Management of international manufacturing networks – a site portfolio approach

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Abstract

Management and design of International Manufacturing Networks (IMN) is becoming an increasingly complex but at the same time important factor for business success. Our research encounters the lack of tools and methods supporting managers in the process of network adaption by providing a portfolio perspective on intra-manufacturing networks. Through an extensive literature analysis and practical input, we derived an artefact with financial performance and strategic performance as relevant dimensions. The case of an automotive supplying company operating more than 40 plants proves the proposed portfolio as applicable and validates that it is a valuable management support framework.

Keywords: IMN optimization, IMN performance, plant comparison

Introduction

Management and design of International Manufacturing Networks (IMN) is becoming increasingly complex but at the same time important to secure business success (Olhager *et al.*, 2015, p. 138). The dynamics of external changes result in increasing pressure for companies to optimize their IMN (Cheng *et al.*, 2015, p. 411; Bartlett and Ghoshal, 1989). Managers need guidelines and tools which support this requirement of constant IMN adaption (Cheng *et al.*, 2015, p. 413).

Improving overall performance of manufacturing networks requires a holistic perspective (Friedli *et al.*, 2014). In practice, however, decisions within the domain of IMN management frequently lack a comprehensive concept. For example, the sole focus on cost is the major driver for offshoring decisions (Johansson and Olhager, 2017). However, the effects of such one-dimensional decisions are not limited to the aspect of cost but affect the overall network in a number of ways. As a result, expectations are frequently not met and reversing the offshoring decision is a common occurrence (Stentoft *et al.*, 2016; Kinkel and Maloca, 2009).

In opposition to practice, research on IMN optimization addresses a strategic perspective (Ferdows, 2014). Several scholars consider interdependence among plants as well as between plant and network level (Cheng *et al.*, 2011; Colotla *et al.*, 2003; Scherrer-Rathje *et al.*, 2014; Feldmann and Olhager, 2013; Thomas *et al.*, 2015). While those findings focus on a strategic perspective of plant and network relation, it does not integrate an operational view. Ferdows (2014, p. 2) also recognizes a gap between existing research on IMN offering "broad and policy-level perspectives and operational guidelines for how multinationals should ensure their global production network evolves in line with their business strategy."

Therefore, it is the objective of this research to link the strategic perspective from existing literature with an operational perspective frequently applied in practice and to introduce a multidimensional and multilevel approach to IMN optimization. Kaplan and Norton (1996, p. 21) state, "If you can't measure it, you can't manage it." Though management of IMN clearly falls within the scope of this statement, measures and performance determination are not widely discussed in IMN literature. Cheng *et al.* identify the need for further research to elaborate performance dimensions for IMN and to implement those in a comprehensive performance measurement system (Cheng *et al.*, 2015, p. 410)

Consequently, this paper is dedicated to answer the following question: What performance dimensions are relevant for managing IMN? Since our research aims to provide guidance in the process of IMN optimization, it is the purpose to answer a second question: How can a site-portfolio integrating these performance dimensions be designed to support the optimization of IMN?

The remainder of this paper is structured as follows: First, the results of a literature review on performance dimensions in IMN are presented. Second, we introduce the design for a site-portfolio based on finding from literature. Third, we demonstrate the application with a case study and discuss the findings as well as implications. Finally, we conclude with a summary and an outlook on further research.

Literature review and research framework

The famous Sir Isaac Newton is frequently quoted stating "If I have seen further, it is by standing on the shoulders of giants". The sapience traces back to Bernard of Chartres stating "Nanos gigantum humeris insidentes" which translates as "discovering truth by building on previous discoveries" (Keith *et al.*, 2016; Prioreschi, 2003). Both statements entail a message that sustains for this paper: The utmost importance of rigor within the scientific process. Scientific work is mainly perceived for its relevance and topicality, however the derivation of any insight ("seeing further") must be substantiated on a rigour methodology. To provide a sound groundwork for our conceptual implications a literature review will help us to "reconstruct the giant" of existing knowledge.

Design

We deploy a five-step literature review methodology designed by vom Brocke *et al.* (2009, pp. 8–12). Initially, a taxonomy provided by Cooper (1988) serves as basis to define the review scope. Cooper (1988) classifies the scope of literature reviews according to focus, goal, organization, perspective, audience and coverage. According to this classification, we focus on research outcomes, theories and models covering performance measurement and management in global production networks. We aim to provide a representative coverage of previous research and address scholars as well as practitioners in operations management.

