Abstract
Factory planning projects that include the planning of the production system and the industrial building are characterized by an increasing specialization of the planners, rising interdisciplinarity, high pressure on time and costs and a dynamic and turbulent environment. Existing planning procedures fall short on addressing these challenges. Consequently, factory planning projects are oftentimes delayed, not within the planned budget or do not deliver a factory fulfilling the set targets, e.g. changeability, output or quality.

In this paper, an agile methodology is presented for condition based factory planning (a modular approach for factory planning). It helps synchronizing the project team and integrating the planning results during the planning process. In case of changes of the planning premises, the planning team is enabled to adapt quickly to the new situation. The new methodology is based on the known agile framework Scrum. The paper starts with an analysis of the challenges in factory planning. Known factory planning approaches are presented and discussed. Factory Scrum is then introduced along with its elements. A discussion concludes the article.

Keywords
Factory Planning, Scrum, Agile Project Management, Production System Planning

1 INTRODUCTION
Factory planning determines the long term structure of production systems of companies and thus to a great part the economic performance of their value generation. This significance is reflected by the amount of money spent on new sites: An average of 8% of the gross national product of the US was spent from 1955 to 2003 on industrial facilities [1].

Due to globalization and economic integration, economic development is more chaotic and turbulent than ever. In addition to the therefore required adaptability and flexibility, factories need to comply with a continuously growing number of opposing requirements such as increased production quality and quantity, higher environmental, health and security standards.

Due to this increasing number of requirements and the higher pace of change, less time and money is at hand to solve increasingly interrelated tasks. More sophisticated technical solutions require a rising number of specialist planners, who are able to navigate in this project environment. All this puts a challenge to factory planning. Problems in factory planning exist in particular at the interface between industrial construction planning and production system planning. For example, essential data is missing at key points or requirements are not clearly defined. This results in a decline in the quality of the final product (the factory), in a longer planning duration or in a greater effort.

2 CHALLENGES
In this environment, three predominant challenges could be identified: The focus in planning is rather on tasks than on interaction between tasks; project plans are designed in a rigid fashion; and finally, planning processes are executed separated by fields. The resulting challenges are illustrated in Figure 1.

Neglecting interactions between planning tasks leads to both interface problems and to a lack of reactivity. Typically, the planning process is interpreted as a wealth of tasks, which need to be performed 'properly' in a 'right' order to reach project success. Meanwhile, little attention is paid to task interdependencies, although this equally is a complex challenge for planners. As the planning of a factory is a collaborative project, unmanaged interactions lead to conflicts at task and organizational interfaces. Often, it is not clear, how much work will need to be invested into efforts, some tasks are performed exceeding the necessary, while the importance of other tasks is underrated and thus creates bottlenecks to other planners. All these challenges show especially, if concerted reactions to unforeseen events are necessary, such as changed market forecasts or process specifications, delayed deliveries or unexpected weather conditions.

Rigid planning methodologies give away flexibility. Typically, the project environment is designed to inform rather than to enable active collaboration. The underlying assumption is that the planning
process is a linear, deterministic process. The idea of the new factory has to be turned into reality by a number of consecutive steps, each one bringing the project closer to its goal. However, as new requirements are discovered for the factory during the planning process, project organization and the plans can be fundamentally challenged due to rigid planning regimes which are not made to cope with turbulence and dynamics. Rather than to anticipate them, design challenges are discovered through planning conflicts, when problems occur. This passive approach has to be handled better.

Separated planning processes lead to local optimization. Although it is known, that working in silos is inefficient for an organization, many factory planning projects suffer from this phenomenon. For instance, production system planning is often conducted by in-house specialists, whereas industrial construction planning (and execution) is performed by external providers. Although both fields are highly interconnected, communication often passes only between the heads of the two fields. Similar inefficiencies can be found, wherever information is held back, not passed on, or never known to exist for various reasons. Due to the resulting lack of information, a local optimization based on the information and priorities of the planner will occur, which will not necessarily represent the optimal solution for the entire factory, and which might in fact run counter to it.

3 STATE OF ART

Existing methodologies to plan factories can be grouped into three categories: production system based factory planning methodologies, industrial construction based factory planning methodologies, and integrated planning methodologies.

Production system based methodologies evolve around value creation and typically neglect the many possible potentials of collaboration with planners from the field of industrial construction [2][1][3]. Similarly, typically industrial construction based methodologies focus on spatial design and construction but miss the opportunities which collaboration with production planners could yield [4][5][6]. Both types of methodologies assume a largely process-oriented, deterministic planning process and concentrate on placing optimized methods for single problems in an optimized order [7]. As external dynamics and turbulences (such as fast economic and technological developments) penetrate the planning process, these traditional methodologies are challenged.

