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METHOD FOR THE IDENTIFICATION OF REQUIREMENTS FOR DESIGNING REFERENCE PROCESSES

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Abstract

A reference process should consider to the needs and behaviours of the process users, as well as all relevant restrictions and boundary conditions within the company and its environment. Therefore, this contribution provides a method to synthesize relevant requirements on reference processes and supports the consideration of these requirements during the design of a new, company-specific reference process based on meta-models. The developed method was used to design a reference process for automotive predevelopment projects and its applicability and usefulness was evaluated successfully.

Keywords: process requirements, design process, design methods, requirements management

1. Introduction

Many different process models for design and development projects exist (Wynn and Clarkson, 2018). These process models differ regarding their purpose and field of application. Hence, they have differences regarding activities, phases and strategies they describe. In practice, each company uses individual process models and approaches for planning product development projects (Eckert and Clarkson, 2010). Especially large companies have dedicated teams or persons that are in charge of the process management, i.e. to provide and improve process models for the different types of business and design processes (Schmelzer, 1999; Richter, 2016). The main objective of design process improvement is to increase the effectiveness and efficiency of the process in order to ensure the development of a sufficiently good product on budget and on time (Clarkson and Eckert, 2010). However, most process models are far too general to help designers or design managers with project planning activities or to support their daily decisions (Clarkson and Eckert, 2010). An additional problem of process models is that most often business departments, as well as IT departments design the process models of a company (Fleischmann et al., 2012). Hence, their perspective on the process differs from the perspective of the process users and is much more technical (Fleischmann et al., 2012). Furthermore, a process is most often considered as sequences of activities and the process models consider the involved stakeholders only implicitly (Fleischmann et al., 2012). According to Eckert and Clarkson (2010), a "design process should be tailored to the product under development, the competence of the design team and the aspirations of the users". Thus, it is necessary to consider the needs and behaviours of designers, as well as all relevant restrictions and boundary conditions within the company and its environment during the design of a process model within a company.

2. Research design

The design and enhancement of reference processes for complex product engineering projects, especially in large companies, e.g. automotive, is challenging. There are plenty restrictions and boundary conditions, as well as needs of product designers that should be considered during the design of reference processes. Although there are many different reference processes available in literature and in practice, there is only little research concerning the systematic identification of requirements for reference processes. Additionally, there is also not much literature regarding the consideration of these requirements during the design and improvement of reference processes. However, many reference processes in practice lack of acceptance and usability due to a poor or incomplete consideration of process requirements during the design of a reference process. Hence, the objective of this contribution is to provide a method for process authors, to identify requirements for reference processes systematically and to consider these sufficiently during the design of reference processes. Therefore, the following research questions will be investigated:

- How can process authors identify requirements for the design of reference processes?
- How can process authors consider these requirements during the design of a reference process?

For answering these research questions, firstly a literature review was executed to investigate existing approaches for identifying process requirements and for designing reference processes. As there is only little research available within this field, the authors considered literature in the field of project management and empirical studies, which are aiming for similar objectives. Based on the results of the literature review, the authors developed a method that aims to enable process authors to identify requirements on reference processes, especially in large companies. The structure of the method is based on the problem solving process SPALTEN, but any other problem solving process can be used for structuring the method. The main contribution of the method is providing a structure support for the identification of process requirements. This can be combined with existing process modelling tools and methodologies like IDEF. For answering the second research question, existing reference processes and process models were investigated, to synthesize different process characteristics. Finally, the presented method was applied within the predevelopment department of an automotive company to investigate requirements for a suitable design of the reference process. Furthermore, the identified requirements were assigned to the synthesized process characteristics, to select a suitable meta-model as basis for the design of a reference process. Therefore, this contribution provides a method to synthesize relevant requirements on reference processes and supports the consideration of these requirements during the design of a new reference process based on meta-models.

