Reduction of Decision Complexity as an Enabler for Continuous Production Network Design

Günther Schuh, Jan-Philipp Prote, Bastian Fränken, Stefan Dany, Andreas Gützlaff

Reduction of decision complexity as an enabler for continuous production network design

Günther Schuh[1], Jan-Philipp Prote[1], Bastian Fränken[1], Stefan Dany[1], Andreas Gützlaff[1]

[1] Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, 52074 Aachen, Germany

Abstract. Today, the continuous design of production networks is challenging due to their high complexity and diverging interests of individual sites. In order to increase the efficiency and agility of global producing companies, this paper presents a method that shifts the often-present focus on locations towards a market and production process oriented design approach of production networks. By subdividing the product range into product families, the complexity of decision-making processes is reduced. Subsequently, target conflicts between product families are resolved systematically from an overall corporate view by deriving the smallest possible holistic decision scope. The method was applied to a machine tool manufacturer.

Keywords: Production networks, complexity management, decision making.

1 Introduction

1.1 Challanges of production network design

While companies are already continuously developing and optimizing their individual production sites by the use of lean management approaches, production networks are mainly designed in individual projects [1]. Manufacturing companies lack a continuous process for systematical network design [2] to face the continuing trend towards globalized value creation [3]. As a result, companies face the constant risk that their production network will quickly lose competitiveness due to poor internal decisions, such as a suboptimal allocation of new products [4].

One of the main reasons for this problem is that production networks are one of the most complex and dynamic man-made systems [5]. The continuing trend towards product diversification increases this complexity [6].

Thus, suitable management approaches are needed which, on the one hand, are capable of simplifying complexity in decision-making processes and, on the other hand, are able to make optimal decisions for the entire company [4]. In the past, many approaches for designing production networks focused on the configuration of the network, which frequently emphasize the site and location design and often do not put enough emphasis on the market and production processes [7].

1.2 Exemplary case study

The considered company is a global producer of machine tools. It has introduced a uniform production system at all its sites to ensure continuous value stream optimization from “ramp to ramp”. The sites are focused on optimizing their own balance sheet. They make independent investment decisions and use individual internal cost allocation methods, which makes it difficult to compare manufacturing costs at the network level. Site roles were defined and parts of the production program were strategically assigned by allocating core competencies to main production facilities. The site managers are incited to allocate as much of the remaining products as possible to their site to distribute overhead costs. Despite numerous acquisitions of new sites, there has not been an optimization from a network perspective for years, and the site roles have not led to the desired optimization of the production network.

Initial analyses suggest high productivity potential through network consolidation. For the continuous development of the network, a stronger focus on the value stream of the products and the target markets shall be achieved.

1.3 Aims of this paper

The aim of this paper is to reduce decision complexity in production network configuration and to shift the design process from a site oriented view towards a stronger focus on the product- and market perspective. In order to achieve this, the paper presents an approach which utilizes the well-established method of value stream mapping [8] on a production network level. The result is a paradigm shift from a site-oriented to a product- and market-oriented configuration of production networks. The approach contributes to enabling a continuous design process for production networks and to the control of complexity in the management of global production networks. The specific challenge stems from industry projects and is summarized in the case study in chapter 1.2. Case study based research was recently recommended by Ferdows in order to gain a practical management approach for decision-making in the context of global production networks [3].

2 State of the Art

2.1 Evaluation Criteria

Continuous network design is a key to long-term competitiveness of producing companies [2]. To enable continuous network design, a method is needed which meets the following requirements to meet the challenges stated in chapter 1.1:

- Production network design decisions must always be taken from a company perspective rather than from a location perspective
- Decision complexity must be reduced systematically to a manageable level in order to enable continuous network optimization
- The method has to be applicable to large, complex production networks

2.2 Discussion of excisting approaches

Cheng et al. [7] and Saenz et al. [9] present numerous approaches for production network design. Most of the approaches focus on finding solutions for singular network design optimization problems. The most promising are discussed regarding the requirements defined above.

Ferdows describes an approach to reduce the complexity of production networks by delayering them into a set of subnetworks based on complexity and proprietary design of the products they produce and complexity and proprietary design of the processes they use to produce them [4]. This approach is not sufficient since it ignores the production process chain in the delayering process.

Schilling provides an approach for the continuous development of production networks with a focus on fast moving consumer goods [10]. However, due to the specific characteristics of the branch focus, complex supply relationships between sites as well as high product and process complexity, as found for example in mechanical and plant engineering, are neglected.

Lanza and Moser present a dynamic multi-objective optimization model for global manufacturing networks, which evaluates the impact of changes of influencing factors and optimizes the global design of the manufacturing network [11]. The model includes objectives like delivery time, quality, flexibility and coordination effort into consideration. Yet it does not describe a management approach to continuously optimize production networks.

