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Requirements For A Model Of Agile Factory Planning

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Abstract

Factory planning has become a permanent task in industrial companies due to an increasingly dynamic and complex environment. The necessary involvement of a large number of experts from different disciplines in the planning process further leads to an increased coordination effort. In addition, in the early planning stage, there is often only fuzzy data available, and the planning procedure is characterised by numerous uncertainties. In order to react adequately to comparable complexity influences and uncertainties, agility is often recommended in the literature.

In order to introduce agility in a targeted and structured manner in factory planning, a factory planning procedure is required that basically has a modular structure suitable for implementing agility and integrates all planning disciplines. In addition, the complexity of factory planning tasks must be reduced to an application-oriented level and linked as well as classified in terms of time. Agility must be holistically integrated into this factory planning procedure and its applicability must be ensured through detailed descriptions and visualisations. When integrating agility in factory planning, it is also important to check in each individual case, company- and project-related, which degree of agility makes sense and how the concrete implementation can be designed in the planning procedure. Since factory planning projects can differ greatly from one another, it is not possible to make a general statement about which agile elements offer which degree of support.

The aim of this paper is to define the requirements for an agile factory planning model under these premises.

Keywords

Factory planning; agility; modularity; uncertainties

1. Introduction

1.1 Challenges in factory planning

Factory planning (FAP) today is confronted with a constantly changing environment [1], [2]. Shorter innovation cycles, more complex technologies and more individual customer requirements lead to shorter product development cycles and production periods as well as an increasing number of variants [3], [4]. In order to cope with the associated time pressure, FAP projects are required with ever greater frequency [1], [2], [5]. In contrast to the beginnings of FAP, it is not a one-time planning task of a decades-old factory, but increasingly has the character of a permanent task [1], [6], [2].

In addition, FAP is nowadays usually associated with a higher effort [7]. This can be explained by the dynamic character of the requirements, which are implemented over the duration of an FAP project [6]. The high degree of interconnection between FAP tasks means that changes do not only have a selective effect,

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but result in a large number of time-consuming adjustments [8]. Additionally, the involvement of a large Settings number of experts from different disciplines in the planning process causes an increased coordination effort [3], [2], [8]. Furthermore, in the early planning stage, often only fuzzy data is available [8] and the planning process is characterised by numerous uncertainties. In order to deal with this dynamic environment, the increasing interdisciplinarity as well as the fuzzy data and uncertainties in the planning context, a high degree of transparency in the informational networking of the FAP tasks is required [8].

1.2 Agility as a solution

According to a survey by REINEMA ET. AL. [9], in the dynamic and complex environment of FAP, classical project management approaches fail in terms of target achievement. In 72 % of the FAP projects investigated, the target achievement was not reached with regard to the planned costs and in 60 % with regard to the completion date [9].

In order to react adequately to complexity and dynamics, the literature often recommends agility. For example, HOFERT [10] defines agility as the ability of teams and individuals to act flexibly, adaptively and quickly in an uncertain, changing and dynamic environment. Other authors recommend agility especially for complex challenges [11], [12], [13], [14], [15], [16], [17].

When integrating agility into unrelated areas, the common agile method Scrum is often used. However, there are other agile elements from lesser-known methods that can offer added value in unrelated areas such as Extreme Programming, Agile Modelling or Crystal method. Examples include "Pair Programming" from Extreme Programming [18] or the integration of an "Intellectual Toolbox of Techniques" from Agile Modelling [19]. Another example is limiting the number of documents and models, as each artefact needs to be adapted over time and therefore causing effort (called 'Travel light', also from Agile Modelling) [19]. As a final example, the element "parallelism and flux" from the Crystal method should be mentioned, which specifies that as soon as a result is stable enough to be verified, it can be carried over to the next task [20]. These examples show only a section of the diversity of agility.

2. Types of factory planning approaches

In order to use this diversity of agility in a targeted way in factory planning (FAP), it must be possible to integrate it into an FAP procedure. In literature and in practice, there are basically two types of FAP approaches – the phase-oriented and the task-/object-oriented FAP, which are briefly presented below.

