. (2002), "Managing the design/manufacturing interface across firms", *Integrated Manufacturing Systems*, Vol. 13 No. 4, pp. 212–221. https://doi.org/10.1108/09576060210426912
Un, C. A., Cuervo-Cazurra, A. and Asakawa, K. (2010), "R&D Collaborations and Product Innovation", *Journal of Product Innovation Management*, Vol. 27 No. 5, pp. 673–689. http://dx.doi.org/10.1111/j.1540-5885.2010.00744.x
Wagner, S. M. and Hoegl, M. (2006), "Involving suppliers in product development: Insights from R&D directors and project managers", *Industrial Marketing Management*, Vol. 35 No. 8, pp. 936–943. http://dx.doi.org/10.1016/j.indmarman.2005.10.009
Veldman, J. and Alblas, A. (2012), "Managing design variety, process variety and engineering change: a case study of two capital good firms", *Research in Engineering Design*, Vol. 23 No. 4, pp. 269–290. https://doi.org/10.1007/s00163-012-0135-z
Von Corswant, F. and Tunälv, C. (2002), "Coordinating customers and proactive suppliers: a case study of supplier collaboration in product development", *Journal of Engineering and Technology Management*, Vol. 19 No. 3–4, pp. 249–261. https://doi.org/10.1016/s0923-4748(02)00020-6
Wynstra, F., Arjan van, W. and Weggemann, M. (2001), "Managing supplier involvement in product development: Three critical issues", *European Management Journal*, Vol. 19 No. 2, pp. 157–167. https://doi.org/10.1016/s0263-2373(00)00090-6
Yin, R. K. (2009), *Case study research: design and methods*, Sage, London.
Zhang, Y., Wang, L. and Gao, J. (2017), "Supplier collaboration and speed-to-market of new products: the mediating and moderating effects", *Journal of Intelligent Manufacturing*, Vol. 28 No. 3, pp. 805–818. http://dx.doi.org/10.1007/s10845-014-1021-5

https://doi.org/10.1017/dsi.2019.224 Published online by Cambridge University Press