ОРГАНІЗАЦІЯ ВИРОБНИЦТВА: ТЕНДЕНЦІЇ РОЗВИТКУ

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SYNCHRONOUS METHOD AND ENGINEERING TOOL FOR THE STRATEGIC FACTORY PLANNING

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СИНХРОНІСТИЧНИЙ МЕТОД І ІНСТРУМЕНТАРІЙ СТРАТЕГІЧНОГО ВИРОБНИЧОГО ПЛАНУВАННЯ
Ця стаття представляє комбінований підхід, у рамках якого використаються два вихідних методи й реалізуючий їх інструментарій, а саме "Планування капіталовкладень і продуктивності підприємства" і "Ідеальне виробниче мережеве планування доданої вартості". Кінцевими цілями синхроністичного методу є підтримка підприємств як у стратегічному плануванні, так і в мережевому. Відповідним інструментарієм є використовуваний для планування ціни, стимулювання збуту, завантаження виробничих потужностей і виробничих витрат у розгляді різних виробничих сценаріїв розподілу динамічних і стохастичних аспектів. Значимість результатів показана поданням реалізації сценарію з використанням синхроністичного методу й інструментарію.
Ключові слова: визначення продуктивності підприємства, сіткове планування виробництва, критерій оцінки.

Эта статья представляет комбинированный подход, в рамках которого используются два исходных метода и реализующих их инструментария, а именно «Планирование капиталовложений и производительности предприятия» и «Идеальное производственное сетевое планирование добавленной стоимости». Конечными целями синхронистического метода является поддержка предприятий как в стратегическом планировании, так и в сетевом. Соответствующим инструментарием является используемый для планирования цены, стимулирования сбыта, загрузки производственных мощностей и производственных затрат в рассмотрении различных производственных сценариев распределения динамических и стохастических аспектов. Значимость результатов показана представлением реализации сценария с использованием синхронистического метода и инструментария.
Ключевые слова: определение производительности предприятия, сетевое планирование производства, критерий оценки.

This paper presents the approach to combine two reference methods and engineering tools, for «Factory Performance and Investment Planning«as well as»Value Added Ideal Production Network Planning». The resulted synchronous method aims to support factories in the strategic planning as well as in the network planning. The corresponding engineering tool is employed for assessment planning, sales planning, capacity planning and production costs planning under the consideration of dynamic and stochastic aspects of different production scenarios. An implementation scenario of the synchronous method and engineering tool is presented to demonstrate the relevance of the results.
Keywords: Factory performance planning, production network evaluation, value creation.

1 INTRODUCTION

Today's manufacturing enterprises in all industrial sectors are confronted with bigger market challenges than in the past. The markets getting global, goods and services are available all over the world within a short period of time. These circumstances increase the market challenge pressure for manufacturing enterprises worldwide [1]. To meet the customer needs, the products have to be cost effective as well as delivered in short period and simultaneously in terms of high reliability. The approach of the synchronous method and engineering tool for the strategic factory planning and network planning provides a large share to master them successfully. Therefore the approach combines two reference methods and engineering tools, for "Factory Performance and Investment Planning" as well as "Value Added Ideal Production Network Planning" developed by the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA). These engineering tools can be used independently within the factory life cycle.

This new approach allows the holistic view of the manufacturing enterprises production network at different scales, starting at the level of the network on the top, down to the machines and work places on the bottom of the planning view. The two combined engineering tools are sharing a database exchange, which is accessed from both engineering tools synchronal. In order to realize this sharing of the database exchange, it is possible to configure the synchronization between the tools. The key performance indicators calculated in the Factory Performance and Investment Planning are available as input for the Value Added Ideal Production Network Planning and vice versa.

For the strategic planning and value added ideal creation of a manufacturing enterprises production network, multiple planning scenarios alternatives are developed, implemented into holistic models and finally benchmarked and evaluated. These alternative planning scenarios are examined in terms of technique and economic aspects. The combined method and engineering tool considers various uncertainties as well as dynamic aspects and its temporal trend. The results are technical and monetary statements to production network costs as well as their factory performance units. Furthermore each of the two reference methods and engineering tools is a high potent support in strategic factories planning and the related decision making process.

