

Value-oriented layout planning using the Virtual Production Intelligence (VPI)

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Abstract

Due to increasing cost pressure, factory planning has to focus on value-adding activities. Layout planning plays a significant role in factory planning, as it must integrate the previous planning results. In order to realize a value-oriented layout planning, a layout assessment approach using the “Virtual Production Intelligence” (VPI) platform is presented.

Keywords: Layout planning, layout assessment, virtual production intelligence

Introduction

Environment of todays factory planning projects

In the context of a continuous globalization of economic activities, producing companies are facing a growing market dynamics. This leads to shorter technology and product life cycles and a growing diversity of variants, caused by the production of customer individual products with smaller quantities. Therefore, companies are under the pressure to be a leader in the key figures: costs, quality, delivery service and customer individuality (Menrath et al. 2003, Cisek et al. 2002). These key figures can be summarized by the term competitive strategy (Frese 2008). The aforementioned developments mean that companies adjust their competitive strategy more frequently in order to remain competitive (Menrath et al. 2003).

The production plays a special role in the operationalization of the competitive strategy as a manufacturing strategy which is optimized to the specific requirements of the production is a major key to improve business efficiency (Menrath et al. 2003). The regular adaption of the manufacturing strategy to changing competitive strategies leads to a more frequent realization of factory planning projects. These are subjected to considerable pressure to improve efficiency. High efficiency of the factory planning project can be achieved not only by low costs, but mainly through a high benefit of the

planned production system.

The implementation of factory planning projects with special emphasis of a comprehensive cost-benefit ratio has already been discussed under the heading "Value-based factory planning" (Burggräf 2012).

Also, the Association of German Engineers (Verein Deutscher Ingenieure) specifies the profitability and sustainability as one of the main objectives of factory planning (Verein Deutscher Ingenieure (VDI) 2011a). The costs of factory planning in general can be determined with sufficient accuracy, while the estimation of the benefit is difficult. This was confirmed in a survey by experts (Burggräf 2012).

To ensure the highest possible overall efficiency of the factory planning project in terms of a "value-oriented factory planning", the impact of decisions have to be known prior to and during the planning. If these mechanisms are well known, the specific planning project can be adjusted to the ideal ratio of costs and benefits. Thereby, the determination of the planning benefit has to be objective, transparent and quantitative. A constraint on the knowledge and experience of the planner is not sufficient, since the economic objectives of the company do not necessarily correlate with the personal goals of the planner.

Despite the described demand for an assessment of the benefit of factory planning projects, there is no theoretical approach to describe the mechanisms between planning effort and planning benefit systematically and quantitatively.

A review of existing factory planning approaches (Verein Deutscher Ingenieure (VDI) 2011a, 2011b, Brieke 2009, Wiendahl et al. 2009, Tompkins et al. 2003, Pawellek 2008, Kettner et al. 1984, Grundig 2009) shows that some authors claim principle elements of value orientation (such as the assessment of planning and tracking of an optimal cost-benefit). A systematic approach or specific tools are not provided. Therefore, the factory planner has to pursue the value orientation in the specific planning project based on his own experiential knowledge.

Layout planning in factory planning projects

Layout planning is the positioning of resources (for example: machines, working places) and functional areas (for example: logistics areas, waste disposal areas) within factory buildings (Wiendahl et al. 2009).

Different requirements can be imposed on layout planning, for example:

- Costs (Pawellek 2008, Tompkins et al. 2003, Wiendahl et al. 2009)
- Space utilization (Pawellek 2008, Schenk 2004, Tompkins et al. 2003)
- Production efficiency (Wiendahl et al. 2009, Pawellek 2008, Grundig 2009)
- Minimization of effort for material transport (Schmigalla 1970, Wiendahl et al. 2009, Pawellek 2008, Kettner et al. 1984, Schenk 2004, Chen, Sha 1999, Grundig 2009)
- Transparency (Wiendahl et al. 2009, Schenk 2004, Tompkins et al. 2003, Pawellek 2008)
- Flexibility, Changeability (Wiendahl et al. 2009, Tompkins et al. 2003, Pawellek 2008, Günther 2005, Heinecker 2006)
- Information flow, communication flow (Wiendahl et al. 2009, Kettner et al. 1984, Grundig 2009, Bergmann 2008)

