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Procedia CIRP 120 (2023) 1059–1064

www.elsevier.com/locate/procedia

56th CIRP Conference on Manufacturing Systems, CIRP CMS '23, South Africa

Strategic fit in global production networks – A decision support model for strategic configuration of global production networks

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Abstract

The configuration of global production networks is a highly complex management task. It involves decisions like site selection, site specialization, and long-term investments. Entering new markets, securing resource access and realizing cost advantages are only examples for the vast variety of strategic motives overlapping in these decisions. However, current material bottlenecks, geopolitical risks, and restrictions due to COVID-19 are increasingly bringing risk mitigation into the focus of decision-makers. In practice, an optimal configuration of the network in line with the production strategy, which is referred to as strategic fit, is rarely considered systematically. Approaches from academia do provide a variety of decision support models. However, these either consider the production network very aggregated and qualitative and are thus limited in their explanatory power, or they only focus on partial decisions, which are only evaluated based on costs. The aim of this paper is, therefore, to provide a decision support model for the configuration of the production network in line with the production strategy. The model derives an optimal, company-specific configuration based on strategic capabilities that constitute both the production strategy and the internal and external company environment. The procedure comprises six steps and is divided into an as-is analysis and a target derivation. In the as-is analysis, the current configuration is first recorded with description models. Subsequently, current strategic capabilities as well as the company environment are captured. Based on this data, a fuzzy inference system assesses the actual strategic capabilities of individual plants and the entire network. The strategic capability gap forms the starting point for the target derivation. First, a strategically fitting network phenotype is selected to provide guidelines for further configuration. Then, capability-oriented design principles are used to further elaborate the phenotypes. Subsequently, the resulting alternatives are evaluated with a fuzzy-TOPSIS evaluation model.

Keywords: global production networks; network configuration, production strategy; strategic fit; decision support models

1. Introduction and motivation

In the past decades, an increasing number of companies of different sizes have decided to globalize their value creation and have built and organized new sites globally. [1] The emerging global production networks (GPNs) are characterized not only by the geographical distribution of individual production sites but also by high dependences between the sites. In this context, global material, information and financial flows enable the distribution of products, technologies and capacities within the network. [2] The physical design of the network with its sites and the allocation of production tasks to the sites is referred to as production network configuration. According to [2], the configuration can be divided into the decision dimensions *network structure*, *specialization of sites*, *allocation of resources* and *design of the internal supply chain* between the sites. In addition, further possibilities exist to divide the GPN configuration into dimension by various authors and shows the complexity and the interdependencies of the network configuration. Such configuration decisions usually include a variety of overlapping strategic motives, which can also change significantly over time. Large structural investments, strategic

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10.1016/j.procir.2023.09.125

paradigm shifts, and corporate acquisitions result in GPNs that are historically complex and prone to change. [3] Therefore, to ensure the competitiveness of the GPN, a strategic focus of the GPN is necessary. This hypothesis stems from the theory of strategic fit. [4,5] In the context of GPNs, it means the congruence of the network configuration with the strategy and the corporate environment. Therefore, constant evaluation of strategic decisions and continuous adaptation of the network is essential. [6] However, this strategic fit is complicated by disruptive events and uncertainties in the business environment, such as geopolitical tensions resulting in, e.g. decoupling scenarios or short-term supply risks challenging global supply chains. Therefore, the central research question is as follows:

Which global production network configuration fits which strategic goals under given company-specific influencing factors?