2 REFERENCE METHOD AND ENGINEERING TOOL FOR FACTORY PERFORMANACE AND INVESTMENT PLANNING – FLIP

2.1 Problem statement

The factory performance planning takes into consideration factory long term objectives as well as the requirements of the working personal and the environment [2].

The evaluation of the factory performance as a basis of replanning is therefore taking into account various aspects. Among these, one is to capitalize the opportunities of the digital engineering systems, and in particular the simulation applications, in order to answer to questions regarding the capacity distribution, the on time delivery synchronization, the employment development or the impact of rationalization measures [2]. The product market strategies of manufacturing enterprises, the so called factories, are usually the base for the development of the production. In the strategic planning, the financial data for product development, the capacity and investments are established. The performance planning needs the development of a technical concept for the production, includingthe expected product and production technologies [2].

2.2 State of the art

Several systems exist to support the engineering in various planning phases of the factory planning e.g. [3, 4]. Missing is an engineering tool for the support of the strategic factory planning in terms of factory performance planning and value added ideal production network planning. The strategic factory planning has been approached by the research works of Grundig [5], Pawellek [6] and Wiendahl [7]. Although each research work considers the strategic factory planning there is a lack of a continuous systematic methodology for the factory performance and investment planning.

2.3 Motivation

During the strategic factory planning the economic framework for the product development as well as for the production capacities and investments are defined. To get significant decisions during the strategic factory planning there has to be designed a technique production concept, including the expected product and production technologies. Therefore the IPA developed the reference methodology and engineering tool for the synchronous factory performance and investment planning.

2.4 Requirements

To get a realistic and systematic support for the factory performance and investment planning, the methodology and engineering tools should be able to take into account the effects of conception and rationalization activities at performance units synchronous. In the context of multiscale factory [8, 9], the factory performance unit is approached at production sites, production segments, production systems, production cells, as well as machines and workplaces. The viewing frame of the performance unit is therefore scalable to meet the individual necessary requirements. Thus, it is possible to decompose complex performance units in components and bring them together again after their successful analysis.

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2.5 FLIP Systematics

The approach for the reference methodology and engineering tool for Factory Performance and Investment Planning is to divide the planning procedure into two synchronized planning levels and eleven planning steps. The planning levels are processed parallel and include planning level overlapping links of the particular planning steps, as shown in Figure 1. Through the adaption of the key performance indicators for the two planning levels, multiple planning scenarios are generated, iteratively optimized as well as analysed and evaluated for the assessment of the planning scenarios.

The first level takes into account the technique planning. Therefore the utilization time, the capacity inventory, the personal planning and the loading of the performance unit are considered. The second level is regarding the economic planning level. This economic planning level takes into account the production cost of the performance unit by considering the cost and performance indicators of efficiency analysis as required in the factory.

2.6 FLIP Workflow

The workflow of activities and steps required to be achieved are in the following presented:

