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How to measure the supplier involvement?

Jak zmierzyć praktykę włączania dostawców w rozwój produktów?

Increasing a degree of supply chain integration is a common strategy today. Therefore, more and more companies decide to implement joint projects with their first tier suppliers. One of the examples of such projects is the joint product development. The purpose of this paper is to present a comprehensive framework of the measurement of supplier involvement (SI) in product development based on the systematic literature review. SLR covered 126 papers published between 1989 and August 2018 in three databases of well-known journal publishers. The results of in-depth analysis of previous quantitative and qualitative research allowed to develop the proposition of supplier involvement measurement. It consists of three constructs, which are: 'degree of supplier involvement', 'partnership in product development process' and 'communication during product development'. They are all expressed with the twenty six different items. The developed SI measurement approach can be used for quantitative research on NPD or other projects implemented in cooperation with suppliers as well as different business partners.

The paper is a result of 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, that is financed by the National Science Centre (NCN) in Poland.

Key words:

supplier involvement, product development, measurement, systematic literature review

Firmy ukierunkowują dziś swoje działania na zwiększanie stopnia integracji w łańcuchu dostaw. W związku z tym, coraz więcej przedsiębiorstw decyduje się na realizowanie wspólnych projektów razem ze swoimi bezpośrednimi partnerami gospodarczymi. Jednym z przykładów takich projektów jest rozwój produktów z dostawcami (ang. Supplier Involvement, SI). Celem artykułu jest zaprezentowanie ram kompleksowego pomiaru włączania dostawców w rozwój produktów w oparciu o systematyczny przegląd literatury. Badanie objęło 126 artykułów opublikowanych pomiędzy 1989 a 2018 rokiem w trzech znanych międzynarodowych bazach czasopism. Rezultaty pogłębionej analizy poprzednich, zarówno ilościowych jak i jakościowych, badań pozwoliły na opracowanie kompleksowego podejścia do pomiaru SI. Składa się on z trzech konstruktów, którymi są: „stopień włączenia dostawcy w rozwój produktu”, „partnerstwo w procesie rozwoju produktu” oraz „komunikacja podczas rozwoju produktu”. Wszystkie trzy konstrukty wyrażone zostały dwudziestoma sześcioma zmiennymi. Zaproponowany pomiar może być wykorzystywany w przyszłych badaniach ilościowych, których przedmiotem są nie tylko projekty o tematyce rozwijania produktów w relacjach z dostawcami, ale także projekty o innej tematyce prowadzone z pozostałym interesariuszami. Artykuł napisany został w ramach realizowanego projektu o numerze 2016/21/B/HS4/00665, pt. „Elastyczność w relacjach z dostawcami a rodzaje współpracy dostawca-nabywca w zakresie rozwijania produktów na rynku B2B”, który uzyskał finansowanie z Narodowego Centrum Nauki.

Słowa kluczowe:

włączenie dostawcy, rozwój produktu, pomiar, systematyczny przegląd literatury

L10, O30, O32

Introduction

Since more than 30 years, the supplier involvement in product development (SI) has been a subject of a lot of qualitative and quantitative

research. The origins of this issue can be seen in the 'concurrent engineering' which is concentrated on designing products and processes by production and other functions including product lifecycle approach (Winner, 1988, pp. 11–13). Birou and Fawcett (1994)

clarified that SI is 'supplier participation in the integrated product development process'. The newest definition of supplier involvement says that it is 'the process of managing the involvement of suppliers in the development of (new) products/services/processes/ technologies for the chosen category' (Luzzini et al., 2015). SI is also explained as a 'supplier integration' (Wagner, 2012) or 'supplier engagement' (Saunders et al., 2015). The main success factor for product innovation development is building partnership with suppliers (Urbaniak, 2017). When analyzing SI, it is impossible not to refer also to early supplier involvement (ESI), which is defined as 'proactively integrating suppliers at an early stage of product development' (Bozdogan et al., 1998).