Integrated planning methodologies account for the possible synergies of integrating the planning fields, but nevertheless lack detail either on planning coordination or on organizing information needed to coordinate planning projects. In 2011, the Association of German Engineers (VDI) published its guideline VDI-5200 concerning “factory planning – planning procedures” [8]. Next to a linearly staged production based planning process, according tasks of industrial construction planning are juxtaposed. The guideline does however not explain how work is to be communicated or what to do in case of turbulences which make prior planning results obsolete. While the methodologies proposed by Schenk and Wirth [9] as well as Pawellek [10] both are specific on how interactions between the different planning tasks exist and which form they may take on, they both miss the opportunity to draft concrete proposals on how to manage and organize them effectively. Wulf and Nyhuis [11] propose an operational process for bringing planners of different disciplines together, lacks however analysis on how planners have to be chosen, tasks be distributed or connected and efforts spent.

Therefore, a methodology is needed which both provides for a proper framework to transparently set up planning tasks and interfaces between them and a proper way to organize the resulting interactions between the planning tasks.

4 FACTORY SCRUM

The new factory planning methodology proposed by the authors is based on Condition Based Factory Planning (CBFP) [7]. In CBFP, planning content is encapsulated into standardized planning domains and planning modules, interfaces between the planning elements are defined and artifacts for communication between modules are explicitly defined and named. The result is the generic process map, which can be compared to a class library for software (Figure 2).
This generic process map serves to structure and define the scope of new factory projects. If needed, new modules can be created and integrated. The encapsulation of planning content into modules decouples the internal stability of planning tasks towards external dynamics of the environment [12].

Figure 2 - Planning modules

However, the generic process map alone does not provide a framework on how to manage the interfaces (coordination) between the modules. Although interface and task transparency are provided, information still needs to be actively managed. Factory Scrum (name in reference to the existing Scrum framework) is hence a system which proposes a way on how to execute and synchronize tasks in such a work environment.

4.1 Concepts of Factory Scrum

Planning tasks are encapsulated in planning modules, following CBFP. Through this, the interfaces between the planning modules are defined. The framework Factory Scrum then organizes the information exchange in an efficient way. The structure of Factory Scrum is of iterative form and follows the principles of Scrum [13].

4.2 Elements of Factory Scrum

A Factory Scrum project evolves around 3 roles for project participants and 2 types of artifacts. They will be introduced first. Next, the preparatory phase and the framework in action will be presented. In the end, a scaling mechanism is introduced to connect work groups within the project team (Figure 3).

4.2.1 Roles

Every Factory Scrum process possesses the following roles: Product Owner, Scrum Master and Planner [14]. Everybody assigned with one of these roles is a team member and a work group member. The (project) team is the number of all persons participating in the project. Most factory planning projects surpass single-digit team sizes allowing for active collaboration in simple meetings. Therefore, the number of project team members needs to be split up into work groups, in which the core process of Factory Scrum, the Scrum process, can be run.

The Product Owner of each Scrum process represents the interests of the stakeholders on the project. He is responsible for the results of each work group by managing the Factory Backlog, from which the Sprint Backlogs are derived. These two types of documents are discussed in the next section.

The planner’s responsibility is the collaborative realization of tasks agreed-upon in the Sprint Backlog. The planners work self-organizing and have to figure out by themselves, how to reach the set objectives. This implies an independence and responsibility beyond the technical and methodological expertise.

The Scrum master has the responsibility for the Scrum process, for the proper application of Scrum principles and Scrum rules. He has the role of a facilitator. In case of internal or external problems coming up during the daily scrums (referred to later on), he will help as a mediator. He does not give instruction or distributes tasks [15]. It is possible for the Scrum master to be a planner at the same time.

Figure 3 - Elements of Factory Scrum
4.2.2 Artifacts

In order to run the project, only two types of documents (artifacts) are used as control and monitoring tools. Analogue to the original version of Scrum [14], the artifacts in Factory Scrum are:

- Factory Backlog
- Sprint Backlog

As an agile methodology, it is ‘light-weight’ and relies on very little organizational documentation. The continuous use of the documents is therefore central to project success. Because the redundancy of documents is kept to a minimum, the importance of the individual document is greater compared to other methodologies where the improper use of a document may be substituted through other resources. The documents are living documents. They are not to be used for documentation purposes only, but as tools to communicate effectively. As the information and situations change, the documents need to be continuously updated and revised [16]. Therefore, they will have to be kept visible and accessible during all meetings.