1. Creation of the process overview;

2. Coordination of the key performance indicators from marketing, sales, production and management;
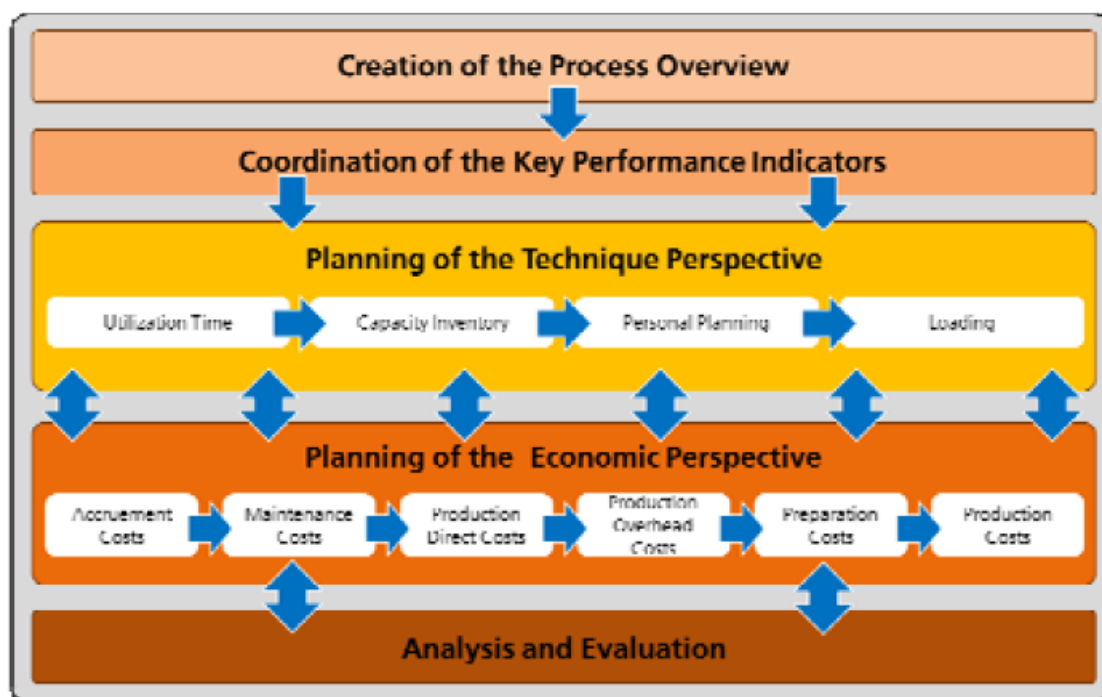

Figure 1 – FLIP Systematic

3. Monitoring and evaluation of: a. Technique performance indicators, e.g.: Performance unit cycle time, utilization time, manpower requirement, capacity inventory and loading b. Economic performance indicators, e.g.: Performance unit installation costs, commissioning costs, personal costs, profitability and payback period.

4. Analysis and evaluation.

2.7 Benefits

The results are monetary statements to life cycle costs, production costs and performance of factory performance units. The benefits are the following:

▪ The holistic and synchronous consideration of costs and performance already during the strategic factory planning;

▪ The analysis and evaluation of technique and economic planning alternatives as well as the utilization analysis of multiple planning scenarios.

3 REFERENCE METHOD AND ENGINEERING TOOL FOR VALUE ADDED IDEAL PRODUCTION NETWORK PLANNING – VPRONET

3.1 Problem statement

The globalization of markets and the related competitive pressure are permanently increasing [10]. This provides manufacturing enterprises and their managers with huge challenges [11]. To meet these challenges, manufacturing enterprises have to be present locally with their own capacity in almost all markets, thereby greatly increasing the complexity in the production networks. This leads to an increasing importance of location and network planning with the goal of flexible and cost effective distribution of the value creation [12, 13]. The significant efforts for the reduction as well as the decrease of the necessary investments are required to enable these companies to select the value added ideal production network.