- Consideration of restrictions of the building (for example: by law or existing building structures)(Wiendahl et al. 2009)

Layout planning is a key task within factory planning. In layout planning, the integration of previous planning results is performed, which partially have been developed independently (Verein Deutscher Ingenieure (VDI) 2011a, Kettner et al. 1984, Rockstroh 1980, Grundig 2009, Tompkins et al. 2003, Nöcker 2011).

Only by layout planning the previous planning results are transformed in a physical form and can be implemented architectural. Figure 1 exemplarily shows the planning approach according to (Verein Deutscher Ingenieure (VDI) 2011a). The results of structure planning, dimensioning of resources (for example: machines, functional areas) as well as concepts of production control, logistics, information flow and communication are integrated.

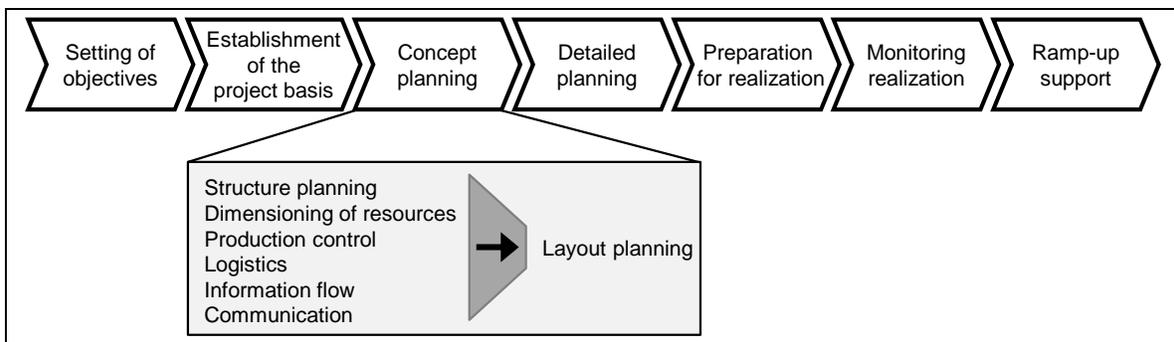


Figure 1 – Planning phases according to VDI 5200 (Verein Deutscher Ingenieure (VDI) 2011a)

Layout planning plays a central and integrating role in a factory planning project. Therefore, the quality of layout planning is a key factor to achieve a high performance of the planned production system. Or, seen from another perspective, a weak layout planning can convert previously created planning results poor, even if they were excellent. Thus, layout planning represents a relevant lever of value creation in factory planning projects.

Challenges of layout planning in today's factory planning projects

Various layout planning approaches were documented comprehensively in the literature (Wirth et al. 2000, Grundig 2009, Aggteleky 1987, Kettner et al. 1984, Wiendahl et al. 2009, Schenk 2004). These approaches start with developing an ideal layout on the basis of given boundary conditions of the production (for example: products, processes, quantities, quantity dynamic) and independently from real restrictions (for example: existing buildings, legal regulations) taking into account material flow relations between objects. Using the ideal layout, the real layout is developed which considers additional design aspects as well as real restrictions.

Considering the existing approaches, two main challenges for the layout planning process can be outlined with regard to the requirements of a value-oriented factory planning:

1. Consideration of individual targets and boundary conditions of production.
2. Objective assessment and project over-arching benchmarking.

Consideration of individual targets and boundary conditions of production

The ideal layout exclusively bases on material flow relations between objects. For the development of the ideal layout, different analytical, heuristic and graphic approaches were developed (Grundig 2009, Singh, Sharma 2006, Domschke 1975). Their objective is to minimize logistics effort (for example: transport costs). Based on the ideal layout, the real layout is developed by integrating additional qualitative design aspects (for example: communication flow, flexibility, changeability Wiendahl et al. 2009, Grundig 2009) as well as real restrictions.

