ASSESSMENT OF PRODUCTION NETWORK SCENARIOS BASED ON ECONOMIC VALUE ADDED

G. Schuh, J.P. Prote, B. Fränken, A. Güttzlaff
Department for Production Management, WZL of RWTH Aachen University, Steinbachstraße 19, 52074 Aachen, Germany

Abstract
Rapidly changing global markets force companies to consciously evaluate and adapt their production network. A common method for the evaluation of production networks is static cost and capacity modelling based scenario creation. Currently used cost models do not fully consider comprehensive aspects of financial and cost accounting, which are essential for a holistic economic efficiency calculation. The approach presented in this paper seeks to help companies to systematically choose the most economic scenario. An economic value added (EVA) based assessment method is used to consider savings and expenses on both financial and cost accounting level, including a systematic derivation of adjustment costs for restructuring the network. The approach results in a method to transfer model based static cost calculations into an economic efficiency calculation and is illustrated by the application in a real business case.

Keywords:
Production networks, scenario assessment, economic value added, economic efficiency calculation.

1 INTRODUCTION AND MOTIVATION
In order to open access to local markets, to ensure customer proximity and to reduce production costs, companies increasingly produce in global production networks [1]. Expanding market access allows companies to reduce their sales fluctuation by balancing declining sales quantities in traditional markets by opening new ones [2]. Simultaneously, manufacturing companies do not only have to challenge an increasing competition with other manufacturers but also face increasing customer needs. Consumers progressively demand shorter product life cycles and alter their purchasing behavior more quickly [3]. Furthermore, new technologies like additive manufacturing are capable of compromising the familiar production process [4]. The ability to adapt the global production network fast becomes a core competence for medium and large producing companies.

Adaptations to the global production network are strategic decisions because of their long-term impact on companies. Many decisions like the opening of new sites are difficult to revise and are connected with many unknowns due to the long planning period [5]. Therefore, thorough decision-making is essential. Hence, the complexity of planning and assessing production networks overwhelms many decision makers [6]. Since the complexity mainly concerns the internal production network while the planning of external networks is reduced to the logistics of the supplier network during the purchase, this paper focuses on the internal production network.

In order to make strategic network design decisions objective and manageable, a quantitative analysis of the production network is essential. Thus, quantitative modeling approaches are used to reduce the complexity of production networks and to create scenarios of possible future network designs [7]. The complexity reduction is caused by an abstraction of the real production network to create scenarios with a reasonable effort [8]. During the abstraction, information about the production process, but also about the production costs is compressed and scaled. This process cannot be reversed after the scenario creation. Therefore, finding the correct abstraction level upfront is important. Furthermore, a method has to be defined to assess possible scenario outcomes with a holistic economy efficiency calculation. This includes costs or profits which are not covered within the modeling approach, but do have an impact on companies economic value.

The approach presented in this paper seeks to provide a generic method to systematically assess strategic network scenarios based on quantitative models. A uniform valuation basis that considers all entrepreneurial-relevant costs, revenues and capital charges has to be defined.

2 STATE OF THE ART

2.1 Models for scenario creation
Modeling approaches for global production networks are distinguished into static and dynamic approaches. For static approaches, a specific aggregated time interval $t$, with $n$ as the future point of time is considered and valued. Dynamic approaches consider time dependences within the production process and are ordinarily desirable. However, when it comes to very complex scenarios and strategic planning, they struggle with creating valid results, which is why static models are preferred for real case strategic scenario planning [9]. Thus, the method presented in this paper focuses on static approaches.

In addition, since the design of production networks is a NP hard problem, heuristic methods are often preferred over optimization [10]. An overview of existing approaches is given by Cheng et. al. [11] and Olanger et al. [12]. However, there are also exceptions. Vahdani and Mohammadi [13] and Moser [14] are examples of approaches to design production networks with mathematical optimization.

2.2 Calculation methods for scenario assessment
A variety of methods for evaluating strategic investment decisions exist. The most widely used method is the net present value (NPV) method, which is listed in numerous textbooks and is scientifically hedged. Investments are valued based on the present value of all future payouts and incoming payments up to a given point of time $t$. The payouts and incoming payments are depreciated by a calculation rate. The aim is to maximize the capital value [15].