3. Processes and process requirements in product development

3.1. Processes in product development

Many different design and development processes have been proposed for a specific purpose and field of application to date (Gericke and Blessing, 2012). The resulting large variety of process models can be categorised using different schemes. Wynn and Clarkson (2018), categorise design and development processes according to the scope of the process, i.e. micro-, meso- or macro-level, and to the type of the process, i.e. procedural, analytical, abstract or MS/OR. Sharafi et al. (2010) compare different process models regarding the three product development domains: product concept, product design and production design, as well as three further process criteria, i.e. product development management, information management and simultaneous development. Gericke and Blessing (2012) analysed 82 process models from nine disciplines considering, whether they are stage-based or activity-based, problem- or solution-oriented and whether they are project- or design-focused. However, these categorisation frameworks represent a scientific and research-driven perspective on design and development processes, but do not consider an application-oriented perspective. An application-oriented perspective should consider process characteristics required by process authors to design a company-specific process model to match the requirements of relevant stakeholders, such as project managers or designers. Table 1 gives an overview on eight process characteristics, i.e. describing the shape and the

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structure of a process model and can be directly established, assigned and modified (Weber, 2014) by the process author, and corresponding values compiled based on a literature review (Jäckle, 2019). The literature review was focussed on publications concerning process models, as well as project management, because reference processes are often used as basis for project planning. Sixteen publications were selected during the literature review and analysed for process characteristics and corresponding values. The **degree of detailing** indicates how precisely the activities or work packages are described. This includes the description of what the designer has to do and how he should do it. The **resource allocation** indicates how restricted the resources of specific activities are. This property describes whether every designer can execute an activity or whether this is restricted to designers with specific capabilities. The **order of the process elements** differentiates between a defined order of activities or work packages and a flexible description of the order of the process elements. The **type of working** indicates whether the process should be executed sequentially, cyclic, opportunistic or whether an iterative way of working is supported by the process. The **proof of results / status** indicates how often the responsible project leader or manager checks and approves the project status and the results. In addition to this, the **communication of the status** indicates how often and intensively the stakeholders are informed about the project status. The **number of work packages** is an indicator for the granularity of the resulting project planning.

Table 1. Process characteristics and corresponding values

Characteristic	Min / max	Literature
Degree of detailing	Low / high	VDI 2221 (2018), Beck et al. (2001), Clarkson and Eckert (2010), Österle et al. (2011), Pfeffer et al. (2019), Smith and Morrow (1999)
Resource allocation	Low / high	VDI 2221 (2018), Albers and Braun (2011), Albers et al. (2019), Beck et al. (2001), Feldhusen and Grote (2013), Lévárdy and Browning (2009), Lyneis and Ford (2007), Österle et al. (2011), Pfeffer et al. (2019), Smith and Morrow (1999)
Order of process elements	Defined / flexible	VDI 2221 (2018), Albers and Braun (2011), Lévárdy and Browning (2009), Lyneis and Ford (2007), Negele et al. (1999), Schmidt (2012), Smith and Morrow (1999), Unger (2003)
Type of working	Sequential / iterative	VDI 2221 (2018), Albers and Braun (2011), Albers et al. (2019), Lévárdy and Browning (2009), Lyneis and Ford (2007), Meißner and Blessing (2006), Negele et al. (1999), Pfeffer et al. (2019), Schmidt (2012), Unger (2003), Wynn and Clarkson (2018)
Proof of results / status	Seldom / often	Albers and Braun (2011), Albers et al. (2019), Beck et al. (2001), Feldhusen and Grote (2013), Lyneis and Ford (2007), Negele et al. (1999), Smith and Morrow (1999), Unger (2003)
Communication of status	Low / intensive	Albers and Braun (2011), Beck et al. (2001), Clarkson and Eckert (2010), Lyneis and Ford (2007), Negele et al. (1999), Pfeffer et al. (2019)
Number of work packages	Low / high	VDI 2221 (2018), Albers et al. (2019), Feldhusen and Grote (2013), Lévárdy and Browning (2009)

The presented process characteristics are relevant from a project manager's perspective and hence, should be considered by a process author during the design of a reference process. To define the specific values of the process characteristics of a future reference process, the process author should firstly identify the requirements on the reference process. According to requirements engineering, requirements are "defining what the stakeholders - users, customers, suppliers, developers, businesses - in a potential new system need from it and also what the system must do in order to satisfy that need" (Dick et al., 2017). Hence, the following section addresses the identification of requirements on reference processes.

