Production Engineering (2019) 13:283–291
https://doi.org/10.1007/s11740-019-00876-5

PRODUCTION MANAGEMENT

Practice-oriented methodology for reallocating production technologies to production locations in global production networks

S. Treber[1] · E. Moser[1] · S. Helming[1] · B. Haefner[1] · G. Lanza[1]

Received: 9 August 2018 / Accepted: 7 January 2019 / Published online: 9 January 2019

Abstract

An increasingly uncertain and dynamic competitive environment is challenging industrial companies nowadays. Against this backdrop, companies are focusing on their core competences. They organize their production in global production networks. While the competitiveness of production networks could be maintained for a long time by optimizing individual production sites, the overall network is increasingly becoming the focus of attention. In particular, the elimination of redundant production technologies offers the potential to exploit economies of scale, to bundle technology-specific competences and to achieve an increase in efficiency. The purely mathematical optimization models disseminated in research are unable to consider all the sub tasks of planning. For this reason, this article proposes a practice oriented methodology for reallocating production technologies to production locations in global production networks. The procedure consists of three phases: the investigation of current production technology-to-site allocation in the production network, the generation and planning of alternative reallocations as well as the evaluation of reallocations. For testing its practical suitability, the procedure is exemplary applied to the global production network for forging processes of a medical device manufacturer.

Keywords Global production network · Reallocation · Scenario planning

1 Introduction

Today, companies of any size act globally in the form of global production networks [1]. These networks offer many advantages such as production of customized and regionally differentiated products close to the market [2]. Other benefits include the exploitation of low production and procurement costs as well as access to local knowledge, skills and resources [3]. However, the planning and operation of production networks is a challenging task. Many influencing factors such as market demand, factor costs, and logistics as well as legal and cultural factors have to be considered. These factors are characterized by an uncertain and complex behavior [4]. The identification of improvement potentials in production networks is an even greater challenge. In the past, efficiency could be increased by means of mass production, implementation of lean principles and an increase in flexibility and adaptability of single production locations. Meanwhile, the production network is increasingly becoming the focus of attention [5]. Production networks often expand through the acquisition of individual sites as well as short-term decisions [6]. Such historically grown production networks offer potential for efficiency improvement [7] which could lead up to cost savings of around 45% [3]. However, the majority of companies only realize 10% of these savings potentials [3]. The use of redundant production technologies in multiple locations is one root-cause of inefficiencies. Economies of scale and possible synergies are not exploited. In order to meet the expectations of a high-performant production, a reallocation of the production technology-to-site allocation is necessary. Issues such as the restructuring of the product portfolio and the determination of vertical integration must be considered integrated. The selection of production technologies and capacities used as well as adjustments in the production layout of the individual production sites have to be taken into account. In addition, various alternative scenarios for reallocations have to be evaluated with regard to their profitability. On the cost side, both one-off costs and changes in running costs are of interest. Besides, an assessment of non-monetary criteria

✉ S. Treber
stefan.treber@kit.edu

[1] wbk-Institute of Production Science, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, 76131 Karlsruhe, Germany

has to be made. Currently there is no holistic methodology for the development of possible alternative technology-to-site allocations that integrates different planning tasks and considers monetary and non-monetary criteria. Therefore, this paper introduces a practice-oriented methodology for the reallocation of production technologies to production sites in global production networks. The approach is particularly suitable for mass production with a limited number of variants. In this form of production, planning efforts for a relocation are manageable, and great efficiency enhancement potentials can be expected due to the high economies of scale.

2 Fundamentals

Production networks are networks in a business context that serve for the cross-company provision of products and services using specific resources and competences of the partners involved [5]. Their structure consists of both horizontal and vertical integrated and open-ended nodes and edges. Nodes of production networks include suppliers and manufacturers involved in direct value adding activities as well as distribution centers. The edges are links that represent relatively stable material, information and financial flows [5, 8]. If the nodes and edges belong to one and the same company, the term intra-organizational production network is suitable. The term inter-organizational production network is suitable, if the production network consists of dynamic business collaborations of several companies that share their resources and plan their value-added processes jointly [9, 10]. This paper is focusing on intra-organizational production networks and proposes a reallocation for the benefit of a focal company.

The tasks of planning and operating global production networks are divided into the three levels: strategic, configuring and coordinating planning tasks (see Fig. 1) [11]. This article looks at configurative planning tasks. The configuration of the production network synonymously describes both the decision-making process for designing the network as well as its result [12]. Sub tasks of the production network configuration include, for example, the definition of the number and location of sites. Other sub tasks are the allocation of products, production steps, capacities and production technologies to the sites [13]. The last-mentioned sub task is referred to as technology-to-site allocation. Making a one-time decision about the shape of the future network configuration is called a reconfiguration [14]. On the other hand, migration planning has to be applied if a dynamic reconfiguration is necessary due to an uncertain future [15]. Migration planning involves transferring a current configuration to a target configuration using multiple reconfiguration steps [15].

