Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 96 (2021) 15–20

www.elsevier.com/locate/procedia

CIRPe 2020 – 8th CIRP Global Web Conference – Flexible Mass Customisation

Methodology for the strategy-oriented distribution of decision autonomy in global production networks

Bastian Verhaelen[a,]*, Benjamin Haefner[a], Gisela Lanza[a]

[a]wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

* Corresponding author. Tel.: +49 1523 950 26 26; fax: +49 721 608 45005. *E-mail address:* bastian.verhaelen@kit.edu

Abstract

Multinational companies deal with production processes in various countries by operating global production networks. These production processes are allocated to production plants with different levels of autonomy regarding strategic and operative decisions. Typically, each plant and the whole network are managed by one or more network managers who have to deal with a decision overload in their daily business. 50% of their decisions are made in less than 9 minutes and only a small amount of decision tasks are dealt with for more than one hour. To reduce this dilemma, it was found that the distribution of decision autonomy can be enhanced. It depends on the company's strategy and complexity dimensions in global production networks. However, so far there is little evidence on how to better distribute decision autonomy in global production networks in detail. Furthermore, it is not transparent at what level of cetralism a global production network should be managed without cutting the capabilities of production plants. This paper presents a methodology, which examines relevant strategy dimensions and derives guidance on how to distribute decisions in global production networks. First, the network and production strategies of global production networks are classified. Second, relevant complexity dimensions and decisions are introduced. Third, the influence of the distribution of decision autonomy on strategy dimensions is quantified by an impact model. Furthermore, the effect of complexity on the distribution of decision autonomy is quantified by an impact model. Here, the integration of empirical data was used to validate the different influences. Finally, the ideal distribution of decision autonomy for specific production plants in the global production network is derived. The methodology is applied in an industrial use case to prove its practical impact.

Keywords: Production network; decision autonomy; production strategy

1. Introduction

1.1. Motivation

An increasingly dynamic worldwide competition and accelerating product requirements due to fast changing customer requirements apply high pressure on efficient production processes [1]. In order to cope with this pressure, companies around the world structure their production processes in global production networks [2]. The different market conditions offer benefits of being close to the customer or using low factor costs (e.g. personnel or logistics costs) [3]. Furthermore, global production networks grow naturally or by merger and acquisition activities [4]. The results are production networks which are not as efficient as if they were planned on in advance. High coordination activities characterize these production networks. Each production plant in the networks needs a connection to related plants or headquarter [5]. To reduce this dilemma, one can increase the autonomy of production plants in global production networks [6]. By increasing the autonomy regarding strategic or operative decisions, the coordination effort can be lowered, but one also has to consider the loss of control of the network managers [7].

10.1016/j.procir.2021.01.045

Moreover, it is increasingly important to take the strategic orientation of the producing company into account. The strategy needs to be deployed throughout the global production network. In addition, it characterizes the ideal structure of the network, the way of efficient network management and the degree of network centralization. [8] Therefore, it determines the way decision autonomy should be distributed in order to align the production strategy of plants with the network strategy of global production networks [9]. Besides the strategy, it is also important to consider the manufacturing environment or the manufacturing complexity when allocating decision autonomy. It was found that the ideal allocation of decision autonomy depends on this environment and the inherit complexity on network and plant level. [7]

Therefore, the allocation of decision autonomy taking into account the strategy and the complexity of networks and plants is a decisive challenge in the management of global production networks.

1.2. Goal

The aim of the paper is to develop a methodology for the strategy-oriented distribution of decision autonomy in global production networks. For this purpose, elementary necessary description models in the areas of strategy and targets, complexity and decisions are developed. Based on this, impact models are developed, which can be used to explain the interdependencies of the elements of the description models. These are used in a selection process to determine the ideal distribution of the decision autonomy for different strategies in global production networks. The results of the paper should be transferable to industrial use cases in order to cope with real world problems. Further, the paper gives recommendations for the management of global production networks in volatile environments. These recommendations depend on the specific setting of global production networks and need to be adjusted for each industrial use case. In relation to research, the interdependencies between strategy, complexity and decisions are worth elaboration.

2. Principles

2.1. Global production networks

Global production networks are considered as man-made constructs that operate in a dynamic environment with the aim to provide products or services [2]. These networks are open-ended as there is a connection to downstream suppliers and upstream customers. The overall goal is to satisfy diverse customer needs in a highly dynamic environment. [1] A global production network consists of at least two production plants, which can be described as nodes. The connection between these nodes is characterized by information, knowledge and material flows. [10]

Global production networks can be structured by considering the main tasks in their operation and design. These tasks occur concerning different time horizons (see Fig. 1) and in different intensities over the lifetime of global production networks.