3.2. Identification of process requirements

Although there is plenty of literature on business and development processes, as well as on process planning and project management available, there is only little literature that addresses requirements on reference processes, as well as the identification of these requirements. According to Browning (2010),

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there are different categories of users of process models, e.g. process owners, designers, process auditors, for who the process model can have different purposes. For example, the purposes of a reference process for project managers can be monitoring of the project status, allocation of resources or estimation of project time, cost, quality and risk. In the field of unstructured business processes, i.e. processes depending "on real-time events, available data and knowledge of knowledge workers", Bukhsh et al. (2017) propose a list of representational requirements to manage and model such unstructured business processes. Based on an experiment to compare Business Process Management and Case Management, they identify representational requirements for unstructured business processes. They conclude that a process support paradigm and a modelling language for managing and modelling unstructured business processes must support these requirements. In the area of software engineering, Liu et al. (2006) present a priority assessment of software process requirements from multiple perspectives, e.g. business, end-user, developer or management perspective. They reason that it is necessary to collect software process requirements from various stakeholder groups for the improvement of software processes. Their framework focuses the prioritization of the identified process requirements from the different stakeholder groups to allocate the best available resources to the most critical requirements. Matook and Indulska (2009) propose an approach for improving the quality of reference processes, based on quality function deployment. They reason that a reference process should be complete, accurate, and easily configurable, i.e. flexible for a specific purpose. Especially the flexibility is an important characteristic of a reference process, because it describes the ease with which a reference process accommodates and adapts to changes of the process requirements. Within their approach, there is a strong focus on the user requirements and their fulfilment. However, they do not describe an approach for identifying the software process requirements. In the field of healthcare information technology, Cruel et al. (2012) developed a procedure model to identify requirements for reference processes. They combine different empirical methods, such as the Delphi method and expert interviews with research-based activities, such as the analysis of valid guidelines to develop a reference process. Furthermore, Gericke et al. (2016) present a life cycle of process models, starting with the identification of the needs of the future process model . These needs can range from a personal desire to gain a better understanding of a process to formal requirements. As an example for the identification of needs, they name a dialogue between managers and team members to understand the tasks that need to be carried out during the process. The presented literature considers different types of process requirements for developing and improving reference processes. However, only one paper was found that describes a procedure to identify process requirements based on the involvement of different stakeholders. Furthermore, the literature does not explicitly address reference processes for product development projects. The acceptance of a reference process within a company depends strongly on the involvement of the process stakeholders during the design of a reference process (Müllerleile, 2019). Thus, there is a demand for a systematic approach to identify process requirements through involving relevant stakeholders and to consider these during the design of a reference process.

4. A method to identify requirements for reference processes

As previously mentioned, there are several possibilities available to categorise and differentiate process models in product development. However, these frameworks do not consider an application-focused perspective. Hence, Figure 1 gives an overview on the process types in product development from a practitioner's point of view. On top of Figure 1, there are meta-models that have a generic character and have a broad scope. These meta-models can be guidelines, such as the Stage-Gate-Process, the Waterfall-Model, the V-Model (VDI 2206) and the VDI 2221 that aim to support the development of technical and mechatronic systems (Cooper, 1990; Royce, 1987; Haberfellner et al., 2019; VDI 2206, 2004; VDI 2221, 1993) . Often, research institutions also provide meta-models for product development. Examples for such meta-models are the iPeM - integrated product engineering model that provides a generic framework to compass through the product engineering process (Albers et al., 2016), the MVM Munich procedure model that supports the planning of development processes (Lindemann, 2009), and the process proposed by Pahl and Beitz (2013) describing a systematic approach for developing and designing technical systems.