Overall, there are three groups of challenges in the configuration of a global production network as stated in fig. 1: first, the detail complexity, second, the hysteresis, and last, the analytical modeling of the decision task resulting from the detail complexity and hysteresis. [3,7]

The *detail complexity* originates from the sheer number and ambiguity of influencing factors. These factors can be divided into two groups, quantitative and qualitative factors. The development of new markets, cost savings by relocating a site to a low-cost country or also the relocation back to a high-cost country due to supply chain risks can represent quantitative influencing factors, even if they are partly contradictory. In addition, qualitative influencing factors exist, such as the skill level of the employees or the political situation in a specific country. These are difficult to quantify and compare in monetary terms. [8] Network configuration faces a highly volatile environment. The frequency of such unpredictable events has increased in recent years, making adaptability and resilience in the production network critical to success. Also, GPN decisions in practice involve several stakeholders, which may have diverging interests, making decision-making more difficult. [9,7] The second major challenge of network configuration is *hysteresis*. It describes the delay between the occurrence of a change in the business environment and the adaption of the configuration. In particular, the high-frequency and unpredictable changes and the change inertia of the GPN due to long-term structural investments represent an area of tension for the network configuration. [7] The third major challenge is the *analytical modeling* of GPN configuration as a decision problem. Making such decisions requires an adequate representation of uncertainty as well as tangible and intangible influencing factors. Multidimensional objectives and conflicting goals must be considered, too. Due to the size of the decision problem, analytical models must also provide a decomposition into sub-decisions regarding potential compound effects. Data acquisition and traceability of the solution path represent further modeling challenges. [10,7]

In order to answer the research question posed at the beginning, Chapter 2 first evaluates existing approaches to deriving a strategically fitting network structure and elaborates the research deficit. Chapter 3 shows the proposed decision model and describes each phase. Chapter 4 summarises the problem statement and solution approach as well as presents planned activities to validate the approach.

2. State of the art

To address the challenges in strategic network configuration, a large number of decision support models exist in the literature. The methodological procedure in the literature analysis follows [11]. The basis is provided by the literature review presented in [7]. Further papers were added through forward and backward search and finally filtered according to their relevance for strategic network design. In total, 23 approaches were identified as relevant for strategic network configuration. These can be divided into qualitative and quantitative models and into process-oriented and non-process-oriented models. The literature stream can be divided into process models, management frameworks and analytical models, as shown in fig. 2. The numbers in Figure 2 refer to the numbered approaches in Figure 3. The classification is not mutually exclusive as some approaches use a combination of models. Management frameworks and qualitative models. The following is a brief description of the most important representatives of each category.

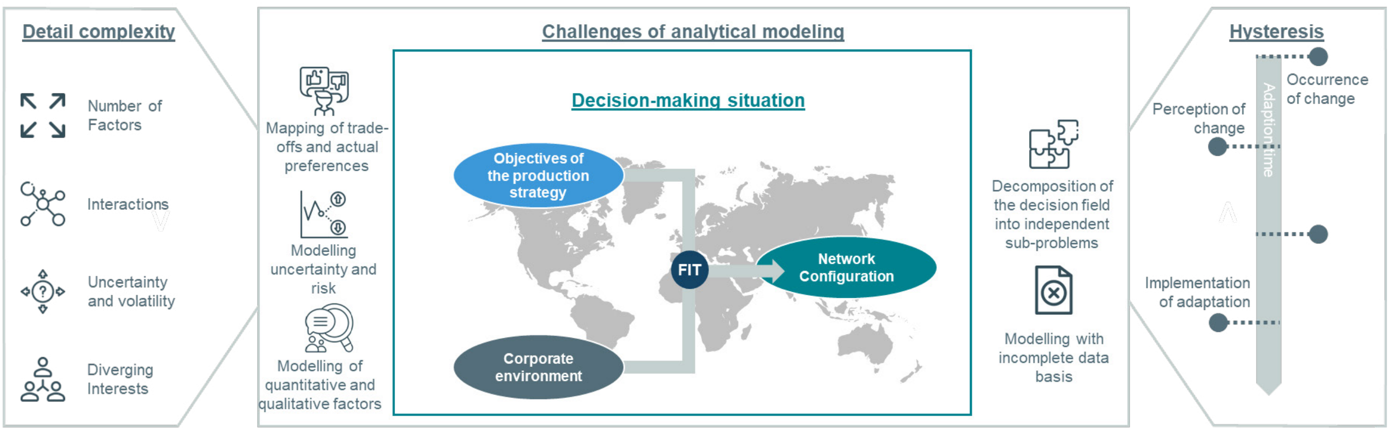

Figure 1: Decision task of the strategic network configuration and associated challenges