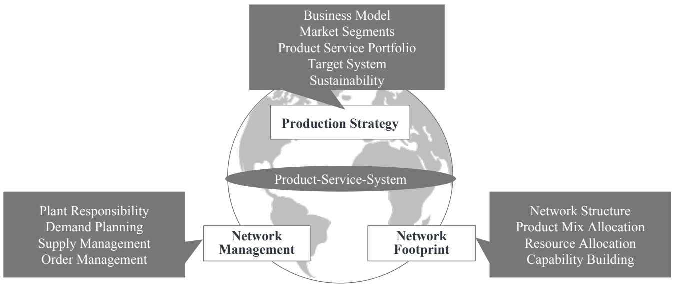

Fig. 1. Tasks of global production networks [2]

The longest time horizon is meaningful for the formulation of a production strategy. The design of the network footprint describes the network structure e.g. the number of production plants, the production mix allocation or the resource allocation. It takes into account the infrastructural elements of the global production network. [2] Herein, one can differentiate between different production network types. Ideal types are: local for local for local, hub and spoke, world factory, sequential chain and the web structure. These network types make it possible to achieve a suitable distribution of production plants for different boundary conditions and to adapt them to the specific characteristics of production. [11]

The third task with the shortest time horizon is the network management focusing on the connections between production plants and the overall network. It involves classical topics such as supply and demand management, but also the task of plant responsibility or decision autonomy. [2]

2.2. Decision autonomy and centralization

Decision autonomy and centralization have been coupled for ages. Autonomy is considered as the condition in an organization if units of this organization are able to make decisions for themselves if in comparable organizations, these decisions are carried out by higher level authorities. Therefore, centralization describes the superordinate construct of high level authorities inheriting the whole decision making power for lower level organizations. [12]

In the context of global production networks, decision autonomy can be described as the independence of a production plant to make decisions autonomously within a framework granted by the management or production network [7,13].

The respective decisions for determining decision autonomy can be taken from the production strategy areas or from other frameworks like the SCOR model [7,14]. Exemplary decisions which can be allocated on network level, plant level or in harmonization between the two extremes are: make or buy decisions, supplier selection, production planning and control decisions, process related decisions or technology related decisions [15]. The allocation of these decisions is strongly connected to the manufacturing environment or complexity on plant and network level [7].

2.3. Complexity in production

The term “complex” is used for objects that people perceive as uncontrollable, unknown and hard to understand [16]. In general, complexity describes the number, connectedness and dynamic of elements in a system [17]. In production, one can differentiate complexity regarding internal and external dimensions. Internal dimensions are product, process, technology, organization and network, whereas external dimensions are customer, competitor, supplier and market. The external complexity is transferred into internal complexity by adjusting the product portfolio to the customer requirements. [18] In each of the complexity dimensions, companies can be assessed to be either highly complex or less complex in comparison to industry benchmarking or internally. Production plants can obtain an assessment of their complexity compared to similar plants.

2.4. Systems engineering and statistical analysis

The analysis of systems requires a systematic procedure. Systems engineering has the aim to give a formally valid theory for natural, social and technical systems. [19] Global production networks can be classified as technical and social systems. Systems engineering can explicitly be used if a variety of solutions is possible and no designated solution procedure is known. Here, the connected thinking method takes place. It enables the solution of complex systems by thinking in connections. Different perspectives need to be considered to enable a sophisticated solution for the problem. [20] In the connected thinking method, the usage of impact models is common practice to solve complex problems. It is often referred to as “paper computer”. [21] The results of impact models are interdependencies between different factors in the form of a matrix.

In order to support the interdependencies in the impact models which are based on the connected thinking method, statistical analysis can be used. As a basis for the analysis of survey data, the t-test for equality of means is useful. Here, the equality of means of different clusters e.g. complexity clusters can be analyzed. To test significance, different hypotheses can be used with different significance intervals. [22]

3. State of the art

There is a large number of publications dealing with the strategy-oriented management of global production networks.