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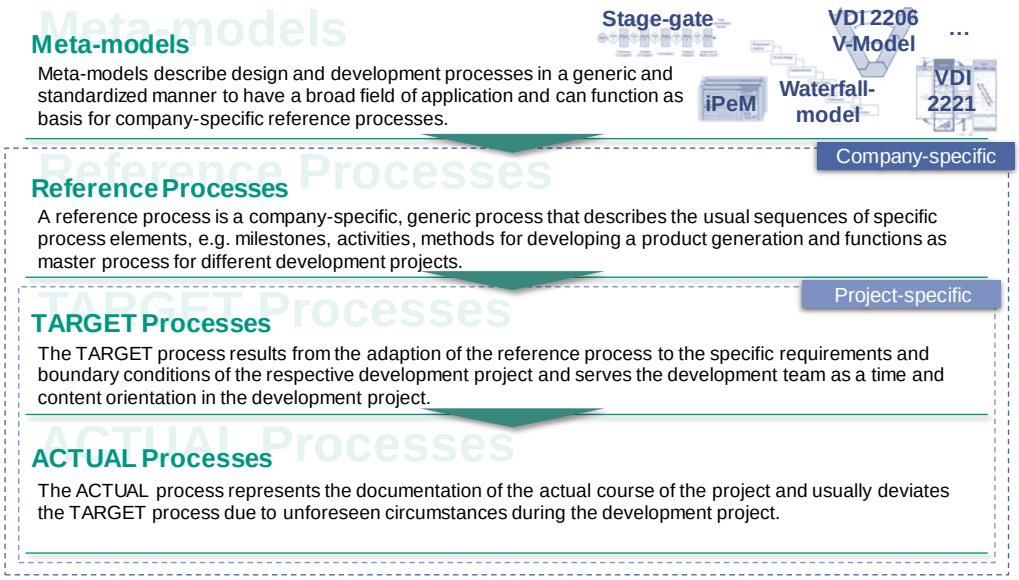

Figure 1. Overview of different process types in product development

In contrast to these generic meta-models, there are company-specific reference processes that describe the usual sequences of process elements, e.g. milestones, activities, methods for developing a new product (Wilmsen et al., 2019b). These reference processes often serve as master processes to derive project-specific TARGET processes that consider the specific requirements and boundary conditions of respective development projects. The TARGET process serves as a project plan, including all relevant contents and resources for developing a new product (Wilmsen et al., 2019b). The ACTUAL process is the actual course of the development project and can deviate from the TARGET process, due to unforeseen circumstances during the design project (Wilmsen et al., 2019b). Many companies use reference processes to describe their development processes standardized. However, these reference processes have a strong focus on objects and results and do not consider sufficiently the designer. Hence, some reference processes are not applicable, and the process users start bypassing the reference process. To ensure the applicability and to increase the acceptance of a reference process, the following sections present a proposal for process authors to identify requirements on reference processes and to consider these requirements during the design of reference processes. Figure 2 provides an overview of the proposed procedure for developing a reference process.

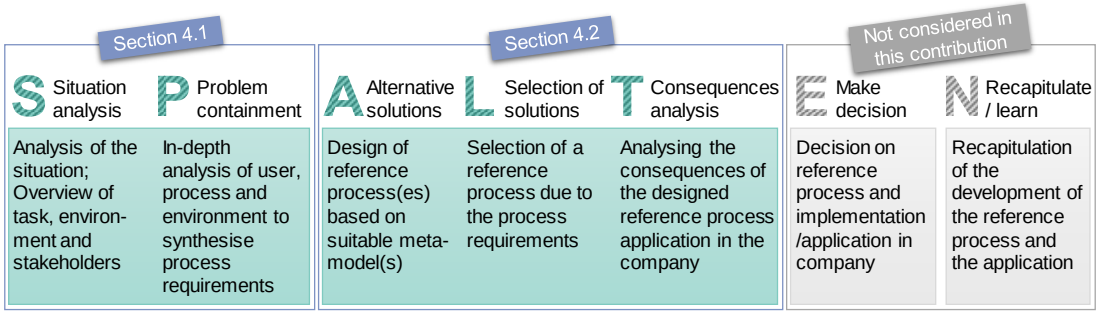

Figure 2. Allocation of the prescriptive results within the SPALTEN problem solving process

The situation analysis includes an overview of the task, the environment and the relevant stakeholders. The problem containment addresses the in-depth analysis of users, processes and the environment to synthesize the relevant process requirements. The next step (alternative solution) focuses on the design of alternative reference processes based on a selected meta-model. The selection of solutions includes the evaluation of the different reference processes and the selection due to the process requirements. Hereby, also different process modelling tools and methods need to be analysed, compared and selected to provide an adequate model of the reference process. During the consequence analysis, the possible consequences of using the selected reference process(es) are analysed. Depending on the

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results of this step, the previous steps can be repeated. If the reference process was evaluated successfully, a decision on the implementation of the reference process can be made and the reference process is applied within the company (make decision). The last step addresses the recapitulation of the design of the reference process and its application.