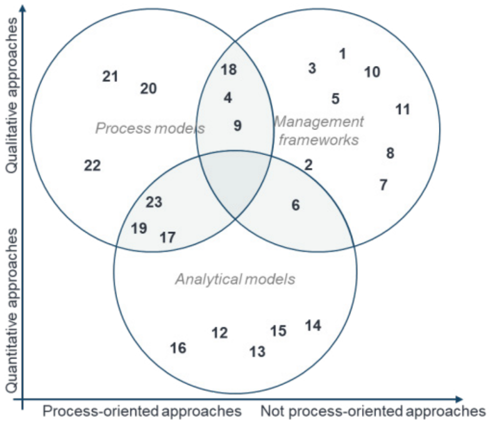

Figure 2: Categorization of relevant literature approaches

2.1. Existing relevant literature approaches

Management frameworks belong to graphical DSS. Through information aggregation and visualization, complex relationships can be easily represented. [12] develop one of the first frameworks for the design of GPNs. It combines two dimensions. The geographic network extent and the degree of coordination between distributed production sites. The framework visualizes seven generic configuration strategies associated with network capabilities. Each configuration is characterized by phenotypic network structures. [13] further develops the model by operationalizing coordination through the degree of adaptation of production activities to local requirements. [14] also examines the relationship between strategic capabilities and the three network structure types product-, process- and market-focused networks in the context of case studies. [15] and [16] address the connection to the corporate environment. [15] defines 8 structure types and relates them to the heterogeneity of the spatial and product environment. [16] derives footless and rooted networks from product and process complexity.

Simulation and optimization approaches are grouped under analytical models. [17] developed a multi-objective optimization model for the configuration of GPNs considering multidimensional future uncertainty from the business environment. The optimization model is then solved for each scenario. This is followed by the determination of the need and timing for a change in the network configuration, taking into account future uncertainties. [18] builds on this and uses dynamic optimization to develop robust migration paths. Further multi-objective approaches are provided by [19] with PROMETHEE and [20] with deterministic optimization.

Process models are characterized by a structured, step-by-step approach to configuration design. The approaches are oriented thereby predominantly at the phases of the decision-making, which vary between the approaches. Thus [21] offers an iterative approach with the four leading questions: "Why?", "What?", "Where?" and "How?". [22], on the other hand, divides their approach to the strategic and cost-appropriate design of GPNs into an identification, design and evaluation phase. [23], who also deals with the agility of GPNs, also divides his process model into three phases, whereby the second, explorative phase is supported by a simulation model.

2.2. Deficits of existing decision support models

The preceding explanations show that a large number of approaches to strategic network configuration already exist. However, existing approaches do not yet sufficiently address the challenges laid out previously. Fig. 3 summarizes the evaluation of the approaches as well as the research deficit.

Requirements
○ not fulfilled
◑ partial fulfilled
● sufficent fulfilled

Abbreviations
emp.=empirical, DES=Disrecte event simulation, MODM=Multi objective decision making, MILP=Mixed integer linear programming

