Analyzing and optimizing international manufacturing networks – learnings from the field

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Abstract: International manufacturing networks have the potential to deliver a wide range of capabilities. However, sound structure and a systematic management approach are crucial to realize the full potential. In this article, we illustrate the applicability, strengths and weaknesses of various tools and methods to analyze and optimize international manufacturing networks. Based on a case study of a German specialty chemicals manufacturer with 19 sites worldwide, we outline procedure and identify critical success criteria for an analysis and implementation phase. The results of the research serve as an orientation for managers with similar challenges and as a foundation for further research.

Keywords: International Manufacturing Network, Global Production Network, Network Management, Network Optimization, Single Case Study, Framework

Analyse und Optimierung globaler Produktionsnetzwerke – Lehren aus der Praxis

Zusammenfassung: Globale Produktionsnetzwerke haben den Vorteil von einem breiten Spektrum an Fähigkeiten zu profitieren. Doch die richtige Gestaltung und Management ist entscheidend um das volle Potential zu schöpfen. In diesem Artikel wird die Anwendbarkeit sowie Stärken und Schwächen verschiedener Werkzeuge und Methoden zur Analyse und Optimierung internationaler Produktionsnetzwerke demonstriert. Am Beispiel eines deutschen Spezialchemieherstellers mit 19 Standorten, zeigen wir die Vorgehensweise auf und identifizieren wichtige Kriterien für die Analyse- und Umsetzungsphase. Das Ergebnis der Studie dient als Orientierung für Manager mit ähnlichen Herausforderungen und als Grundlage für weitere Forschung.

Stichwörter: Internationales Produktionsnetzwerk, Globales Produktionsnetzwerk, Netzwerkmanagement, Netzwerkoptimierung, Einzelfallstudie, Framework

1. Introduction

Since the late 1980s, manufacturing represents the single largest type of FDI in most countries (*Ferdows*, 1997; *Kogut*, 1989; *Yip*, 1989). These investments occur as greenfield investment or mergers and acquisitions. The main factors encouraging investments in the globalization of production activities include cost savings, market access or gaining specific competences (*Dunning/Lundan*, 2008). The pace of globalization has shifted the role of manufacturing companies from supplying domestic markets with products, via supplying international markets through export, to supplying international markets through local manufacturing. As the role has changed, the concepts of manufacturing systems have also changed, shifting from a plant focus to one on international manufacturing networks (IMNs) (*Rudberg/Olhager*, 2003). Accordingly, this development has had a significant impact on the future progress and profitability of a company (*Colotla et al.*, 2003; *Miltenburg*, 2009; *Shi/Gregory*, 1998). Since the late 1980s, the management of an IMN has become increasingly important not only in practice but also in theory, throughout the field of Operations Management (*Cheng et al.*, 2015; *Ferdows*, 2018). Thus, it has attracted the attention of multiple leading scholars, who have developed a number of frameworks to optimize the design and management of IMNs, as illustrated in Chapter 2.

The purpose of this paper is to analyze the structured application of various tools to optimize IMNs in a comprehensive case study and to elaborate on their applicability, strengths and weaknesses. The paper is organized as follows: Chapter 2 reviews tools and approaches to analyze and improve IMNs. The research methodology is described in Chapter 3. Chapter 4 describes the application of selected tools in the respective case. Chapter 5 provides conclusions, managerial implications and suggestions for future research.

2. Literature review

An IMN does not simply constitute an aggregation of individual production entities. The network is seen as an independent and complex system in which the sites interact and