"Making the Right Things in the Right Places" is an approach for continuous production network design presented by Christodoulou et al. [12]. Several methods for global footprint design are presented and embedded as part of cyclic business planning that should be fully owned by all levels of management. The presented framework is proposed as a definitive basis for all manufacturing footprint decision-making. Friedli recognizes it as one of the most relevant approaches to date [13]. Nonetheless the method does not consider complexity reduction as a mayor challenge for continuous production network design.

Schuh et al. present a reference process for the continuous design of production networks [2]. The reference process divides the network design process in a strategic, a tactical and an operational sub process with cyclical interaction. The approach does not provide a detailed proceeding, but is used as a framework for the method described in this paper.

Other approaches like Gölzer et al. aim to make complexity in global production networks manageable through big data analyses instead of complexity reduction [14]. A review of recent big data approaches for supply chain management is given by Tiwari et al. [15].

2.3 Deficits of existing approaches

In summary, existing management approaches partly address the problem of enabling continuous production network design, but they are not directly applicable in practice, since they do not include an approach for complexity reduction or ignore main complexity drivers such as process chains. Big data approaches try to enable complexity management but do not consider qualitative, strategic decision factors in decision-making. Furthermore, Olhager et al. support the need of an integrated view of product structure and production process in the network by pointing out that more research is needed to obtain fuller understanding of the mutual impacts of product architecture and supply chain design [16].

3 Approach

The aim of this approach is to reduce the complexity of decision-making processes for production network design to a level that enables continuous production network design. At the same time, it should be ensured that optimal decisions are made from an entrepreneurial point of view.

As shown in **Fig. 1**, the presented method is divided into five steps, which are arranged according to the reference process by Schuh et al. [2] into a strategic and a short cyclical, tactical process, which are interrelated. At a strategic level, the company's product program is divided into product families. At the tactical level, optimization potentials per product family are identified. Afterwards, target conflicts between product families are derived and the smallest possible decision scope per optimization case is identified in order to subsequently optimize from a company perspective.

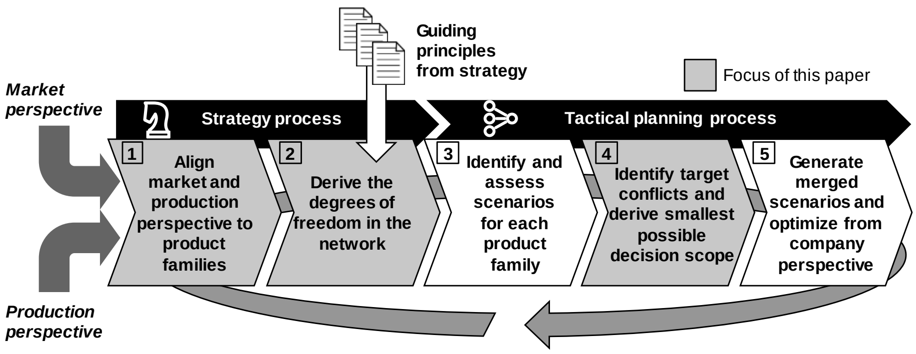

Fig. 1. Integrated approach for complexity reduced, continuous decision-making processes based on product families

Step 1: The first step is a re-orientation of the network structure from site- to product- and production perspective. For this purpose, proven structures from lean production and product development are adopted and transferred to a network view. Rother and Shook describe product families as "a group of products that pass through similar processing steps and over common equipment in your downstream processes" [8]. In the design process of modular systems, modules are formed by means of an external market analysis and an internal production process analysis [17].

Transferred to network design, product families are initially formed from a market perspective as shown in **Fig. 2**. The product families are categorized according to the sales markets and the product features that are perceived by customers. The assignment is company-specific, since it depends heavily on the product program. For example, a manufacturer of products with a low value density will likely take geographical aspects in focus when forming product families due to the proportionately high transport costs. A manufacturer of equipment used in the medical or food industry may focus on product requirements.

Subsequently, the product families are detailed from a production perspective. The product families are further subdivided according to the similarity of their value chains. Here, the comparability of the process steps is crucial. The current assignment of process steps to locations is not taken into account in this process step.