As shown, the arrangement of objects within factory buildings is initially based only on a material flow analysis. Only in the second layout planning step, additional design aspects are considered. Besides material flow and invest costs, a lot of additional design aspects are documented in the literature, which can be applied in the planning of production layouts (cf. chapter „Layout planning in factory planning projects“). They are only documented in a qualitative and abstract way. Explicit references are not given describing which design aspects have to be applied under which boundary condition of the production and which impact on the achievement of the production targets (costs, quality, time) is expected. Therefore, the case-specific selection and application of design aspects is in the responsibility of the experts of the planning project. In practice, the quality of the layout highly depends on the experiential knowledge and “instinct” of the planner. A systematic selection of specific design aspects is not yet possible, as their impact on the achievement of the production targets (costs, quality and time) cannot be assessed methodically using state of the art factory planning approaches.

Objective assessment and project over-arching benchmarking

After creation, the real layout alternatives are assessed against each other, to select the preferred variant for implementation. Considering existing layout planning approaches, the assessment is based on criteria which have been selected individually for the planning project (for example: invest costs, logistics effort, communication, transparency, changeability). Except invest costs and logistics effort, the assessment is qualitative. The project team has to develop an assessment scale for the qualitative assessment criteria. After the assessment, the different criteria are aggregated to a key figure. This is usually made by using a value benefit analysis or a point rating system (Wiendahl et al. 2009, Grundig 2009, Wirth et al. 2000). The final layout is selected by comparing the quantitative and qualitative key figures.

A transparent traceability of decision findings within the project as well as a possibility to compare the layouts of different planning projects is not given, because the planning and assessment procedure is dominated by subjective decisions of individual experts.

Requirements on a value-oriented layout planning

Foundation of a value-oriented layout planning is the consistent pursuit of value creation as a direct result of the planning activity. This requires knowledge of the mechanism of value creation as well as the measurement of the value added, which facilitates the determination of the benefit of a layout already during the planning process.

Existing layout planning approaches cannot fulfill these requirements. In practice, this means that the decision about the final layout alternative is made based on invest costs,

logistics effort (as an approximation of the operating costs) and a qualitative assessment (as an approximation of the expected performance of the planned production system). This situation is not satisfying and suggests that many production systems may have a significant potential that could be realized by a different layout.

Based on a weak-point analysis of current layout planning processes, four requirements to a value-oriented layout planning were defined:

1. Pursuit of the added value through layout planning:

Core objective of a value-oriented layout planning is the consequent pursuit of added value through layout planning. Therefore, layout properties and their impact on the achievement of production targets have to be assessed taking into account simultaneously different criteria (for example: production efficiency, logistic effort, transparency, changeability).

2. Considering the individual targets of the production:

The layout assessment has to consider the individual targets of the production (for example: cost efficiency, quality, lead time). Production targets can be derived from the company and its product strategy. Different production targets can exist within a factory depending on the product or production segment.

3. Considering the individual boundary conditions of production:

Individual boundary conditions of the production for example are: lot sizes, quantities, processes, technologies)

4. Provide an objective assessment and project over-arching benchmarking:

To measure the benefit of the layout planning in accordance to value orientation, the layout assessment has to realize the benchmark of the layout with other planning projects. Therefore, the assessment has to be conducted objectively and without any subjective decisions of the planner.

Development of a layout assessment approach

Based on the identified four requirements, five fields of action can be derived which are described in detail in the following chapter (Figure 2).