		Decision elements of the network configuration				Elements of the strategic fit		Evaluation of the strategy fit		Recommen-dation for network decision		
		Network structure	Network specialization	Network resources	Internal supply chain	Network configuration & strategy	Network configuration & environment	Strategic fit conceptuation	Research method	Network phenotypes	Specific configuration	Systematic, strucutred approach
Approaches for strategic fit at the phenotype level (mainly management frameworks)												
1	Schmenner (1982)	●	●	●	●	○	○	Fit as Gestalt	emp.-quantiative	●	○	○
2	Shy und Gregory (1997)	◑	●	○	◑	◑	◑	Fit as Gestalt	emp.-qualitative	●	○	◑
3	Rudberg (2004)	◑	◑	○	○	◑	○	Fit as Match	emp.-qualitative	●	○	○
4	Harre (2006)	●	◑	◑	○	○	●	Fit as Match	emp.-qualitative	●	○	○
5	Abele et al. (2008)	●	◑	○	○	◑	○	Fit as Gestalt	conceptionell	●	○	○
6	Kouvelis et al. (2013)	◑	◑	○	○	●	○	Fit as Mediat.	emp.-quantiative	○	◑	◑
7	Thomas (2013)	●	●	●	●	◑	◑	Fit as Gestalt	emp.-qualitative	○	◑	◑
8	Ferdows et al. (2016)	●	●	○	○	○	●	Fit as Match	emp.-qualitative	●	○	○
9	Mengel (2017)	◑	◑	○	○	●	○	Fit as Match	emp.-qualitative	●	○	●
10	Pashaei & Olhager (2019)	●	●	●	○	◑	◑	n.a.	emp.-quantiative	○	○	○
11	Feldmann & Olhager (2019)	●	○	●	○	◑	◑	Fit as Gestalt	emp.-qualitative	○	○	○
Approaches for strategic fit at the network configuration level (mainly analytical models)												
12	Ude (2010)	◑	◑	●	○	◑	◑	n.a.	PROMTHEE	○	●	●
13	Liu & Papageorgiou (2013)	○	◑	◑	◑	◑	○	n.a.	MILP	○	●	◑
14	Moser (2014)	◑	○	●	○	◑	◑	n.a.	MODM	○	●	◑
15	Prinz (2016)	●	○	○	●	○	◑	n.a.	MODM	○	●	◑
16	Moser (2017)	◑	○	◑	○	◑	◑	n.a.	Dyn. Optimiz.	○	●	●
17	Sager (2018)	◑	○	◑	◑	◑	◑	n.a.	MILP	○	●	●
Approaches for practice-oriented process models for network configuration (process models)												
18	Miltenburg (2009)	◑	◑	◑	◑	◑	○	n.a.	emp.-qualitative	◑	○	◑
19	Varandani (2014)	◑	○	◑	◑	○	◑	n.a.	Genetic algorith.	○	◑	●
20	Rittsteig (2018)	◑	○	◑	○	○	●	n.a.	Regression	○	◑	●
21	Christodoulou et al. (2019)	●	●	○	○	◑	◑	Fit as Gestalt	emp.-qualitative	◑	○	●
22	Ays (2019)	◑	◑	◑	○	○	◑	n.a.	emp.-qualitative	○	◑	●
23	Auberger (2022)	○	○	●	●	○	◑	n.a.	DES	○	◑	●

Figure 3: Evaluation of relevant literature approaches

With respect to the considered *decision scope*, it shows that the approaches mostly consider only a subarea of the network configuration. In particular, the analytical models, due to their detailed and thus more complex modeling, usually pick out a partial decision such as investment in resources or the allocation of products. Management frameworks, in contrast, usually cover a larger scope, but this is at the expense of the depth of detail and thus support potential due to the reduction in complexity. Only [24] and the further development in [25] cover all partial decisions.

With respect to the *consideration of the strategic fit*, the existing approaches show considerable deficits. For example, network configuration often only partially considers strategy as well as the company-specific environment. In particular, soft, non-quantifiable factors such as access to skilled labor or learning ability are often neglected because causal relationships to network configuration are difficult to map. This is also reflected in the *evaluation of strategic fit*. Thus, qualitative models often refer to “fit-as-matching” or “fit-as-gestalt” (compare to [26]), which justify strategic fit by patterns that are frequently observable in empirics. Only [27] attempts to derive network configuration elements using a structural equation model (“fit-as-mediation”).

Regarding the *recommendation for network configurations*, process models mostly allow practice-oriented stepwise decision-making but are limited in their explanatory power.

Management frameworks usually focus on network phenotypes, whereas analytical models derive recommendations for action on a more tactical level of network configuration. This can result in inconsistencies between different aggregations levels. Only [23] considers different aggregation levels, but starts on a rather tactical view missing the interface to the strategic network configuration.