The Factory Backlog is a list of requirements and helps to understand the functionalities which specify the future factory. Based on these requirements, planning items are defined, together with estimates on the necessary effort. Their generation will be described in 4.2.3.

Like the Factory Backlog, the Sprint Backlog serves to communicate and monitor project progress. Whereas the Factory Backlog does so for the entire project, the Sprint Backlog is an operative tool used during one work iteration by each work group. Every work group has its own Sprint Backlog. It is obtained by taking items off the Factory Backlog and by breaking them up into smaller tasks.

The Sprint Backlog features additional information on the status of the planning modules in terms of the progress of their subtasks. Since the methodology is an open framework, the work groups can adjust the tool by adding additional information to their backlogs to facilitate cooperation. Like the Factory Backlog, all items on it are presented in form of a prioritized list.

For the duration of the Sprint, items or tasks cannot be removed from, added to or changed on either of the lists. This “freeze” ensures that the teams members can fulfill their commitments without changed objectives interfering [13]. If tasks are not listed, they can be defined during the next Sprint and then be tackled. The same happens if prioritization changes.

4.2.3 Preparation of Factory Scrum

Factory Scrum needs preparation prior to starting the actual planning activities. An initial Factory Backlog is derived by using the generic process map and its modules stemming from CBFP. Items are listed, set into comparison and prioritized. Since the Product Owner will later on have to negotiate with the work group(s) about the workload for the Sprint, he will want the important items to be placed as top priorities at the top. The workgroups will tackle them first. It is difficult to reach an unambiguous definition of what should be prioritized, so it will be necessary to have the project team help to break down requirements and goals into smaller pieces or to advise and share insights [13]. In order to ensure buy-in from C-level and other stakeholders, it is proposed to name the items from the initial Factory Backlog in a project brief and to establish milestones or deadlines to outline the scope of the project. This reassurance is very helpful as experience shows. Some stakeholders fear agile planning will bring a lack of robustness in project advancement, although the opposite is the case. This impression can be repelled from beginning on by offering transparency in terms of traditional progress and success indicators.

Factory projects surpass small team sizes. Therefore, the number of project team members needs to be split up into work groups, in which the Scrum process can be run. Although the distribution of project members into work groups could be done by hand, a systematic approach is likely to help gaining additional insights and thus better results. The authors propose using Design Structure Matrices (DSM) to optimize group composition based on linkage information from CBFP [17].

4.2.4 The Framework in Action

After the preparation phase, the Factory Scrum routines can begin. Factory Scrum is an iterative process. Repetitions take place on two time-scales: The unit of the first one is the Sprint, the second one the day. This methodology proposes to choose for Sprints the time-span of four weeks. All factory planning activities taking place on Sprint level would be therefore repeated every four weeks. On the daily frequency, only one type of meeting takes place: The daily Scrum.

The Sprint begins with a Sprint planning meeting. The work groups meet, preferably physically. Physical proximity is not only an asset in itself (better communication through less disturbances) but also has been found to facilitate and endorse collaboration in general [18]. The Sprint planning meeting takes one day and is separated into two parts, each with a duration of 4 hours. The reason for this rigid time frame (timeboxing) is to force the teams to not get entangled into overly detailed planning but to reach decisions and work time-conscious.

First, the work group reviews the roadmap, deadlines (milestones) and the Factory Backlog prepared by the product owner. Then, the planners review the estimates for features on the Factory Backlog and confirm that they are accurate. Due to a prior assignment of team members to planning modules (cf. 4.2.3), a clear allocation of tasks to
work groups is possible. The method of CBFP provides information on task dependencies. Based on this information, the planners in the work group decide, how many items they can take into their Sprint Backlog. By choosing to pull an item into the Sprint Backlog, the work group commits to deliver within the timeframe of the Sprint. If the Sprint is not the first Sprint of the group, the members know how much effort they are realistically able to muster during one cycle. It is important that the team members “pull” items from the top of the Factory Backlog as this ensures that the prioritized tasks are tackled first, since they are ordered from top to bottom.

In the second part of the Sprint planning meeting, the workgroup without the Product Owner sets up the Sprint Backlog. During the process, the group asks questions, clarifies details and interdependencies and checks the assumptions on estimated effort. It is then determined, in which order the derived tasks are executed. As specialist planners depend on each other, planners have at this point the possibility to optimize their workflow.

