

ESI IN THE SUPPLY CHAIN OF MODULAR PRODUCTS

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ABSTRACT

Discussion around the product development collaborations is very actual today because of growing pace of technological change. However, there are still few qualitative papers on product development in the perspective of more than one supply chain link. The aim of this paper is to recognize the role of an internal and external cooperation in product development process as well as identify the determinants of Early Supplier Involvement in supply chain of modular products. The paper consists of following sections: introduction, methodology, research results, conclusions and the proposal of future research. Author used in-depth interview and case study methods. There are many factors that are of importance while deciding on ESI (e.g. product characteristics, production environment, the company's responsibility for detailed product specification). Based on conclusions, three hypothesis were formed. They can be an input to the further (quantitative) research: H1: Modularization strategy positively influences ESI, H2: Partnership positively influences ESI, H3: Modularization strategy positively influences partnership.

KEYWORDS

ESI, modularization, supply chain

INTRODUCTION

The aim of this paper is to recognize the role of an internal and external cooperation in product development process as well as identify determinants for early involving suppliers in product development in supply chain of modular products. Article takes an attempt to fill the literature gap which is the lack of qualitative research on product development in the perspective of more than one supply chain link. The most popular approach to the presentation of product development issue is a process approach. Literature describes a product development process in relation to different stages agreeably (Cooper, 2001; Handfield, Lawson 2007; Wagner, 2012). In different sources of knowledge, these stages are presented in a similar way. Still, their explanation is complex and mostly the theoretical one. Therefore, author decided to identify this process under specific business conditions and using in-depth interview method.

The starting point for presented considerations is a classification of supplier-purchaser types of cooperation on product development and in the B2B market. In the second part of the paper the empirical results based on conducted interviews are widely described. This part is enriched by the theoretical background derived from the literature. Finally, the conclusions on ESI in the supply chain of modular products is provided as well as the directions of future research.

SUPPLIER-PURCHASER COOPERATION IN PRODUCT DEVELOPMENT PROCESS

Managers are more and more convinced that product innovations are the key to business growth factors (Tylman, 2015, p. 11). The General Electric report “Global Innovation Barometer 2014 – Insight on Disruption, Collaboration and the Future of Work” informs us that companies are increasingly willing to cooperate in the area of research and development as well as in production (Harary, Pulizzi, 2014). Most often, companies cooperate in this regard with suppliers. The leading interaction performed in relationships with suppliers is joint product development (JPD) (Price-waterhouseCoopers, 2013, p. 14). Product development collaborations means that “two or more partners joining complementary resource and experience with mutual aims, in order to design or develop a new or improved product” (Büyüközkan, Arsenyan, 2012, p. 47). Early Supplier Involvement (ESI) is recently one of the most popular approach to supply chain R&D. It means involving suppliers in product development at a very early stage (Handfield, Lawson 2007). Suppliers can be engaged at each stage of product development (Handfield, Lawson 2007). However, involving suppliers as early as possible guarantees the success of R&D projects (Wagner 2012) and advantages in terms of costs, quality, time and flexibility.

Based on literature (Trent, Monczka, 1999; Christopher, 2000, Nellore, Söderquist, 2000; Lee, 2002; Handfield, Lawson, 2007; Wagner, 2012), the author of paper identified the several models (types) of supplier-purchaser cooperation on product development. ESI and JPD have the leading role in this classification:

- a) early supplier involvement, ESI:
 - involving supplier in the stage of idea generation,
 - involving supplier in the stage of idea screening,
 - involving supplier in the stage of idea selecting;
- b) joint product development:
 - company consults with suppliers on project – informal cooperation,
 - supplier and purchaser conduct common product design development – formal cooperation,
 - following general requirements from purchaser, the supplier develops product design,
 - purchaser provides the supplier with a full specification,
 - purchaser chooses a product from the supplier’s portfolio;
- c) sharing new product introduction NPI plan:
 - plan is prepared by the supplier,
 - plan is prepared by the purchaser,
 - joint new product introduction NPI plan;
- d) sharing component/product life cycle;
- e) cooperation on the type of product:

- cooperation on the component development,
- cooperation on the final product development offered by supplier,
- cooperation on the final product development offered by purchaser.

The criteria for classification of these models include mainly the stage at which the supplier is involved in the product development process and the responsibility for the creation of product specification. The conducted research is going to confirm the presence of the types of cooperation defined by other criteria, e.g. trust, involvement, balance of power between supplier and purchaser (dependencies), purchased item.