Traditional phase-oriented FAP approaches divide an FAP project into different phases according to the waterfall principle. These approaches have a strong temporal focus, and the planning result becomes more and more detailed over time. Established phase-oriented FAP approaches are described, for example, by AGGTELEKY [21], GRUNDIG [22], KETTNER ET. AL. [23], PAWELLEK [2], ROCKSTROH [24], SCHENK ET. AL. [25], WIENDDAHL ET. AL. [4] and VDI 5200 [26]. Because of the fixed structure and the lack of including iterations, the phase-oriented approaches are criticised for not being able to react sufficiently to possible dynamics. Although, for example, approaches already exist that include other planning disciplines in the FAP procedure, the description of the integration of other disciplines is usually neither holistic nor application-friendly. The use of the phase-oriented FAP approaches is also difficult for companies because the phases are described in a generally valid way and cannot easily be adapted for the individual demand. It is not clear which tasks should be carried out by the factory planner in which detail and at what time, where parallel execution of the tasks is possible and how a project- and company-specific individual adaptation of the procedure can take place. In summary, due to these points of criticism, the integration of agile elements is only possible to a limited extent.

Newer approaches usually describe task-/object-oriented FAP procedures that structure an FAP project in terms of content according to the tasks to be carried out or the objects to be planned. Thus, they have a strong focus on content. Approaches from the literature are, for example, by Bergholz [6], Burggräf [27], Bussemer [28], Graefenstein [29], Hilchner [7], Kampker et. al. [8] or Nöcker [30]. These approaches aim to create modules with defined work content, interfaces and information flows [30]. Linking and parallelizing the individual modules as well as decentralised processing in different planning teams are essential elements [8]. Due to their modular structure, task-/object-oriented approaches are fundamentally better suited for implementing the required agility. The main criticism of these approaches is the lack of relation between tasks and phases. This makes the systematic allocation of planning content and the hierarchical structure of the planning tasks difficult. The user is confronted with a complex relationship of tasks in which it is not clear when which task is to be worked on and to what level of detail. The parallelisation of tasks is not designed in a user-friendly way due to the lack of assignment to phases and the complicated determination of the chronological order of the modules (e.g. [30]) or the representation in matrix form (e.g. [28]). What is missing in all approaches is a holistic integration of agility as well as offering individual user-oriented solutions.

3. Requirements for a model of agile factory planning

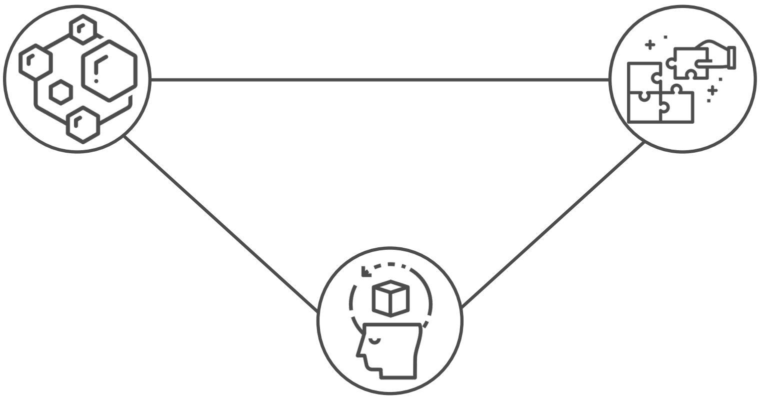
To address the weaknesses of the existing approaches, a new approach to agile FAP is needed. Therefore, the three-overarching premises of holism, individualisation and applicability were identified on the basis of reflection on existing approaches. These premises are subdivided into concrete requirements for an agile factory planning procedure, which are shown in Figure 1.

Holism

- Use the diversity of agile elements
- Integrate related planning disciplines
- Combine object and phase orientation

Individualisation

- Adapt individual elements of agile methods
- Integrate agile elements based on uncertainty
- Adapt FAP procedure based on project and company requirements



Applicability

- Detailed description
- Transparent visualisation

Figure 1: Requirements for a model of agile factory planning

3.1 Holism

Both the phase-oriented and the task-/object-oriented FAP approaches have advantages and disadvantages. Phase-oriented approaches offer advantages especially in the structuring of a FAP project. The chronological order makes it easier to implement these approaches in practice. The object/task-oriented approaches primarily support a high degree of individualisation through modularisation and are fundamentally better suited for the use of agile elements. In order to exploit the full potential and enable a holistic approach to factory planning, it is necessary to combine both perspectives. FAP is influenced by numerous related planning disciplines. These must therefore also be taken into account in a holistic FAP approach. Especially in software development, but also in other areas, numerous agile methods have developed. To make the FAP model agile, it is necessary to use this diversity of agile elements. It should be avoided to use only the common agile methods like Scrum. Instead, it should be holistically reviewed which agile methods have suitable elements that can help to make the FAP more agile.