The reallocation of production technologies consists of the definition of the product portfolio, the determination of vertical integration, technology and capacity planning as well as layout planning (see Fig. 1). The definition of the product portfolio serves to narrow the product portfolio. Adjustments in the product portfolio may become necessary due to sales policy considerations or technological changes in the production process [16]. The determination of vertical integration determines the degree of in-house or third-party production. Within the determination, the own strategic importance of the products is compared with their market availability [3]. Capacity planning is carried out by comparing the capacity needs with the capacity available. After a reallocation, the capacity available has to meet the capacity need in order to meet the demand [17]. Layout planning deals with the spatial arrangement of objects within the considered production locations. These include, for example, machines and storages as well as in-house flows in the areas of materials, information and energy [17].

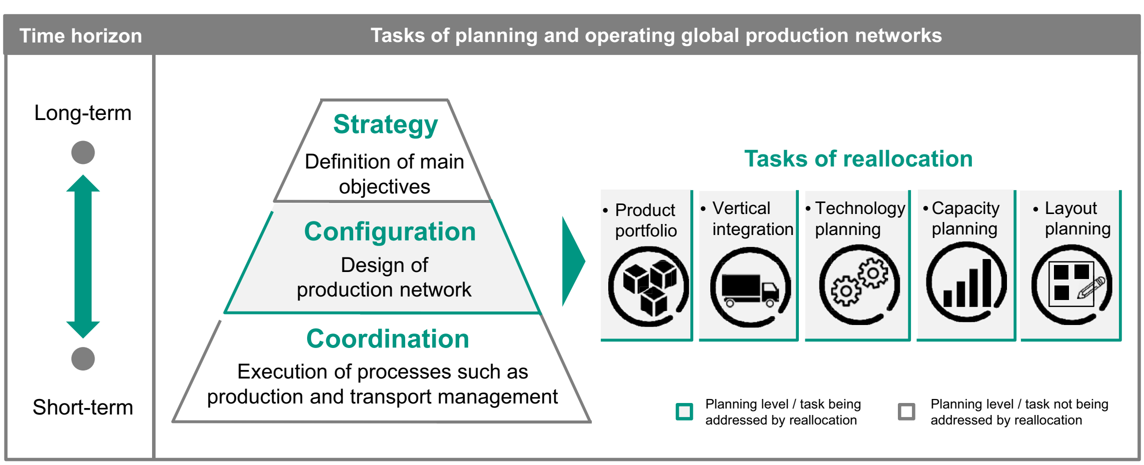

Fig. 1 Tasks of planning and operating global production networks

Reallocations of technology-to-site allocations depend on the emergence of an uncertain future environment. The profitability of a reallocation is influenced by uncertain market developments, changes in factor costs or changes in political and governmental factors. One methodology to support decisions in an uncertain environment is called scenario management [18]. Scenario management is based on the principles of networked thinking and multiple future. The principle of networked thinking focuses on the analysis of the interlinkage of the influencing factors of the production network. The principle of the multiple future postulates the development of consistent visions of the future by neglecting contradictory combinations of development paths of the influencing factors. Scenario management generates different future pictures of possible future environmental conditions being consistent within themselves [18].

Reallocation of production technologies require investments. For example, new machines have to be procured or existing machines have to be transferred and put into operation. In addition, the running production costs of the products as well as the logistics costs may change. Valuation methods of investment accounting serve for the quantification of the consequences of a reallocation. The methods can be differentiated into single-criteria monetary assessment methods as well as multi-criteria methods. Single-criteria monetary methods include static methods of investment calculations. This includes cost comparison, profit comparison, the calculation of profit margins as well as the calculation of the amortization time. Only one relevant time period for the investment project is being considered by these methods. Methods of dynamic investment accounting consider the timing of payments by discounting and compounding. Procedures which assume a uniform calculation interest rate are, for example, the calculation of net present value, annuity and internal rate of return. Procedures such as the asset valuation and the life-cycle costing take different interest rates into account [19]. Multi-criteria methods quantify the achievement of different alternatives by means of non-monetary indicators. Examples of these methods are the value benefit analysis, the Analytic Hierarchy Process (AHP), the Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) method and the multi-attribute utility theory [20, 21].

3 Literature review

In this section, existing research approaches with regard to the reallocation of technology-to-site allocations in global production networks are presented.