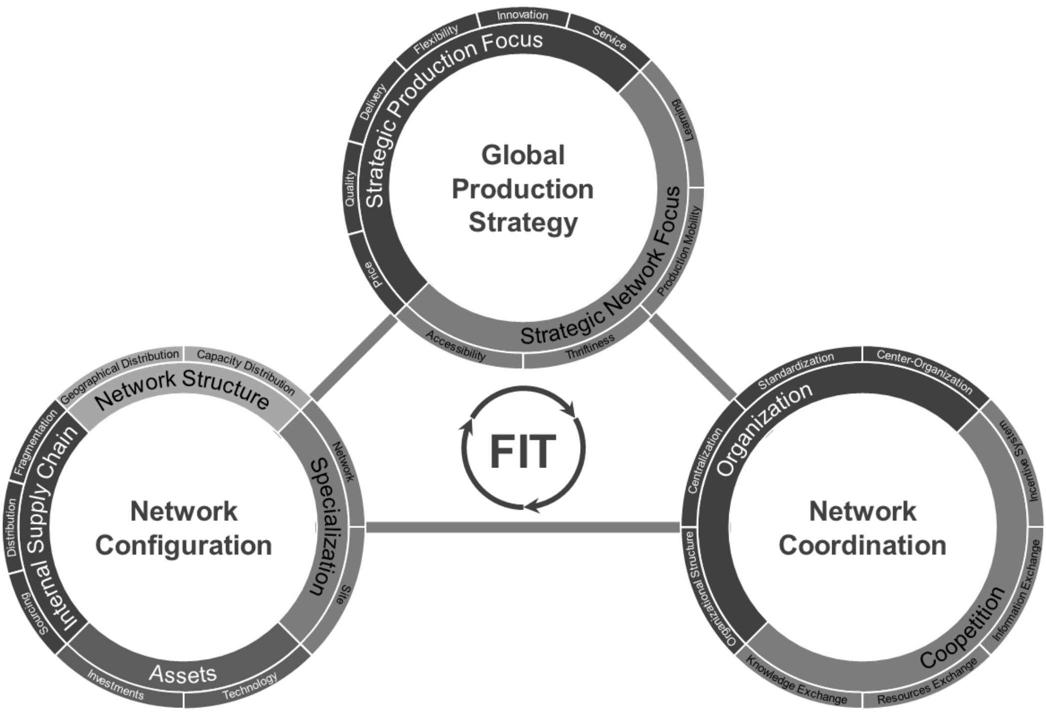

Figure 1: St.Gallen Global Manufacturing Management Model for optimizing global production networks. Reprinted from "Strategic Management of Global Manufacturing Networks", by *T. Friedli et al.*, 2014, Berlin Heidelberg: Springer, p. 46.

influence each other (*Shi/Gregory*, 1998). All entities within the network execute direct value-adding activities under a joint corporate strategy (*Lanza et al.*, 2019). In the course of globalization and the resulting global transformation of IMNs through offshoring, reshoring, restructuring, mergers, acquisitions, and divestments, the development of IMNs in most industrial cases has been evolutionary and to some degree accidentally rather than systematically driven. The resulting complex and inefficient structures have made it difficult for managers to successfully manage their IMNs (*Ferdows*, 2018; *Friedli et al.*, 2014). The literature provides numerous frameworks and tools to analyze and optimize an IMN. *Friedli et al.* (2014) provide an overview of various tools by consolidating them into the three fields of action: strategy, configuration, and coordination (see *Figure 1*) (*Miltenburg*, 2015).

2.1 Network strategy

The layer "Global Production Strategy" shown in *Figure 1* consists of two decision dimensions: Production strategy and network strategy. The production strategy, like other functional strategies, is derived from the corporate strategy. The production priorities to be supported therein are decisive for the framework, and essential for the market success of the company: price, quality, delivery, flexibility, innovation and service (*Friedli et al.*, 2014; *Miltenburg*, 2009; *Slack*, 2015; *Thomas*, 2013). The concept of production priorities is often used as a notation with both goals and objectives for manufacturing and for requirements demanded by the market (*Dangayach/Deshmukh*, 2001; *Wheelwright/Hayes*, 1985). According to *Hill* (1993), each of these priorities can be rated as "not relevant", "order qualifier", "critical order qualifier", "low priority order winner", "high priority order winner", or "highest priority order winner". Complementary to the production priorities, additional network priorities, or so-called network capabilities, can be realized on different levels, depending on how the network is configured and coordinated (*Colotla et al.*, 2003; *Jonsson/Rudberg*, 2014). *Shi and Gregory* (1998) propose four capabilities, which can be reached on a network level: accessibility, thriftiness, mobility, and learning.

The purpose of the "Global Production Strategy" layer is to identify the relevant production priorities and derive the necessary network capabilities. By means of the configuration and coordination layers, these network capabilities can be supported and coordinated, thereby supporting the implementation of the production strategy in the best possible way (*Friedli et al.*, 2014).

2.2 Network configuration

The configuration of the network describes the physical set-up of the individual sites and the network as a whole and includes (*Friedli et al.*, 2014): the network structure with the geographical allocation (*Abele et al.*, 2008; *Miltenburg*, 2009; *Shi/Gregory*, 1998) and capacity allocation of the sites in the network, and also the specialization and strategic site roles (*Feldmann et al.*, 2009; *Feldmann*, 2011; *Feldmann/Olhager*, 2013; *Ferdows*, 1997; *Maritan et al.*, 2004; *Schmenner*, 1982; *Vereecke et al.*, 2006; *Vereecke/van Dierdonck*, 2002; *Vokurka/Davis*, 2004).