After the sprint planning meeting, the agreed-upon tasks are executed for the remaining work days of the Sprint. This is the main body of planning work. The work is organized on a rhythmic basis. On a daily routine, short work group meetings called Scrums take place at a fixed time of the day. This makes it a routine activity and facilitates meetings of globally distributed participants.

Scrum is the core mechanism, around which the entire methodology of Factory Scrum evolves. As this methodology strives to organize factory planning effectively by synchronizing different planning fields (notably production system and industrial construction planning), the Scrum is the operative tool to provide the organizing and coordinative platform to this end. The daily Scrum lasts only 15 minutes. Again, all project members should attend physically if possible. Only the following three questions are to be answered by every planner:

- What have I done since the last meeting?
- What is planned until the next Scrum?
- Which impediments have I encountered while working towards the goals of my tasks?

The goal of the meeting is not to talk about the information each collaborator has given, but to collect information and to synchronize in order to push the project and tasks ahead. Talks and dates are supposed to be organized afterwards, independently from the Scrum.

At the last day of the Sprint, the Sprint review meeting takes place (4 hours). The finished tasks are presented to the product owner. The meeting serves to check results and concepts early and to prevent mistakes from happening. In addition, purpose of this meeting is to bring people together (the meeting is “open to the public”) and to figure out, what the work group should do next.

Next, the Sprint retrospective meeting takes place. It takes about three hours and is used to improve the way the work group managed its development process (its planning), in reference to the Scrum process as well as to the individual tasks and ways to collaborate (such as work standards, conducting meetings, office work, etc.).

4.2.5 Scaling the framework

The team is split up into smaller work groups. This makes it necessary, to coordinate and control the work between these work groups. Synchronization does not only need to take place within work groups, but also between work groups.

In the spirit of keeping the methodology simple and lean, the individual work groups will be connected through the same processes, which are used to coordinate the planning within the work groups. These are Team Sprint Meeting and “Scrum of Scrums” [13]. At the very beginning of every Sprint, delegates from each work group meet up to coordinate project progress. It is determined, what steps are according to the current situation most valuable and vital for project progress. The Sprint Backlog is hence reviewed for actuality and priority. This is necessary for individual work groups to prioritize their activities by the needs of the other workgroups. The Scrum-of-Scrums is a 15-minute long meeting. One delegate (ideally a planner or the Scrum master) from each work group attends, the following three questions are answered:

- What has our work group done since the last meeting?
- What have we planned until the next Scrum meeting?
- Which impediments have we encountered while working towards the goals of our tasks?

By staging the Scrum of Scrums after the Daily Scrum (e.g. 30 minutes later), it is possible to address impediments external to the group right away. Information can thus travel extremely fast through the organization. By using the same process on a higher coordinative level, the process of transferring information is transparent to every project team member. The delegates will have to condense the information they are conveying in the Team Sprint Planning and the “Scrum of Scrums”, as they will not have the time to go into elaborative detail. The selection and aggregation on the other hand is necessary to achieve efficient communication.

4.3 Discussion

In Factory Scrum, project organization is based on modules, therefore, on the basis of the set of interactions between planning tasks. Roles of project participants relate to their function during the interactions necessary for project completion.
Interaction and integration are hence clearly and efficiently designed and therefore considerably strengthened. Especially during turbulent times and unforeseen events, the institutionalized routines of Factory Scrum will provide with the help of the planning environment of CBFP for rapid and coordinated responses.

Planning objectives and tasks are constantly updated and prioritized and fixed transparently in a Factory Backlog (strategic) and Sprint Backlogs (operational). Through this, an iterative planning process is implemented, which routinely reacts on changes. Risks are tackled before they turn effective. Rigid project plans won’t hinder robust project advancement.

Timeboxed Sprints and Scrum enable short and fast connections between expert planners. High transparency and high communication intensity from beginning to the end of the project support global optimization through the use of individual knowledge.

5 CONCLUSIONS

Factory Planning Scrum is a new methodology, which addresses the growing challenges of complexity and project dynamics by managing task interdependence and interaction.

Missing management of task interaction, rigid planning and local optimization are tackled through decentralized intensified knowledge transfer and dynamic execution of tasks. Hence, turbulence and uncertainty are acknowledged by designing the planning process as an iterative, proactive organization.

6 REFERENCES


7 BIOGRAPHY

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