In past research, supplier involvement usually concerned developing new or significantly improved products. These two situations directly refer to the product innovation definition (OECD and Eurostat, 2005, p. 48). Many authors studied both SI and product innovativeness e.g. (Song, Song and Di Benedetto, 2011; Bahemia, Squire and Cousins, 2017). Luo, Mallick and Schroeder (2010) as well as Fossas-Olalla et al. (2015) examined 'product newness' and 'product novelty', whereas Bozdogan et al. (1998) was interested in the innovation types (e.g. incremental and radical).

There is a growing role of strategic foresight for innovation management (Adegbile, Sarpong and Meissner, 2017). In the light of current challenges for supply chains such as advanced information and communication technologies, global sourcing or the urgent need of design for environment, an investigation into the product development is a critical topic today. Interestingly, manufacturing companies functioning in Poland develop product innovations in relationship with suppliers the most often (Ocicka, 2018).

The quantitative research is especially important for statistical calculations. Scientists verify conceptual models to track the relationships between particular variables. To build such a research it is necessary to propose constructs that would define specific areas.

In the literature of the subject, the constructs expressing the supplier involvement in product development also appeared. However, they are diverse and knowledge about them is unordered. Still, there is a lack of a comprehensive approach to SI measurement. Therefore, the paper aims to fill this gap.

The manuscript makes three specific contributions to the literature. First, it presents SI constructs that have been confirmed by researchers in the last decades. Then, it analyses them in terms of the content and used items. Finally, based on the observations from the SLR it proposes an integrated approach to the measurement of supplier

involvement in product development. It can be used in the future quantitative research on various projects implemented in cooperation with suppliers and other business partners.

This article is structured as follows. Section 2 explains the methodology utilized to perform the systematic literature review as well as the main descriptive results. Findings on the previous SI constructs are presented and discussed in Section 3. The final sections show the SI measurement framework, implications and conclusions.

Research method

The research is based on a Systematic Literature Review (SLR) applied following Tranfield, Denyer and Smart (2003). The review process consisted of the following phases: question formulation, keyword search in databases, screening phases (Table 1) and analysis of articles. First, the research question - how scientists measured the supplier involvement in product development so far? - was constructed. This question, though very general, was supported by five sub-questions:

- What are the names of SI constructs?
- From what number of items are SI constructs built?
- To what refer the SI constructs' items?
- What are the similarities between the content of constructs?
- What variables appeared in the research articles on SI in addition to full constructs?

In the second phase, the author used the leading providers of research databases, which are EBSCOhost Online Research Databases, Emerald Insight and Wiley Online Library. The following search terms and restriction were used in the phase of the databases search:

- two search terms: 'supplier involvement' and 'product development',
- restriction: occurrence in abstract.

'Supplier involvement' can refer to various supply chain processes. To select the appropriate papers, the 'product development' search term was also applied, with this phrase being used to avoid limiting the issue to only new products. There was no restriction on the date of publication and the type of paper, in order to identify as many articles presenting the results of research as possible. For the final analysis 126 papers were taken into account (Table 1).

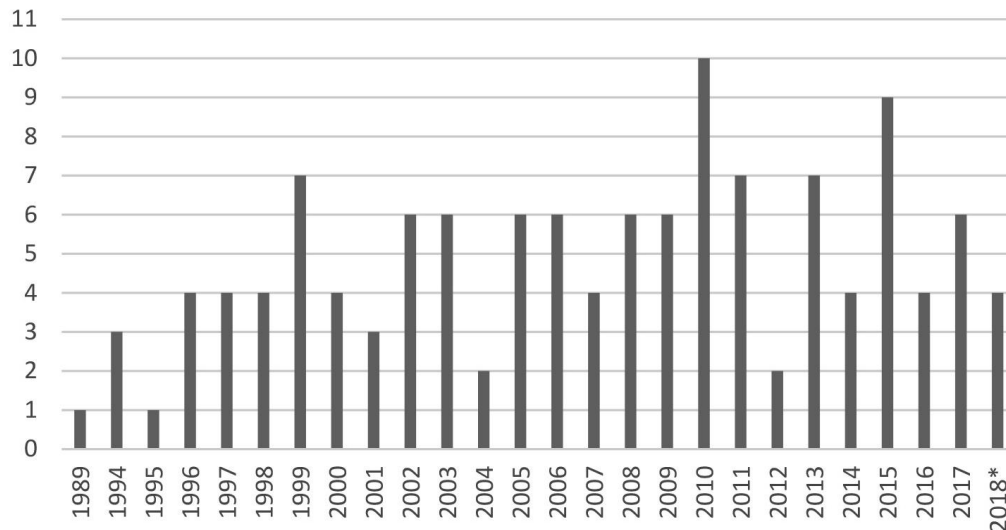
The identified articles were published between 1989 and August 2018. Papers appeared every year. The largest number of articles on this subject was published in the 2010 year (Figure 1). It can be noticed that interest in the subject has not been diminishing for examined years.

