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CONTEXT-SPECIFIC AGILE PROCESS DESIGN TO SUPPORT THE PLANNING OF PRODUCT DEVELOPMENT PROJECTS

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Abstract

Modern products are often developed in local distributed teams involving various engineering domains. As a result, product development processes are characterized by a high degree of complexity and individuality. However, the project context is often not integrated into the project planning, which can lead to uncertainties in the processes. In addition, reflection does not take place adequately in process execution. Therefore, this paper presents a concept for agile process design that enables reducing uncertainties based on context-specific reflections and adapting the processes.

Keywords: agile process engineering, reflection, process modelling, process analysis, process improvement

1. Introduction

The processes for the development of products are characterised by a high degree of individuality and complexity today (Albers et al., 2019; Riesener et al., 2019; Hüsselmann et al., 2019). Modern products are often developed by locally distributed teams, that involve different engineering domains such as electronics, mechanics and software (Vietor et al., 2015). This fact results in complex projects and extensive processes in product development (PD), which have to be planned and structured within the framework of project management. Due to fast changing boundary conditions such as schedule shifts, agile methods such as Scrum become more important. However, each project has a specific optimal degree of agility that has to be considered. For some projects, clearly defined and structured processes are suitable, but other projects require agile approaches in order to react flexibly to unexpectedly occurring problems and thus reduce uncertainties and risks in product development (Komus et al., 2019). Therefore, for effective project and process planning, the boundary conditions - described in this paper as a project context factors - have to be analysed before the start of the project. Some context models already demonstrate the influence of certain context factors (e.g. type of product, on a project and their processes (Meißner et al., 2005; Browning et al., 2006). However, a systematic determination and analysis of these context factors in order to derive a suitable degree of agility for product development projects as well as for modelling and adapting the processes in the framework of project management is rarely established in enterprises today (Lindemann and Reichwald, 1998; Lindemann, 2009).
Therefore, the aim of this paper is to systematize context factors described in the literature. On this basis, a concept shall be presented, that proposes the planning and agile adaptation of processes in the framework of project management.

1.1. Concept of agile process engineering

As part of our research in agile process engineering (Baschin et al., 2019), we focus on the application of targeted reflection in the product development process. Through the integration of reflection activities into the process model and the following execution by the project team members, it is possible to react to problems agilely and to derive appropriate adaptation and improvement measures. These correlations are presented in Figure 1.

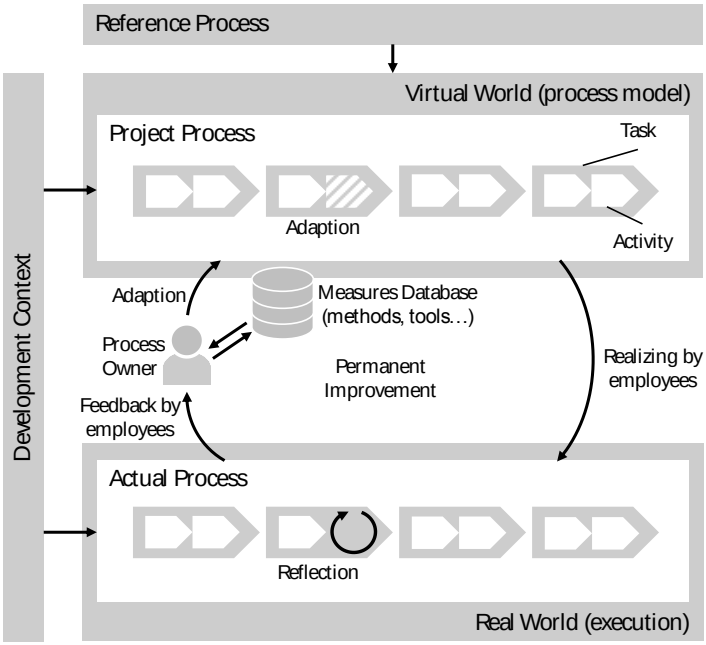

Figure 1. Concept of agile process engineering, based on Hollauer and Lindemann (2017)

With the help of the experiences from reference projects, a project process is modelled, which includes the development activities. After realizing and reflecting by the employees, the process owner receives feedback and adapts the process model. The process owner is supported by a measures database including methods and tools for adapting the project process. After that, the cycle starts again. However, for a more detailed consideration and modelling of the processes, the dependency on the project context have to be considered more closely (e.g. local distribution of development teams). It is expected, that this context will also have an influence on a suitable degree of reflection and agility. Therefore, a more detailed examination has to be carried out here as well.