METHODOLOGY

In July 2017, author conducted two in-depth interviews (IDI). They were aimed at the identification of product development processes in manufacturing companies. IDIs based on following questions:

- Please, describe the phases of product development process in your company.
- Please, describe internal communication in product development process.
- Please, describe cooperation with your direct business partners in product development process.

Owing to the need to obtain an in-depth knowledge the case study methodology was adopted. Multiple case study methodology gives a possibility to present researched issue in more accurate and deep way in comparison with the quantitative method. It allows for a deeper relationship between researcher and respondent and reach more accurate information (Matejun, 2012). This methodology is also considered to be preferred by operations management researchers (Voss, Trent, Monczka, 2002).

The interviewed companies are:

- manufacturer of household appliances. Respondent was a manager responsible for Supplier Relationship Management, including the issue of selecting suppliers for product development process.
- manufacturer of electric motors, which are the modules of different devices and machines, e.g. washing machine. This manufacturer is the first tier supplier for the manufacturers operating in various industries, e.g. household appliances industry. The respondent was the engineer responsible for product development process.

Interviewer was going to gather the information on the product development from the point of view of the supplier as well as from the point of view of the purchaser. This allowed the identification of determinants for ESI in the following supply chain relationship: second tier supplier – first tier supplier – purchaser. Research was performed under the project „Flexibility in relationships with suppliers in terms of supplier-purchaser models of cooperation on product development in the B2B market”, no. 2016/21/B/HS4/00665, which is financed by the National Science Centre, Poland. One of the aims of this project is to recognize the supplier-purchaser models of cooperation on product development in B2B market. The conducted interviews supported achieving this aim efficiently. They also supported the construction of a new conceptual model.

PRODUCT DEVELOPMENT PROCESS IN THE COMPANY OF PURCHASER

Enterprise is a strong leader operating in a household appliances industry. It has a number of factories located in different geographical regions. Enterprise offers products in the global market. It performs make to order (MTO) and assemble to order (ATO) production and follows production levelling strategy. Production plans are mainly based on demand forecasts. Products have a modular construction. “Modular product is made up of modules, building blocks. The more of the components that fit into these modules, as opposed to lying around independently, the more modular a product is” (Gershenson, Prasad, Zhang, 2003). Enterprise is working on the reduction of number modules from the perspective of global manufacturing system. However, it takes time to develop improved product lines as well as to implement changes in the supply chain’s structure. This approach will reduce a supply chain complexity and allow for greater flexibility in the face of supply, demand and product uncertainties.

There is a high competition in household appliances industry. Innovative ideas are rapidly copied. The enterprise’s innovation model is a technology driver one. This model is defined by technological capabilities, investments in R&D and incremental changes (Jaruzelski, Dehoff, 2007, p. 9). In the light of a classification of innovation strategies presented by Dodgson, Gann and Salter (2008), the enterprise rather prefers reactive strategy. To minimize risk, company improves its operations and implements changes already tested by other organizations.

An example of a product manufactured by interviewed enterprise is a washing machine. This product is mature and has a modular and widely known construction. Product development process is strictly related to the particular modules’ improvement. Referring to the classification of new products described by Crawford and Benedetto (2013, p. 14), company introduces: additions to existing product lines, improvements and revisions to existing products as well as cost reduction changes (providing clients with the product of the same performance but a lower cost). In general, product improvements are focused on:

- cost reduction e.g. in manufacturing, logistics process,
- product quality improvement e.g. increasing savings associated with the use of the product by customer, product durability improvement (decreasing number of product breakdowns in a defined period of time).

Company follows recently very popular model of new product development (NPD) which is a Stage-Gate model. It is related to project management methodology and requires cross-functional teams. Stages consist of specific activities, whereas gates consist of deliverables, the criteria for evaluation of achievements and the output which is a decision on acceptance of the stage (Cooper, 2008). Stage-Gate process is described by its creator in the following stages (Cooper, 2001): stage 0 (idea generation), stage 1 (scoping), stage 2 (build business case), stage 3 (development), stage 4 (testing and validation), stage 5 (full launch).

There are internal and external impetuses for portfolio improvement listed in a theory (Drucker, 2006, p. 36–44). The enterprise identifies especially such sources of ideas as: marketing (new ideas coming from market), employees (source of rationalization changes), suppliers (e.g. changes in packaging), complaints or competition.

Ideas are an input to screening process. The chosen concept of product change is assessed in a number of ways. Usually it starts with economic-financial analysis. It is also crucial to rec-

ognize if the supply chain has all necessary capabilities and resources for the implementation of idea. Subsequently, engineers determine how the concept of improvement translates into the product's characteristics. Usually, improvement refers to the specific module and its construction or material. When the concept is approved, a new specification is written and presented to the procurement department.