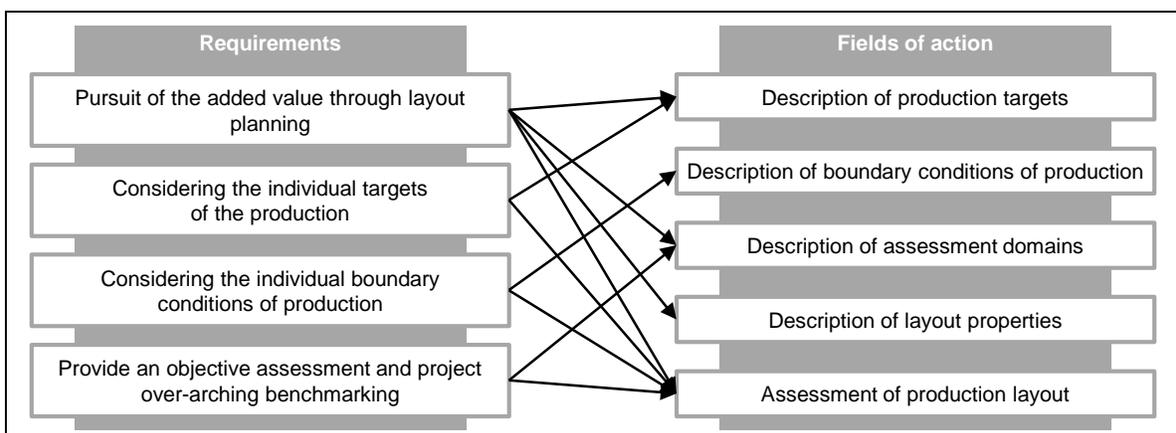


Figure 2 – Five fields of action derived from the identified requirements

Key aim of the layout assessment approach is to measure an existing layout (hereinafter called “current layout”), which can arise from an existing factory or a layout planning project, and provide information about its “fit” in regard to production targets and

boundary conditions of production. Consequently, the development of the layout planning approach is started at this key aim.

To assess the “fit” of the current layout, it is compared with a theoretical ideal layout. Then, the determined difference between the current and the ideal layout is used to calculate key figures which represent the negative impact on the achievement of the production targets. The key figures can be used to compare different layout alternatives regarding their fulfillment considering different impacts on the achievement of production targets. The structure of the proposed approach is shown in Figure 3.

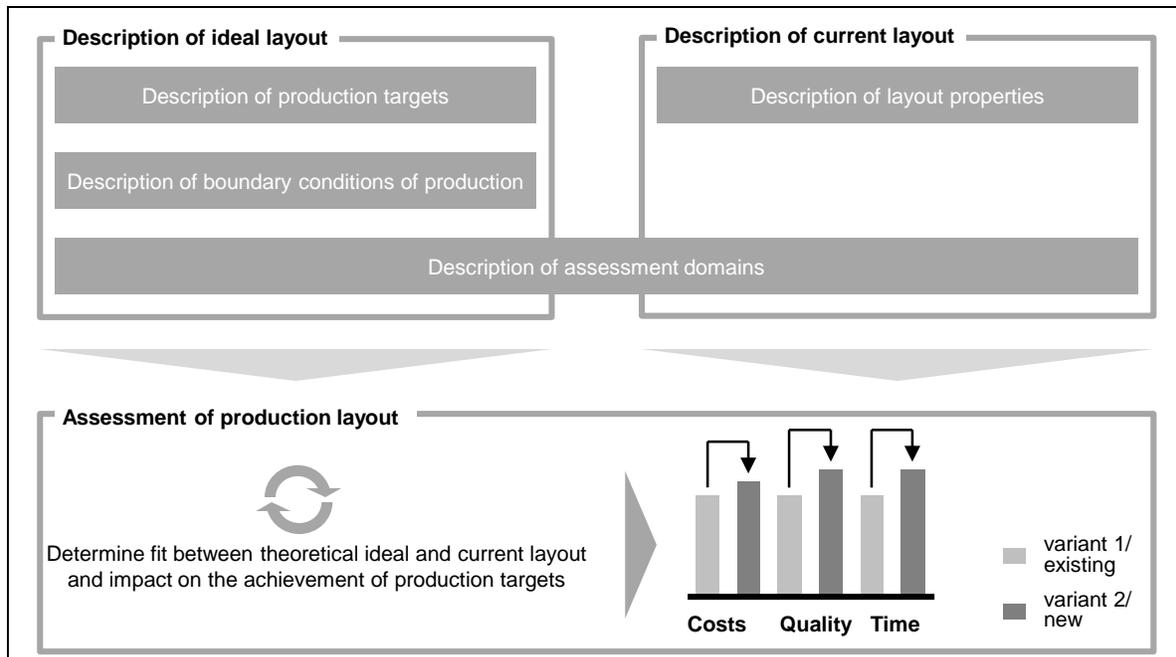


Figure 3 – Proposed structure of the layout assessment approach

Description of ideal layout

Because there can be multiple solutions for the ideal layout, “assessment domains” are used as a meta-level to describe the properties of the ideal layout uniquely. For example, “assessment domains” are logistics efficiency, transparency, changeability and communication. To describe the ideal layout, the characteristic configuration of the “assessment domains” is determined.