The second step constitutes the topic conceptualization (vom Brocke *et al.*, 2009). We formulated working definitions to structure the topic a priori. Therefore, our research integrates the performance definition by Neely *et al*. They distinguish performance measurement "as the process of quantifying the efficiency" (Neely *et al.*, 1995, p. 80) and performance measure "as a metric used to quantify the efficiency and/or effectiveness of an action" (Neely *et al.*, 1995, p. 80). Regarding the topic of manufacturing networks, we follow the operations strategy perspective of Rudberg and Olhager (2003). We focus on intra-firm networks consisting of multiple sites operated by a single organization. Combination of both, the perspective on performance and network management sets the scope we aim to address.

Finally, we conducted a literature search based on 12 keyword combinations in two databases. The analysis includes publications from 1985 to 2017. Furthermore, we ensured relevance by limiting the findings to the fields of economics, operations management and production engineering. A forward and backward search added further publications that qualified for an extensive evaluation.

Results

In total, we identified 41 sources of mainly high topicality and relevance. More than half of the sample was published after 2010 with around a third of publications even younger than three years. The majority (35 out of 41) of publications are peer reviewed journal papers. Three PhD theses and books each complete the literature body.

The identified sources offer a variety of approaches to performance measurement and management in IMN. We observe three dominant clusters of performance categories within the literature: Operational performance, network performance and financial performance.

Sources in the operational performance cluster mainly focus on a plant-level analysis. Operational performance measures trace back to the 1960s when cost was the most commonly deployed performance dimension (Hon, 2005). Later in the 70s and 80s among others productivity, time or flexibility extended the set of competitive priorities. Defining authors were for example Skinner (1969), Hayes and Schmenner (1978), Hayes and Wheelwright (1984), Roth and van der Velde (1991) or Ward et al. (1998). Neely *et al*. (1995) state in an often-cited article that scholars use competitive priorities to assess performance of the manufacturing task. Miltenburg (2005) echoes on this and describes the concept as "six strategic outputs provided by a production system in a factory […] and they are called the factory manufacturing outputs." Friedli *et al.* (2014) provide an up-to date description of the relevant dimensions: The first dimension is price or cost which is either defined as the price a manufacturer can sell a product at the market for or the costs which accrue to meet customer expectations. Product quality and specification reliability are the defining attributes for the dimension quality. Flexibility builds upon the range of products a company is able to produce next to design flexibility and the flexibility of order volume. The dimension service refers to product related services where the last dimension, innovation, is a proxy for solutions for products and processes. An extensive set of KPIs to operationalize theses dimensions can be found at Hon (2005).

Miltenburg (2005) as well describes a more recent concept to assess IMN performance stating that "[a] manufacturing network provides four additional strategic outputs. They are accessibility, thriftiness, mobility, and learning [...] and they are called the network manufacturing outputs." The concept traces back to the research efforts of the University of Cambridge with a pioneer article of Shi and Gregory (1997) who advanced the concept of competitive priorities and developed a concept of "global competitive capabilities."

These capabilities, from now on referred to as network capabilities, provide an opportunity for holistic IMN assessment. Consequently, this research stream can be referred to as network-level analysis or macrolevel-perspective in opposition to the microlevel-perspective deploying competitive priorities. Friedli *et al*. (2014) provide a comprehensive set of network capabilities developed in prior research: Accessibility, thriftiness, mobility and learning. The dimensions divide into several subcategories. Accessibility for example describe the access to markets and customers, image factors, competitors, socio-political factors, resources like suppliers, raw material, low-cost labour, skilled labour and finally external sources of knowledge. Thriftiness or cost-effectiveness/efficiency bundles the advantages an IMN obtains by maintaining economies of scope and scale and by avoiding redundancies by concentration of business processes. The network capability mobility consists out of two dimensions: mobility of products, processes and personnel and mobility of volume. The learning ability can be divided into internal learning and external learning.

The third identified performance cluster, financial performance, emanates from the classical accounting and controlling research in business administration and economics. This cluster complements, specifies and operationalizes both the operational and network performance cluster. Measures for financial performance of production networks are manifold. Knight and Bertoneche (2001) distinguish four kinds of financial performance measures: Profitability measures (e.g. ROS, ROA, ROE), efficiency metrics (e.g. asset turnover, days sales in receivables, inventory days), financing measures (e.g. debt ratio, debt equity ratio, leverage, times interest earned) and liquidity measures (e.g. current ratio, cash cycle days). Profitability measures offer three general benefits. They assess a company's ability to obtain more revenue than expenses and secondly, indicate the company's ability to satisfy shareholders, which involves both a statement about financial health of the cooperation and shareholder value. The last but in our case the most important advantage is that they are a proxy for value creation and show how competitive positions of a firm according to their competitive priorities and network capabilities translate into profit margins (Bertonèche and Knight, 2001).