Cisek develops a procedure to identify the needs and to implement structural adaptations of a production system. Using computer-aided layout planning, he creates various structural alternatives as well as timed migration paths for the factory. These are valued monetarily in terms of their migration costs and the costs of production interruption [22]. Chen and Fan present a two-stage scenario-based stochastic programming model for simultaneous migration and capacity planning. Machines and tools that are available in different capacities are considered as migration objects. The migration path is defined under uncertainty with profit maximization as objective function [23]. Reuter et al. develop a multi-stage rolling process to determine a strategic migration plan for global production networks. Starting from an initial configuration and a fixed target configuration, intermediate migration steps are created and evaluated for their contribution to the target configuration as well as their cost [24]. Grunow et al. implement a mixed-integer optimization model for product and capacity expansion of global production networks. They take the maturity of the products, the ramp-up phase for the production start-up and the availability of highly qualified personnel into account. The goal is to minimize the net present value of the costs incurred. Production, logistics, investment and complexity costs are taken into account [25]. Moser et al. present a dynamic optimization model for the migration of global production networks. It is based on a Markov decision process and proposes robust migration paths. The focus is on the proactive selection of change enablers to achieve an optimal level of adaptability for migration [6, 15]. Hochdoerffer et al. present a methodology for the integrated design of global production networks. The methodology enables the determination of a product allocation strategy and a network configuration sequence. The unique selling point is the identification of potential for improvement by clustering analysis of product portfolios [13, 26]. Mourtzis et al. investigate production network performance for mass customized products using a software framework. A multi-stage manufacturing network design problem for single multi-component products is solved to optimality using the three search methods Tabu Search, Simulated Annealing and Intelligent Search Algorithm. The method utilizes multi-criteria decision making as well as the exploitation of statistical design of experiments for calibrating the search methods [2].

The approaches show that research addresses the challenge of technology-to-site reallocations in global production networks. Many approaches take capacity and technology planning into account. However, an integrated consideration of all relevant sub tasks integrating product portfolio restructuring, determination of vertical integration, capacity, technology and layout planning does not yet take place. Complex optimization procedures being implemented in superior software tools are proposed for decision support. However, from our experience it is critical to map all aspects through mathematical equations. Production networks are systems that are far too complex to be evaluated purely analytically [27]. In addition, practitioners often do not understand neither the analytical model itself nor the solution algorithms. Therefore, this paper gives practitioners a guideline in executing reallocations in global production networks. It proposes a methodology which deliberately dispenses with mathematical optimization.

4 Methodology for the reallocation of production technologies

This chapter presents a practiced-oriented methodology for the reallocation of production technologies to production locations in global production networks (see Fig. 2). The main focus of the methodology is the integrated consideration of sub tasks as well as monetary and non-monetary evaluation of alternative reallocation scenarios.

4.1 Investigation of current production technology-to-site allocation

The aim of the first phase of the methodology is the investigation of strategic guidelines and the current production technology-to-site allocation as well as the formulation of a requirement profile for the reallocation.

The investigation of *strategic guidelines* serves to classify the reallocation into the corporate production strategy. The production strategy provides the core reason for the reallocation. Decisive factors for a reallocation can be, for example, the desire for greater market proximity, for increased efficiency through reduction of overcapacities, for technological change in production process or for risk diversification. In addition, the production strategy sets the degrees of freedom for future technology-to-site allocations. If the company wants to differentiate itself from competitors based on the factor price, the reallocation should take into account monetary aspects. If the production strategy aims for a high delivery capability, technologies must be reallocated close to the customer. Further orientation is provided by literature on the strategic management of global production networks [11].

The investigation of the current production technology-to-site allocation is done with a *production network quick check*. The procedure of the quick check is based on an extension of the classical value stream method. The detail level of the analysis is chosen less deep. The focus is not on individual shop floor elements but on elements of the production network such as external customers, suppliers, logistics as well as characteristics of the internal production sites [28]. At production network level, the customer analysis of the network quick check provides an overview of the most important sales markets including sales figures of the products being offered to the customer. In order to understand the customer needs, a customer analysis with identification of existing as well as potential new customers should be carried out. The analysis of the supplier structure reveals the depth of added value in the production network. Based on the sourcing strategy, it is determined whether the supply of vendor parts takes place via one or multiple suppliers. In addition, the sourcing strategy shows whether