3.2 State of the art

The ideal connection of the different production sites is a critical point in assuring the competitiveness of manufacturing enterprises. Researches have already addressed the complexity of planning production networks with mathematical or electronic support in the early 90s. Hagedorn [14] developed one of the first models to handle new production capacities in production network. The model divides a production network into two levels, the production site level as well as the headquarter level. By dividing the network into these levels Hagedorn generated a simulation model to analyze the future changes in the production program, as presented in Figure 2.
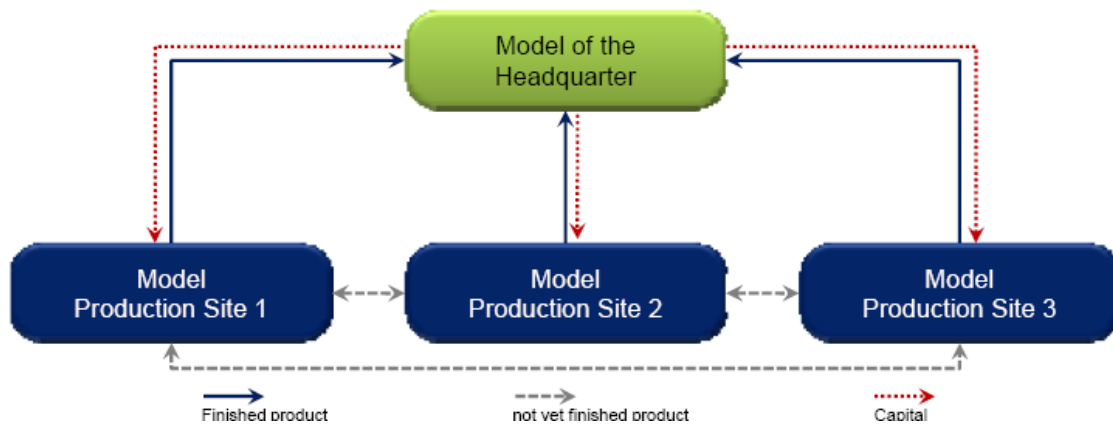
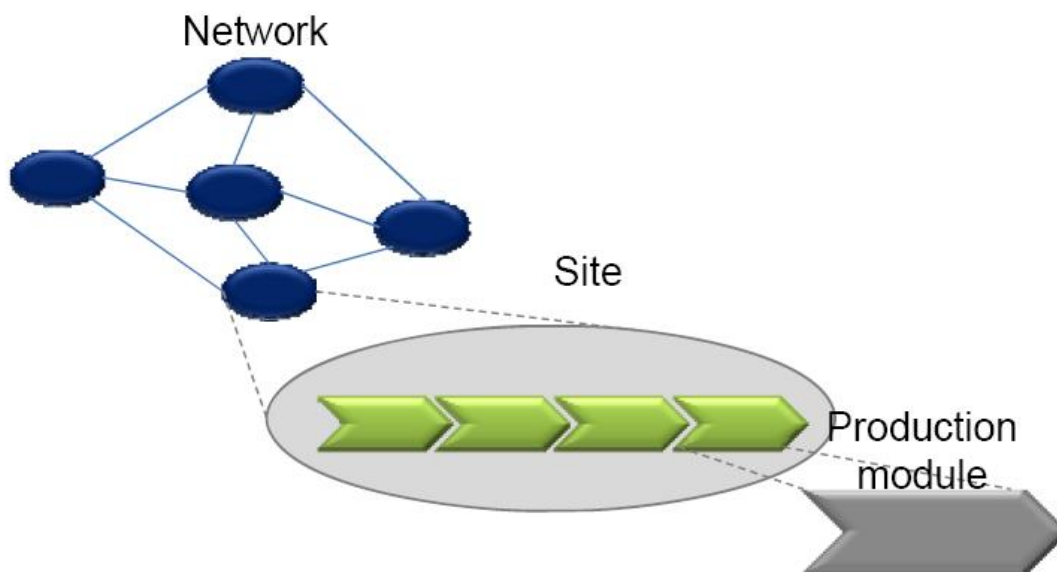Figure 2 – Two network level definition (adapted from [14])

Figure 3 – Definition of Different network level [16]

Schellberg [15] and Merchiers [16] adopted the division of networks and extended it to the three. Within the network level, production sites are chosen and their roles are defined. In the site level, the production program of the single production sites is planned while the detailed planning of production processes is connected to the level "production module", presented in Figure 3.

Nevertheless the general idea of defining different levels is not found in all modern researches. One important work dealing with planning of production networks has been composed by Meyer [17]. He developed a method for designing and evaluation global production networks focused on a quantitative analysis of network costs by using a mathematical optimizing. Other research works as Wunderlich [18] and Kohler [19] focus more on the aspect of analyzing costs at one production site and neglect the extension to production networks.

In conclusion several approaches of research exist which deal with the matter of simulation or mathematical supported planning of networks or with the detailed analysis of cost structures in production sites. Although financial aspects are included in most of the methods, there is to date no method contains all the relevant costs in production networks. Furthermore the aspect of dynamic examination is less addressed as well as the consideration of uncertainly factors; most of the generated methods focus on static optimization.