Combining Concepts

We propose a framework building on network capabilities and financial performance representing manufacturing sites as integral entities of IMN (see Figure 1). A network itself achieves superior performance in comparison to the aggregated performance of the single entities (Shi and Gregory, 1998). This holistic aspect of IMN performance assessment needs to be incorporated in specific IMN measures. Cheng *et al.* (2015) state that IMN performance needs to be assessed with measures that are specific, multi-dimensional and cross-functional. The concept of network capabilities incorporates such network effects. Adequately represented in this concept is the site role of a plant (cf. Ferdows, 1997). For example, a factory that is strategically positioned in a high-cost country in Western Europe may account for higher costs than a plant in Eastern Europe but can still maintain a significant position for the company to acquire access to markets or access to skill, etc. This additional perspective allows a derivation of long-lasting decisions that implement strategic targets. We earlier referred to the current reshoring debate, which may very well emanate from the negligence of these nonfinancial aspects. The scarcity of suitable KPIs to quantify network capabilities is a challenge (Mengel, 2017). Furthermore, depending on the firm strategy and situation, not all network capabilities are equally relevant and additional factors should be included. Therefore, we propose a three-step approach to develop a strategic performance evaluation (see

Figure 1). First, managers decide, which network capabilities are relevant for their IMN. Second, the weighting of the remaining factors clarifies the priorities of the network strategy. Third, a qualitative assessment of the contribution of each entity with regard to the selected and weighted network factors yields the strategic performance of each network entity.

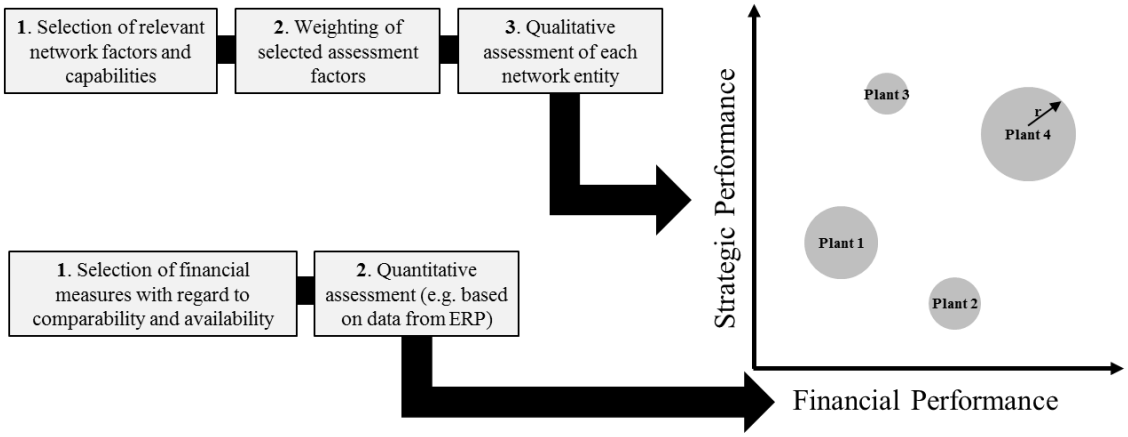

Figure 1: Conceptualization and framework

The horizontal axis of the framework presents the financial performance of each plant. Competitive priorities and financial performance measures have a longer history in research and practice and thus offer a variety of KPIs. (Hon, 2005; Gama Boaventura *et al.*, 2012). They allow conclusions on the operations and shop-floor level of the IMN entities. Moreover, they are a proxy for a company's financial health and show how network capabilities actually translate into monetary company success. As depicted in Figure 1, we propose a two-step approach to evaluate the financial performance of network entities. Measures allowing a fair comparison of network entities are the basis for a conclusive operationalisation. In practice, however, availability of data required at all sites to calculate such measures are a limiting factor. Thus, financials measures are selected according to availability and comparability in a first step. The second step is the actual assessment based on the prior defined measures. IT-systems, for example the Enterprise Resource Planning, may provide the data required about each manufacturing site.

The radius of the circular presentation of each network entity within the portfolio matrix represents the relative impact of one plant compared to other network entities. Adding this information into the portfolio helps to assess the importance of sites and prioritize measures. The radius representing revenue produced at each entity is one potential operationalisation. For example, management decisions that change the position of a plant presenting a substantial revenue share have a higher impact on the overall network than shifting a small plant. Accordingly, the circular radius helps to identify entities with high impact on the overall network and to lead management attention. Besides revenue, number of employees or the site competence level based on an assessment following Vereeck and Van Dierdonck (2002) are other potential information represented by the radius.