Table 1
The screening phase results

Phase description	Database	Output (number of papers)
First database search with the use of two search terms	EBSCOhost	172
	Emerald	24
	Wiley Online Library	28
Screening 1: checking titles and abstracts	EBSCOhost	120
	Emerald	24
	Wiley Online Library	22
Screening 2: removing duplicates	EBSCOhost, Emerald, Wiley Online Library	144
Screening 3: closer inspection, checking cited articles	EBSCOhost, Emerald, Wiley Online Library	126

Source: own study.

Figure 1
Year-wise distribution of publications (*up to the end of August 2018)



Source: own study.

Among analyzed papers, 62 of them present survey results on supplier involvement in product development, 57 show cases studies and 1 paper is

related to the literature review. Further, 13 papers are conceptual, whereas 3 articles are analytical one. Finally, 6 papers propose a research framework (Table 2).

Table 2
Methodologies used in the publications

Survey	Case study	Literature review	Conceptual	Framework	Analytical
62	57	1	13	6	3

Source: own study.

The SI constructs appeared only in papers presenting survey results. The quantitative papers examined also such variables as SI enablers, barriers or drivers. The enablers as well as SI definitions are an important input to the framework presented in the penultimate part of this publication. In general, six papers provided 'supplier involvement' definition, whereas five articles elaborated 'early supplier involvement' definition.

In terms of the sector, all analyzed publications examined production industries. In several cases, authors studied distribution sector at the same time. The research perspective most often concerned the relationship between the manufacturing company and its business partners. This viewpoint is therefore a main perspective of the following considerations.

Findings

For the purposes of this article the analysis was mainly focused on the quantitative measures. Twelve original and confirmed SI constructs appeared in gathered articles (Table 3). Some of them were used in more than one research and some were developed with regard to the previous studies. Similarly, several ESI constructs were recognized in the past publications (Table 4).

Usually, authors used 'supplier involvement' or 'early supplier involvement' as a construct's name.

However, in some cases this name was modified into a longer explanation, e.g. Supplier Involvement in New Product Development (NPD) (Li, Gu and Wang, 2010; Danese and Filippini, 2010) or Integration in FFE ("fuzzy front end") phase of NPD (Wagner 2012). FFE concerns only generating and evaluating ideas as well as developing product concept.

Most research models are based on a single SI or ESI construct. Here, the highest number of items (seven) was proposed by Primo and Amundson (2002). Contrarily, Chien and Chen (2010) examined 'supplier involvement' referring to the three following subconstructs: 'early supplier involvement' (4 items), 'technology and cost information sharing' (2 items) and 'customer knowledge of supplier' (2 items). Similarly, Li, Gu and Wang (2010) proposed two subconstructs: 'involvement time' (6 items) and 'involvement degree' (3 items). ESI constructs usually consist of three items. There are also studies that used exactly the same SI construct (Feng et al., 2013; Feng et al., 2014; Zhang, Wang and Gao, 2017). Interestingly, some ESI constructs were adopted from previous studies (e.g. Brewer and Arnette, 2017).

The research on SI in product development has been present in the literature for the last 30 years. Most recognized constructs differ not only with the number of items, but above all on how these items are formulated. Nevertheless, some similarities can be distinguished and, more specifically, certain thematic areas that they describe.

