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An Adaptable Model for the Factory Planning Process: Analyzing Data Based Interdependencies

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Abstract

Various models of the factory planning process have been developed in the past decades. For these process models, we conducted a literature review with focus on dealing with unexpected changes in planning premises due to the turbulent corporate environment. The results were compared with the best-practice approach, which we identified in numerous interviews with industry experts. It can be concluded that a process model which takes into account data based interdependencies and at the same time allows adaptation to individual planning cases, is lacking. With the aim of defining a reference process for factory planning, we adopted the modular approach of Condition Based Factory Planning in which the planning data is regarded as input and output of each planning task. In order to minimize planning effort, a tool named *aranea* to individually adapt this reference process is introduced. Within this tool we implemented an algorithm to automatically convert the interdependencies between the planning tasks into a Design Structure Matrix. This step enables the factory planner to apply methods from structural complexity management to identify planning data for which fuzziness is especially critical and which could lead to delays and iterations in further planning tasks.

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1. Introduction

In a turbulent environment caused by increasing market dynamics, product individualization, shorter product lifecycles and higher innovation frequency [1], companies strive for flexible and changeable manufacturing systems [2].

Whereas changeability of the manufacturing system is in the focus of current research [3], the factory planning process has not been developed further with regard to changeability in the same intensity. Even though methods for agile project management are established in software development, they are not yet common in manufacturing systems planning [4]. The many different existing process models for factory planning present a rather unstandardized, heterogeneous amount of approaches with different terminology [5] which need to be compared and consolidated.

A reference process for factory planning which is adaptable to individual companies' planning procedures without great effort and at the same time takes planning data into account does not exist so far. Especially a changeable model considering the existing interdependencies between different planning phases resulting from their in- and output data has not been developed yet. However, these interdependencies are vital for designing an efficient planning process and assess the effects of fuzzy planning parameters caused by the turbulent market environment.

In this paper, we first review the state of the art for classical phase oriented factory planning models. We then pay special attention to continuous and modular process models as the more recent approaches and give an introduction to structural complexity management (chapter 2). In order to analyze how practitioners conduct factory planning, the results of 18 expert

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interviews are summarized in the description of planning tasks which form the basis for a modular and data oriented reference model. We introduce the software tool *aranea* as a support for the planner to design individual process models (chapter 3). Based on the proposed reference process, methods from structural complexity management are applied to analyze which planning parameters have the greatest influence on the feasibility of tasks located later in the planning process (chapter 4). The paper is completed with a conclusion and outlook (chapter 5).

2. State of the Art

2.1. Classical Phase-oriented Factory Planning Process

The classical approaches for the factory planning process have several aspects in common. The first principle comprises starting with broad and rough steps (e.g. in a block-layout) and then continuously detailing and refining the results (e.g. workplace design, ergonomics). The second principle is that the first steps are rather abstract (e.g. a Sankey diagram) and the more a factory planning project advances, the more concrete are its results (e.g. the detailed facility layout). The third principle leads from an aggregated state (strategic level) in the early steps to focusing single separated aspects (tactical level) [6].

The process models developed by [7] and the Association of German Engineers (VDI 5200, [8]) consist of 5 respectively 7 steps. These steps are ordered in a sequence, meaning the following step cannot be started as long as the current step is not finished. A similar approach is the process model by [9] which distinguishes 10 partly overlapping planning phases. The process by [5] also follows this phase-based approach.

The first authors to consider iterations are [10]. They developed a factory planning process based on steps which are arranged in consecutive, overlapping phases. Each step provides a back-ward-link to the preceding step making iterations possible and thus enabling the planner to repeat certain activities in case of inconclusive or low-quality results.

[11] was the first to integrate iterations which cover more than one step. If the developed concepts of the production system are not approved by management, for example, the planner restarts the process several steps earlier.

The model developed by [12] integrates generic planning phases and specific tasks, enabling the planner to derive interactions between different tasks und visualizing the workflow.

[13] emphasizes that every component and aspect influencing the factory should be addressed in an approach for integral factory planning. He provides an adapted problem-solving cycle to check if the results of each phase are satisfactory and, if not so, uses iterations to improve the solution. Instead of iterations, [14] integrates a stage-gate model into his factory planning process and ensures satisfactory results with quality gates located between each pair of planning steps.

A method for synergetic facility planning is proposed by [15] with the aim of improving interaction and cooperation of space view (architecture, technical building equipment, facility structure, etc.) and process view (production process, logistics, factory layout, etc.).

presents another idea: He argues that the factory can be split into a social and a technical subsystem and provides an overview of how the different planning phases of both systems overlap and interact. He further develops principles on how to design the social and the technical subsystem of a factory.

[16] as well as [17] also combine the problem solving cycle as it is used by [13] and the factory planning process. [16] defines further subtasks for each step. However, he does not explicitly allow for iterations. [17] differentiates between different planning cases. These cases consist of a certain state in the factory lifecycle (first axis of the matrix) and the organizational level of the factory (second axis of the matrix).

2.2. Continuous and Modular Factory Planning Approaches

Continuous and modular factory planning models, in contrast to classical approaches described above, consider the fact that due to shorter product lifecycles [1] and an increasing number of product variants [18] the factory is changing almost constantly [19]. Thus, the process of factory planning advances from a project with a defined beginning and end to a continuous activity that has to be carried out while production is running [2]. Furthermore, the generic phase-based process often does not represent the planning process of each individual enterprise, as the conducted expert interviews (see chapter 3.1) showed. That is why the planning process model itself should be adaptable [20].

An overview on continuous factory planning approaches is provided by [21], in this section, we therefore focus on the most relevant continuous and especially on modular approaches for factory planning.

[22] introduces an approach which uses the concept of control loops to design a model for planning transformable and modular factory structures. The factory is modelled as control route and production controlling is engaged as measuring unit. A transformability monitor which receives impulses from the turbulent environment and executive management works as regulator sending control variables to the factory planning department which serves as control unit. The control loop is closed by the factory planning sending control variables (i.e. changes in the factory structure) back to the control route, the factory.

This iterative concept for factory planning is adopted by [23] in a way which separately considers flexibility and reconfigurability as measures of the changeability level.

[24] also provides an iterative concept for facility planning. In addition to the authors mentioned above, his approach focusses the idea of continuous improvement of the factory but stays on a more generic level.

An early modular approach for facility planning is developed by [25] to create a continuous and cost-oriented planning methodology. The modules contain planning tasks like defining the material flow, dimensioning of the system or layout planning. These tasks that, if accumulated, form the whole factory planning process, are supported by the modules

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