In sum, there is no approach that systematically derives a strategic GPN configuration based on strategic goals and company-specific environmental factors. With regard to the decision parameters, often only partial aspects are considered, but a holistic view is usually missing. In particular, the consideration of the strategic fit is insufficient. Intangible strategic goals and their interaction with decision parameters and einvoronemental factors are often neglected. Most of the approaches do not provided a decision support for deriving a target picture of the production network.

3. Decision support model for strategic GPN configuration

To address the research deficits, this paper proposes a decision-support model, which derives a strategically fitting network configuration based on strategic goals and the corporate environment. The procedure (depicted in fig. 4) is based on the strategic management process according to [28] and consists of a *status quo analysis* and a *target derivation*, which consists of 3 phases each. In the first phase, the current network configuration is analyzed and recorded using standardized description models. In phase two – also based on the developed description models – the target state of the strategic capabilities as well as the corporate environment are analyzed. The third phase of the status quo analysis is the quantification of the actual GPN performance in terms of strategic capabilities based on the information captured in the first two phases. The actual and target state of the strategic capabilities can then be compared to identify strategic miss-fits. Based on the gaps, the target derivation starts in phase four of the procedure and initially defines configurative guidelines with network phenotype. For this purpose, explanatory models are used, which express the interdependencies between strategy, network structure and environment. In phase five, the phenotype is developed into a company-specific configuration using network design principles. The resulting configuration alternatives are then evaluated with respect to monetary as well as qualitative terms to select the best configuration.

3.1. Analysis of the production network

In order to be able to identify and evaluate the relationships between strategy, environment and network configuration, a description model is used to capture the current state of the existing network. A distinction is made between the network and site perspectives in order to cover different aggregation levels. Therefore, the relevant partial decisions are identified. Subsequently, a morphological analysis is performed on the network and site levels, respectively, to extract descriptive elements. These are, for example, on the network level, the *plant specialization*, *material flow* relations between the plants, *connections* to the *sales* and/or *procurement markets*, as well as the *geographical distribution* of the plants. So overall a recording of network elements and the definition of the system boundaries of the design decision is performed.

3.2. Analysis of the strategy and environment

The production strategy is operationalized by strategic capabilities. Therefore, in step two the current capabilities at the network and site levels are recorded. A large body of literature already exists defining strategic capabilities. [29] For example, [2] defines strategic network capabilities as *market access*, *resource access*, *efficiency*, *learning ability* and *mobility*. In order to cope with current disruptive events such as supply bottlenecks, geopolitical risks and sustainability requirements by stakeholders and legislation, the description model is extended in particular to include aspects of adaptability and sustainability. Through the company-specific weighting of strategic capabilities, both actual and target states can be described. Discrepancies between actual and target states indicate the need for action in the network configuration and thus allow a targeted approach. Furthermore, strategic patterns or ideal types can be derived by combining weighted strategic capabilities.

In addition to the strategic capabilities, the identification and description of the corporate environment are essential and thus form the second aspect influencing the strategic network configuration decision (fig. 1). This consists of the external and the internal environment on the other. The latter consists (following [9]) of product and process characteristics and are factors that cannot be influenced from the network configuration point of view. Therefore, the factors of the external environment are particularly considered. According to