Recent accounting approaches such as strategic cost management (SCM) include strategic factors like value chain analysis, cost driver analysis and competitive
advantage analysis [16]. However, SCM is a collection of different accounting tools and data model based creation of production network scenarios consider these factors not only from a financial but also from a technical point of view. Therefore, this paper does not cover these approaches.

Total landed costs (TLC) are a measure for the efficiency of production networks. TLC include all direct and assignable indirect production costs until products reach their sales destination. Expenses for research and development, marketing and distribution, special depreciation, amortization of goodwill, restructuring and not assignable administrative activities are not included. Moreover, the net sales required for an EBIT calculation is not taken into account [17]. The calculation is defined as [18]:

\[
C_{\text{total}} = \sum_{j=1}^{n} C_{\text{site},j} + \sum_{j=1}^{n} (c_{\text{fix},j} + c_{\text{var},j}) + \sum_{l=1}^{q} c_{\text{trans},l} \sum_{i=1}^{q} c_{\text{duty},l}
\]

with

\[
c_{\text{site},j} \quad \text{= Sum of the basic costs of a location, for example consisting of the costs of management and rents or depreciation on buildings}
\]

\[
c_{\text{fix},j} \quad \text{= sum of fix costs of one site}
\]

\[
c_{\text{var},j} \quad \text{= sum of variable production costs of one site}
\]

\[
c_{\text{trans},l} \quad \text{= sum of transport costs per connection}
\]

\[
c_{\text{duty},l} \quad \text{= Sum of duties per compound}
\]

Economic Value Added (EVA) measures the value generated in a defined period \( t_n \) by increasing margins or the modified use of unused assets. EVA is used to decide on resource allocation, budgeting and acquisitions as well as disinvestments [19]. Advantages of the EVA method are the creation of a uniform basis for budget decisions, the performance assessment and the evaluation of the value-adding potential of strategic and tactical options. It can also be used for company management and company evaluation [20]. The EVA at a point of time \( t_n \) is defined as:

\[
EVA = NOPAT - (\text{Capital} \times c^*)
\]

with

\[
EVA \quad \text{= economic value added}
\]

\[
\text{NOPAT} \quad \text{= net operating profit after tax}
\]

\[
\text{Capital} \quad \text{= bound capital}
\]

\[
c^* \quad \text{= total cost of capital}
\]

The total capital cost rate \( c^* \) is based on company specific financing decisions. Commonly used is the weighted average cost of capital WACC [21]. Critics point out that EVA is not suitable to compare different companies with each other and that the WACC can be manipulated to come up to different results, especially if EVA is used as a reward system [22]. Both arguments do not apply for the approach presented in this paper since it is used for the holistic assessment of scenarios of the same company.

### 3 DEFICITS OF EXISTING APPROACHES IN SCENARIO EVALUATION

The established method for decision-making in strategic investment decisions is NPV, which is based on continuous payouts and incoming payments series. On the other hand, aggregated, single period quantitative models are commonly used to create production network scenarios. This models use simplified cost models like TLC that do not cover all entrepreneurial-related economic effects. Hence, this cost calculations cannot be transferred into an NPV calculation directly since the aggregated cost models for scenario creation aggregate and simplify cost information that do not necessarily represent all NPV relevant costs in \( t_n \). Recent scientific approaches do not challenge that gap since the research is done either from a technical or a financial point of view. Technical approaches mainly focus on a detailed cost driver analysis to create valid scenarios [23]. Financial approaches focus on the choice of the correct calculation rate and the handling of uncertainty [24]. A connection with production network scenario assessment is not considered.

Furthermore, static cost models such as TLC expressly do not consider adjustment costs of scenarios as they are incurred at another time period. In order to maximize the NPV, the adjustment costs must be known at their respective payment times. High adjustment costs can make scenarios unprofitable against alternative scenarios with lower conversion costs despite higher savings at the target period \( t_n \) (Figure 1). Therefore, a purely sequential scenario creation in which the best scenario based on the TLC is determined first and the adjustment costs are determined afterwards is not permissible.

Figure 1. Dependency of cost savings, adjustment costs and NPV.