The individual targets and boundary conditions of the production influence the characteristic configuration of the “assessment domains” (Figure 4). Production targets are cost, quality and time, but need to be described more in detail to describe the layout relevant impact (for example: change costs, operational costs, invest costs). They are derived from the company and product strategy.

For example, boundary conditions are lot sizes, quantities, processes or technologies of the assessed production segment. Boundary conditions influence the relationship between production targets and layout properties described by “assessment domains”. For example, a high quantity production with low variety will strive for a process oriented layout with a high logistics efficiency, whereas a customer-individual low quantity production will be implemented with a layout which focusses more on communication and flexibility.

Vice versa, changes in the layout will have a different impact on production targets depending on the boundary conditions of the production. For example, a worse communication flow will have a higher impact on FPY (first pass yield) if production processes are less stable and change frequently.

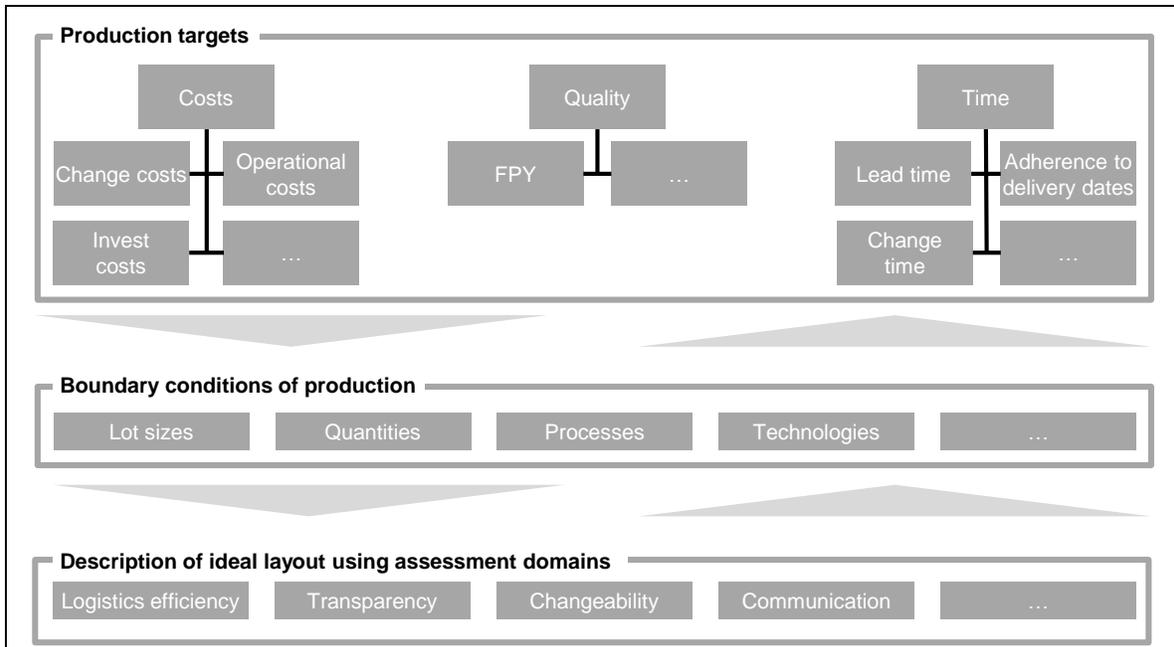


Figure 4 – Description of the ideal layout using assessment domains

Description of current layout

To assess the current layout, real physical properties of the current layout need to be transformed into the description language for layouts (“assessment domains”) used by the assessment approach.