Typologies of networks provide support for a reduction of complexity to make better decisions (*Ferdows et al.*, 2016). So-called 'site portfolios' offer another way to reduce complexity and make better configurational decisions. One example is the Mountain

Model by *Christodoulou et al.* (2007) which is intended to support the definition of site roles. *Friedli et al.* (2014) extend this model and complement both *Ferdows*' role model (1997) and *Feldmann and Olhager's* research on the classification of plant competences (2009). Another important approach in the IMN literature has been developed by *Ferdows et al.* (2016). According to them, today's manufacturing networks have to fulfill a wide range of strategic tasks that make design and management increasingly complex. Therefore, in order to reduce this growing complexity, the network should be delayered into smaller sub-networks.

2.3 Network coordination

The coordination layer covers the organization and management of the globally distributed activities in the network and is represented by the decision dimensions organization and coopetition. Among these are decisions on the autonomy of the sites (*Feldmann*, 2011; *Maritan et al.*, 2004; *Miltenburg*, 2005; *Rudberg/Martin West*, 2008), on the allocation of resources in the network, on the design of information and knowledge exchange between sites (*Mundt*, 2013; *Thomas*, 2013), and on incentive systems to promote the intensity of competition of cooperation in the network (*Bartol/Srivastava*, 2002).

Although many researchers are convinced that proper coordination of the network is an important part of optimization (*Cheng et al.*, 2011; *Fredriksson/Wänström*, 2014; *Rudberg/Olhager*, 2003), the topic has found less attention in the literature than network configuration (*Cheng et al.*, 2015; *Pontrandolfo/Okogbaa*, 1999; *Sayem et al.*, 2018).

2.4 Network fit and continuous improvement

The "network fit" can be divided into two different categories – internal and external (*Arogyaswamy/Byles*, 1987). The internal fit is achieved through the consistent alignment of the chosen strategy and structural as well as infrastructural elements of the network (*Hill/Brown*, 2007). External fit refers to the degree of alignment between a network's competitive environment and its organizational design, including the three layers of strategy, configuration and coordination (*Friedli et al.*, 2014). In order to remain competitive, the continuous improvement of network configuration and coordination is an important factor (*Cheng et al.*, 2015; *Colotla et al.*, 2003; *Friedli et al.*, 2014).

2.5 Research Gap

The literature review demonstrates that various approaches already exist to support the analysis and improvement of networks. Depending on the purpose and method, they have specific strengths and weaknesses and are also applied differently in practice. Hence, this paper aims to elaborate the applicability, strengths and weaknesses of the various tools and frameworks for analyzing and optimizing manufacturing networks.

3. Methodology

A descriptive, embedded single case study approach was selected for this paper because the topic is broad and highly complex, and a variety of data sources need to be included (*Eisenhardt/Graebner*, 2007; *Yin*, 2009). The benefit of this single-case approach is that information sources are more likely to be available, ensuring that certain information can be interpreted more reliably by contextualizing the descriptive data (*Edwards*, 1998). Additionally, the approach is particularly suitable for the examination of management-related tasks, as it is usually carried out in close cooperation with practitioners (*Amabile et al.*, 2001).

The research was conducted in a multi-plant intra-firm setting, focusing on one business unit (unit of analysis). The IMN of the business unit operates 19 sites worldwide. Two factors were crucial for the selection of the unit of analysis: a holistic analysis of the IMNs had not yet been conducted and the wide range of products with different customer requirements caused a high degree of complexity. The primary source of data in this paper are semi-structured interviews and workshops with the management team of all 19 sites. In addition to the management team, plant managers, experts and functional managers from the sales and product management departments were involved. Furthermore, we collected and analyzed data from site observations, questionnaires and publicly available information such as company reports. The gathered data was primarily used in the con-

	Strategy (4.2)	**Configuration (4.3)**	**Coordination (4.4)**	**Roadmap and PS (4.5, 4.6)**
Involved roles	▪ Vice President Operations ▪ Director Operations ▪ Head of Process Technology ▪ Product Group Manager ▪ Site Managers ▪ Technical Sales Manager	▪ Vice President Operations ▪ Director Operations ▪ Head of Process Technology ▪ Site Managers	▪ Vice President Operations ▪ Director Operations	▪ Vice President Operations ▪ Director Operations ▪ Head of Operations Excellence
Interviews	▪ 7 product group interviews ▪ 6 network capabilities interviews	▪ Questionnaire refining interview, ▪ 4 interviews to validate data		
Workshops	▪ Consolidation workshop	▪ Discussion of Site portfolio and definition of site roles	▪ Centralization & standardization, ▪ Information & knowhow exchange, ▪ Incentive systems	▪ Roadmap and PS
Additional data source	▪ Company reports, ▪ Publicly available information	▪ Questionnaires		

Table 1: Overview of data sources, involved roles and number of interviews and workshops

text of the management frameworks from *Friedli et al.* (2014), and other tools described above, to depict the current IMN status, and to discuss feasible optimization potentials. Workshops helped to validate the data and to derive the desired IMN target state. Results were verified continuously. The data was collected from June to October 2018. *Table 1* gives an overview of the data sources used, the procedures and the persons involved for each work package. This approach enabled a triangulation across and within methods, and therefore provided more informative, complete, useful and balanced research results (*Mathison*, 1988).