Table 3
SI constructs in past studies

No.	Authors (year of publication)	Construct name	No. of items
1	Primo and Amundson (2002)	Supplier Involvement	7
2	Petersen, Handfield and Ragatz (2003)	Supplier Involvement in Decision-Making	3
3	Carr et al. (2008)	Supplier Involvement	3
4	Luo, Mallick and Schroeder (2010)	Supplier Involvement effort	4
5	Chien and Chen (2010)	Supplier Involvement: Early Supplier Involvement + Customer knowledge of supplier + Technology and cost information sharing	422
6	Danese and Filippini (2010)	Supplier Involvement in NPD	4
7	Li, Gu and Wang (2010)	Supplier Involvement in NPD: Involvement time + Involvement degree	63
8	Najafi, Sharifi and Ismail (2013); Najafi et al. (2013)	Supplier Involvement	5
9	Feng and Wang (2013)	Supplier Involvement	4
10	Feng et al. (2013) Feng et al. (2014) Zhang, Wang and Gao (2017)	Supplier Involvement	4
11	Cheng and Krumwiede (2018)	Supplier Involvement	4
12	Ye et al. (2018)	Supplier Involvement	4

Source: own study.

Table 4
ESI constructs in past studies

No.	Authors (year of publication)	Construct name	No. of items
1	McGinnis and Vallopra (1999)	Early Supplier Involvement (Suppliers in a Major New Product Development Role)	3
2	Wagner (2012)	Integration in FFE ("fuzzy front end") phase of NPD.	4
3	Kähkönen, Lintukangas and Hallikas (2015), adopted from Trent (2007)	Early Supplier Involvement	3
4	Brewer and Arnette (2017), adopted from two previous papers	Early Supplier Involvement	3
5	Kähkönen et al. (2017), adopted from Trent (2007)	Early Supplier Involvement	4

Source: own study.

First, it is noticeable that most papers refer to the participation of 'key supplier' (e.g. Primo and Amundson, 2002; Feng et al., 2013; Cheng and Krumwiede, 2018) as well as the process of new product development (e.g. Danese and Filippini, 2010; Li, Gu and Wang, 2010).

Secondly, the items are measured with the five or seven-point Likert scale. The questions to the items refer to the level of described phenomenon or a degree to which a respondent agrees with the particular statement.

Thirdly, the SI and ESI constructs very often include the aspect of communication during product development. This string appears several times, both in regard to its 'closeness' (Primo and Amundson, 2002; Danese and Filippini, 2010; Najafi, Sharifi and Ismail, 2013; Najafi et al., 2013) and to its 'extent'. Petersen, Handfield and Ragatz (2003) were interested in the extent of supplier 'participation', whereas other scientists (Najafi, Sharifi and Ismail, 2013; Najafi et al., 2013) included the variable concerning the supplier's 'activeness in NPD'. In

addition, the question about the 'frequency' of consultations with suppliers occurred in some constructs (Luo, Mallick and Schroeder, 2010; Chien and Chen, 2010; Ye et al., 2018).

Further, the items present different practices that are related to building partnership in supply chain. They concern long-term supplier-buyer relationships (Zsidisin and Ragatz, 2008; Wagner, 2012), sharing resources (McGinnis and Vallopra, 1999; Brewer and Arnette 2017, Cheng and Krumwiede, 2018) and supporting suppliers in achieving the appropriate quality (Primo and Amundson, 2002).

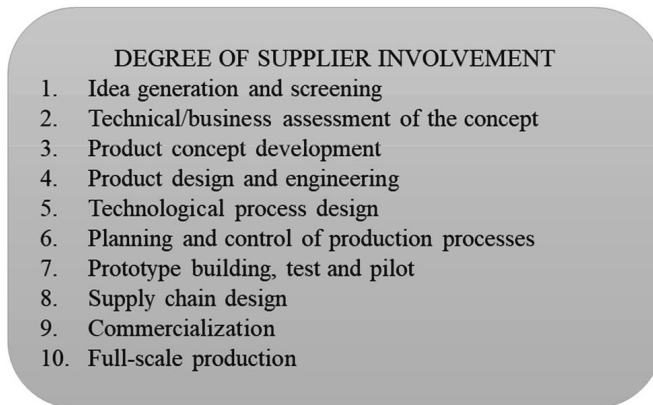
Finally, some constructs refer to the moment of supplier involvement with the reference to the NPD stages. In the studied articles, it was sometimes described as a separate construct, which is called 'timing'. This aspect is especially important for research on ESI (e.g. Wagner, 2012). Early supplier involvement refers to the early NPD stages (Bozdogan et al., 1998). For example, according to the Handfield et al. (1999), these stages are the idea generation, preliminary business/technical

Figure 2
The proposition of the supplier involvement measurement — three constructs



Source: own study.