In a first step, the real physical properties of the layout as well as the objects within the layout are transformed into the descriptive properties, such as “open space between objects” or “visual axis between objects” (Figure 5). For every descriptive property a calculation procedure is developed. Calculation procedures can use absolute properties of objects (for example: position and orientation) or relative properties which base on absolute properties of two or more objects (for example: quantity of workstations in direct sight).

Real physical as well as descriptive properties are not independent of each other. For example, the descriptive properties „visual axis between objects“ and „buffer in visual range of source and sink“ can not be fulfilled totally within the same layout because they interfere with each other. This has to be considered within the assessment approach to prevent a negative assessment due to layout property combinations which can not be fulfilled.

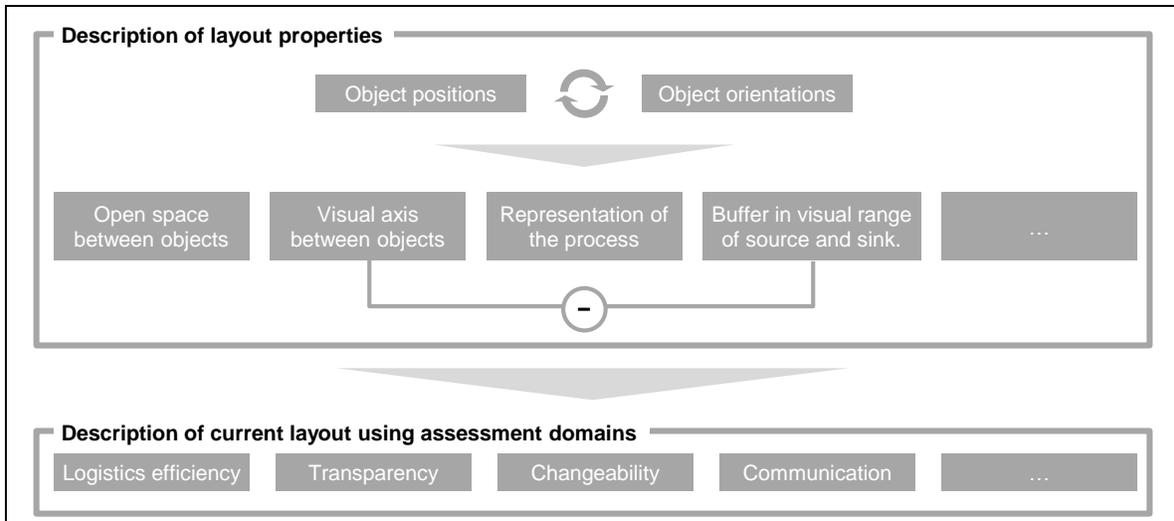


Figure 5 – Description of the current layout using assessment domains

Layout assessment with the Virtual Production Intelligence

Aim of the layout assessment is the application in the planning of new factories or for the optimization of existing production systems. This can be achieved by integrating the layout assessment into existing layout planning approaches. For this, the “Virtual Production Intelligence” (VPI) platform can be used. VPI is a tool for the planning of production processes, which provides data integration and investigation from several data sources. The VPI platform provides an integrative and centralized administration and maintenance of the stored data and therefore allows holistic data investigations within the factory planning process. The VPI has been described in detail in (Brecher 2012, Meisen 2011).

To use the layout assessment within existing layout planning approaches, the VPI platform gets connected with several data sources. Exemplary, the application of the layout assessment approach using the “factory planning table” is shown. The “factory planning table” is a layout planning tool consisting of a large touchscreen showing the 2D view of the production layout and a projection showing a live rendered 3D sight. The layout can be manipulated using the 2D layout on the touchscreen. It is used in interdisciplinary layout planning workshops and was described in (Kampker et al. 2012). To enrich the “factory planning table” with information from the layout assessment, the “factory planning table” is connected to the VPI platform using a network protocol. Real time data of the layout (position and orientation of objects) are transferred from the “factory planning table” to the VPI platform considering all changes in the layout. Additional information regarding the boundary conditions of the production (for example lot sizes, quantities or processes) gets integrated from different sources (for example from the companies’ Enterprise-Resource-Planning (ERP) system) into the VPI platform. Based on this information the VPI calculates assessment key figures of the layout, which can be integrated into the visualization on the “factory planning table”. Figure 6 shows the information flow of the described application scenario.