1.2. Research questions and structure of the paper

As already mentioned, processes in enterprises are predominantly set up prescriptively to plan and manage engineering projects without explicitly addressing the project context at hand. As a result, projects are often implemented with an unsuitable degree of agility. Thus, important information and knowledge about the status of design activities and suitability of applied methods and techniques are not exchanged between the stakeholders effectively. Therefore, the following research questions result for the further development of agile process engineering:

- How can the development context be considered adequately in planning of product development projects?
- How can processes be modelled, tailored and adapted in product development projects on the basis of the project context?

For this, the paper is organized as follows: Section 2 defines essential approaches and relevant terms like process, activity, process models, development context and reflection. Section 3 illustrates a concept for agile process engineering under consideration of the development context. Here, the determination of a suitable degree of agility in product development processes is examined in more detail. An example for

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planning reflection in process modelling is presented in Section 4. Section 5 discusses the findings and describes future work.

2. State of the art - processes, context and reflection in the framework of project management in product development

In the following section, some basics of project management with focus on product development will be explained. Processes and process models, dependencies and influences on processes and reflection in processes are presented.

2.1. Activities, processes and process models

Processes are core elements in the organization of companies. Becker et al. (2012) distinguishes between structural organization and process organization. In a company, the structural organization includes systems such as departments or business divisions and focuses on the distribution of tasks to these systems. The process organization focuses on the execution of the tasks and the coordination of the temporal and local aspects (Becker et al., 2012). Here, each process has a starting point and a certain goal for solving a problem, and an ending point, when achieving the goal. A large variety of different tasks has to be processed between the starting point and the ending point. This tasks are solved by the execution of several activities, which are essential elements of a process.

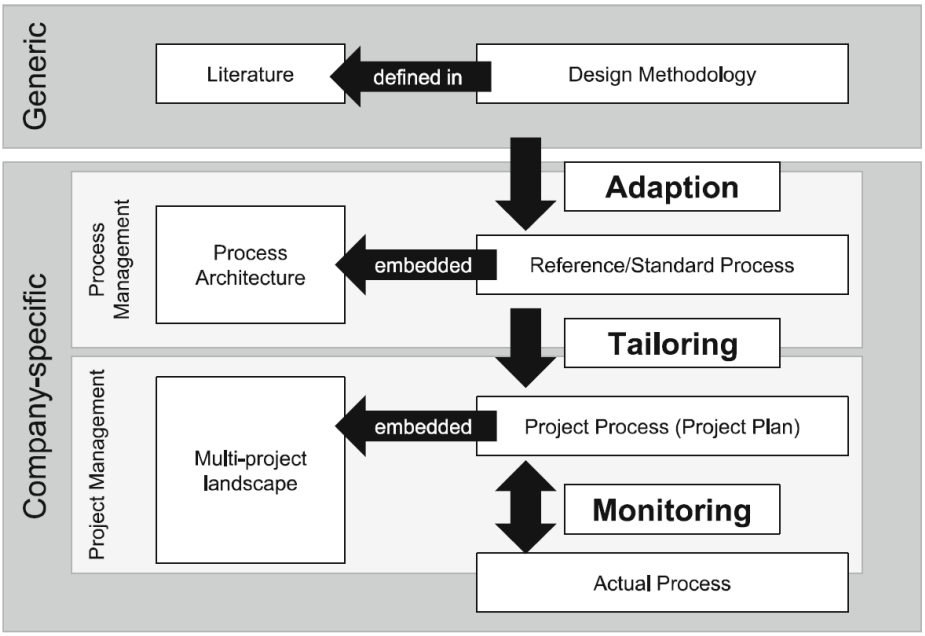

Figure 2. Levels of engineering design processes (Hollauer and Lindemann, 2017)