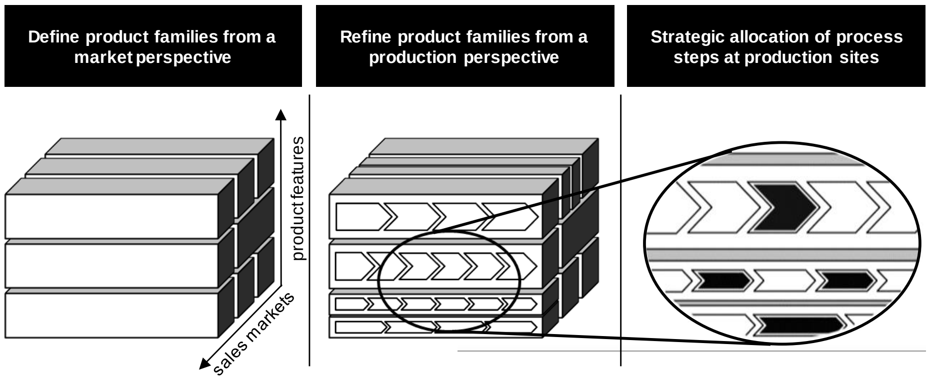

Fig. 2. Market and production specific product family segmentation and match with guiding principles from the production strategy

Step 2: The degrees of freedom in the network are derived by comparing strategic specifications and the current distribution of the value added. This can be, for example, the linking of production and development for a product at a specific site. Aim is the reduction of network design complexity by not constantly challenging previously defined core competencies at specific sites on a tactical level. Core competencies can be reworked within the strategy process.

Step 3: In the next step, the optimization potential is identified and evaluated for each product family. Methods for identifying optimization potential are not the focus of this paper. Hence, an exemplary reference for an existing approach regarding this topic is given by Shi et al. [18].

Step 4: Afterwards, the design projects of the individual product families resulting from step 3 are set in an overall entrepreneurial context. In order to keep complexity as low as possible, the aim is to find the smallest possible decision-making scope that allows an overall entrepreneurial decision. This is done by analyzing the resources concerned. Resources can be defined company-specifically as individual production and assembly areas within a location or, in more detail, as individual machines or production lines.

The procedure shall be explained by using the example shown in **Fig. 3**: The value added of product family 1 at location 1 is to be relocated to location 3. This has an impact on all four product families: Product family 2 is closely linked because resources are shared. The removal of product family 1 in plant 1 could also make the relocation of product family 2 from plant 1 beneficial. At the same time, product family 3 uses a resource at site 3 to which the relocation is intended. This results in the new scenario scope, which must take into account product family 1 and parts of the product families 2 and 3. The relocation from location 1 to location 3 increases the contribution margins per unit for product family 4, which reduces the profitability of production, but cannot be shifted for the time being due to strategic specifications. However, the investment calculation must also take product family 4 into account.

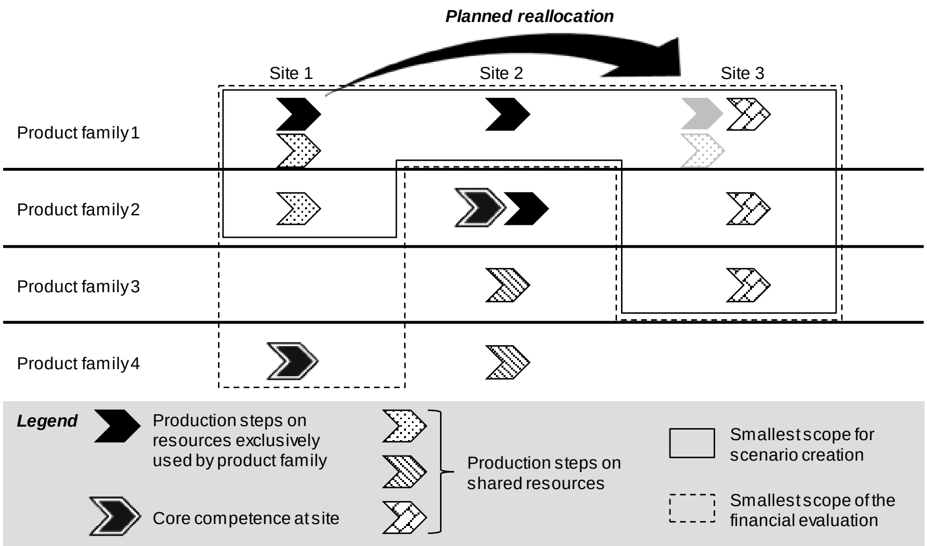

Fig. 3. Derivation of the smallest possible decision scope using the example a the relocation of value added for a product family

Step 5: Finally, the combined scenarios are evaluated. Schuh et al. [19] for example provide a method for holistic scenario evaluation from an overall company perspective. In addition, a financial evaluation of strategic decisions is possible. If, for example, the business case for the example shown in **Fig. 3** is positive without taking product family 4 into account, but negative with product family 4, this results in a negative assessment of the relocation from an overall company perspective. The difference to the relocation scenario without consideration of product family 4 are the costs for a strategic decision to be questioned. This must be reflected in the strategy process and the core competence at that site should be questioned.

4 Discussion and future research

The strategic process steps 1 and 2 of presented approach have been applied to the company described in the case study in chapter 1.3. Main driver for the product family separation has been the final assembly of the products. In total, eight product families have been derived.