4. Process and Outcomes

4.1 Case: Specialty Chemical Products Manufacturer

The single case is a German manufacturer of specialty chemical products. The company mainly has grown through mergers and acquisitions. The project was part of a comprehensive restructuring program to improve the financial performance of the company. The aim was to align the structure and management of the business units according to the new circumstances in terms of efficiency and effectiveness. In addition to the As-Is analysis and the derivation of the target state, the company also emphasized the importance of defining a process that would enable it to carry out network optimization independently and regularly.

The company offers products along the whole value chain from raw materials up to entire system solutions, which requires a high degree of integration. Some production processes are highly complex and can endure several months. Accordingly, a high degree of individuality is offered to customers from about 35 different industries. The broad product range was already clustered into seven product groups.

4.2 Global Production Strategy

Thus, apart from volume flexibility and innovation, every item was considered "highest priority order winner" by at least one product group. In order to meet the varying requirements as much as possible, while keeping the complexity to a minimum, the network was subdivided into smaller units of analysis according to the framework suggested by *Ferdows et al.* (2016). Due to the great differences in production processes, technologies and customers, the sites were initially divided into a *raw material* and *post-processing* network. In addition, based on the varying production priorities within these networks, it was necessary to define comparable units of analysis by further subdividing them into sub-networks. As a result, the post-processing network was further subdivided into *mass production* and *small series* network. The raw material network was further separated into 4 sub-networks, one for each raw material produced. The subdivision was a crucial step as a baseline for the further progress of the project.

According to the identification of the main production priorities, the required network capabilities were defined for each of the six networks, within the "network capabilities" framework. Operation managers evaluated the capabilities in the categories of accessibility, thriftiness/efficiency, mobility and learning: rating each from 1 (not significant) to 5 (very significant) within an internal perspective. First, the actual situation was assessed. Subsequently, the possible target state for the fulfillment of the production priorities was identified. The deviation of this differentiation offered an important indication of the urgency to build or strengthen a particular capability. An exemplary comparison is illustrated in *Figure 2*.

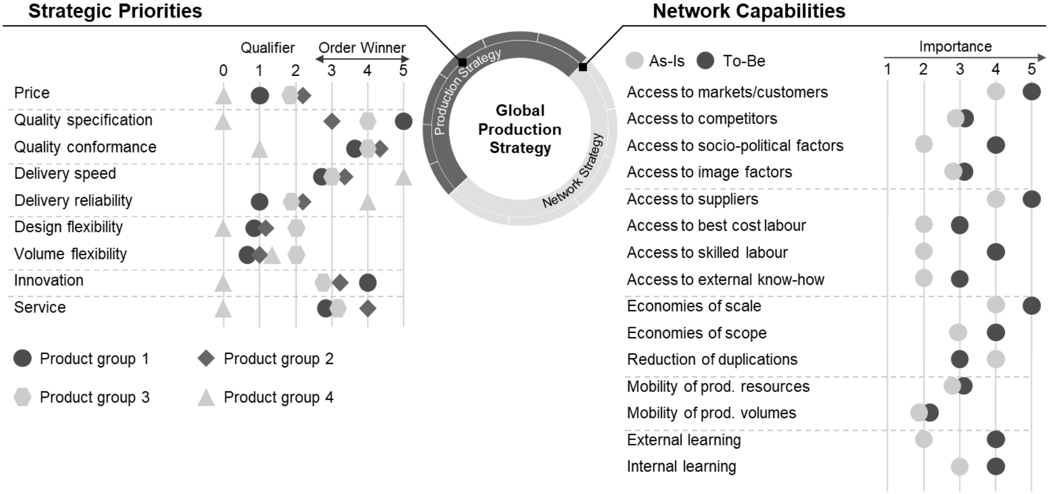

Figure 2. Production priorities and network capabilities. Adapted from "Strategic Management of Global Manufacturing Networks", by *T. Friedli et al.*, 2014, Berlin Heidelberg: Springer, p. 75.

This first initial individual qualitative assessment indicated capabilities with strategic gaps. Major concerns regarding finding and keeping skilled personnel as well as shifting capacity to more appropriate sites were identified. These are two issues that some multinational companies and researchers have also been dealing with in recent years (*Dunning*, 1998).