Product development processes are often of high individual and complex character with many special activities. In order to structure and manage this different development activities, process models become a key role in the framework of project management. Process models can support the visualization, planning, execution, controlling, adaption, and optimization of processes (Lindemann, 2016). But originally, process models were often used to schedule and manage projects to anticipate delays and bottlenecks. Thus, the temporal structure and definition of checkpoints is predominant. As described by Lindemann (2016), processes consists of different temporal phases, which include activities. To support product development, the description of these activities and the information required for these are further important (Browning et al., 2006). According to Wynn and Clarkson (2017), activity-based process models do not describe strictly temporal sequence but recurring activities within iteration loops. The definition of activities performed in these processes is important for reflection and continuous adaptation. In order to generate the process model, a reference process can be created from a design methodology from the literature. Then, the reference process is tailored to a company specific project

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process. After that, the project process is realized by the project members. The project process and the real process are continuously monitored for improvement (Hollauer and Lindemann, 2017).

2.2. Project context in product development

The context of product development, differentiated in internal context factors (e.g. development, project) and external context factors (e.g. market, environment) has a significant influence on the processes (Hales and Gooch, 2004). Into the framework of project management in PD, the context is defined as an environment that has a significant influence on product development due to various factors, e.g. the market or the structure of the enterprise (Meißner et al., 2005). As Negele et al. (1997) describe, the context of product development is characterized by several systems. The focus is on the process system, the product system, the agent system and the goal system. The systems are related to each other and affect each other. This model is extended by Browning et al. (2006) adding the tool system. In this way, the used software tools influence the activities of the employees with each other and affect the process. Huth et al. (2018) and Inkermann (2019) adapt this model and notes that changes in one of the systems inevitably affect the other systems. This fact has to be taken into account during process planning and process execution in order to react agilely to problems in an effective way. Meißner et al. (2005) and Bavendiek et al. (2018) also underline, that the competencies of employees have to be considered in the execution of development processes. Wilmsen et al. conducted an extensive literature-based research on existing context factors in product development. Thereby, 946 context factors have been identified. This context factors are categorized into the different levels "environment", "company", "department", "development project" and "project progress". In addition, the influence on essential activities in product development was examined (Wilmsen et al., 2019).

Hüsselmann et al. (2019) also demonstrate the importance of context-specific project planning. Accordingly, specific adaptations for the optimization of the processes can be suggested by project typing. According to Snowden and Boone, the four project types "obvious", "complicated", "complex" and "chaotic" can be distinguished in their cynefin-framework. By analysing the project context, the available project types are determined in order to propose a suitable methodology for carrying out the project (Snowden and Boone, 2007). On this basis, Albers et al. 2019 suggest a model for the selection of a situation- and demand-oriented degree of flexibility in product development projects, named agile systems design.

The research shows that the context of project management in the framework of product development can be described by factors with different levels of detail and factors with different focus. Table 1 summarizes the analysed context models of project management in PD. There are a number of context factors that have varying degrees of impact on the product development process. The challenge is to identify the key influencing context factors and use them in a targeted way in process planning.

Table 1. Context factors in literature

References	Described context factors and context-dependent models
Meißner (2005)	Society, market, enterprise, development order, resources, individual, team
Negele et al. (1997)	ZOPH-model, goal system, product system, process system, agent system
Browning et al. (2006)	Based on ZOPH-model, tool system
Huth et al. (2018), Inkermann (2019)	System of processes, system of product models, system of tools
Bavendiek et al. (2018)	Process layer, methods & tools layer, competencies & qualifications layer
Hüsselmann et al. (2019)	Complexity, distribution, commitment, experience, interdisciplinarity, expenditure, client base, service, quality requirements, urgency, strategic relevance, degree of innovation, plannability, level of technology
Wilmsen et al. (2019)	Environment, company, department, development project, project progress, 946 context factors within these fields
Hales and Gooch (2004)	Differentiating between internal factors (e.g. development, project) and external factors (e.g. market, environment)
Snowden and Boone (2007)	Model for differentiating between the project types "obvious", "complicated", "complex" and "chaotic"
Albers et al. (2019)	model for the selection of a situation- and demand-oriented degree of flexibility in product development projects

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2.3. Reflection in the framework of project management