Thus, current approaches lack of a systematic approach to determine the NPV of production network scenarios that are created by single period methods. For this purpose, EVA offers the possibility to act as an interface between static cost models like TLC and the calculation of NPV as it provides a uniform basis for budget decisions from the company’s viewpoint.
4 APPROACH

For the approach presented in this paper, the WZL developed scenario generation for network design, which is presented e.g. by Reuter and Hausberg [25], is used as a reference since it combines several advantages:

- The degree of abstraction of production is selectable and allows the user to scale how exact the production network has to be mapped to achieve meaningful results.
- Sub-divisions of the production network or the entire production network can be considered.
- The approach allows the use of mathematical optimization and heuristics as well as the creation of scenarios on the basis of experience knowledge and is validated by the use in real companies.
- The approach compares network scenarios based on production costs. Capacities are automatically scaled and serve as barriers, e.g. for the expansion of a site.

The initial approach based on five steps: At first, the scope of the production network and the degree of abstraction of the modeling are determined. In the next step, the model is calibrated by mapping the production network in its current state and comparing the costs and capacities of the model with the companies accounting data. The approach uses TLC for cost modeling. The third step is the identification of the ideal future scenario. For this purpose, either optimization methods can be used or scenarios based on user knowledge can be established. For example, network types such as a single world factory or a local for local production network approach can be compared. In the fourth step, the most promising approaches are supplemented by strategic guidelines such as location product specifications and sensitivities. A decision is derived from this and the conversion roadmap is derived in the fifth step.

The approach is modified by two major aspects (Figure 2):

- Step 1: Consideration of the main cost drivers when choosing the abstraction level based on an EVA driver tree
- Step 3 and 4: Iterative assessment of scenarios creation by taking adjustment costs and the overall value development from the company view based on the EVA into account instead of a green field scenario creation

4.1 Consideration of the main cost drivers

Determining the degree of abstraction drivers is essential for creating a network model that is able to generate valid
scenarios. For this purpose, not only the product structure and the production process but also the main cost drivers must be taken into account. An EVA driver tree (Figure 3) is used to contrast pagatoric and capital costs. The decision maker gets an overview about the total sum of all relevant costs such as current and noncurrent assets, fixed costs and variable costs as well as net sales. Each of these aspects can be spitted further by products or locations. As a result, the decision maker gets a detailed cost and revenue overview on different abstraction levels. The identification of the main cost drivers results in the determination of modeling areas that require an exact mapping of the production network and areas in which a rough picture of the reality is sufficient for the modeling. In addition, the levers that presumably lead to the greatest cost savings can be derived and used for the scenario creation in the next steps.

Next, the degree of abstraction regarding the product and process structure are defined for the modeling process. In order to validate the model, the current production network is then compared with the previously build EVA driver tree.

![EVA Driver Tree](image)

**Figure 3. Economic added value driver tree.**

### 4.2 Scenario evaluation via EVA

While Total Landed Costs are a good measurement indicator for the performance of a production network, a holistic assessment of scenarios, considering uncertainty, is fundamental for an entrepreneurial valuation. Therefore, the existing approach to initially design an ideal footprint and subsequently reduce it to a realistic level is not sufficient. It is replaced by a two-step scenario assessment that combines information from the data model itself. Therefor separated calculations have to be done. Noncurrent assets can be taken from accounting information if they already exist. If not, they have to be estimated. While noncurrent assets in buildings are nearly constant over time, assets in machines are changing due to depreciation. Since old machines have to be replaced over time it can be appropriate to average the machine value for a long distanced period $t_m$. For NOPAT (2), the tax rate and the EBIT have to be calculated. The tax rate depends on the company’s overall EBIT. If only parts of the production network are in scope of the scenario model, other costs and net sales have to be added. For the production network within the scope of the created scenarios, the EBIT can be calculated by subtracting the cost of the TLC calculation from the assumed sales quantities multiplied with their specific sales price. The EVA driver tree presents a holistic scenario evaluation for $t_n$. Moreover, the capital tie-up of each scenario is presented and can be considered to calculate the profitability of the scenarios. Due to strategic specifications, scenarios can be discarded at this point if the profitability does not match with the company’s requirements. In addition, the impact of the capital tie-up on the revenue management has to be taken into account since it can have a significant impact on the liquidity of the companies.