Figure 3
Degree of supplier involvement



Source: own study

assessment and product/process/service/concept development. It happens that NPD stages are also listed in the constructs expressing SI degree e.g. (Li, Gu and Wang, 2010).

The framework of SI measurement

Due to the fact that SI measurements presented in previous papers are diverse and often inconsistent, it is suggested to propose a standardized approach for this research issue. This is not easy due to the many research threads discussed in the studied articles. Nevertheless, after the in-depth analysis of all gathered papers it can be concluded that recognized SI variables directly refer to three main areas. These three topics refer to the supplier-buyer partnership and the communication carried out with suppliers during the product development. Except that, a very common aspect is the moment and the level of involvement of the supplier in the various stages of NPD process. Some of the studies refer to the involvement of supplier base in general, whereas some of the research concentrate on a single supplier-buyer relationship. The following proposition refers to the second situation because it was advised by Wynstra and Ten Pierick (2000) that different NPD practices should be implemented depending on the segment of suppliers. Therefore, relationships with suppliers should be considered individually, especially in terms of projects on developing new products.

In the face of these observations, the following approach is proposed to measure the phenomenon of SI in product development. It is based on three

following constructs that consist of different number of items (Figure 2):

1. Degree of supplier involvement on each of the new product development stages.
2. Partnership in product development process.
3. Communication during product development process.

Each proposed construct is built based on the identified research items (Table 3) as well as the other variables from the previous studies on SI. Regarding the first construct (degree of supplier involvement), many different variants were presented in the analysed papers. They differ from each other with a number and type of NPD stages. Authors distinguish three (Wagner, 2012), four (McIvor and Humphreys, 2004) or more NPD stages (Danilovic, 2006; Cantarello et al., 2011). The new construct includes all recognized proposals by integrating them into a consistent list (Figure 3). For the previous research, especially on the early supplier involvement, it was crucial to recognize the first stage in which the supplier was engaged. That is why, the question about the first stage as well as an option '0 - lack of involvement' are suggested to be included. Engaging supplier at one of the first three listed stages is regarded as ESI (Handfield et al., 1999; Schoenherr and Wagner, 2016).

All items in a 'degree of supplier involvement' construct (Figure 3) are the NPD stages that were usually distinguished by authors in the analysed papers. Like in the previous papers, first three stages concern early supplier involvement (Handfield et al., 1999; Wagner, 2012):

- Idea generation and screening the ideas (e.g. Hartley, Zirger and Kamath, 1997; Handfield et al., 1999; Parker, Zsidisin and Ragatz, 2008; Klioutch and Leker, 2011).

Figure 4

Partnership in product development process

PARTNERSHIP IN PRODUCT DEVELOPMENT PROCESS

1. Cooperation with the supplier was based on partner relations
2. Cooperation with the supplier was based on jointly set goals
3. Cooperation with the supplier was based on mutual willingness to develop a long-term relationship
4. Cooperation with the supplier was based on equitable risk and reward sharing
5. Cooperation with the supplier was based on sharing knowledge
6. Cooperation with the supplier was based on sharing cost information
7. Cooperation with the supplier was based on the sharing physical assets
8. Cooperation between the company's employees and the supplier's employees was very close
9. Cooperation with the supplier was based on mutual supporting in the improvement of e.g. quality, production capacity
10. Cooperation with the supplier involved various levels of management