Reflection is understood as critical scrutinizing of own thinking and acting. Thus, reflection is the basis for the adaptation of processes. Product developers are often confronted with unpredictable and fast-changing situations, when executing development activities (Weixelbaum, 2016). Methods can be used to help structure and deal with the difficulties that have arisen. However, due to the large number of fast occurring problems, only a limited number of suitable methods are available. Therefore, reflections can be used to scrutinize own actions and to transmit important information to different stakeholders. The information and knowledge can be used to adapt the product development process. Therefore, reflection loops provide an agile way to react to problems and optimize processes continuously (Weixelbaum, 2016). Seegrün (2019) considers reflection at three different levels: the strategic reflection, the tactical reflection and the operational reflection. Strategic reflection scrutinizes long-term processes and objects. For example, superior processes are analysed. Key questions could be: should project planning be structured differently? Does the business model have to be adapted? Tactical reflection concentrates on objects such as sub-processes, budget or schedule. Here, some key questions could be: do specific processes have to be changed? Do we need more employees to execute the tasks? Here, the mid-term context will be analysed. The operational reflection includes reflecting tasks, activities, methods used, etc. Thus, operational reflection refers to the short-term context. For example, it could be questioned whether the right methods are being used?

For the realization of reflections, different reflection methods and reflection models are suggested in the literature. In his thought of "Reflection-in-action", Schön (1983) describes four phases in handling problems. First, a problem situation is identified (naming). Then, the situation is set in relation to a similar known problem and measures for improvement are derived (framing). Afterwards, the measures are executed (moving). Finally, the effect of the measures is analysed (evaluation). "Reflection in action" thus describes thinking and reflecting in the present while carrying out the activity. On the other hand, "Reflection on action" is described as reflection of completed activities in past (retrospective). In this way, information about occurred problems and completed activities can be communicated to other stakeholders in order to formulate implicit knowledge in an explicit way (Schön, 1983). Reymen and Hammer (2002) also regards reflection as learning from completed activities in order to generate future activities. Structured reflection is, therefore, important for improving the development process. This can be achieved by dividing the process into "design sessions" and "breaks". Into the "breaks" between the "design sessions", a reflection process is carried out, that scrutinises the completed activities and derives conclusions for future activities.

3. Context-specific agile process design

Based on the research, a model for the analysis of the context of product development projects is suggested in section 3.1. Afterwards, section 3.2 presents a concept of how this model can be used to plan, reflect and adapt processes to support the project management in the product development.

3.1. A context model to support the planning of processes in PD

Based on Negele et al. (1997) and Browning et al. (2006), the following five overall project context factors are used in the suggested context model to plan the processes in the product development into the framework of the project management: goals respectively specifications, product, organization, tool and process. These five project context factors are each extended by several specific context factors, which are derived from the work of Meißner et al. (2005), Bavendiek et al. (2018), Hüsselmann et al. (2019), Wilmsen et al. (2019) and Hales and Gooch (2004). The resulting context model is shown in Figure 3.

The "specifications" define goals and regulations that are set by external institutions (norms, laws etc.) or internal departments (budget, scheduling etc.). They thus form the guidelines for achieving the project goals. The "product" describes essential properties that have to be realized during the execution of the process. For example, these properties result from the type of product, the product complexity and the technical requirements. The "organisation" specifies the local conditions and the distribution of resources. Factors such as interdisciplinarity in the project (different engineering

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domains), distribution of the development teams and the number of the employees, involved in the project, should be taken into account. In the shown context model, the term "tools" describes tools that are used by the project members by executing the activities. Examples are used ERP-, PDM-, and CAD-tools or communication systems.