3.2 Individualisation

Complete agile methods such as Scrum, Extreme Programming and Agile Modelling cannot be transferred to FAP as a whole, neither in terms of phase nor task/object orientation. An individualised adaptation is required. Since FAP projects can differ greatly from one another, no fundamental statement can be made about which agile elements should be used in FAP and to what degree. According to HOFERT, the point is not to introduce the same concept for all, but to understand agility as a regulator that can assume different levels [Hof 18]. The recommendation of integrating agile elements into FAP must be determined individually based on the expression of uncertainties. A project that is characterised by only minor uncertainties can be successfully completed without agile elements. However, the greater the degree of existing uncertainties, the more sense it makes to use agile elements for better coordination of the planning disciplines, visualisation of result status, etc. In order to be able to respond to the individual requirements of the company and the project, the FAP procedure itself must be structured in a way that can be customised in addition to the use of agility. In order to make individualisation practical, it is necessary to provide companies with assistance. This can be done, for example, in form of targeted leading questions and enquiries about basic conditions.

3.3 Applicability

A good applicability can be achieved by creating the necessary transparency [8]. This requires detailed descriptions and user-friendly visualisations. The modules and the tasks they contain must be clearly described and linked to each other by means of inputs and outputs. The clear chronological order of the modules within the phases should enable an application-oriented parallelisation of the modules. The involvement of related planning disciplines, such as architects or product planners, should be systematically prepared and described. In addition, it is necessary that a transparent visualisation further increases the applicability. Within this visualisation, it should be possible to quickly grasp the modules within the phases and the integration of the planning disciplines. The additional visual integration of agile elements further increases transparency. The individualisation options of the users should also be prepared in catalogue or questionnaire form in a transparent and visually quickly comprehensible way.

4. Approaches from science

From a scientific point of view, there are numerous FAP approaches that are more or less related to agility. In the following overview, selected approaches from the areas of "phase orientation", "task/object orientation", "agility in FAP" and "uncertainty in FAP" will be reflected on the established requirements (see Table 1).

Table 1: Evaluation of existing approaches

		Requirements							
		Holism			Individualisation			Applicability	
		Use the diversity of agile elements	Integrate related planning disciplines	Combine object and phase orientation	Adapt individual elements of agile methods	Integrate agile elements based on uncertainty	Adapt FAP procedure based on project and company requirements	Detailed description	Transparent visualisation
Phase orientation	Aggteleky 1987 [21]	○	◐	○	○	○	○	◐	◐
	Grundig 2015 [22]	○	◐	○	○	○	○	◐	◐
	Kettner et. al. 2011 [23]	○	◐	○	○	○	○	◐	◐
	Pawellek 2014 [2]	○	◐	○	○	○	○	◐	◐
	Rockstroh 1980 [24]	○	○	○	○	○	○	◐	◐
	Schenk et. al. 2014 [25]	○	◐	○	○	○	○	◐	◐
	Wiendahl et. al. 2014 [4]	○	◐	○	○	○	○	◐	◐
	VDI 5200 2011 [26]	○	◐	○	○	○	○	◐	◐
Task/object orientation	Bergholz 2005 [6]	◐	◐	◐	○	○	●	◐	◐
	Burggräf 2012 [27]	○	◐	○	○	○	●	◐	◐
	Bussemer 2019 [28]	○	◐	◐	○	○	●	◐	◐
	Graefenstein 2019 [29]	○	◐	◐	○	○	●	◐	◐
	Nöcker 2012 [30]	○	◐	◐	○	○	●	◐	◐
Agility in FAP	Bertling 2019 [33]	◐	◐	○	○	◐	○	○	○
	Hilchner 2012 [7]	◐	◐	◐	○	○	●	◐	◐
	Kampker et al. 2013 [32]	◐	○	○	○	◐	●	○	◐
	Meckelnborg 2015 [31]	◐	◐	◐	○	◐	●	◐	◐
Uncertainty in FAP	Hawer 2019 [34]	○	○	○	○	○	○	◐	◐
	Krunke 2017 [35]	○	○	○	○	○	○	◐	◐
	Unzeitig 2014 [36]	○	○	○	○	○	○	◐	◐
	Weig 2008 [37]	○	○	○	○	○	○	◐	◐

4.1 Holism

In the literature, fragments of agility have already been successfully transferred to FAP, especially in task-/object-oriented approaches. For example, Hilchner [7] describes the integration of solution space

management in FAP in his model. Meckelnborg [31] and Kampker et. al. [32] foresee a synchronisation of the interdisciplinary project team and resort to common agile methods such as Scrum. Bertling et. al. transfer the concept of the Minimal Viable Product to factory planning, which enables rapid validation of production processes and provides feedback on the producibility of a new product [33]. However, these and other approaches from the literature only ever represent sections of agility in the context of FAP. An approach making holistic use of the diversity of agile elements is lacking.