As pointed out in section 2.4, the adjustment costs are not included in static production network models. These must therefore be determined afterwards. Adjustment costs for the restructuring of production networks depend on a wide variety of factors. In particular, they are company-specific because of the production process and product properties. Abele et al. for example present methods for the determination of conversion costs [1]. The adjustment costs are distributed over one or several periods from $t_1$ to $t_n$, with $m \leq n$. In the next step, the temporal difference between adjustment costs and the future scenario savings in $t_n$ must be taken into account. The EVA calculation provides the basis for the NPV calculation since all payouts and incoming payments for $t_n$ are included (Figure 3). The periods between $t_0$ and $t_n$ can be interpolated. Depending on the assumed development of the production network and the sales quantities, linear, progressive and degressive interpolation can be chosen. Since the specific periods would be modeled with the same assumptions as the model in $t_n$, a separate modeling of each period would not lead to a different outcome since the chosen parameters are identical and dependences between the periods are not considered in a static model. Hence, the gain knowledge would be redundant, but the effort is significantly higher. The conversion costs are added to the resulting values for $t_1$ to $t_n$. If no scenario was previously excluded due to strategic considerations, the scenario with the highest NPV should be chosen.

In the next step, the final assessment, the previously selected scenario is tested for sensitivity to factors such as sales fluctuations, currency fluctuations, fluctuations in transport costs and labor costs developments. These factors are selected and determined in advance. For each factor, upper and lower limits are established. Subsequently, best and worst-case scenarios are formed from the sensitivity factors. Both scenarios are transferred to an EVA driver tree. On basis of the EVA calculation, the sensitivity of sales prices and their effect on the EBIT are
tested. Furthermore, the profitability of the scenarios in $t_0$ is calculated. The results show whether the sensitivity analysis has a strong imbalance towards a worsening of the scenario or if strategic requirements cannot be fulfilled. In both cases, the scenario is dismissed and the scenario with the next highest NPV of the pre-assessment step is examined. This procedure is iterated until a scenario with a solid sensitivity is found. This way it is ensured that the most advantageous scenario is chosen from the company perspective.

5 APPLICATION

The approach presented by Reuter and Hausberg [25] has been applied since 2011 within more than 10 projects of the WZL with industrial partners. In the following, a selected case is presented in which the production network for 2025 is defined by using the modified procedure. The initial situation of the industrial partner was a historically grown production network, which had a multitude of locations in geographic proximity to one another through merger and acquisition activities. The scope of the project contained six production sites in Europe. The products are sold in Europe, North America and Asia. 83 products and their modules and components were considered in the scenario creation process. The modeling was done by use of the software tool OptiWo, the scenarios were created on a knowledge based approach.

The cost analysis of the network on an EVA basis showed, in addition to the initially known moderate utilization of the production network, in particular a high capital tie-up by noncurrent assets in buildings. Therefore, the aim of the project was to examine the scale effects that can be realized by reducing the number production sites in order to increase the profitability. The core issues of the project were

- Which products can be combined in one location?
- Which levers offer the greatest savings potential?
- Which revenue growth can a reduced number of sites cover until an expansion of the network is required?

After the validation of the model by comparison with the current production network, four different scenarios were developed based on strategic considerations. The TLC calculation showed a savings range of 6% to 11% for the scenarios. The EVA evaluation showed an EVA improvement from 4% to 16% by taking net sales and capital charge into account. Especially scenarios with a lower capital commitment displayed a significantly better EVA compared other scenarios than it was shown in the TLC calculation. The NPV calculation, including adjustment costs, confirmed the economic efficiency of the scenario with the highest EVA. At the same time, the scenario is robust against revenue growth and the following sensitivity analysis did not unfold high risks which led to a systematic scenario selection.

6 CONCLUSION

The presented approach provides a holistic process to assess production network scenarios based on static cost models from an entrepreneurial point of view. Therefore, an EVA calculation is used as a uniform basis for the evaluation of strategic scenario options. This allows decision makers to transform single period cost calculations to continuous calculations like NPV systematically. Advantages of the model are the flexibility in the choice of optimization methods, the consequent consideration of capital costs and transparency in the decision making process. The approach was validated in a real case scenario. Further research needs to be done in the interpolation of single period cost calculation to multiple periodic calculation. More validation needs to be done to ensure the applicability in various specific applications.