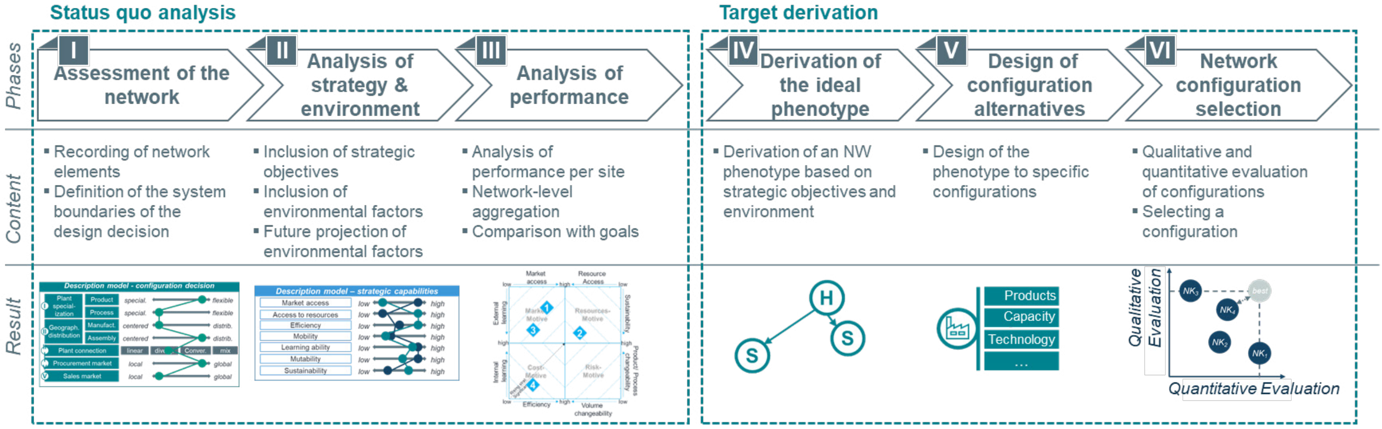

Figure 4: Proposed approach for strategic configuration of GPN

[3], the external environment can be structured into market factors, factor costs, logistics, political, legal, and cultural factors. Just like strategy and network configuration, the corporate environment can be described from a network and site perspective. Via degrees of heterogeneity and homogeneity (according to [15]), factors influencing the site level can be aggregated to the network level. Finally, future forecasts are developed based on the relevant environmental factors.

3.3. Assessment of the GPN performance

The evaluation of the network's performance follows a bottom-up approach, assessing the contribution to the strategic capabilities of each site and the whole production network. The evaluation is based on the concept of strategic fit. Here, it is also evaluated to what extent the previously described strategic capabilities are fulfilled by the given corporate environment and existing network configuration. To identify the causal relationships between these three elements, the method of networked thinking, according to [30] is applied. In this method, the interdependencies between the elements as well as their influenceability are examined. Fuzzy inference systems are used to quantify the strategic capabilities per plant. These allow conclusions to be drawn based on vague, fuzzy data and are, therefore, ideally suited for the mapping of strategic capabilities as there are mainly influenced by qualitative aspect. The basis for this is provided by the identified causal relationships and domain knowledge from experts. The site-specific scores are then aggregated into network scores using capability-specific weighting keys.

3.4. Derivation of an ideal production network phenotype

In this step, the goal is to derive the network phenotypes that fit the strategy and the corporate environment also using the concept of the strategic fit. These represent the starting point for a top-down strategy process. The phenotypes include the network structure, specialization of the sites, and the sales and procurement market strategy. They define the basic strategic orientation of the network and thus form guidelines for the further shaping of configurational decisions with regard to product allocations, capacities and technologies. This is operationalized by “fit-as-gestalt” and “fit-as-matching” [26]. The concept “fit-as-gestalt” serves for the aggregation of strategic skills to strategic patterns, configuration decisions to network phenotypes, and influencing factors to environmental patterns. The resulting pattern are then correlated in a “fit-as-matching” approach.

3.5. Detailed design of GPN configuration alternatives

Summarizing from the last steps, an ideal phenotype and a current network configuration are now available. These are now brought together by assigning a concrete role of the selected phenotype to each site of the current network. This can be systematically supported using site role profiles. Fixed design elements that cannot be changed by configuration are then identified. These are, for example, works council agreements, trade barriers, local content requirements or operating points of manufacturing facilities. In the next step, deviations between the ideal phenotype and the actual configuration are identified and analyzed, and measures to resolve the deviation are discussed. Finally, the phenotype is further detailed according to the preceding strategic analysis. These details cover, for example, the capacity of the products or used technologies. In line with the top-down approach, the deviations between the actual and target configurations of the strategic capabilities are now analyzed at the site level and measures are assigned to them. For this purpose, the design guidelines extracted from the causal relationships found at the site level in step 3 are used.