Department of purchasing is responsible for choosing a vendor. First, the inquiry is sent to the qualified suppliers, using an internal platform. If current partners are not able to meet the new requirements, a process of searching for a new supplier begins. Based on market analysis and quick scans of suppliers, the buyers select a shortlist of the best potential suppliers that subsequently are assessed during an audit. If the audit result is positive, the supplier can submit a tender. Sometimes the supplier is unique and promising in terms of price and resources but did not pass the audit. In such a situation, the company re-audits the partner after previously suggesting improvements. Selected supplier is responsible for building a prototype of module (e.g. electric motor). At this stage, the consultation with a purchaser is crucial. When a prototype is approved, the manufacturing process at the supplier's plant is begun and then process performance regularly controlled. From time to time, the company even buys the machines or tools and lends them to the supplier on particular terms.

PRODUCT DEVELOPMENT PROCESS IN THE COMPANY OF SUPPLIER

Manufacturer belongs to the group that designs and produces electric motors for different industries, e.g. household appliances industry. Interviewed company offers motors mainly for industrial machinery. In its portfolio, it has more than a dozen of standard products. The premise for its design process is to rely on the standard projects and, if necessary, adjust them to the client's current requirements. Technical infrastructure of the factory consists of various machines (e.g. milling machines, lathes) and devices (cutters, screw taps, threading dies). Production is a nested one and usually engineer to order (ETO).

Plant cooperates with various suppliers of subassemblies and intermediates. These suppliers are the second tier suppliers for the purchaser of motor:

- suppliers of copper wire to make windings in the motor. The wire must be oiled, temperature resistant and of appropriate thickness (tolerance +/-),
- suppliers of aluminium of adequate purity and shape, e.g. factory needs small aluminium blocks, which can be put into the furnace and melt easily,
- suppliers of bearings. If the motor need to be durable, the bearings need to be as well. there are companies from Asia offering very cheap bearings. The policy of the company, however, is to buy the best quality bearings,
- suppliers of nut bolts, washers, screws, discs, sealants, electrodes, welding gases, aluminium/iron components.

Company makes various sub-assemblies itself. There are, however, subassemblies that company need to buy because their production would be unprofitable. An example of such a subassembly is a production of junction box. It must be airtight and resistant to mechanical damage. If there is no required product in the supplier's catalogue, there are two possibilities:

- company sends to supplier a technical drawing made by its designers,
- supplier sends to company a technical drawing, the company's designers submit the changes and return changed drawing to supplier. Company provides technical information on material or colour too.

Technical changes in the motor may involve different aspects, such as dimensions, power, and type of mounting (foot or flange mounting). In the case of use of motors, the greatest engineering problem is a heat they give. It is therefore necessary to cool the engine. There are two major types of cooling. These are: liquid cooling (the heat transfer medium is water) or air-cooling (a windmill is located at the end of main shaft). The working environment is sometimes a very big challenge for constructors. For example, the engine may be periodically flooded (e.g. on drilling platforms). The key feature that determines the quality of motor is durability. Company is focused on quality improvement. The service is a source of important information on the direction of product changes (e.g. motor is crashed because of too dusty room therefore it is considered to use a larger windmill, or some connection is broken because of excessive vibrations, therefore its fortification is reconsidered).

Clients usually send general requirements within the inquiry. It happens that these are the data written out of the rating plate of the previously used motor. That is why, received data need to be thoroughly verified. Client is not always aware of certain risks. For example, in case of large motors, the company's employees go to a local vision to the client. From time to time it happens that client provides a technical specification or technical drawings. Each motor needs to fit to specific conditions and the technical design of final product (e.g. washing machine).

Various departments are directly involved in motor development process. These are: design office, construction department, technology department, purchasing department. Sales department receives inquiries and is responsible for sending offers and price negotiations. Design office develops general guidelines for construction department. It defines which engine components are not a subject to change and what should be re-designed. Constructors do technical drawings in accordance with guidelines and ensure that designs meet the requirements of technical standards. Engineers work in Auto CAD program. New engine design, in a form of technical drawing, gets a new number and is transferred to technologists who accept its feasibility through assessing production resources and capabilities. Technology department defines production technology. It cooperates with the designers and constructors. The final version of technical drawing is a basis for the work of operative staff. Each employee receives a specific task to perform. In some cases, workers need to get an additional training. Each produced component requires a quality control. When the quality of elements is accepted, the final assembly begins. Each assembled motor is tested. Simultaneously, a technical DTR documentation is prepared. Motors are the subject of conformity assessment system. The company follows 2006/42/WE directive. Electric motor is "an interchangeable equipment" that is why the company applies the EC type-examination procedure system.