Young and Tavares (2004) give a brief overview of the literature regarding centralization and autonomy. They consider activities and decisions in the area of production, but also areas like marketing or research and development. Therefore, the scope is not focused on production only. The authors identify a gap in research regarding the implications from autonomy on strategy and vice-versa. Furthermore, the authors identify that there is no procedure which allows determining the ideal amount of autonomy for a subsidiary or a production plant. [23] Scherrer and Deflorin (2017) analyze the influence of production plants and the production network on the strategy fulfillment. They constitute relationships between plant and network capabilities, coordination, configuration and strategy. Thus, the field of research is large and fundamental interdependencies are given. However, they do not focus on the influence of decisions on strategy. [24] Mourtzis et al. (2012) formulate a methodology for the identification of efficient supply chain partners in centralized and decentralized production environments. The authors use operations research methods to find optimal production and transportation schemes. Nonetheless, the authors do not focus on the finding of an optimal degree of centralization regarding decisions and autonomy. [25] Matt et al. (2015) analyze the need for distributed manufacturing in today’s manufacturing environment due to sustainability and customer orientation. The authors identify the need for scalable and flexible organizational models. Further, the authors present the drivers for decentralized production. In addition, special forms of decentralized production are shown. E.g. production franchise is a model factory operated independently by franchisees, with flexible production units for distributed production in franchise networks. [26] Yet, the authors do not explicitly show how decentralized production networks should be designed. A focus on decision autonomy is not given. Maritan et al. (2004) examine whether production plants with different plant roles have different levels of autonomy. The authors use Ferdows’ model of plant roles [27]. It was found that lead plants do not always have the highest amount of autonomy. Still, the authors do not present a way to determine the ideal level of autonomy. For the purpose of relevant decisions, this paper is meaningful. [13] Olhager and Feldmann (2018) analyze the way decision-making authority is distributed in multi-plant networks. By using survey data of 107 production plants, three different structures are identified: centralized, decentralized and integrated. In addition, the authors find relationships of the decision-making authority with process type and product volume as elements of complexity. [7] The authors use relevant decisions coming from production strategy which are the basis for this paper. Additionally, the authors claim that there is a relationship between the manufacturing environment and the ideal decision-making structure which will be analyzed by using the complexity of global production networks. Nevertheless, the authors do not present a methodological way for companies to find the ideal degree of decision autonomy for single and multiple production plants in global production networks.

The state of the art shows that there is a variety of methodologies and models regarding the strategic management of global production networks. But, only few are focusing on centralization issues. In summary, there is no concrete methodology which supports companies in finding the ideal degree of centralization or decision autonomy for production plants in global production networks. This indicates the apparent gap in research literature which is the basis for the following methodology.

4. Methodology

The proposed methodology for the strategy-oriented distribution of decision autonomy in global production networks consists of four steps. The first step includes the characterization of the strategic guideline of companies with a global production network. By characterizing the strategy, the fundament for the strategy-oriented distribution of decision autonomy is laid. Different dimensions of strategy are analyzed and ideal target systems are derived from the strategy. In the second step, the relevant decisions for determining the decision autonomy are introduced. The decisions are characterized by the SCOR model and a classification scheme for companies is given. Furthermore, relevant complexity dimensions are presented and qualitatively compared with each other. These models of strategy, target system, decisions and complexity dimensions are the basis for the third step. In the third step, structures of impact models are elaborated which guide the way to the ideal distribution of decision autonomy in global production networks. The last and fourth step derives the ideal distribution of decision autonomy by applying selection methods.

4.1. Strategy and target system description models

In the first step of the methodology, typical strategies of global production networks need to be categorized. Friedli et al. (2014) use the terms network and production strategy to illustrate different strategic areas of global production networks [9]. In this article the two perspectives are combined as both are relevant for the overall strategy of production networks. By doing so, the external and internal view of a company are brought together. Therefore, also the network type, which is a product of the strategy and should be aligned to the strategy is assessed here. An exemplary combination is the network strategy of being close to the market in combination with the production strategy of being the customer king. This strategy is particularly relevant for automotive suppliers which differentiate through being flexible regarding changing customer demands in different markets. The network type "local for local" is often chosen to operate this strategy. These idealistic strategy types are transformed into specific target systems in order to get an understanding of the importance of relevant target dimensions like cost, quality, time, delivery, flexibility or market access. The analytic hierarchy process (AHP) is used to determine the relevance of the target dimensions for each idealistic strategy [28].

4.2. Decision and complexity description models

Following the characterization of the strategy and the relating target system, and complexity dimensions are described.