3.3 vProNet Systematics

The flexible and cost optimized distribution of the value creation in production networks depends on three factors: costs, time and quality. These factors influence each other and the optimization of a single factor may adversely affect the other two factors. Therefore, these factors have to be considered parallel. The developed reference method for the production network selection due to the simulation based distribution of the value creation consists of seven phase, shown in Figure 4.

The first phase of this method is the **Analysis**. It builds the basic for further phases and concludes the following steps:

A1. Product Analysis: This step aims to analyze the product main parts and modules as well as the parts to be transported.

A2. Production Network Analysis: This step analyzes the current status of the production network composed of the network level, site level and the production level and leads to an abstract production network as well as the process structure.

A3. Cost Structure Analysis: This analysis requires the costs for producing new products as well as the exchange rate. The costs will be related to the production network as shown in Figure 5. The dynamic trend of these costs will be taken also into account.

Modeling is the second phase of this reference method. Based on the results of the previous phase a simulation model will be developed and implemented according to the "top down" strategy. In this model various uncertainly factors and dynamic factors as well as their trend have to be presented.

The third phase is the **Scenario Development** and addresses the link between the sites. This phase consists of the following steps:

SD1. Development of production scenarios: Different goal and evaluation criteria have to be defined within this step. Based on these criteria, production scenarios will be developed and parameterized.

SD2. Mapping of production scenarios: the developed scenarios will be mapped in the previously developed simulation model with low complexity.

The fourth phase is called **Simulation**. One more, simulation studies will be accomplished. The results of this phase will be visualized and exported as well as used in the following phases. The fifth phase evaluation consists of two steps:
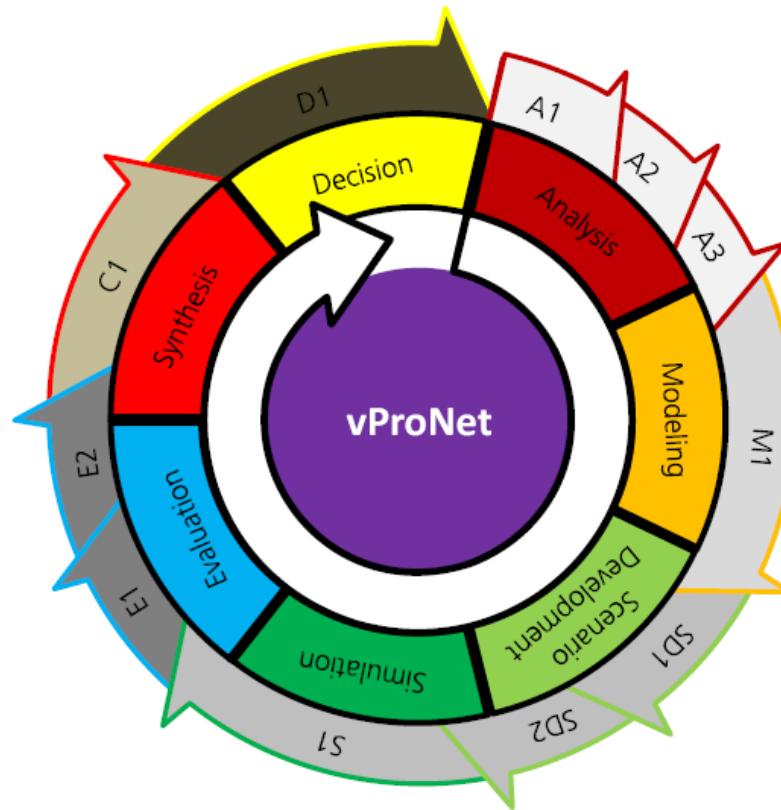

Figure 4 – vProNet phases

E1. Weighting the goal criteria: Using an utility analysis, qualitative as well as quantitative evaluation criteria are compared to each other and weighted.

E2. Multi criteria evaluation: The various production scenarios will be evaluated according to the weighted criteria above.

The sixth phase **Synthesis** compares the results of different simulation studies taking into account the goal and evaluation criteria as well as the degree of performance. The last phase is the **Decision**. Within this phase and based on the results of the previous phases, the value added ideal production network will be selected.