The application of the proposed framework helps network managers to make effective and sustaining decisions in network coordination and configuration due to its foundation on the required cross-functional and holistic measures. It can be the groundwork for strategic scenario development and considerations based on a comprehensible as-is evaluation.

Case study method

This research applies a case study method to validate a framework concept. Following Yin (2009), case studies are particularly suitable to answer explanatory questions. Since we engage in how to support IMN optimization, a qualitative case study approach is followed (Eisenhardt, 1989; Yin, 2009)

Selection and design

Case selection needs to consider the related context and research question. By nature of the studied topic, we focused on companies that operate manufacturing sites worldwide and were willing to participate. We excluded companies with a footprint of less than 10 production sites. Furthermore, to discuss the topic of IMN optimization we only selected companies with a strategy or mission for their manufacturing network.

We thoroughly considered the effort to conduct multiple cases and the exploratory goal of our research. Aiming to gain deep insights, we decided to conduct a single case study (W. Gibb Dyer, JR. and Alan L. Wilkins, 1991). Although we selected a single firm case, ultimately this study benefits from two distinct IMN cases within one company.

The selected case describes a German headquartered automotive supplier operating more than 40 manufacturing sites in Asia, Europe, North- and South America. Production of filter systems for combustion engines is the core business of the case company. Two distinct processes characterize the production of filter systems. Likewise, two clusters of manufacturing plants exist, which represent two distinct manufacturing networks connected by a vertical supply link.

In a first step, the objective of the case design was to gain insight into the firms manufacturing network and understand the challenges of this industry sector. Therefore, two researchers conducted interviews with network managers as well as with sales and marketing managers from two business units. Secondly, interviews and workshops with the chief operating officer and high-level network managers were conducted to identify and operationalize the relevant IMN performance dimensions for the case firm. Finally, we gathered historical and up-to-date site information based on a standardised questionnaire. Each regional network manager completed the questionnaire for all corresponding plants. Finally, workshops and interviews with high-level network managers (e.g. COO, all regional managers) served to verify the framework and develop a strategic goal for the network and each plant.

Data analysis

As a first-tier supplier, the case company needs to provide quality products, mainly high volumes and most decisive competitive prices. Hence, operations management recognized financial performance as an important building block to evaluate the overall network and the corresponding manufacturing entities. Standardized data available from the ERP-system provides the operationalization of the financial performance dimension. More precisely, financial performance is operationalized by the operative margin of each entity, compared to a target margin set for the respective manufacturing cluster.

From a strategic perspective, the network capabilities learning and access are the equally relevant strategic performance aspects for the case company. So far, the firm did not asses any non-financial information about the network and its entities. Therefore, a Likert scale questionnaire forms the basis for the qualitative assessment. To ensure reliability and comparability, a high-level operational management team discussed and aligned the results from the assessment. Finally, the equally weighted and aggregated strategic network data provides one compressive measure for each network entity.

Findings

Figure 2 displays the comprehensive visualization of one manufacturing cluster of the case company. The network entities span a broad range within both dimensions. A superior strategic performance characterizes the eight European sites. This reflects the German roots of the case firm and the fact that still most of the R&D as well as manufacturing centres are located within Europe. Additionally, a top technology level characterises the western European sites, which operate with highly automated production lines.

On the other hand, most of the Asian sites have been established only a few years ago. Therefore, these entities lack manufacturing experience, do not exhibit high competences and rely on knowledge inflow from Europe. However, the pure focus on manufacturing results in superior financial performance. The low strategic performance of all Asian sites follows a deliberate strategy. This confirms lowest strategic "to get the product produced" and run the plants with focus on efficiency (Vereecke and van Dierdonck, 2002, p. 500).