4.1. Identification of process requirements

Figure 3 gives an overview of the method to identify requirements for reference processes, which is based on the principles of requirements engineering for developing technical systems. The first part of the method represents the situation analysis and aims to get an overview of the task, the environment and the relevant stakeholder groups. S1a. Firstly, the process author should analyse his task to design a reference process. The process author should get to know the background of the task and gather information regarding the boundary conditions, such as time schedule, available resources, e.g. project team, budget, as well as the objectives, e.g. increase efficiency, and reduce uncertainties, of the task. Anyway, the process author should procure the commitment of the management before proceeding with the problem containment. S1b. Through the characterisation of the process environment, the process author describes the scope and intended use of the reference process as detailed as possible. Therefore, it is recommended to use existing context-factors from literature (Gericke et al., 2013; Wilmsen et al., 2019a) to assess the process environment in a standardised way. The detailed and comparable characterisation of the process environment will be relevant for the second part of the method. S1c. The next step focuses the identification of relevant stakeholder and user groups. Therefore, the process author should first investigate the different roles that will interact with the reference process, to synthetize stakeholder groups within the company. One of the stakeholder groups will be the process users. This stakeholder group is of great importance for the success of the reference process. Hence, it is recommended to separate different process user groups, e.g. by using the persona method.

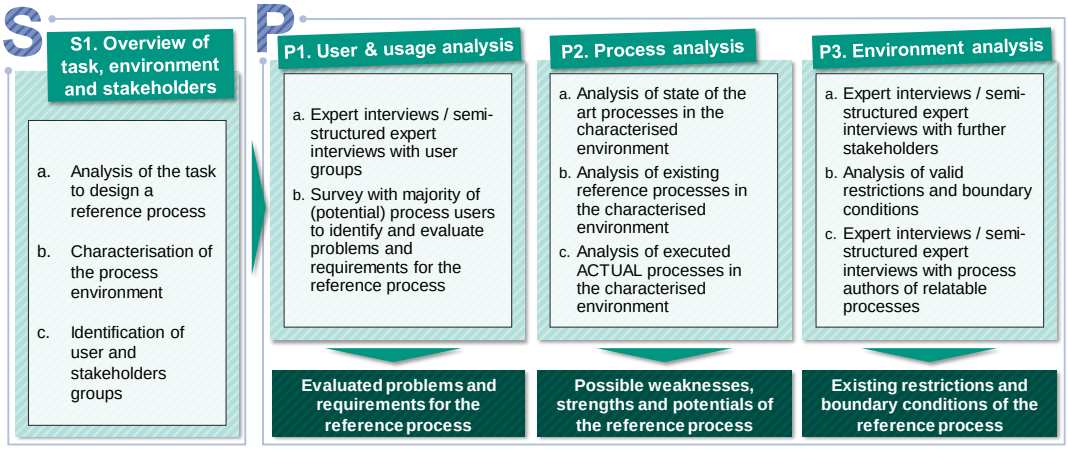

Figure 3. Overview of the method to identify requirements for reference processes

The second part of the method consists of three areas: user and usage analysis, process analysis and environment analysis. The steps within these three areas can be executed simultaneously depending on the project set-up and project plan of the process author. **P1.** The first aspect is the analysis of the users and the usage of current reference processes. The results are evaluated problems and requirements on the reference process from the process users' perspective. **P1a.** In this step, the process author should execute expert interviews with the different **user groups**. The objective of this step is the understanding of the user and the usage context of the reference process. Understanding the user means to know which types of users are there, what are the roles and responsibilities of the user, e.g. designer, project manager and how do they interact with a reference process. Furthermore, the usage context defines the different situations in which the user interacts with the reference process, e.g. when he makes a project plan, when he is reporting the project status and includes the user itself, his task, resources, e.g. software, hardware, material, as well as the physical and social environment of the reference process (ISO 9241-210, 2010). Therefore, the process author can ask the participants to describe their ACTUAL process. Additionally,