Source: own study

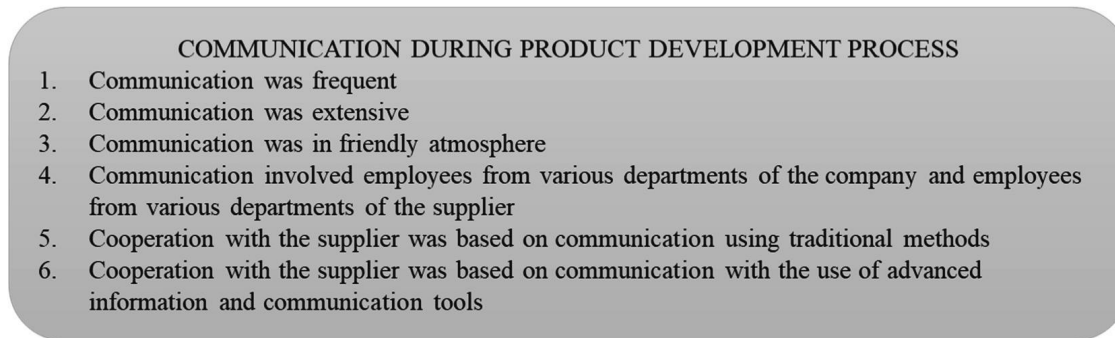
- Technical and business assessment (e.g. Handfield et al., 1999; McIvor and Humphreys, 2004; Danilovic, 2006; Spaulding and Wood, 2006; Parker, Zsidisin and Ragatz, 2008; Klioutch and Leker, 2011).
- Product concept development (e.g. Handfield et al. 1999; Wynstra, Weggemann and Van Weele, 2001; McIvor and Humphreys, 2004).
- Product design and engineering (e.g. Handfield et al., 1999; Wynstra, Weggemann and Van Weele, 2001; McIvor and Humphreys, 2004; Cantarello et al., 2011; Klioutch and Leker, 2011).
- Technological process design (e.g. Wagner, 2012; Lyu and Chang, 2007).
- Planning and control of production processes (e.g. McIvor and Humphreys, 2004; Kähkönen, Lintukangas and Hallikas, 2015);
- Prototype building, test and pilot (e.g. Handfield et al., 1999; Wynstra, Weggemann and Van Weele, 2001; Jayaram, 2008; Wagner, 2012).
- Supply chain design in the sense of selection of supply sources or distribution channels (e.g. Wagner, 2012).
- Commercialization of product (e.g. Spaulding and Woods, 2006; Cantarello et al., 2011; Najafi et al., 2013).
- Full-scale production in the sense of production development and improvement (e.g. McIvor and Humphreys, 2004; Sjödin and Eriksson, 2010; Cagli, Kechidi and Levy, 2012).

Next construct, which is the 'partnership in product development process' refers to various practices that determine win-win cooperation as well as NPD success (Figure 4). Several items are

proposed here, following past research considerations:

- Cooperation with the supplier was based on partner relations (e.g. Hoegl and Wagner, 2005; Li, Gu and Wang, 2010; Wagner, 2012).
- Cooperation with the supplier was based on jointly set goals (e.g. Hoegl and Wagner, 2005; Parker, Zsidisin and Ragatz, 2008; Wagner, 2010; Kähkönen, Lintukangas and Hallikas, 2015).
- Cooperation with the supplier was based on mutual willingness to develop a long-term relationship (e.g. Primo and Amundson, 2002; Song, Song and Di Benedetto, 2011).
- Cooperation with the supplier was based on equitable risk and reward sharing (e.g. McGinnis and Vallopra, 1999).
- Cooperation with the supplier was based on sharing such knowledge as technical/technological (e.g. McGinnis and Vallopra, 1999; Hoegl and Wagner, 2005; Jayaram 2008; Chien and Chen, 2010).
- Cooperation with the supplier was based on sharing cost information (e.g. McGinnis and Vallopra, 1999; Hoegl and Wagner, 2005; Jayaram, 2008; Chien and Chen, 2010).
- Cooperation with the supplier was based on the sharing physical assets, for example plant or only equipment (e.g. Birou and Fawcett, 1994; Bozdogan et al., 1998; McGinnis and Vallopra, 1999; Parker, Zsidisin and Ragatz, 2008).
- Cooperation between the company's employees and the supplier's employees was very close. For example, product development team consisted of employees of the company and the supplier (e.g.