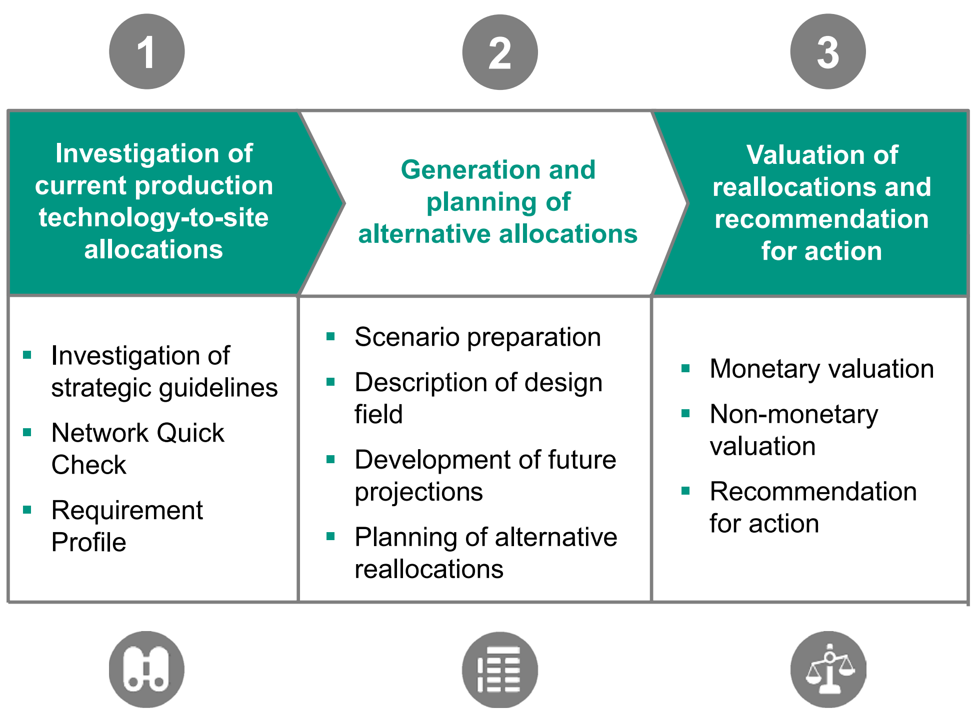

Fig. 2 Overview of methodology for reallocation

all production sites in the network are supplied by the same suppliers or whether each production site is pursuing a local sourcing strategy. Logistics activities such as transportation or storing are investigated in the context of a logistics analysis. In particular, the mode of transport (e.g. sea, air, rail or road) and the stocking strategy are relevant.

At the level of the production sites, the site-specific production program and the production technologies are relevant. To record the production program, the product portfolio and the variants being produced are captured for each production site. Cluster analysis and variant trees help to subdivide products and variants into subgroups. In the next step, a production process analysis is carried out. Priority graphs or production schedules break down the production process and assign individual production steps to corresponding production technologies and machines. A comparison of capacity offerings and capacity needs allows for an estimation of resource bottlenecks. On the other side, unutilized capacity may be identified. It creates flexibility corridors and serves as a necessary robustness buffer to compensate demand fluctuations. However, unutilized capacity offers potential for optimization in the course of the reallocation. Work plans discover more technology-related information for the reallocation. Floor plans of the production areas help to understand production processes and the internal material flow. They show up free space in the production area that could possibly be filled with new production technologies within the reallocation.

The results of the analysis on the level of production network and production sites are combined in a visualization. The visualization follows the symbols of the global value stream analysis presented by Arndt et al. [28]. It gives a graphical overview over the networks' productions processes, redundant production technologies at different production sites and helps to identify reallocation scenarios.

Based on the strategic guidelines and the actual state of the technology-to-site allocations, a *requirement profile* for future allocations is developed. The requirement profile limits future reallocations and consists of co-criteria in the areas of production program, vertical integration, production technology and production capacity, which have to be fulfilled after the reallocation. The goal is to consider only a manageable amount of strategic plausible reallocations.

4.2 Generation and planning of alternative reallocations

The second phase of the reallocation of production technology-to-site allocations aims to create and plan alternative reallocations. The focus of this phase is on the integrated consideration of reallocation sub tasks such as product portfolio restructuring, determination of vertical integration, technology, capacity and layout planning. The procedure is based on the phase model of scenario management presented by Gausemeier and Plass [18].

Within the first step, the *scenario preparation*, the objectives of the reallocation are determined and the design field is specified. The objective of the reallocation is predefined by the production strategy (see Sect. 4.1). The design field of the reallocation is limited by the current technology-to-site allocation investigated within the production network quick check as well as the requirement profile (see Sect. 4.1).

In the second step, the *design field* is described by influencing factors. Influencing factors that are relevant for a reallocation in production networks include external influencing factors of a global production such as trends in market demand as well as changes in factor prices, technology or legal-administrative conditions. Important internal influencing factors are the reallocation sub tasks product portfolio restructuring, determination of vertical integration, capacity, technology and layout planning. The external and internal factors with the greatest influence on the reallocation are determined based on an influence matrix and a relevance analysis. For technical details of this procedure refer to Gausemeier and Plass [18]. The goal is to consider only those influencing factors that have a high significance in the further detailing of the alternative reallocations.

The aim of the third step is to develop *future projections* for the external factors influencing the reallocations. Consistent scenarios shall be formed in this step. The most selective future developments for the reallocation environment are predicted using analytical and creative methods such as extrapolation. Subsequently, the developments are combined into consistent scenarios. A consistent scenario, for example, is a strong increase in market demand with a simultaneous increase in logistics costs. A decline in demand combined with a tightening of legal and administrative conditions would also be conceivable.