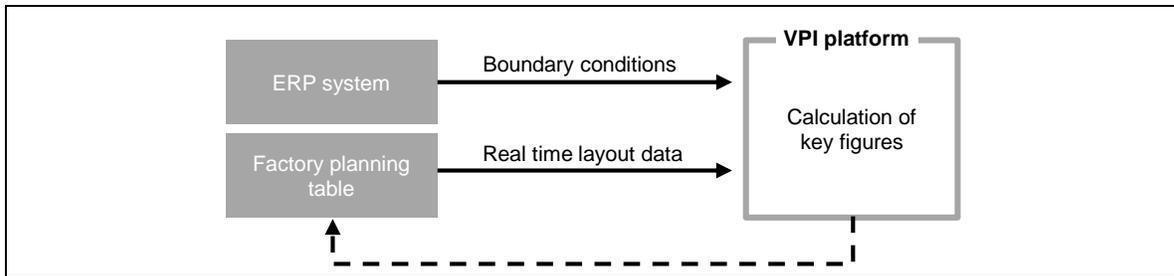


Figure 6 – Using the VPI platform for layout assessment with the “factory planning table”

To demonstrate the application of the layout assessment approach, a demonstration case is developed. The case uses the “factory planning table” connected to the VPI platform. In a first step, key figures of production targets (i.e. costs and time) are implemented. To visualize the key figures and show the difference between several layout alternatives, an assessment dashboard is developed which can be displayed in the 2D and 3D view. The case is used to test different possibilities of using the assessment data in the planning process as well as to test data integration in the VPI platform and calculation of key figures.

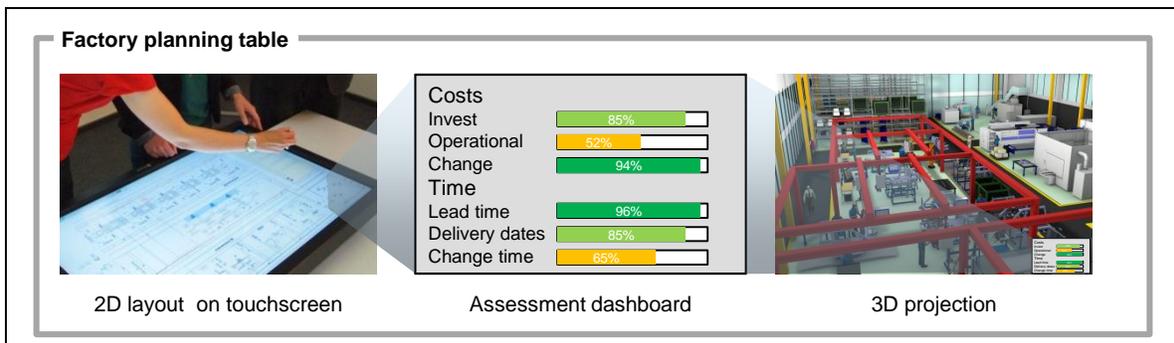


Figure 7 – Integration of layout assessment in “factory planning table”

Conclusion

Due to increasing cost pressure, factory planning has to focus on value-adding activities. Layout planning plays a significant role in factory planning, as it has to integrate the previous planning results. In order to realize a value-oriented layout planning, the layout needs to be assessed during the planning phase regarding its influence to the achievement of the production targets. In this paper four requirements on a value-oriented layout planning and a layout assessment approach consisting of five working packages were presented (Figure 2). The layout assessment approach can be integrated into existing layout planning approaches and tools using the VPI platform which was shown in a use-case.

Acknowledgments

The presented work is being investigated within the publicly funded research project “Cluster of Excellence - Integrative production technology for high-wage countries” by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) at RWTH Aachen University.

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