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the process author should ask for common problems, challenges and requirements concerning the reference process. The gathered information is the basis for the next step. **P1b.** This step surveys the majority of **process users** to identify and evaluate the problems, challenges and requirements of the reference process. It is important that the participants of the survey are representative for the relevant user groups of the reference process. The survey should focus the evaluation of the previously identified problems, challenges and requirements of the reference process, but should also give the participants the possibility to comment missing problems, challenges and requirements. Additionally, this survey can be used to assess context-factors to get to know the heterogeneity of the projects. Based on this, similarities or differences between different user groups and project types can be identified. The results of the survey are important to underpin the need for a new or improved reference process and can be used to reason the significance of the reference process. Additionally, the usage and suitability of the current process and project management tools can be evaluated within the survey. **P2.** The second aspect is the process analysis. The objective is the synthesis of possible weaknesses, strengths and potentials of the reference process. For executing a proper process analysis, it is important to be aware of the process environment. Hence, the process author should investigate different process types that already exist in the characterised process environment. **P2a.** It is useful to analyse state of the art process models that have a similar scope as the reference process in development. **P2b.** If there is already a previous reference process within the company, the process author should make an in-depth analysis to identify weaknesses and strengths of the previous reference process. **P2c.** Through an analysis of different ACTUAL processes within the characterised process environment, it is possible to discover deviations of the theoretical reference process and its practical application within the company. **P3.** The third aspect is the **environment analysis** for the reference process. The objective is to identify existing restrictions and boundary conditions that should be considered throughout the reference process. **P3a.** In detail, it is important to execute **expert interviews** with the **further stakeholder groups**, such as managers, innovation, risk and quality management. **P3b.** Furthermore, the **existing boundary conditions** and **restrictions** should be identified. Especially, the functionalities and boundaries of the available process and project management tools have to be considered. **P3c.** Additionally, it is helpful for the process author to conduct **expert interviews** with other process authors that developed similar reference processes. Hereby, the process author can get information on common hurdles and challenges of designing a reference process. The previously described method does not function as static procedure to follow before designing a reference process. Indeed, this proposal should serve as a suggestion and orientation for process authors for identifying process requirements for designing a reference process.

4.2. Consideration of process requirements

In accordance to Figure 2, the next step, alternative solutions, addresses the design of multiple reference process based on a suitable meta-model. Therefore, the identified process characteristics from section 3.1 can be used to define the necessary values of the process characteristics based on the identified requirements on the reference process. For example, the process requirement “supports agile ways of working” leads to the necessary process characteristics of “flexibly ordered process elements” and an “iterative way of working”. Based on this information, the process author can select a suitable meta-model or another process model that matches all or the majority of the necessary process characteristics. The usage of an existing meta-model as basis for the reference process eases the internal and external communication of the reference process and provides a suitable terminology and process structure. Based on the selected meta-model, the process author has to specify the process model according to the company-specific context. The process author can use existing context-models from literature that support the identification and analysis of relevant context-factors (Gericke et al., 2013; Wilmsen et al., 2019a) or use previous experiences in designing a reference process for a specific context. Sometimes, the context-factors or process requirements can be contradicting, hence, it is useful to develop alternative reference processes and evaluate these afterwards. For the evaluation and selection of the most suitable reference process, the process author should use the identified process requirements as criteria and assess the fulfilment rate of these requirements by the alternative reference processes. Additionally, the available process and project management tools have to be assessed, to ensure a sufficient realisation of the reference process. Based on the selected reference process and tool, a consequences analysis should

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be executed. Therefore, the process author can use different methods, such as the SWOT analysis or a validation of the reference process through expert interviews or a small pilot project. The results of the consequences analysis can lead to a revision and improvement of the reference process and the tool.