In the last step, the *reallocation alternatives* are planned out. Within this step, the internal influencing factors as well as the requirement profile are relevant. The first step includes the definition of the product portfolio. Changes in demand, technology or other influencing factors can lead to products being added to or removed from the product portfolio. Consequently, the product portfolio has to be adjusted. The second sub-step of planning deals with the vertical integration. In this task, the depth of value creation is defined which is not outsourced even after the reallocation. Outsourcing may be relevant to high volume products to be able to fall back on additional external production capacity. On the other hand, relocation of low-volume products may make additional production capacity available. It is appropriate for new or old products and have low contribution margins. The two sub steps adjustment of the product portfolio and vertical integration have to be considered integrated. These steps are followed by the integrated planning of production technologies, production capacities and production layouts. The planning of production technologies involves determining which products are produced with which technology. The elimination of redundant technology-to-site allocations as well as the prevention of the emergence of potential new redundant allocations are most important. The allocation is predetermined by the production process of the product to be produced. However, single work tasks such as mechanical joining or assembly may be aligned, pooled or standardized. By doing so, redundant technology-to-site allocation are eliminated and potentially new redundant allocations prevented. Together with the expected sales volumes, technology planning specifies which adjustment must be made in the reallocation of the production technology-to-site allocation. The production capacity requirements to be covered by the ramp-up of additional or the removal of existing production capacities have to be specified. Purchases of new machines, adjustments in the production process, the development of the necessary skills and know-how of human workers as well as the training of additional employees are to be considered. As changes in production capacities result in changes in the required production areas, layout planning is closely tied to the planning of production capacities. Since reallocation is a brownfield approach, the available production area is limited. The capacity planning must therefore compare the space released by the reallocation with the additionally required space. In the case of net area requirements, expansion of the production site may become necessary. Free space should be used by other production activities in the long term. For further information related to the sub tasks product portfolio definition, vertical integration, technology and capacity planning as well as layout planning, refer to the fundamentals of this article as well as the corresponding literature.

4.3 Valuation of reallocations and recommendation for action

The final phase of the reallocation consists of the multicriteria assessment of reallocations and the formulation of a recommendation for action. In order to preserve practical relevance, a monetary static valuation method is chosen. In practice, monetary valuation information is often limited and highly uncertain. For this reason, the monetary valuation is integrated in a superior multicriteria evaluation method.

For the *monetary valuation*, the one-time costs of the reallocation as well as the changes in the ongoing operating costs are considered (see Fig. 3). The one-time costs consist of three components: costs for production technology change, costs for construction measures and costs for building up know-how. Costs for production technology change arise, for example, through the acquisition of new machines. Construction, changeover or transfer of existing machines may also cause costs. Examples of reconstruction costs include the build-up of new production halls and the installation of additional foundations for the machines. Expenses for the development of know-how include expenses for the training of local employees and the use of expatriates. The changes in operating costs occur in the three areas of production, logistics, and supplier costs. They are summed over

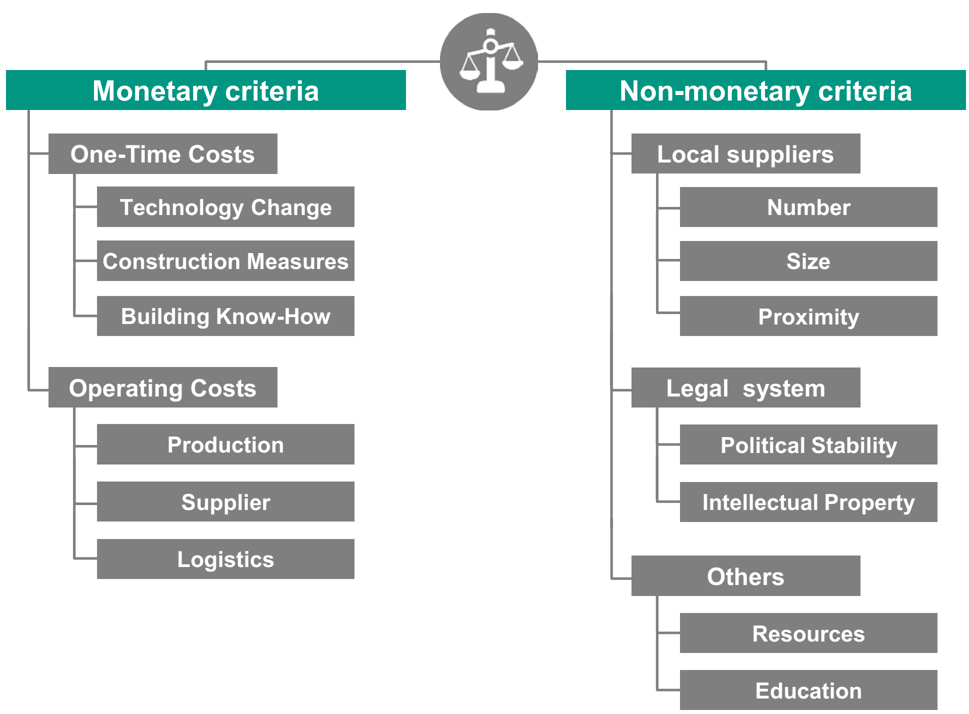

Fig. 3 Criteria for evaluating the reallocation

several periods according to the time horizon of the reallocation. Production costs can arise, due to changes in material, personnel or overhead costs. Logistics costs are divided into transport and customs costs. In particular, customs costs vary widely for raw materials, semi-finished products and finished products. Changes in supplier costs must be taken into account, if the product portfolio or the value creation depth is changed. According to the costs comparison principle, costs only have to be taken into account if the costs change as a consequence of the reallocation.