3.4 Benefits

Besides the evaluation of dynamic production networks, this method offers a user friendly and library based simulation as well as a cost optimized distribution of the value creation.
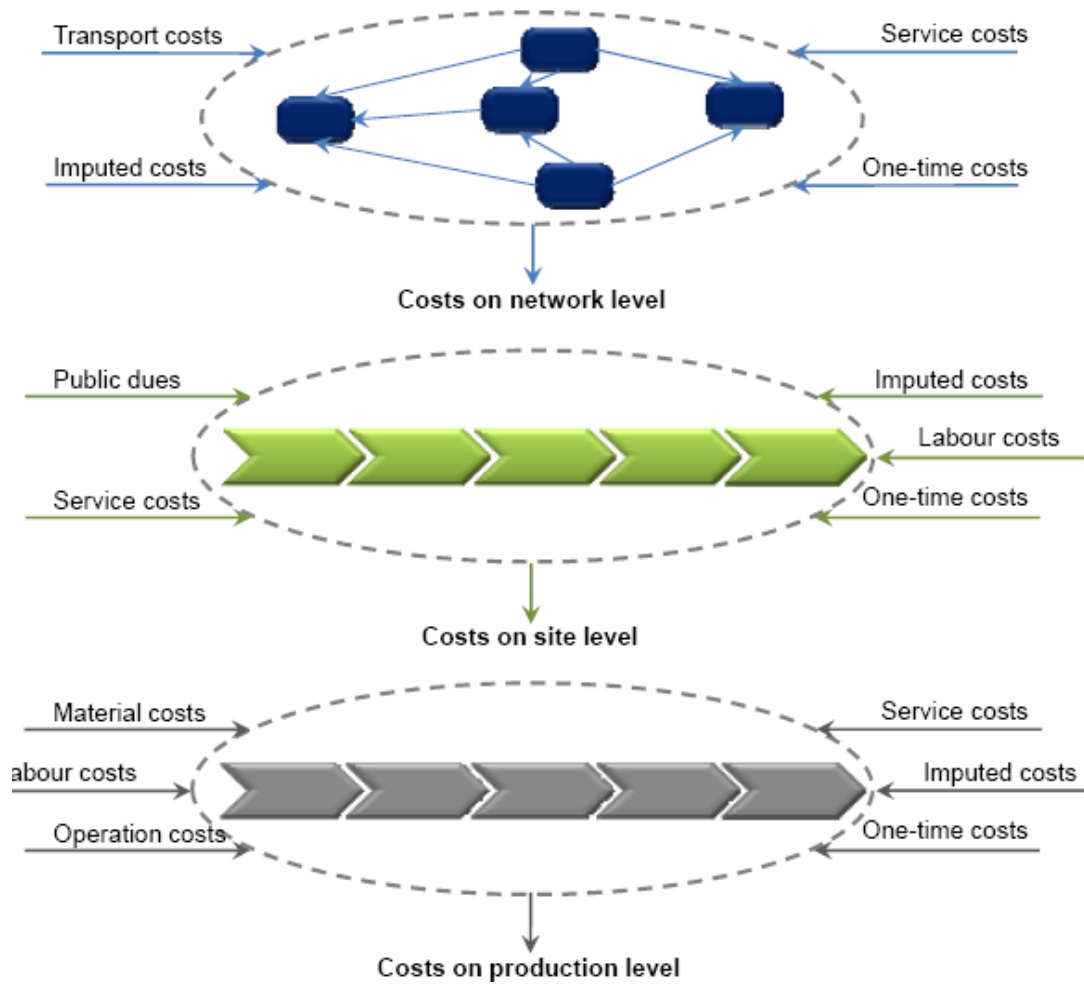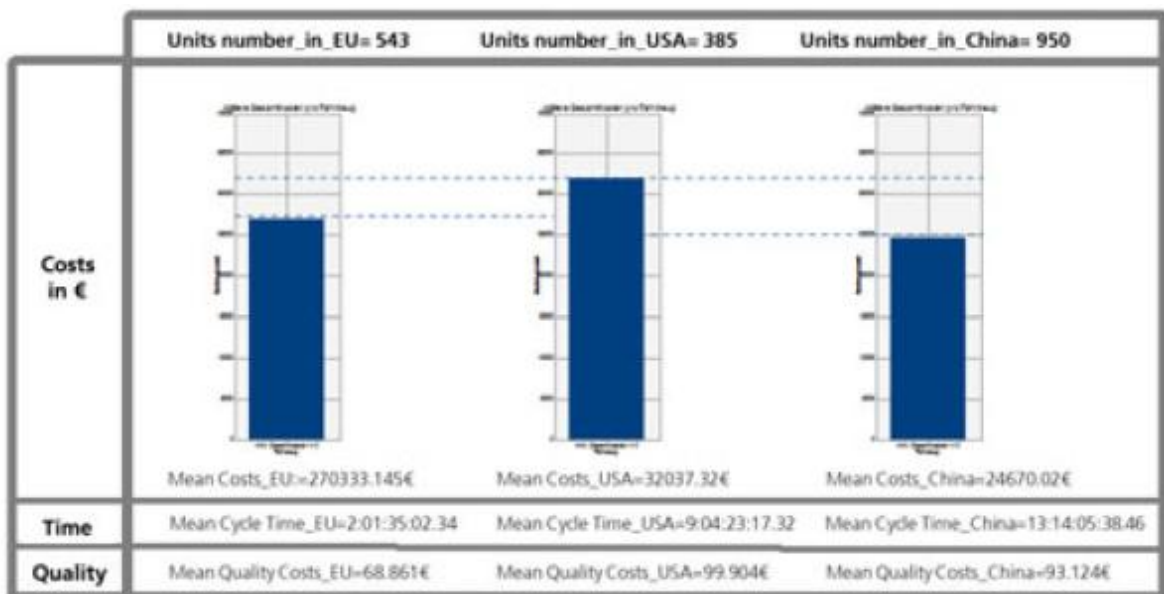
Figure 5 – Costs related to a production network