Following the works of Olhager and Feldmann (2018) complemented by the SCOR model as a theoretical frame, the decision categories are the following [7,14]: plant role, organizational structure, IT, make-or-buy, supplier selection, production process, technology selection, short and long-term production, transfer pricing, distribution, capacity planning, timing of capacity planning, product allocation and continuous improvements. Each decision can be allocated between the two extremes network and plant level. With this allocation, the degree of autonomy of single production plants in global production networks is determined. (see Fig. 2)

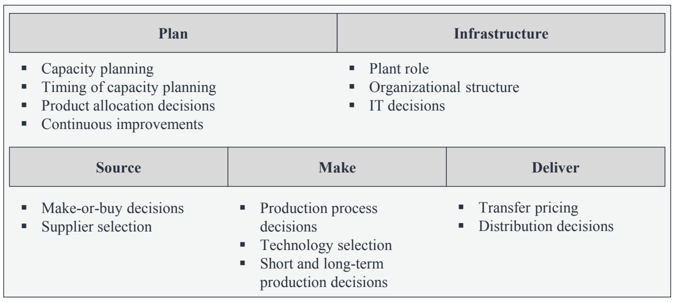

Fig. 2. Decisions and SCOR model

For determining the degree of complexity of different manufacturing environments in global production networks, a similar description model is developed. In this article it is differentiated between the internal and external complexity. Internally, there is a focus on the product complexity, products per production plant, process complexity, technology complexity and network complexity. Externally, the focus is on time, cost and quality pressure, competitor complexity, customer base complexity, demand complexity, globalization of customer base, supplier base complexity and supplier reliability. These dimensions were found to be the most influencing for the manufacturing environment of a company. Each complexity dimension is classified qualitatively by a morphological box with the intensities ranging from low (1) to high (5).

The aforementioned description models of strategy, target system, decisions and complexity serve as the basis for the upcoming impact models which use systems engineering [19] to connect the description models in order to detect interdependencies.

4.3. Impact models

Following the description models, several impact models are designed which make interdependencies between the basic dimensions transparent. By doing so, the technique of the paper computer is used which is suitable for solving complex problems with a dynamic environment [20,21]. First, the impact model considering decisions and the target system is described. It is called decision-target impact model (see Fig. 3).

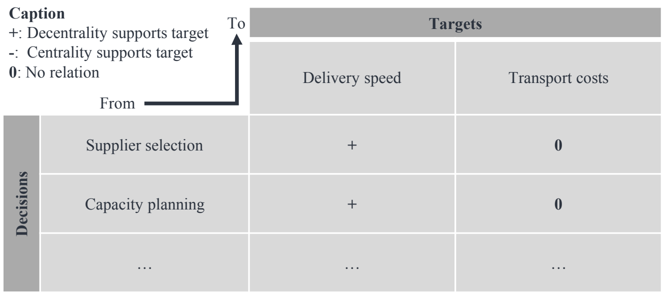

Fig. 3. Decision-target impact model

Here, the interdependency of an autonomy change of one decision regarding one target is analyzed. E.g. if the decision supplier selection is allocated from the network to the plant level, the target delivery speed can be achieved better. These interdependencies are relevant for the specific targets of single companies and single plants. By applying the paper computer technique, experts in workshops can judge the intensity in each grid in the matrix.

The second impact model considers the influence of complexity dimensions on the distribution of decisions. It is called complexity-decision impact model. Here, e.g. the growing complexity in the supplier base needs a more central handling of supplier selection due to high numbers and possible synergy effects. These relationships are analyzed for each dimension of complexity and decisions. Here, t-test for equality of means is used for validating the relationships based on empirical data coming from an international benchmarking project with a focus on the management of global production networks. In the benchmarking, the relationship of each complexity dimensions and each decision was analyzed. It serves as the data pool for the impact model. Complexity is modelled as independent variable, because the complexity is not focused for optimization. Decisions are modelled as dependent variable which can be adjusted in order to find the ideal fit of autonomy. Exemplary correlations between the complexity dimensions product quality, products per plant and the decisions supplier selection and capacity planning can be found in Fig. 4.

Caption
+: Decentrality supports decision
-: Centrality supports decision
0: No relation

From → To

		Decisions	
		Supplier selection	Capacity planning
Complexity	Product complexity	+	+
	Products per plant	-	+
	Supplier base complexity	+	**0**

Fig. 4. Complexity-decision impact model

4.4. Selection of the ideal distribution

In order to interpret the impact models, the specific target systems of a company need to be considered first.