Transportation process need to be the sustainable one (Wieteska-Rosiak, 2013), especially when client is a socially and environmentally responsible corporation. The appropriate conditions of logistics processes are crucial to ensure the technical quality of product. For example, in the case of a large engine, it is important to provide not only an effective mounting but also perfect road conditions. Minor damages, such as dents in a construction, may adversely affect the motor's durability and result in a reduction in the number of hours specified by the warranty.

Therefore, company sends a person responsible for starting up the motor at the client's localization. A special checklist is used for that.

THE EXAMPLE OF PRODUCT DEVELOPMENT PROBLEMS IN SUPPLIER-PURCHASER RELATIONSHIP

In this section the typical design problem is described. The supplier's constructor defines the type and location of a drilling hole in a motor structure and the supplier's technologist determines which device the hole will be drilled with and using what parameters (e.g. rotation frequency). After the assessment, the technologist may find out that the hole defined by the constructor is not possible to drill due to the constraints that can result from the strength of the proposed material or lack of a suitable machine. For a unit and small-scale production, clients do not want to incur the additional purchasing costs of additional machinery/equipment. At this stage, the project may therefore need changes. For example, it is possible to drill a hole of smaller diameter and thus the construction requires more holes. nevertheless, this change should be consulted with a client. Purchaser does not always accept such a change because for example a motor is to be attached to the rest of the machine in which the number of holes cannot be increased.

In a problematic situation, designers and technologists need to contact with purchasing department as well. The change in the width of a hole can mean the necessity of searching for the other type of screws. This can generate additional costs. For example, only few screws are needed but they can be bought only in packages of 100 pieces. The supplier of motor and the purchaser of motor must decide who will bear the additional costs of screws.

Due to various technical and technological issues that may arise as well as depending on the complexity of the project, the ETO lead time can be different. When the purchaser and supplier of motor work together from the beginning, NPD project time is reduced because potential problems are eliminated in a proactive way. With certainty, the design of a completely new motor requires the cooperation of both parties already in the phase of defining general requirements. This means, that in some industries ESI is just a necessity.

CONCLUSIONS ON ESI IMPLEMENTATION IN THE SUPPLY CHAIN OF MODULAR PRODUCTS

The case study refers to the three types of supply chain links: supply chain leader (purchaser of electric motor), first tier suppliers (supplier of electric motor) and second tier suppliers (sources of supply the manufacturer of electric motor).

In the light of research results, the following phases of modular product development can be distinguished: idea generation, screening, general requirements development, concept development (e.g. transforming qualitative requirements into quantitative parameters using QFD method), product design development (design specification development, financial analysis), product construction development (technical drawings), process technology definition (the process can come back to the product engineers), prototype, pre-pilots, final production. In the supply chain of modular products, joint product development is definitely present. However, ESI can be understood as involving suppliers in product development before the design specification is defined.

In the case study, both supplier and purchaser can be a source of product improvement ideas. However, the phase of generating ideas is implemented separately. When purchaser is a source of an idea, it looks for potential partners relatively late. On the other side, the supplier of motor prefers contacting with client as early as possible, because this enhances project time and costs (e.g. design failures) savings. Research highlights the key following factors that are of importance while deciding on ESI:

- who (purchaser or supplier) generates idea,
- who (purchaser or supplier) is responsible for detailed product specification,
- size of product/module change (incremental or radical innovation),
- product characteristics, e.g. complexity, modularity, newness, phase of product life cycle, price,
- importance of purchased item (costs of an item, value-added profile of an item),
- supply risk (number of potential suppliers of an item, supplier strength, supplier competencies),
- type of supplier-purchaser cooperation,
- type of innovation strategy,
- production environment (e.g. MTO, ETO).