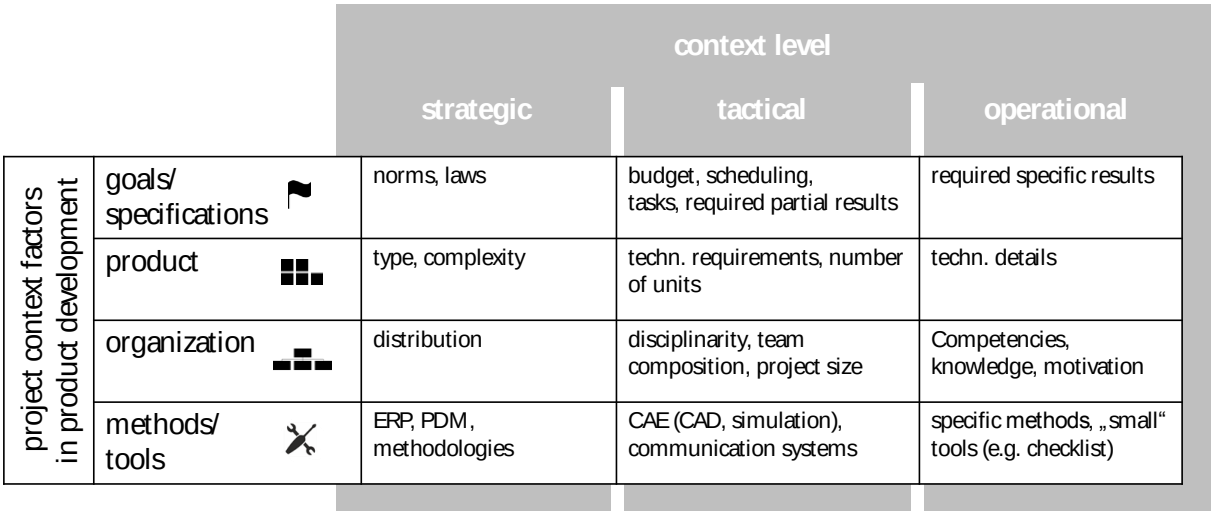

Figure 3. Project context factors in product development and their levels

The project context factors have a high impact on the product development processes to be planned. Thereby, the specific context factors, derived from the overall project context factors, are assigned to the three levels strategic, tactical and operational and have a different impact on this levels in process planning. Strategic changes, that have to be observed during process execution (e.g. laws, norms, changes in the documentation of safety-relevant components), have a significant impact on the processes and affect a large number of project members. On the other hand, influences on the operational level (e.g. wrong communication in the team, competencies) affect only a few employees and usually do not have a large impact on the project result. Of course, a single misinformation can also have a major impact. However, the probability of this is significantly lower than at the strategic level. In summary, it can be stated, that the described context factors influence the product development process, which makes it necessary to analyse the context factors before the project start in order to ensure effective process planning. Furthermore, the impact on the different levels of the processes have to be considered when planning the processes.

3.2. A concept for planning, reflection and adaption of processes in PD

The context factors, mentioned in section 3.1, describe topics that affect the process. Uncertainties and problems, occurring within these topics, lead to risks that can endanger the project goals. This situation can be countered with specifically planned processes, including reflections for analysing arising problems at an early stage. The knowledge gained can be used to derive adaptation measures for the process and minimize project risks. For this, a concept is proposed, which is explained in more detail below (s. Figure 4):

- First. Analysing of the project context: in a first step, the specific context factors are listed and each of them are rated. Here, the context model, presented in section 3.1, can serve as an aid (s. Figure 3). For example, the context factor product can be subdivided on a strategic level into product complexity and product type (software, mechatronic, mechanical or new construction, adaptation design). Then, the product complexity can be rated via the number of components (e.g. 1-number of components 0-100, 2-number of components 100-1.000, 3-number of components 1.000-10.000, 4-number of components over 10.000). This ensures an objective rating of the individual context factors. After that, an average value is calculated for the different context levels. The average value indicates how many uncertainties are to be expected on the context levels. For example, more uncertainties are to be expected in the

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development of complex products with many components than in the development of simple products with less components.

- Second. Process planning: The reference process is planned based on the result of the rated context factors at the strategic level. Depending on the expected uncertainty, iteration loops/reflection loops are planned and methodologies are used for the modelling of the reference process. From the reference process and the result of the rated context factors at the tactical level, the project-specific process is modelled then. After that, the development activities are derived by the same analogy from the project process and the result of the rated context factors at the operational level. In this way, the process is specified and detailed progressively. Similar to the reference process, iteration loops/reflection loops or reflection methods can be considered in the project process as well as the development activities if uncertainties are expected.
- Third. Process realization: after completion of the process planning, the project members execute the defined development activities. Occurring problems are identified by the planned reflections and are communicated to the stakeholders at an early stage, which enables a quick and agile adaptation of the project process and re-planning of the development activities, if necessary. In the case of major problems, the reference process also has to be reflected and adapted. The adapted reference process serve as a knowledge base for following similar projects.