Criteria for *non-monetary valuation* of a reallocation are intangible and difficult to grasp (see Fig. 3). For example, the number, size and proximity of local suppliers affect the benefits of a reallocation. The presence of local resources can also affect the reallocation. The political stability of a site, environmental protection requirements as well as the existence of health and safety measures must also be taken into account. The criteria should be weighted according to the specific case.

After the valuation of the reallocations, a *recommendation for action* can be given. Therefore, the criteria of the monetary valuation have to be reconciled with criteria of the non-monetary valuation. This can be done by performing a utility value analysis or by using complex procedures such as Analytic Hierarchy Process (AHP) or Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). For more information on possible procedures, refer to Greco et al. [21]. Ultimately, the decision for a reallocation must be taken from an overall entrepreneurial point of view and has to be in line with the guidelines of the production strategy (see Sect. 4.1).

5 Application to industrial use case

The methodology for reallocating production technologies to production locations in global production networks has been exemplary applied to a leading company from medical technology sector. The company's production program includes surgical instruments for minimal invasive access, implants as well as surgical sutures. The production network consists of more than 15 production locations which are distributed around the world. The overall value creation process of each individual product takes place at one production location. It is not fragmented. A global distribution center at the company's home location serves for the handling of all goods shipments from the production locations to the globally distributed customers. For the reallocation, a subnetwork of the overall production network was been considered. It consisted of two production locations being located in Europe and Asia.

The investigation of the current production technology-to-site allocation included an analysis of the superior production strategy. According to the production strategy, the task of the reallocation in the specific case was to carry out a technological change for the forging processes. Besides, spare capacities should be created at the Asian production location. In addition, it was the objective to bundle competences in personnel and to circumvent US trade barriers for products from Asia. The strategic guidelines were recorded and had to be fulfilled in the context of the reallocation. As part of the network quick check, the product portfolio comprising scissors, clamps and forceps was recorded. The structure of the customer and supplier base as well as logistics processes were recorded (see Fig. 4). On the site level, the focus was on the production processes, technologies and capacities (see Fig. 4). The production process consisted of sub-processes such as cutting, oven and forging, processing and milling.

Within the generation of alternative reallocation scenarios, the reallocation of forging processes within the production network was identified as the scenario field. The most important external factor was the market demand. Internal influencing factors were the production volume to be allocated between the production sites as well as the procurement of new and the relocation of old machinery.

Besides, the outsourcing of subparts of the production volume as well as the outsourcing of sub-steps of the production process to external suppliers was of interest. Depending on the production volume to be relocated, two reallocation scenarios with nine sub scenarios each were planned out (see Fig. 4). For each sub scenario, the planning included the determination of the production volume to be reallocated from Asia to Europe. The necessary technology and capacity changes were determined and the production layout at both locations was designed.

The monetary valuation of the sub scenarios (see Fig. 4) identified the one-time costs of the reallocation as the biggest cost driver. In particular, the procurement of new forging ovens, the construction of foundations for the forging hammers and the expansion of the available production space generated high one-time costs. Compared to the relocation of existing machines, the acquisition of new machines was almost 10 times more costly. Cost drivers for running costs were changes in production and logistics costs. The reallocation relocated from Asia to Europe decreased duty costs of almost 30%. In the same time, production costs in Europe were higher. In total, overall running costs remained almost the same.

The qualitative assessment considered the risks of re-using existing machines. Besides, the outsourcing of sub steps of the production process has been assessed qualitative. However, it was rejected due to an expected increase of the overall production network complexity. An outsourcing of product portfolio with low market demand such as spare parts was also discussed. It was decided