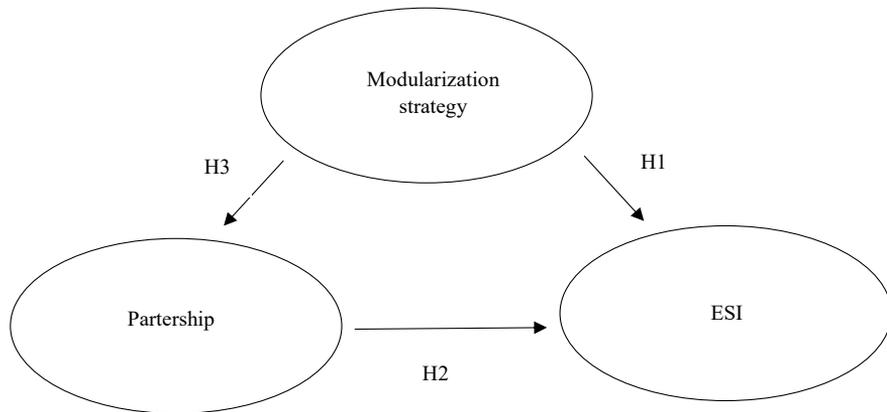
Furthermore, the following conclusions on ESI implementation in the supply chain of modular product can be formed:

- modular product improvement generally means that product is mature,
- modular product development is concentrated on the improvement of particular modules (their construction, material or manufacturing technology). This affects both product design (the purchaser's processes) and module design (the first/second supplier's processes),
- manufacturer of modular product can reduce the number of the first suppliers what can simplify building partnership with suppliers on the area of product development,
- the NPD phase at which supplier is involved depends on the supplier's responsibility for module specification,
- company that has more than one plant should consider implementing modularity strategy in its manufacturing system,
- modular products should be manufactured in a stable supply chain structure what can enhance supplier involvement at the phase of idea generation and screening,
- involving supplier in product development process depends on the type of purchased item;
- involving supplier in product development process depends on the trust, involvement and balance of power between supplier and purchaser (dependencies),
- the critical for R&D success are non-financial resources of supplier: NPD knowledge, skilled people, reliable technical infrastructure.
- effective product development requires suitable B2B communication from the very beginning. NPD communication canals and procedures need to be clearly defined and known,
- product development requires project management methodology. Project teams should consist of (both the first and the second if possible) supplier's and purchaser's representatives employed in various departments (marketing, purchasing, R&D, production),
- supplier-purchaser cooperation in supply chain of modular products is crucial to avoid design failures, especially for modules manufactured in ETO environment,
- supplier development programs (e.g. investing in its infrastructure) requires mass production for investment to return,

- the role of an internal and external cooperation in the product development is crucial for the R&D success.

FURTHER RESEARCH

Considering research results, the following conceptual model and hypothesis can be proposed (Figure 1). They need a further, quantitative verification.



H1: Modularization strategy positively influences ESI

H2: Partnership positively influences ESI

H3: Modularization strategy positively influences partnership

Figure 1. Conceptual model

Source: own study.

Each latent construct (ESI, modularization strategy, partnership) is going to be described by several observable indicators. The source of the descriptions will be research results and further literature analysis. It is suggested that the ESI construct would consist of a finite number of situations (stages) at which supplier can be involved. Modularization strategy would refer to six different areas identified by Piran et al. (2016): modularity in design, modularity in production, modularity in use, organizational modularity and modularity in services, environmental modularity. Finally, as there is a confirmed impact of product modularisation on supply chain relationships (Dube, Muyengwa, Battle 2013), the three main attributes of relationship would be taken into account in model: trust, involvement and dependency (Caniëls, Gelderman, Ulijn, 2010).

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ESI W ŁAŃCUCHU DOSTAW PRODUKTÓW MODUŁOWYCH

ABSTRAKT

Dyskusja na temat współpracy nad rozwojem produktów jest dziś bardzo aktualna z powodu rosnącego tempa zmian technologicznych. Jednak wciąż zbyt mało jest artykułów dotyczących rozwoju produktu w perspektywie więcej niż jednego ogniwa łańcucha dostaw. Celem tego artykułu jest poznanie roli wewnętrznej i zewnętrznej współpracy w procesie opracowywania produktu, a także określenie czynników warunkujących wczesne zaangażowanie dostawców w łańcuch dostaw produktów modułowych. Artykuł składa się z następujących części: wprowadzenie, metodologia, wyniki badań, wnioski i propozycja przyszłych badań. Autorka wykorzystała pogłębione wywiady i metody studium przypadku. Na podstawie wniosków sformułowano trzy hipotezy. Mogą być one wkładem do dalszych (ilościowych) badań: H1: Strategia modularyzacji pozytywnie wpływa na ESI, H2: Partnerstwo pozytywnie wpływa na ESI, H3: Strategia modularyzacji pozytywnie wpływa na partnerstwo.

SŁOWA KLUCZOWE

ESI, modularyzacja, łańcuch dostaw

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