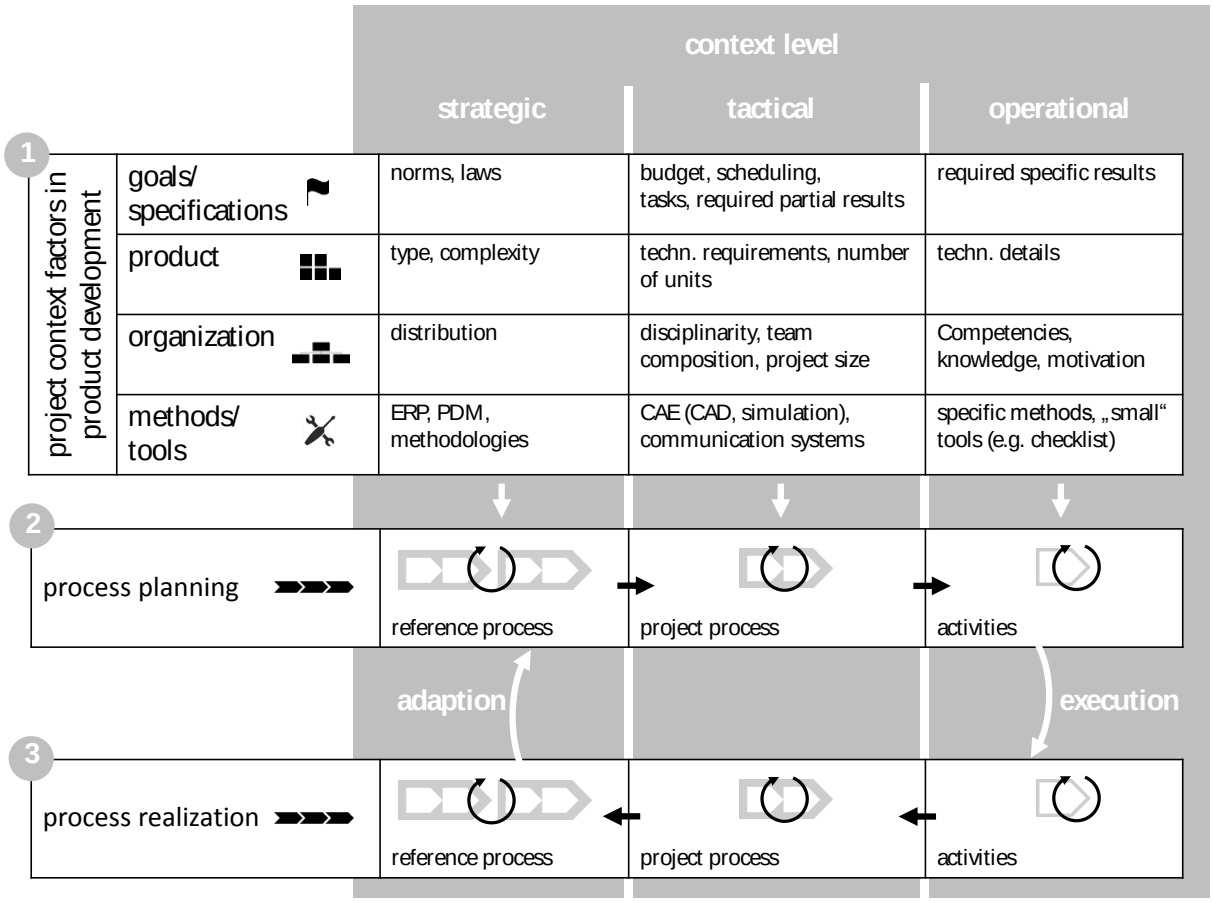

Figure 4. Concept for planning, reflection and adaption of product development processes in the framework of project management

As shown, the described concept can support in planning, reflection and adaption the product development processes in the framework of project management based on the project context. However, the specific context factors have to be considered in more detail in order to specify the rating scheme for process planning. Then a classification into project types “obvious”, “complicated”, “complex” and “chaotic” could be made, as suggested by Snowden and Boone (2007).