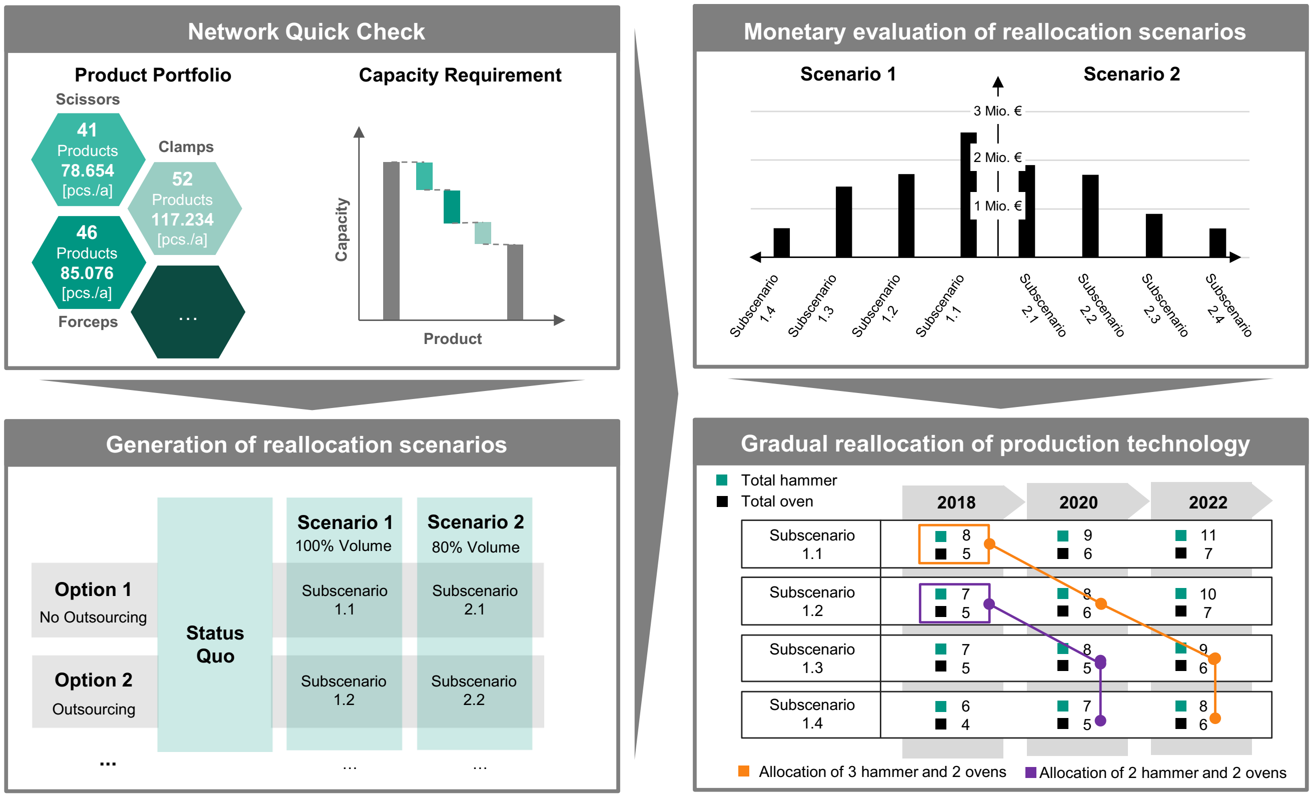

Fig. 4 Application of methodology to a medical device manufacturer

that spare parts with low demand will be produced on stock until the end-of-lifetime of the forging tooling. The tooling will not be replaced afterwards. Therefore, spare parts won't be outsourced but at the same have not to be considered within the reallocation.

All sub scenarios were compared with a utility analysis for the evaluation criteria. The sub scenario for the reallocation of the entire product portfolio using old machines without any outsourcing turned out to be the best reallocation scenario. From a monetary point of view, this scenario generates the lowest one-time costs. From a non-monetary view, it fulfils given strategic guidelines such as performing a technological change for the forging process, creating spare capacities in Asia and bundling of competences in Europe. Therefore, this sub scenario was chosen even if predicted changes in running costs were not as high as desired. In order to maintain pressure on the company's internal team of experts in production network planning, management decided not to build up excess capacity at the European production location. Instead, production technology will be reallocated stepwise in line with the increase in market demand (see Fig. 4).

6 Conclusion

This article presented a practice-oriented methodology for reallocating production technologies to production locations in global production networks. The methodology is subdivided into three phases: investigation of current production technology-to-site allocations, generation and planning of alternative reallocations as well as valuation of reallocations and recommendation for action. The unique selling point of the methodology is the integrated consideration of sub tasks of the reallocation. The sub tasks consist of product portfolio restructuring and determination of vertical integration. Capacity, technology and layout planning are also considered. The approach intentionally dispenses with complex optimization models. It fulfils practitioner's need of easy to use decision support by proposing a simple scenario-based generation and evaluation of reallocation alternatives. The method was successfully applied to a medical device company. A reallocation of forging processes between two production locations in Europe and Asia demonstrated its usability. The case-study proposed a gradual reallocation of production technologies. Such migrations from an initial state to a target state could be a further logical extension of the methodology. Although theoretical models and optimization based approaches do exist, there is a requirement to develop practical and simple procedures for migration planning of global production networks in future.

Acknowledgements This research work was funded by the German Research Foundation (DFG) within the research project "Methodical decision support for dynamic allocation planning of product variants in global manufacturing networks" (LA 2351/49-1). We thank the DFG for promoting and facilitating the research.