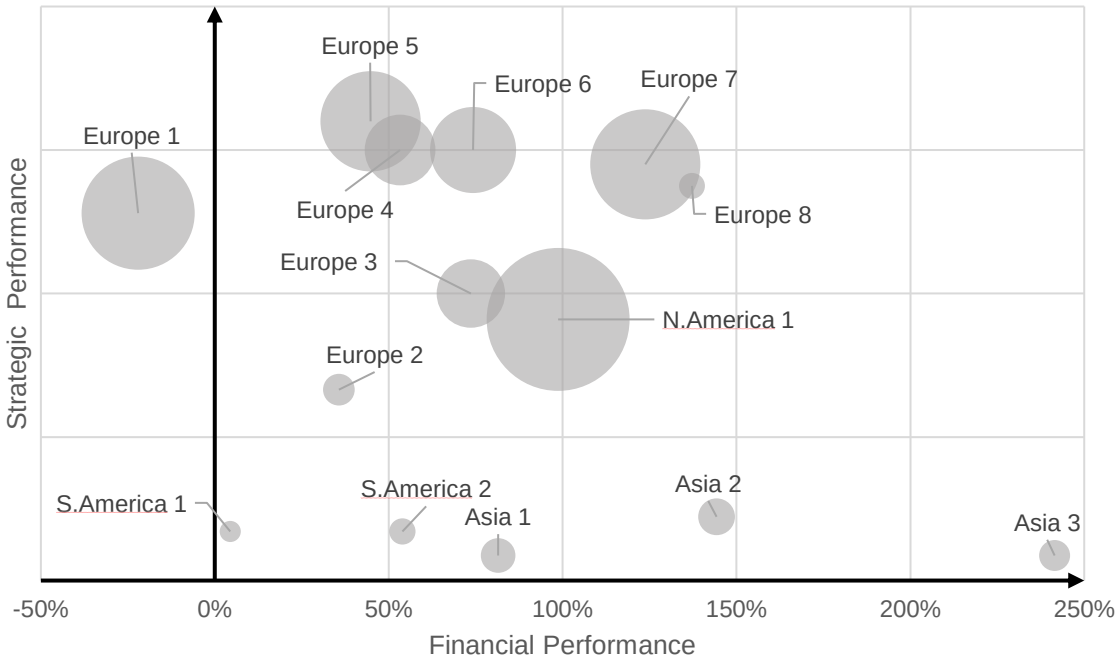

Figure 2: Site portfolio – each circle represents a plant assigned to one manufacturing cluster of the case company

All involved operations mangers confirmed that the visualization in Figure 2 correctly represent the current state of the manufacturing network. The site portfolio creates a high degree of transparency and allows to identify levers for optimization. In the following,

the examples of “Europe 1” and “Asia 3” demonstrate the operations management discussion of future plant positions within the network based on the developed site portfolio. Either high strategic and low financial performance or low strategic and high financial performance characterize both plants. The current position of “Asia 3” is in accordance with the intended strategic role for this plant. It is a deliberate decision to keep a low strategic level but benefit from advantageous production cost and high customer demands.

In contrast, the current financial performance of “Europe 1” highlights the need for a management decision. The multidimensional site portfolio can support this decision process by illustrating, that “Europe 1” is from a strategic performance perspective important to the network. The plant serves as lead and knowhow centre for one manufacturing process. “Europe 1” provides learning and access to knowhow for the network. Thus, a plant closure of “Europe 1” would have a negative effect on the performance of several other plants and consequently on the overall network. Instead, the operations management recognized the importance of “Europe 1” and decided on a roadmap to enhance capacity utilization. Furthermore, the roadmap includes investments for lean initiatives that shall restore profitability and shift the plant within the portfolio to the right.

Based on the current position of each network entity, the management developed an individual profile with targets for each plant comprising the considered performance dimensions. On a yearly basis, an update of the performance data serves to monitor the network development and individual site target achievement. This facilitates periodical and continuous steering of the IMN and improves transparency about management decisions.

Discussion

The objective of this research was to identify performance dimensions relevant to the management of IMN. We built a multidimensional framework driven by literature to support management decisions about manufacturing sites as integral network elements. Therefore, the proposed approach takes on several shortcomings from existing literature. Specifically, the lack of performance dimensions and approaches to quantify the success of IMN and the contribution of manufacturing sites.

We strived to validate the proposed framework by conducting a single case study. Even though a single case study limits the generalisability of our findings, we believe it provides valuable insights for practitioners. The case demonstrates how the proposed framework can be integrated into a network management process. First, it requires an internal discussion about the relevant performance dimensions and its operationalization. Second, it brings transparency about each manufacturing site and its contribution to the network. Furthermore, this transparency discloses current shortcomings and levers for optimization within the network. Third, the integrated perspective is a sound basis for decisions about single network entities, which also considers potential network effects.

The relationship between network performance dimensions remains unclear. Further research might investigate this aspect on empirical basis and explore potential trade-offs between the dimensions. We recognize the limitation of a single case study and therefore see the requirements of a broader empirical base. Such research might look for industry specific performance dimensions or management strategies for plants characterized by certain performance levels.

In summary, our research contributes to the field of IMN performance and management (Cheng *et al.*, 2015, p. 413) by building a framework that provides a starting

point for managers aiming to optimize their IMN and other scholars investigating holistic IMN performance.

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