5. Application of the method in automotive predevelopment

The method presented in section 4 was applied in practice to identify requirements on a reference process in automotive predevelopment. At the beginning, the task was defined and specified in cooperation with responsible managers. The task was to develop a reference process that suits all predevelopment projects. A context-model was developed to assess the context-factors that affect the reference process (Wilmsen et al., 2019a). Through the persona method, it was possible to get an overview of the different stakeholder groups. The analysis of the users and the usage of the reference process started with five expert interviews in automotive predevelopment electrics/electronics (E/E). The result were common problems of the reference process, an understanding of the process usage and execution, as well as rough process requirements. The problems, challenges and process requirements were evaluated based on an online survey with 96 participants from different predevelopment departments. The process analysis, which was done in parallel, included the analysis of ten suitable state of the art meta-models, as well as an analysis of four previous reference process models for predevelopment projects (Wilmsen et al., 2019c). Furthermore, 15 predevelopment projects were analysed in detail to gather enough information for understanding the ACTUAL processes of predevelopment projects (Wilmsen et al., 2019c). One important finding was that while the process elements of the investigated process models differed only slightly, their execution was done much more iteratively than proposed by the underlying reference processes. As result, 208 sub-activities and 104 artefacts that are relevant for the reference process were synthesized. The environment analysis started with expert interviews covering a broad spectrum of stakeholders, such as managers of the different predevelopment departments, coordinators of predevelopment projects, innovation management, risk and quality managers. These expert interviews provided valuable information for the identification and analysis of valid boundary conditions and restrictions, such as the process certification. Additionally, the implemented IT-Tools were investigated to identify their possibilities and boundaries. The last step included expert interviews with nine process authors of similar reference processes in three companies to consider their experiences with reference processes. Finally, different process requirements were identified. The three most important requirements were facilitating iterations and agile ways of working, including best practices, guidelines and methods, as well as providing project (context) specific process elements. Based on the identified process requirements, the corresponding specific values of the process characteristics were defined and are listed in Table 2. This detailing was the basis to identify a suitable meta-model as basis for the reference process. Hence, the process author selected the new VDI 2221 guideline (2018) and aspects of the iPeM (Albers et al., 2016) as basis for the reference process. The flexibility of these meta-models was perceived as an enabler to design a reference process that allows deriving process models (TARGET processes, compare Figure 1) for a broad range of heterogeneous projects. The reference process was realised as process toolkit, with process modules that are linked to the values of different context-factors. Hence, a suitable reference process is configured based on the respective design project.

Table 2. Process characteristics and specific values to select a suitable process model

Process characteristics	Specific value	Reason
Degree of detailing	high	Process should include methods, guidelines and best practices
Resource allocation	optional	Resource allocation was evaluated as less important
Order of process elements	flexible	Process users desire an agile way of working
Type of working	iterative	Process users desire an agile way of working
Proof of results / status	~monthly	Risk and quality management require regular proof of status
Communication of status	medium	No explicit requirement
Number of work packages	divergent	Heterogeneity of the predevelopment projects

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6. Discussion and outlook

This contribution provides a method that enables process authors to identify relevant requirements on reference processes and supports them during the design of a reference process. Through the application of the presented method, the principle applicability and usefulness of the method was initially evaluated. However, it will be necessary to execute further case studies to improve and to validate the presented method. The method focuses currently the identification of requirements on the structure and architecture of the reference process. Due to the strong linkage of process models and process modelling and management tools, it will be necessary to consider these aspects within the method. The scientific contribution of this paper focuses the comparison of process models and their characteristics from an application-oriented perspective. Furthermore, this paper addresses the systematic identification of requirements on reference processes, which is not yet discussed widely in design research. Although there are many contributions on design processes and their purposes, there is only little research on the identification of needs and requirements on reference processes. Based on this, it will be necessary to research the correlation of requirements, properties and characteristics of process models. For the identification of process characteristics, different literature on design processes and on project management was considered, because most often, large companies do use both, process and project management within their product development departments. Although there is already some research on planning development processes, e.g. Eckert and Clarkson (2010), it will be necessary to compare and combine the process requirements from a project management and a process management perspective to improve the development of reference processes.

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