3.6. GPN configuration evaluation and selection

The goal of this last step is the evaluation of the resulting configuration alternatives and the selection of the best alternative. Since network decisions, as mentioned at the beginning, pursue a multiplicity of strategic motives equally, approaches of multicriteria optimization are applied. Since concrete decision alternatives are to be evaluated on the basis of a multiplicity of decision criteria, it concerns an approach from the range multi-attribute decision-making. Monetary as well as qualitative target values are used as decision criteria. Monetary target variables are decision-relevant costs such as production costs, hourly machine rates, material costs, transport costs, customs duties as well as one-time investments for relocations or expansions of production plants. The qualitative target figures are based on the description model of the strategic capabilities to enable a consistent evaluation throughout. The qualitative targets, such as market access, supplier availability or hedging against risks, are validated by expert interviews. Regarding the use of decision criteria as well as combinations, please refer to [7]. The target variables are quantified and aggregated using a fuzzy-TOPSIS approach and thus allow a ranking of the configuration alternatives. Fuzzy-TOPSIS could also be used to aggregate assessments from different decision-makers, reflecting decision-making in practice even better.

4. Conclusion and outlook

The strategic configuration of production networks is a major challenge for globally operating companies. Multidimensional target requirements resulting from the strategy, as well as the multitude and ambiguity of influencing factors, which furthermore behave in an increasingly volatile way, as recent events around Covid-19, the semiconductor crisis and the China-Taiwan conflict show, complicate a strategic alignment between network configuration, strategy and environment. But existing approaches do not assess the strategic fit in the GPN systematically. Especially, intangible factors are usually neglected, although they significantly influence competitiveness [8]. Furthermore, no model creates a consistent strategic alignment between network and site level.

Therefore, the objective is to develop a model to support the decision-maker in the strategic configuration of the GPN step by step. For this purpose, the current configuration, corporate environment and strategic goals are first captured at the site and network level. Then, the performance of the site or network is evaluated using fuzzy inference systems and compared with the objectives. Based on the gap analysis, appropriate design guidelines are derived in the form of phenotypes based on a strategic fit model on the phenotype level. With the help of design principles which also evolve from the strategic fit analysis on the site level, the user is enabled to derive a specific network configuration in line with strategy and environment. The chosen approach combines an analytical FIS model with a framework for strategic fit at the phenotype level through a 6-phase process model. The central element is the causal relations between network configuration, strategy, and environment, denoted as the strategic fit. The FIS models depict the causal relationships between configuration, strategic goals and influencing factors, which operationalise the strategic fit. Thus, compared to existing approaches such as [14,15,16], both the fit to the strategy and to the environment are covered. The detailed representation of each strategic goal enables dedicated recommendations for action to be derived for each configuration decision. This means that the the informative value is higher than in most of the presented graphical modells.

The validation of the causal relations will be done in a multiple-case-study design, according to [31]. A broad study is to be carried out to validate the status-quo analysis. One case from the status-quo analysis is to be continued within the target derivation (depth study). The findings from the case studies will be fed back into the sub-models by questioning existing causal relationships and identifying new ones. The process tracing method will be used to systematically work through the causal relationships. In this method, the causal chain leading to a decision is broken down into sub-elements. Empirically facts (e.g. data, interviews) are then assigned to the sub-elements.

Future research should consider the influence of current megatrends such as the circular economy, mass personalisation and cloud manufacturing. Here, [32,33] offers the first exciting investigations of how mass personalisation can influence strategic network configuration. Furthermore, it should be investigated to what extent the results from resilience and robustness studies such as [34], which take place on a more tactical level, can flow back to the strategic level in order to proactive prepare the network for future disruptions.

Acknowledgements

This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – 513193218.

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