Figure 6 – Visualisation of the scenario results

4 PROTOTYPICAL IMPLEMENTATION

Both reference methods and engineering tools share a common database, where the common data (e.g. cost structure or key performance indicators) are stored. The rest of the data is stored local.

The combination of both methods is prototypical implemented for a process chain within the automotive industry. The Goal is to calculate the costs and performance of a production network consisting of three sites (EU, USA and China) as well as the ideal value added distribution. Therefore, several scenarios are modelled, simulated and evaluated regarding the Magical Triangle criteria costs, time and quality. Figure 6 shows the visualisation of the results of this implementation scenario.

5 SUMMARY

The upcoming challenges for manufacturing enterprises as globalization, flexibility and adaptability in today's and future markets lead to the customer needs of high potent support in strategic factory planning and the related decision making process. The IPA approach to combine two reference methods and engineering tools, for »Factory Performance and Investment Planning« as well as »Value Added Ideal Production Network Planning« has the aim to support the strategic factory planning of the manufacturing enterprises. The presented approach regards factory long term production network and factory performance objectives as well as the requirements of the working personal and the environment. Therefore different technique and economic key performance indicators have to be taken into account e.g. technical performance and labour cost in different countries, regions and cities as well as various market requirements and legal regulations. Based on these indicators different planning scenario alternatives are developed and evaluated regarding quantitative and qualitative criteria.

6 ACKNOWLEDGEMENTS

REFERENCES: 1. *Westkämper, E.,* 2006, Digitale Produktion - Herausforderung und Nutzen. In: Heisel U. [Hrsg]: FTK 2006 - Fertigungstechnisches Kolloquium Stuttgart, Stuttgart, Germany. **2.** *Westkämper, E.,* 2008, Fabrikplanung vom Standort bis zum Prozess, Konfe-