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".

REVERENCES

[1] Abele E., Meyer T., Nährer U., Strube G., Sykes R., 2008, Global production: a handbook for strategy and adjustment, Springer, Heidelberg, 26.
[2] Dunning J.H., Lundan S.M., 2008, Multinational enterprises and the global economy, Edward Elgar Publishing Limited, Northhampton.
[3] Roland Berger Strategy Consultants, 2012, Mastering product complexity, Hamburg.
[4] Beyer C., Strategic Implications of Current Trends in Additive Manufacturing, Journal of Manufacturing Science and Engineering, 2014, 136, December.
[5] Salemi H., A hybrid algorithm for stochastic single-source capacitated facility location problem with service level requirements, International Journal of Industrial Engineering Computations, 2016, 7, 295-308.
[6] McKinsey & Company, PTW, 2004, How to Go Global – Designing and Implementing Global Production Networks.
[7] Schuh G., Potente T., Kupke D., Varandani R., Hausberg C., An Evolutionary Approach for Global Production Network Optimisation, Procedia CIRP, 2012, 3, 382-387.
[8] Reuter C., Prote J.P., Stöwer M., Aggregation of Production Data for the Strategic Planning of Global Production Networks, Applied Mechanics and Materials, 2015, 794, 461-469.
[9] Jacob F., 2006, Quantitative Optimierung dynamischer Produktionsnetzwerke, Shaker, Darmstadt.
[10] Vahrenkamp R., Mattfeld D.C., 2007, Logistiknetzwerke. Modelle für Standortwahl und Tourenplanung, Gabler, Wiesbaden.
[11] Cheng Y., Farooq S., Johansen J., International manufacturing network. Past, present, and future, International Journal of Operations & Production Management , 2015, 35, 3, 392–429.
[12] Ollagner J., Pashaei S., Sternberg H., Design of global production and distribution networks: A literature review and research agenda, International Journal of Physical Distribution & Logistics Management, 2015, 45, 1/2, 138-158.
[13] Vahdani B., Mohammadi M., A bi-objective interval-stochastic robust optimization model for designing closed loop supply chain network with multi-priority queuing system, International Journal of Production Economics, 2015, 170, Part A, 1, 67-87.
[14] Moser R., 2014, Strategische Planung globaler Produktionsnetzwerke – Bestimmung von Wandlungsbedarf und Wandlungszeitpunkt mittels multikriterieller Optimierung, Shaker, Karlsruhe.
[15] Magni C.A., Investment decisions, net present value and bounded rationality, Quantitative Finance, 2005, 9, 8, 967-979.
[16] Shank J. K., Govindarajan V., 1993, Strategic cost management. The new tool for competitive advantage, Free Press, New York.
[17] Meyer T., 2006, Globale Produktionsnetzwerke, Shaker, Darmstadt.
[18] Schawel C., Billing F., 2012, Top 100 Management Tools, Springer Gabler, Wiesbaden, 86-88.
[19] Chen S., Dodd J.L., Economic Value Added (EVA™): An Empirical Examination Of A New Corporate Performance Measure, Journal of Managerial Issues, 1997, 9, 3, 318–333.
[20] Ehrbar A., Using EVA to measure performance and assess strategy, Strategy & Leadership, 1999, 27 3, 20-24.
[21] Bruner R.F., Eades K.M., Harris R.S., Higgins R. C., Best practices in estimating the cost of capital: survey and synthesis, Financial practice and education, 1998, 8, 13-28.
[22] Daru M.U., Economic Value Added (EVA) as tool for Measuring Financial Performance, International Journal of Research in Economics and Social Sciences, 2016, 6, 9, 40-44.
[23] Schuh G., Prote J.P., Schmitz T., 2017, Resource-Based Cost Modeling – a New Perspective on Evaluating Global Production Networks, 50th CIRP Conference of Manufacturing Systems, Taichung City.
[24] Bhaumik P.K., An appropriate risk addendum for risky projects, Managerial Finance, 2016, 42, 6, 604-616.
[25] Reuter C., Hausberg C., 2015, An IT Driven Approach for Global Production Network Design, Proc. of the International MultiConference of Engineers and Computer Scientists 2015 Vol II, Hong Kong, 888-893.