As described in the challenges, FAP today is characterised by a high degree of interconnection and parallelism of planning tasks. The clear linkage and chronological classification of tasks in FAP is of particular importance in this context, as changes not only affect the next task, but also influence further tasks through second, third and higher order dependencies [32]. In addition, FAP is influenced by a variety of other disciplines. In the literature fragmentary approaches on how to integrate other disciplines into FAP already exist (e.g. synergetic factory planning according to Wiendahl [4]). The demarcation between the activities of the factory planners and other disciplines usually remains unclear and the integration of the disciplines usually cannot be carried out in the dynamics required by FAP due to rigid project management. Problems that arise as a result are, for example, a late involvement of the planning disciplines involved and thus planning errors that occur. The need for research is therefore to work holistically through the lack of understanding the connections between the planning disciplines and the planning tasks in FAP.

This requires bringing together the phase-oriented and the task-/object-oriented approaches. The combination of both views is already partly present in approaches of task-/object-oriented FAP, in which identified modules are placed in a temporal context. However, this is done either in a complicated determination of the chronological order of modules (e.g. [30]) or as a unclear matrix form (e.g. [28]).

4.2 Individualisation

In terms of individualisation, none of the approaches shown can serve the requirement for an individual adaptation of agile elements. MECKELNBORG [31] and KAMPKER ET. AL. [32], for example, use the entire Scrum method without taking further agile elements of other methods into account. BERTLING [33], KAMPKER ET. AL. [32] and MECKELNBORG [31] justify the introduction of agile methods with the existing uncertainties in the environment of FAP, but the uncertainties are not directly included in the individualisation of the agile elements. The approaches from the research area of uncertainty in FAP provide a comprehensive insight into uncertainties, fuzziness in planning data and risk management in FAP. However, they do not transfer agile elements to deal with uncertainty in the project ([34], [35], [36], [37]). An individual adaptation of the factory planning procedure is already fulfilled in approaches of the task-/object-oriented approaches and the agile approaches.

4.3 Applicability

The concrete application of agile elements in FAP is often difficult due to complicated and incomplete descriptions. For example, it is questionable when which disciplines, and stakeholders should exchange information. Another example is the question of where decisions have to be made and where, on the other hand, planning should still be done with an open solution space. It is also questionable up to what point agile planning makes sense and for which tasks or over which time horizon which agile elements should be implemented. Moreover, FAP is often carried out on the basis of empirical values and rules of thumb [22], [4]. Phase-oriented procedures are only described in a very general way, whereby different levels of detail of the various planning tasks are not made clear. The task descriptions of task-/object-oriented approaches also do not offer the user sufficient support due to the complexity of the links, the lack of assignment to the temporal context and the associated difficulty of hierarchically structuring the work breakdown structure. In addition, the described tasks show a strongly diverging degree of detail and parallelisms are not prepared in a user-friendly way.

5. Conclusion

In summary, the approaches presented cannot deal with the dynamic environment and agility cannot be integrated into these approaches in a holistic, individualisable and application-oriented way. In terms of holism, it is advisable to combine the task-/object-oriented and phase-oriented approaches. The goal is a FAP approach that basically has an agility-oriented modular structure, integrates all planning disciplines, and breaks down as well as links the complexity of the FAP tasks in an application-oriented way, setting them in chronological order. In order to use agility in a targeted manner, the diversity of the different approaches should also be integrated. It is important not to implement complete agile methods rigidly, but to select individual elements from different approaches. Based on uncertainties, these should be selectable for specific FAP projects. Similarly, the modules of the FAP approach must also be individually adaptable to project and company requirements in order to fully meet the idea of individualisability. The entire procedure must also ensure applicability through detailed descriptions and visualisations.

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Prof. Dr.-Ing. habil. Peter Nyhuis (*1957) studied mechanical engineering at the Leibniz University Hannover and afterwards worked as research associate at the Institute of Production Systems and Logistics. After receiving his doctorate in engineering, he also received his postdoctoral degree followed by his employment as manager in the field of supply chain management in the electronic and mechanical engineering sector. Since 2003, he is head of the Institute of Production Systems and Logistics (IFA) at Leibniz University of Hannover.