renzbeitrag des Deutschen Fachkongresses Fabrikplanung, 28-29 October, Ludwigsburg, Germany. **3.** *Papakostas, N., Efthymiou, K., Mourtzis, D., Chryssolouris, G.,* Modeling the complexity of manufacturing systems using nonlinear dynamics approaches, 2009, CIRP Annals - Manufacturing Technology 58, p. 437-440, 2009. **4.** *Lalas, C., Mourtzis, D., Papakostas N., and Chryssolouris, G.,* A Simulation-Based Hybrid Backwards Scheduling Framework for Manufacturing Systems, International Journal of Computer Integrated Manufacturing, (Vol. 19, No. 8, 2006), pp. 762-774 **5.** *Grundig, C.-G.,* 2006, Fabrikplanung. Planungssystematik – Methoden – Anwendungen, 2. aktualisierte Auflage, Hanser, München, Germany. **6.** *Pawellek, G.,* 2008, Ganzheitliche Fabrikplanung: Grundlagen, Vorgehensweise, EDV-Unterstützung. Springer, Berlin, Germany. **7.** *Wiendahl, H.-P., Reichardt, J., Nyhuis, P.,* 2009, Handbuch Fabrikplanung - Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten. Hanser, München, Germany. **8.** *Scheibe, A., Constantinescu, C., Decker, M., Ye, Q., Westkämper E.,* 2006, A comprehensive and holistic approach of multi-scale modeling and simulation of manufacturing systems. In: The 6th International Workshop on Emergent Synthesis, IWES06, 18-19 August, Kashiva, Japan, p. 205-211. **9.** *Westkämper, E., Constantinescu, C., Hummel, V.,* 2006, New paradigms in Manufacturing Engineering: Factory Life Cycle. In. Annals of the Academic Society for Production Engineering. Research and Development, XIII/1, Volume XIII, Issue 1, p. 143-147. **10.** *Risse, J.:* Time-to-Market-Management in der Automobilindustrie: ein Gestaltungsrahmen für ein logistikorientiertes Anlaufmanagement. Haupt, Bern 2003, ISBN 3258066566. **11.** *Klöpfer, R.:* Konfiguration der internationalen Produktionswertschöpfungskette. Eul, Lohmar 2000, ISBN 3890127533. **12.** *Fleischer, J., Herm, M., Schell, M.-O.:* Wertschöpfung in Netzwerken – Integrierte Planungsmethodik zur Konfiguration von globalen Produktionsnetzwerken; in ZwF – Zeitschrift für wirtschaftlichen Fabrikbetrieb, Jahrgang 99 (2004), Heft 9, S. 470-476. **13.** *Kinkel, S., Lay, G., Jung Erceg, P.:* Produktionsverlagerungen und Auslandsproduktion im deutschen verarbeitenden Gewerbe-Stand, Trend, Motive und Effekte, in Kinkel, S.: Erfolgsfaktor Standortplanung: in- und ausländische Standorte richtig bewerten, Springer, Berlin, 2004, S. 17-31. **14.** *Hagedorn, A.:* Modellgestützte Planung und Kontrolle von Produktionsstandorten. Univ., Diss.– Hildesheim, 1992, Dt. Univ.-Verlag, Wiesbaden. **15.** *Schellberg, O.:* Effiziente Gestaltung von globalen Produktionsnetzwerken. Techn. Hochsch., Diss.– Aachen, 2002. Shaker, Aachen, 2002. **16.** *Merchiers, A.:* Bewertung globaler Standortstrukturalternativen im Maschinenbau. Techn. Hochsch., Diss.–Aachen, 2008, Apprimus-Verlag, Aachen. **17.** *Meyer, T.:* Globale Produktionsnetzwerke. Ein Modell zur kostenoptimierten Standortwahl. Techn. Univ., Diss.--Darmstadt, 2005. Shaker, Aachen. **18.** *Wunderlich, J.:* Kostensimulation. Simulationsbasierte Wirtschaftlichkeitsregelung komplexer Produktionssysteme. Meisenbach, Bamberg, Erlangen, 2002. **19.** *Kohler, U.:* Methodik zur kontinuierlichen und kostenorientierten Planung produktionstechnischer Systeme. Techn. Univ., Diss.–München, 2007. Utz, München, 2008.