For companies with a network-focused strategy, the decisions which are relevant for these network targets are prioritized for centralization. For companies with a plant-focused strategy, e.g. market-oriented companies, the decisions which are relevant for the plant's competitiveness are distributed to the plant. Other decisions with no correlation to the target systems are allocated based on the complexity-decision impact model. Here, the different correlations are aggregated for each decision and the ideal distribution is derived.

This ideal distribution fits the strategy of the company and adapts to the complexity of the manufacturing environment. The analysis needs to be done after each opening of a new production plant or when the complexity changes.

5. Application to industrial use case

The methodology for the strategy-oriented distribution of decision-autonomy in global production networks has been successfully applied to an industrial use case. For this purpose, a global production network from the automotive supply industry which produces electrical components for the interior has been analyzed. The analyzed production network consists of three production plants. One is located in Germany, the other two are located in Eastern Europe. In the beginning, all decisions are distributed at the plant in Germany which serves as headquarter and lead plant for the other two locations. The company's strategy concentrates on being customer king and being close to the customer by having production plants near automotive original equipment manufacturers (OEMs). Due to this, the targets delivery speed, flexibility and market penetration were considered to be the most important. Therefore, the competitiveness of the single production plants is important.

In the second step, the determination of the complexity and decision levels, several workshops were conducted. For the internal complexity, the dimension "products per plant" was used to categorize the plants, as this dimension has the highest impact on the target achievement in the company. Externally, the customer base and the supplier base were considered as relevant for the production plants. Internally, the plants in Eastern Europe were more complex due to several production lines and various products being manufactured. Externally, the Eastern European production plants were also more complex due to a large supplier base and different customers being located in Eastern Europe. Eastern Europe was highly frequented by incoming and outgoing logistics.

In the third and fourth step, the impact models were applied and combined to find the ideal distribution of decision autonomy. The strategic focus led to a shift of autonomy to the Eastern European plants based on the decision-target impact model. Further, due to the high complexity, more autonomy was considered to be ideal for these production plants based on the complexity-decision impact model. Only the decisions plant role, IT and organizational structure were found to be ideal in a centralized way. All other decisions with a strong focus on manufacturing and logistics were found to be ideal when distributed to the Eastern Europe plants. Therefore, the network needs to shift from a highly centralized to a more decentralized structure.

The industrial use case proves the usefulness of the methodology. It provides guidance for the task of finding the ideal distribution of decision autonomy in order to centralize or decentralize production decisions in networks. Motivated by the results of the methodology, the company considers to restructure their global production network in a more decentralized manner.

6. Summary and outlook

The objective of this paper was to present a methodology for the strategy-oriented distribution of decision autonomy in global production networks. The presented methodology includes a four step procedure which uses description and impact models in the areas of strategy, target system, decision and complexity in the interest of combining these dimensions to find the ideal distribution of decision autonomy. The achieved results help managers to find the sweet spot between autonomous production plants and a highly centralized production network which is managed by a single lead plant or headquarter. Furthermore, the results show that systems engineering and statistical analysis can be combined to supplement each other. In addition, causal relationships between the dimensions of strategy, target system, decision and complexity are elaborated. Future research activities will focus on a catalogue of measures to support companies in deploying the ideal degree of autonomy to show specific actions which increase the autonomy of production plants. Furthermore, production networks which need to be centralized will be assisted by other measures which support centralistic networks e.g. by implementing a data pipeline from each production plant to a headquarter for real-time access to relevant data [29]. In addition, future research can focus on determining new plant roles which have a distinction in the autonomy of each production plant and which should be reflected in regard to different network types.

Acknowledgements

The authors would like to extend their thanks to the German Research Foundation (DFG) for supporting the research project "Migration planning of global production networks" (LA-2351/ 45-1).