References

1. Wiendahl H-P, ElMaraghy HA, Nyhuis P et al (2007) Changeable manufacturing—classification, design and operation. CIRP Ann 56(2):783–809. https://doi.org/10.1016/j.cirp.2007.10.003
2. Mourtzis D, Doukas M, Psarommatis F (2015) A toolbox for the design, planning and operation of manufacturing networks in a mass customisation environment. J Manuf Syst 36:274–286. https://doi.org/10.1016/j.jmsy.2014.06.004
3. Abele E, Meyer T, Näher U et al (eds) (2008) Global production: a handbook for strategy and implementation. Springer, Berlin Heidelberg
4. Ferdows K (2018) Keeping up with growing complexity of managing global operations. Int J Prod Operat Manag 38(2):390–402. https://doi.org/10.1108/IJOPM-01-2017-0019
5. Váncza J (2016) Production Networks. In: Laperrière L, Reinhart G (eds) CIRP encyclopedia of production engineering. Springer, Berlin
6. Moser E, Stricker N, Lanza G (2016) Risk Efficient Migration Strategies for Global Production Networks. Procedia CIRP 57:104–109. https://doi.org/10.1016/j.procir.2016.11.019
7. Friedli T, Lanza G, Schuh G et al (2017) Active design of production networks. ZWF 112(5):279–283. https://doi.org/10.3139/104.111716
8. Wiendahl H-P, Lutz S (2002) Production in networks. CIRP Ann 51(2):573–586. https://doi.org/10.1016/S0007-8506(07)61701-6
9. Treber S, Lanza G (2018) Transparency in global production networks: improving disruption management by increased information exchange. Procedia CIRP 72:898–903. https://doi.org/10.1016/j.procir.2018.03.009
10. Kádár B, Egri P, Pedone G et al (2018) Smart, simulation-based resource sharing in federated production networks. CIRP Ann 67(1):503–506. https://doi.org/10.1016/j.cirp.2018.04.046
11. Friedli T, Mundt A, Thomas S (2014) Strategic management of global manufacturing networks: aligning strategy, configuration, and coordination. Springer, Berlin
12. Neuner C (2009) Konfiguration internationaler Produktionsnetzwerke unter Berücksichtigung von Unsicherheit. Zugl.: Bayreuth, Univ Diss, 2009, 1. Aufl. Gabler Research Schriften zum europäischen Management. Gabler Verlag / GWV Fachverlage GmbH Wiesbaden, Wiesbaden
13. Hochdörffer J, Berndt CV, Lanza G (2016) Resource-based reconfiguration of manufacturing networks using a product-to-plant allocation methodology. In: Proceedings of the 6th CIRP international conference on competitive manufacturing—resource efficiency for global competitiveness pp 511–516
14. Abele E, Liebeck T, Wörn A (2006) Measuring Flexibility in Investment Decisions for Manufacturing Systems. CIRP Ann 55(1):433–436. https://doi.org/10.1016/S0007-8506(07)60452-1
15. Moser E, Stricker N, Liebrecht C et al (2016) Preparation of Papers for IFAC Conferences and symposia: migration planning for global production networks using markovian decision processes. IFAC-Papers online 49(12):35–40. https://doi.org/10.1016/j.ifacol.2016.07.546
16. Cooper R-G, Edgett S-J (2014) Portfolio management for new products: picking the winners
17. Wiendahl H-P, Reichardt J, Nyhuis P (2015) Handbook factory planning and design. Springer, Heidelberg
18. Gausemeier J, Fink A, Schlake O (1998) Scenario Management. Technol Forecast Soc Chang 59(2):111–130. https://doi.org/10.1016/S0040-1625(97)00166-2
19. Wouters M (2012) Cost management: Strategies for business decisions, International ed. McGraw-Hill Higher Education, London
20. Mardani A, Jusoh A, MD Nor K et al (2015) Multiple criteria decision-making techniques and their applications—a review of the literature from 2000 to 2014. Econ Res 28(1):516–571. https://doi.org/10.1080/1331677X.2015.1075139
21. Greco S, Ehrgott M, Figueira JR (eds) (2016) Multiple criteria decision analysis: state of the art surveys. Springer, New York
22. Cisek R (2005) Planung und Bewertung von Rekonfigurationsprozessen in Produktionssystemen. Zugl. In: München, Techn. Univ., Diss., 2005. Forschungsberichte iwb/Institut für Werkzeugmaschinen und Betriebswissenschaften der Technischen Universität München, vol 191. Utz, München
23. Chen Y-Y, Fan H-Y (2015) An application of stochastic programming in solving capacity allocation and migration planning problem under uncertainty. Math Probl Eng. https://doi.org/10.1155/2015/741329
24. Reuter C, Prote J-P, Schmitz T et al (2015) Ermittlung eines strategischen Migrationsplans für globale Produktionsnetzwerke. ZWF 110(7–8):425–428. https://doi.org/10.3139/104.111371
25. Grunow M, Günther HO, Burdenik H et al (2007) Evolving production network structures. CIRP Ann 56(1):427–430. https://doi.org/10.1016/j.cirp.2007.05.102
26. Hochdörffer J, Laule C, Lanza G (2017–2017) Product variety management using data-mining methods—reducing planning complexity by applying clustering analysis on product portfolios. In: 2017 IEEE International Conference on Industrial Engineering and Management E (IEEM). IEEE, pp 593–597
27. Law AM (2015) Simulation modeling and analysis, 5. edn. McGraw-Hill series in industrial engineering and management science. McGraw-Hill Education, New York
28. Arndt T, Buderer C, Hofmann M et al (2016) Simulation-based evaluation of quality control strategies in global manufacturing networks. AMR 1140:473–480. https://doi.org/10.4028/www.scientific.net/AMR.1140.473