Figure 5
Communication during product development process



Source: own study

Fan, Russel and Run, 2000; Primo and Amundson, 2002).

- Cooperation with the supplier was based on mutual supporting in the improvement of e.g. quality, production capacity, through the specific activities: education and training programs, audits (e.g. Birou and Fawcett, 1994; Ragatz, Handfield and Petersen, 2002).
- Cooperation with the supplier involved various levels of management, e.g. strategic and operational (e.g. McGinnis and Vallopra, 1999; McIvor, Humphreys and Cadden, 2006; Van Echtelt, Wynstra and van Weele, 2007; Van Echtelt et al., 2008).

For all above items (Figure 3, Figure 4), the following question is proposed: 'please, indicate to what extent you agree with the following statement'. The seven (or five) point Likert scale is suggested too. The same assumptions apply to the last proposed construct.

The research on 'communication during product development process' usually covered communication frequency and intensity. However, an in depth analysis of identified papers also led to the inclusion of other issues for the communication construct, like for example cross-functional integration (Figure 5):

- Communication was frequent (e.g. Hartley, 1997; Culley, Boston and McMahon, 1999; Hoegl and Wagner, 2005; Jayaram, 2008).
- Communication was extensive (e.g. Tavani et al., 2013; Hoegl and Wagner, 2005).
- Communication was in friendly atmosphere (e.g. Wagner and Hoegl, 2006).
- Communication involved employees from various departments of the company and employees from various departments of the supplier (e.g. Birou and Fawcett, 1994; Dowlatshahi, 1998; Swink, 1999; Maffin and Braiden, 2001; Lakemond,

Berggren and van Weele, 2006; Parker, Zsidisin and Ragatz, 2008).

- Cooperation with the supplier was based on communication using traditional methods, which can be a telephone, fax or direct meetings (e.g. Birou and Fawcett, 1994; Hartley, 1997; Culley, Boston and McMahon, 1999).
- Cooperation with the supplier was based on communication with the use of advanced information and communication tools (e.g. Tang, Eversheim and Schuh, 2004; Huang, Mak and Humphreys, 2003).

Summarizing, many authors have referred to various variables in research on SI. The presented approach takes into account and organizes them into three latent constructs defined by 26 observable indicators. In the further stage of the research they are going to be verified using the statistical analyses.

Conclusions

The paper provides both theoretical and practical implications. The systematic literature review allowed to build the first comprehensive approach to the SI measurement that can be used in future research. Simultaneously, all identified items can be a guide for managers on key determinants of joint product development. It is also possible to transfer these practices to the relationships with other participants in NPD process.

The partnership construct as well as the communication construct can also be used to study joint projects with a different themes from product development. For example, these can be projects focused on the supplier development or improvement of supply chain maturity.

Although the issue of SI has been present in the

literature for the last several decades, this topic still requires new studies, especially in the face of an increasing rate of technological changes and growing role of innovations for building competitive advantage. There are many areas that can be studied in the future in terms of their relations with SI in product and process development, e.g. design for circular economy (Bocken et al., 2016), design of resilient supply chains (Bak, 2018), developing open innovations (Ebersberger, 2012) or building relational capital in supplier-buyer cooperation (Ocicka and Wieteska, 2019). Despite the diversity of research threads, the proposed approach to SI measurement can be applied to each of them due to its scope.

This work has several limitations. First it is SLR, so it used secondary sources and desk research method. However, the methodical rigor and detailed analysis of the quantitative methods used by scientists over the last 30 years guarantees a high level of quality of the framework. A developed

approach to SI measurement hasn't been verified yet. However, it can be assumed that it is highly appropriate due to the fact that it is based on previous considerations and constructs so far confirmed. Finally, although the 126 papers were studied very carefully, some items may have been unintentionally underestimated due to the multithreading nature of the research carried out so far. But yet, three proposed constructs refer to the most common and important aspects of past studies.

Acknowledgments

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