References

[1] Váncza J Production Networks. *2016 – CIRP Encyclopedia of Production Engineering*, pp. 1–8.
[2] Lanza G, Ferdows K, Kara S, Mourtzis D, Schuh G, Váncza J, Wang L, Wiendahl H-P (2019) Global production networks: Design and operation. *CIRP Annals* 68(2):823–41.
[3] Koren Y, Hill R (2010) *The global manufacturing revolution: Product-process-business integration and reconfigurable systems*. Wiley, Hoboken, N.J.
[4] Masoumi AH, Yu M, Nagurney A (2017) Mergers and acquisitions in blood banking systems: A supply chain network approach. *International Journal of Production Economics* 193:406–21.
[5] Lanza G, Treber S (2019) Transparency increase in global production networks based on multi-method simulation and metamodeling techniques. *CIRP Annals* 68(1):439–42.
[6] Mourtzis D, Doukas M, Psarommatis F (2012) A multi-criteria evaluation of centralized and decentralized production networks in a highly customer-driven environment. *CIRP Annals* 61(1):427–30.
[7] Olhager J, Feldmann A (2018) Distribution of manufacturing strategy decision-making in multi-plant networks. *International Journal of Production Research* 56(1-2):692–708.
[8] Wheelen TL, Hunger JD (2011) *Strategic management and business policy: Achieving sustainability.* 13th ed. Prentice Hall; Pearson Ed., London.
[9] Friedli T, Mundt A, Thomas S (2014) *Strategic management of global manufacturing networks: Aligning strategy, configuration, and coordination*. Springer Berlin Heidelberg, Berlin, Heidelberg, s.l.
[10] Lanza G, Moser R (2014) Multi-objective optimization of global manufacturing networks taking into account multi-dimensional uncertainty. *CIRP Annals* 63(1):397–400.
[11] Abele E (2008 ;) *Global Production: A Handbook for Strategy and Implementation*. Springer London; Guildford, Boulder.
[12] Brooke M (1984) Centralization and autonomy. *Public Admin. Dev.* 6(1):109–10.
[13] Maritan CA, Brush TH, Karnani AG (2004) Plant roles and decision autonomy in multinational plant networks. *Journal of Operations Management* 22(5):489–503.
[14] Zanon LG, Munhoz Arantes RF, Calache LDDR, Carpinetti LCR (2020) A decision making model based on fuzzy inference to predict the impact of SCOR® indicators on customer perceived value. *International Journal of Production Economics* 223:107520.
[15] Vereecke A, van Dierdonck R, Meyer A de (2006) A Typology of Plants in Global Manufacturing Networks. *Management Science* 52(11):1737–50.
[16] Schuh G, Potente T, Varandani RM, Schmitz T (2013) Methodology for the Assessment of Structural Complexity in Global Production Networks. *Procedia CIRP* 7:67–72.
[17] Perona M, Miragliotta G (2004) Complexity management and supply chain performance assessment. A field study and a conceptual framework. *International Journal of Production Economics* 90(1):103–15.
[18] Schuh G, Dölle C, Schmitz S, Koch J, Höding M, Menges A (2018) Data-Based Determination of the Product-Oriented Complexity Degree. *Procedia CIRP* 70:144–9.
[19] Haberfellner R, Weck O de, Fricke E, Vössner S (2019) *Systems Engineering: Fundamentals and Applications.* 1st ed. Springer, Cham.
[20] Probst G, Gomez P (1991) *Vernetztes Denken: Ganzheitliches Führen in der Praxis.* 2nd ed. Gabler Verlag, Wiesbaden.
[21] Vester F (1999) *Unsere Welt - ein vernetztes System.* 10th ed. Deutscher Taschenbuch-Verlag, München.
[22] Howell DC (2002) *Statistical methods for psychology.* 5th ed. Duxbury Press, Pacific Grove, CA.
[23] Young S, Tavares AT (2004) Centralization and autonomy: back to the future. *International Business Review* 13(2):215–37.
[24] Scherrer M, Deflorin P (2017) Linking QFD and the manufacturing network strategy. *International Journal of Operations & Production Management* 37(2):226–55.
[25] Mourtzis D, Doukas M, Psarommatis F (2012) Design and Planning of Decentralised Production Networks Under High Product Variety Demand. *Procedia CIRP* 3:293–8.
[26] Matt DT, Rauch E, Dallasega P (2015) Trends towards Distributed Manufacturing Systems and Modern Forms for their Design. *Procedia CIRP* 33:185–90.
[27] Ferdows K (1997) Making the Most of Foreign Factories. *Harvard Business Review*.
[28] Saaty TL, Peniwati K (2012) *Group decision making: Drawing out and reconciling differences*. RWS Publications, Pittsburgh, PA.
[29] Lanza G, Schuh G, Friedli T, Verhaelen B, Rodemann N, Remling D (2020) Transformation globaler Produktionsnetzwerke. *ZWF* 115(4):196–9.