4.3 Network Configuration

In order to depict the current network structure in more detail and to stress the implications of the product group interviews, a questionnaire for the sites was developed jointly with the operations management. Based on the results of the first layer, the performance dimensions for the evaluation of site competencies were determined. The focus of the evaluation was mainly on product competencies, process competencies and knowledge sharing.

The questionnaire was filled out by the site managers, with five completed questionnaires for the raw material network and 14 for the post-processing network.

4.3.1 Site Portfolio

Based on the data from the questionnaire, a site portfolio for each sub-network was created for further discussion of the network structure. The Site Portfolios represent the current situation. They offer the greatest possible transparency, consolidate important information in one picture and simplify the discussion of different actions or optimization scenarios. *Figure 3* illustrates an example of one of these site portfolios for a subnetwork. The first dimension, the edges of the framework, visualize the strategic site objectives proximity to market, a site's mission is to provide access to a local or regional market, access to low-cost, a site's mission is to provide access to low factor costs and access to skills & know-how, site's mission is to provide access to know-how (e.g. access to educated workforce, proximity to excellence clusters or universities). A possible combination of two goals can be depicted in the corresponding intermediate areas.

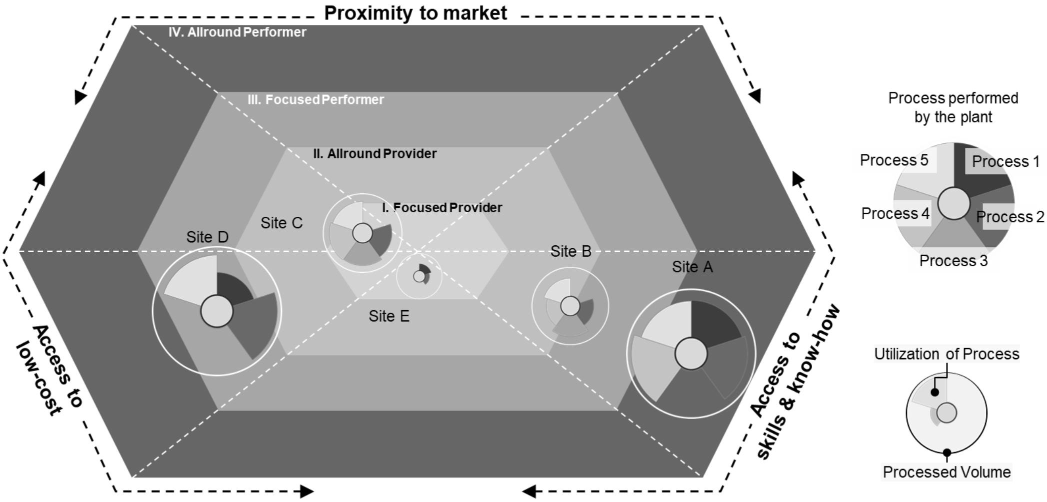

Figure 3: Site portfolio. Adapted from "Strategic Management of Global Manufacturing Networks", by *T. Friedli et al.*, 2014, Berlin Heidelberg: Springer, p. 94.

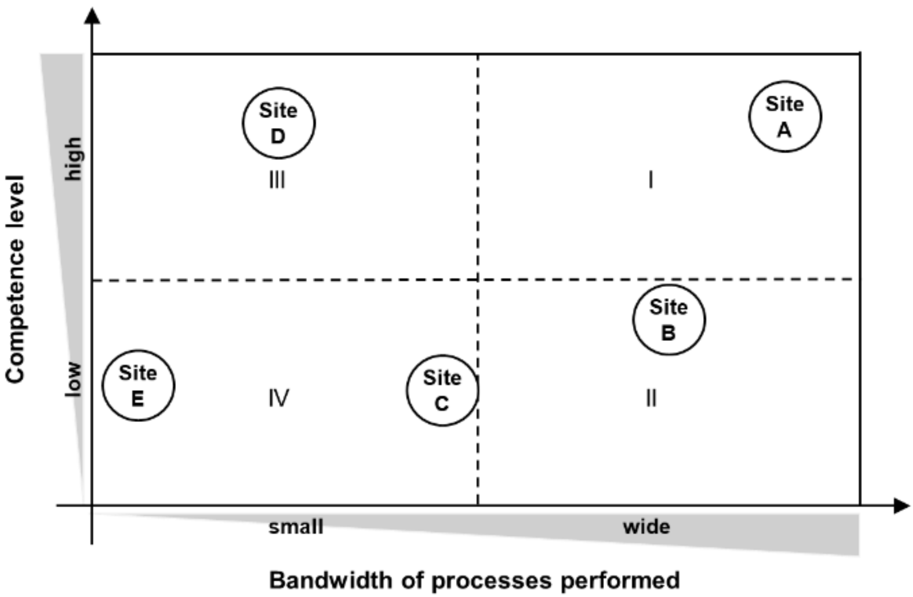

Figure 4: Classification of site competencies. Adapted from "Strategic Management of Global Manufacturing Networks", by *T. Friedli et al.*, 2014, Berlin Heidelberg: Springer, p. 94.