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4. Case study

The methodology, presented in section 3.2, shall be applied within a research project of TU Braunschweig in cooperation with a project partner. The project partner is a medium-sized enterprise that develops bulk material grabs and sells them worldwide. In a current project, development activities (adaptation of constructions, drawing creation) will be relocated from Germany to India in order to improve customer contact in India. Some activities (such as administering data in the PDM system) are still carried out in Germany. However, new development processes in India have to be defined. First, the context, that has an influence on the processes, was analysed. The project is of small size. Difficulties in exchanging information can be expected due to local distribution. The product is of moderate complexity. Because no new constructions are created, no significant problems and uncertainties are to be expected. However, new competences in creation of drawings have to be trained.
Strategic changes such as adaptations of norms or similar are not to be expected. Overall, it seems that problems can arise to a limited extent at tactical and operational levels. Therefore, the processes and essential activities were modelled in the BPMN (Business Process and Modelling Notation) standard (s. Figure 5) in a process modelling tool, development during a research project at TU Braunschweig. The employees involved in the process have the possibility to add specific comments to activities of the process model for reflection, which are analysed by the project leader. Hereby, the project leader has the opportunity to adapt the process. For support in the selection of suitable adaption measures, a methods and measurements database is available, which is integrated into the process modelling tool.

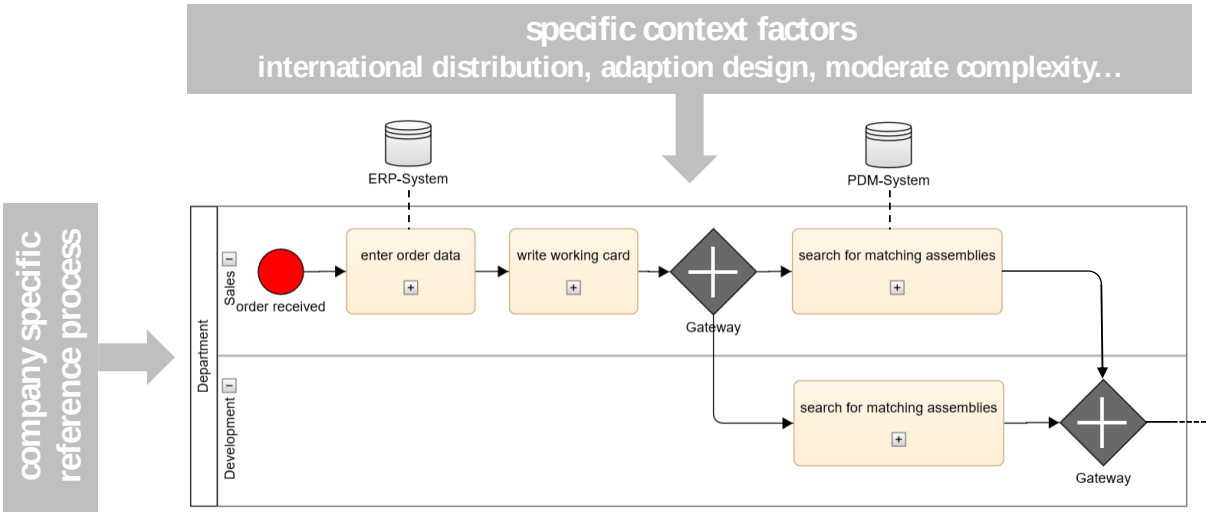

Figure 5. Process planning through context factors

5. Conclusion and future work

The research has shown that product development processes can be planned more effectively, if the project context has been analysed beforehand. With these findings it is possible to estimate uncertainties on strategic, tactical and operational levels that have an impact on the product development process. Then, the process can be modelled on this basis and with the help of reference processes. In addition, reflection loops at the different levels (strategic, tactical, operational) can be integrated into the process model to provide a permanent analysis and optimization of the process and a reducing of uncertainties. However, the described methodology cannot cover all context factors affecting the product development process. Additional context factors may further specify the method, but this complicates the usability and effort. Therefore, the concept should be seen only as an aid for the targeted use of reflections. Furthermore, the described concept hast to be evaluated in more detail. On the one hand, the influence and scope of the context factors identified have to be examined more closely. On the other hand, the concept has to be applied in bigger projects. In addition, more concrete reflection methods and adaptation measures need to be elaborated in order to enable the continuous improvement of the processes.

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