In order to implement the entire approach in a sustainable way, it is necessary to create the appropriate organizational structures. Therefore, the assignment of decision-making competencies to a value stream manager per product family managers is required and committees have to be defined that solve target conflicts from an overall network perspective. In addition, the method leads to an increased number of evaluation processes in the network, therefore methods are required that are able to evaluate these situation-specific scenarios with an adequate effort.

Furthermore, testing with companies from other industries is necessary to examine the general validity of the procedure. However, the following advantages are expected from the presented approach:

- By dividing the product range into product families, the network design focus is directed towards the value-added process instead of conflicts of interest between production sites
- The derivation of optimization projects per product family enables a complexity reduction for the identification of optimization potentials
- Target conflicts between product families create a value-added oriented discussion within the company and are resolved from an overall entrepreneurial perspective

Acknowledgment

The authors would like to thank the German Research Foundation DFG for the kind support within the Cluster of Excellence "Integrative Production Technology for High-Wage Countries".

References

1. Ferdows, K.: Managing the evolving global production network, in: Markides, C., Murray, J.A., Galavan, R. (Eds.), Strategy, innovation, and change. Challenges for management. Oxford University Press, Oxford, New York (2008).
2. Schuh, G., Prote, J.-P., Dany, S.: Reference Process for the Continuous Design of Production Networks, in: 2017 International Conference on Industrial Engineering and Engineering Management (IEEM) (2017).
3. Ferdows, K.: Keeping up with growing complexity of managing global operations. International Journal of Operations & Production Management 14 (1), 73 (2018).
4. Ferdows, K., Vereecke, A., Meyer, A.: Delayering the global production network into congruent subnetworks. Journal of Operations Management 41, 63–74 (2016).

5. Váncza, J.: Production Networks, in: CIRP Encyclopedia of Production Engineering. Springer, Berlin, Heidelberg, pp. 1–8 (2016).
6. Mourtzis, D., Doukas, M.: The Evolution of Manufacturing Systems, in: Handbook of research on design and management of lean production systems. IGI Global, Hershey, Pennsylvania, pp. 1–29 (2014).
7. Cheng, Y., Farooq, S., Johansen, J.: International manufacturing network: Past, present, and future. International Journal of Operations & Production Management 35 (3), pp. 392–429 (2015).
8. Rother, M., Shook, J.: Learning to see: Value-stream mapping to create value and eliminate muda, Version 1.4 ed. Lean Enterprise Institute, Cambridge Mass (2009).
9. Maria Jesus Saenz, P., Xenophon Koufteros, Olhager, J., Pashaei, S., Sternberg, H.: Design of global production and distribution networks. Int Jnl Phys Dist & Log Manage 45 (1/2), pp.138–158. (2015).
10. Schilling, R.: Manufacturing network development in fast-moving consumer goods industries. Kovač, Hamburg (2012).
11. Lanza, G., Moser, R.: Multi-objective optimization of global manufacturing networks taking into account multi-dimensional uncertainty. CIRP Annals 63 (1), pp. 397–400 (2014).
12. Christodoulou, P., Fleet, D., Hanson, P., Phaal, R., Probert, D., Shi, Y.: Making the right things in the right places: A structured approach to developing and exploiting 'manufacturing footprint' strategy. University of Cambridge Institute for Manufacturing, Cambridge (2007).
13. Friedli, T., Mundt, A., Thomas, S.: Strategic management of global manufacturing networks: Aligning strategy, configuration, and coordination. Springer, Berlin, (2014).
14. Gölzer, P., Simon, L., Cato, P., Amberg, M.: Designing Global Manu-facturing Networks Using Big Data. Procedia CIRP 33, 191–196 (2015).
15. Tiwari, S., Wee, H.M., Daryanto, Y.: Big data analytics in supply chain management between 2010 and 2016: Insights to industries. Computers & Industrial Engineering 115, 319–330 (2018).
16. Pashaei, S., Olhager, J.: Product architecture and supply chain design: A systematic review and research agenda. Supp Chain Mnagmnt 20 (1), pp. 98–112 (2015).
17. Schuh, G. (Ed.), 2015. Leitfaden zur Baukastengestaltung: Ergebnisse des Forschungsprojekts Gestaltung innovativer Baukasten- und Wertschöpfungsstrukturen (GiBWert), VDMA Verl., Stuttgart (2015).
18. Shi, Y., Gregory, M., Naylor, M.: International manufacturing configuration map: A self-assessment tool of international manufacturing capabilities. Integrated Mfg Systems 8 (5), pp.273–282 (1997).
19. Schuh, G., Prote J.-P., Fränken, B., Gützlaff, A.: Assessment of production network scenarios based on economic value added, in: 24th International Conference on Production Research (ICPR 2017). DEStech Publications Inc, Lancaster, pp. 116–121 (2017).