The site competencies are represented by the concentric levels and allow a classification of the sites into four types: I. focused provider, II. allrounder provider, III. focused performer and IV. allrounder performer. These types are determined by the matrix shown in *Figure 4*. The x-axis represents the bandwidth (the number of processes performed on each site) and the y-axis, the average competence level of processes currently performed at the respective location. In addition to the positioning within the framework, the size and content of the indicated circle provide important information. The diameter of the circle marks the annual production volume. The pieces representing the individual process steps available and its size indicate the percentage of utilization of each performed process step.

Various scenarios per network were discussed in joint workshops with global operations managers based on the existing site portfolios and additional information from the questionnaire. During these workshops, several necessary strategic implications were identified. For cost-sensitive product groups, it was intended either to relocate processes to a plant with access to low-cost factors or to consolidate processes to increase economies of scale. The importance of developing and strengthening sites with strategic access to skills and knowledge became explicit. New potential sources were also identified to strengthen know-how by exploiting external sources of knowledge (universities, technology hubs, etc.). The need to strengthen market proximity was decided for a specific product group due to the rapidly growing regional market demand. For sites reaching the limits of their capacity, it was concluded that, depending on expected growth and suitability, the production units should be modernized or expanded. In order to increase the level of competence and to be more independent from suppliers, it was decided to integrate specific outsourced production steps into one site. Furthermore, the position and characteristics of potential new greenfield investments could be defined.

The strategic implications were visualized in new site portfolios, which defined the intended new network structure. To implement and strengthen the positioning of the individual sites in the new structure, site roles were defined. Three different roles are defined based on the strategic rationale, competencies and scope. *Emerging plants* represented focused providers or all-around providers. *Competence plants* represented focused performers or all-around performers supporting emerging plants. *Lead plants* represented all-around performers with access to skills and know-how. They have dedicated process engineering resources to support emerging sites, organizing regular exchange between all sites, and are preferred for a new product or, process implementations.

4.4 Network Coordination

Based on the results from the layers of strategy and configuration, the decision was made to focus on the areas of *competence teams*, *centralization/standardization*, *knowledge and information sharing* and *incentive systems*. Each of these were addressed in joint workshops with identical procedures: first, the content to be discussed was agreed upon (within certain areas), then the current state was described and analyzed, and the target state was derived.

4.4.1 Operations Lead Teams (OLT)

The Lead Team provides a platform to foster knowledge exchange across networks and value streams. This ensures the systematic sharing of best practices, problems, challenges, or process and technology knowledge across sites. During the project, one OLT for the whole network was defined. The team also has the responsibility to develop and implement processes and systems to achieve the highest quality and efficiency. The team is led by the network manager, and team members are composed of specialists from the individual locations, depending on the project content. Exchange meetings take place at least twice a year.

4.4.2 Centralization and Standardization

The centralization and standardization framework enables the determination, discussion and adjustment of autonomy in the production network based on the dimensions of centralization and standardization.

Figure 5 shows the framework. The x-axis represents the standardization, and centralization is shown on the y-axis. The items marked represent different subject areas from the fields of systems (1–12), decisions (13 and 14) and processes (15–34). Due to sensitive data, it is not possible to name the actual topics here. A detailed description of the framework with exemplary topics are described by *Friedli et al.* (2014) on page 120 ff.

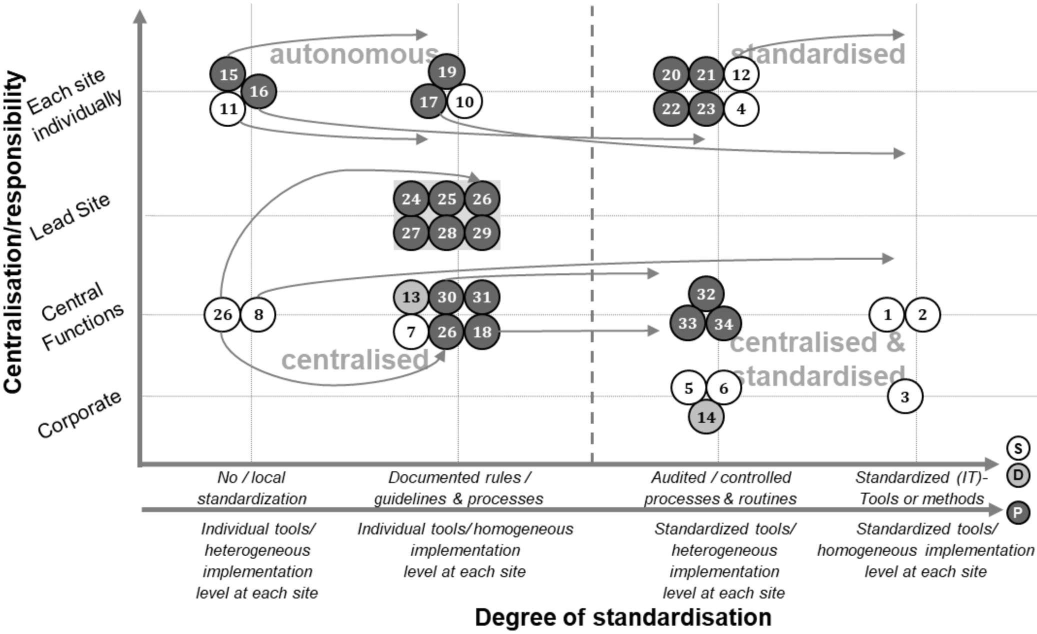

Figure 5: Standardization, centralization framework. Adapted from "Strategic Management of Global Manufacturing Networks", by *T. Friedli et al.*, 2014, Berlin Heidelberg: Springer, p. 117.

The framework shows the actual state and the intended target state (arrows), which supports the strategic implications as well as possible. The optimal design depends strongly on the prevailing conditions and the management philosophy. During a joint workshop with global production managers, it was decided that cross-site issues should be organized centrally, while individual issues should be organized in a distributed fashion. The responsibility of the lead plants for processes 24–29 was also defined in this framework.

4.4.3 Knowledge and Information Sharing

One of the main strategic issues of the company is insufficient skills and know-how. In this case, the framework is very suitable for the design of a functioning information and knowledge network. Different information and knowledge from categories of *external information*, *internal information* and *know-how* can be positioned based on an assessment of their exchange structure and the degree of availability in the network. The exchange mechanism can also be supplemented. Figure 6 shows the result of the completed framework for external information, which has been filled out during a joint workshop with global production managers.

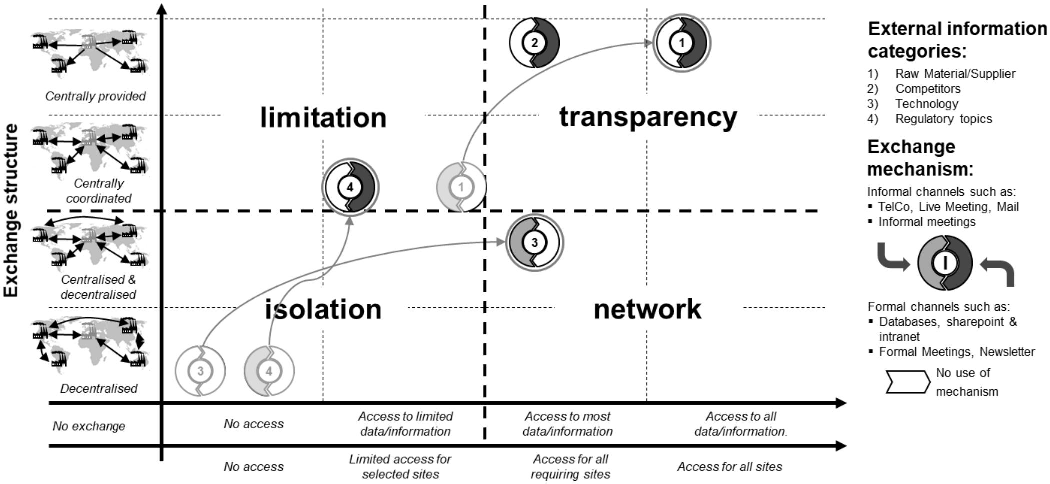

Figure 6: Information sharing framework. Adapted from “Strategic Management of Global Manufacturing Networks”, by *Friedli et al.*, 2014, Berlin Heidelberg: Springer, p. 138.

In conclusion, most of the topics aim at a mostly centralized, transparent exchange of product and process knowledge. This encourages the development of know-how and skills but also reinforces a common network thinking.

4.4.4 Incentive System

In order to further strengthen the common network thinking, a supporting incentive system was defined in a joint workshop with global production managers. Thus, sub-network-wide goals were defined for conversion costs, production fulfillment, lead time, successful relocation projects and others which are rewarded with financial compensation in equal shares among the sites. Due to the many sub-networks, it is particularly difficult to encourage a high level of common network thinking. With the actions taken in terms of coordination, collaboration is strengthened in the most appropriate form.

4.5 Roadmap

All actions and implications were documented, described, divided into work packages and the interdependencies and interactions identified. To prioritize the work packages, the potential benefits and the expected effort were evaluated in a joint workshop with the global production managers attending.

Based on the results, a roadmap for the implementation of the new network design and management was developed.

4.6 Production System

The company has a production system consisting of six elements: "Strategic Alignment and Objectives", "Organizational Set-Up", "People and Performance Culture", "Performance Management", "Shopfloor Management" and "Methods and Tools". In order to give sufficient priority to the network issue and to enable regular independent network optimization, it was decided to embed parts of the tools and approaches into the system. Manufacturing and network priorities, target site portfolio, site role development, centralization/standardization, knowledge and information sharing, and incentive systems were integrated in the subitem "Strategic Alignment and Objectives".

5. Conclusions

The purpose of this study was to improve the understanding of the analysis and design of international manufacturing networks in today's complex manufacturing context, by applying different tools and methods and elaborating the fit. It is not always obvious under which circumstances certain tools are helpful. The applicability, strengths and weaknesses of the tools and frameworks used are summarized below to assist in the selection process:

- *Production Priorities and Network Capabilities*: These two frameworks are very well suited to determine and map the differentiators and the necessary network capabilities. They are particularly valuable when the company aims to restructure after acquisitions. The basic prerequisite is a well-founded business strategy, which is given in the case. However, a detailed strategy discussion based solely on the two frameworks is inappropriate. Considering the elements elaborated by *Kulkarni et al.* (2019), which are crucial for a production strategy, we can see that the two frameworks are not sufficient to conduct a fully comprehensive strategy discussion. It is also worth mentioning that production priorities and their dimensions keep changing over time. Hence, it is important to both modernize and identify new operations capabilities that serve the current competitive environment more efficiently (*Sansone et al.*, 2017)
- *Delayering the network into congruent subnetworks*: According to *Ferdows et al.* (2016), today's manufacturing networks have to fulfill a wide range of strategic tasks, which makes design and management increasingly complex. Therefore, in order to reduce this growing complexity, the network should be structured into smaller sub-networks. This approach was integrated to the case described. The networks were first divided according to production technologies and then according to customer requirements.
- *Site Portfolio*: The site portfolio comprises the four different dimensions or elements: strategic sites objectives, site competencies, annual production volume per site and

available process steps per site. They offer transparency, consolidate important information into one picture and enable a qualitative discussion of different network structure scenarios. However, they are not very easy to read and data quality and accessibility of production-related KPIs are required from all plants in order to enable the comparison of process competencies and performance across plants.
- *Site Roles*: In the course of the case study, we focused on three different roles to implement and strengthen the positioning of the individual sites in the new structure.
- *Operations Lead Teams (OLT)*: Lead teams or OLTs are appropriate to provide existing know-how and skills to the whole network. They tend to increase overhead costs but companies should still make use of them if, as in our case study, they rely on knowledge but have difficulty finding and retaining skilled staff.
- *Centralization & Standardization*: This framework is particularly well suited for this project because the company has grown through various mergers and acquisitions and required restructuring. Additionally, it helps to reduce the complexity due to the many sub-networks and to avoid unnecessary organizational duplication.
- *Knowledge & Information sharing:* Due to the main issues of the analyzed company, including lack of skills and know-how, it is absolutely necessary to exploit the existing knowledge as much as possible. This framework enables the development of a structured exchange of information very well.
- *Incentive Systems*: The division into many subnetworks can make it difficult to develop a common understanding of the network. This can be counteracted through the selective use of incentive systems. Unfortunately, there is no detailed information on which systems are particularly beneficial under certain circumstances.
- *Production Systems*: The approach from *Friedli et al.* (2014) lacks guidance on how to use existing frameworks and tools for the purpose of continuous improvement. The company in our case study maintains a production system. In this context, we decided to integrate the tools used in order to give sufficient priority to the network issue and to enable a continuous network improvement.

The study also demonstrates that the tools are not just an end in themselves. By combining different approaches, it is possible to optimally adapt the analysis and improvement of the manufacturing network to the given conditions and issues. Results based upon a single case study, and thus the generalizability of the findings, are limited. For further research, it is recommended to combine and apply further approaches, including those from different industries. Issues that could not be integrated in this study, but are covered by other approaches, include dealing with uncertainties and risks (e.g. *Lanza et al.*, 2019) and integrating cultural aspects (e.g. *Arellano et al.*, 2020).

Finally, many of the tools used in this study are based on qualitative assumptions and are therefore only as accurate as the assumption itself. Especially for the strategic implications derived in chapter 4.3.1, because capacity expansion, back sourcing and greenfield investments, using quantitative analyses and simulations could lead to more reliable results.

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