21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

DESIGN OF FLEXIBLE PRODUCT DEVELOPMENT PROCESSES - AN AUTOMOTIVE CASE STUDY

Hollauer, Christoph; Frisch, Bianca; Wilberg, Julian; Omer, Mayada; Lindemann, Udo
Technical University of Munich, Germany

Abstract

Structured, flexible and tailorable standard processes help companies to conduct development projects successfully. When putting them into practice major issues arise. Often, there is an inadequate documentation of these processes. An additional problem is that the project leaders do not have sufficient support through appropriate methods in order to adjust the processes to their projects. They do not have a detailed overview of all the influencing factors affecting their processes, which effects they have on the development process and how they change over time. Hence, an initial methodological procedure to determine process specific influencing factors has been developed in order to generate project specific adoptable development projects. This work covers the validation and improvement of this procedure via a case study in an OEM in the automotive sector. Furthermore, part of the influencing factors, which were conducted with the mentioned method, are presented along with a developed categorisation scheme.

Keywords: Design process, Tailoring, Process modelling, Organizational processes, Process context

Contact:
Christoph Hollauer
Technical University of Munich
Institute of Product Development
Germany
hollauer@pe.mw.tum.de

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 2: Design Processes | Design Organisation and Management, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION AND MOTIVATION

In times of increasing global competition, highly demanding customers and technological changes such as electro mobility and digitalisation, companies are under pressure to develop innovative products (Lindemann et al., 2009; Cooper and Edgett, 2005). On the one hand there is a rise in technical complexity, more diverse product variety and a demand for higher quality, on the other hand development times and costs for development are shrinking. In this area of conflict, effective and efficient processes are necessary in order to guarantee innovativeness, competitiveness, and the ability to release successful products (Markham and Lee, 2013). Since product development has to cope with a high amount of dynamically changing influencing factors (context factors), product development processes (PDPs) need to be structured yet flexible and tailorable (Hollauer et al., 2016). Unfortunately, inadequate process documentation as well as lack of methodical support for project leaders impedes the ability to tailor reference processes to projects-specific circumstances (cf. case study in section 4). This results in often abstract and inflexible processes, which cannot be instantiated appropriately to specific project contexts.

In order to improve the efficiency of process models, project leaders need support to adjust the standard processes to the current circumstances of their development projects. This starts with giving project leaders a better overview of the currently existing influencing factors together with the probable process impacts, because a sound understanding of the development context is a precondition for the successful adaption of a design approach (Gericke et al., 2013). Through transparency, project leaders should be able to estimate the impact of context factors on a new project and enable the optimization of the projects process by tailoring it accordingly. Strategically, the determination of context factors improves plannability for process management in the long run, since changes of context factors over time can be better estimated and possible consequences inferred.

For this reason an initial methodology has been created for analysing the application context of a PDP, in order to develop tailorable PDPs (Hollauer et al., 2016. The approach combines a top-down concept for process acquisition with a bottom-up concept to analyse context factors. In this work a first validation and improvement of the methodology will be presented via a case study at an automotive OEM. Furthermore part of the identified context factors will be introduced together with a categorisation scheme.

The paper is structured as follows: First, the research methodology is introduced, after which the necessary background regarding PDPs as well as tailoring is presented. In section 4, our own related work is presented, in particular a methodology draft for the acquisition of the process application context. The following section covers the validation and improvement of this procedure via a case study. The paper closes with a conclusion and an outlook on further work to achieve the set objectives.

2 RESEARCH METHODOLOGY

The work presented in this paper follows the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti (2009). The case study presented in this paper (section 5) represents part of the descriptive study II (DSII), as an initially drafted solution support is applied in industry, its applicability and benefit evaluated and potential for further improvement is derived. The DSII represents a single case study selected from a portfolio of several case studies we have conducted, with a common objective. The DSII has been preceded by a prescriptive study where the initial solution support in the form of a methodology has been designed. Thus within the PS and DSII, so far a methodology has been developed based on the experience and data gathered from seven case studies.

Within the scope of the initial research clarification and descriptive study I, we have performed a literature review regarding engineering design/product development processes (used synonymously within the scope of this paper), process adaptation and tailoring, as well as process context analysis. The initial need for more flexible processes and a context-oriented process design methodology has been derived from literature as well as empirical sources (cf. Hollauer et al. 2016).

3 BACKGROUND AND FUNDAMENTALS

3.1 Product development processes

“Engineering processes are the glue that hold the activities within product development and design together. Engineering processes structure these tasks appropriately and ensure the correct and timely use of the appropriate approaches & procedures, methods, data, and tools in order to improve the design process, improve products and services, and properly document product development processes and the products themselves.” (Qureshi et al., 2013)

Four levels of abstraction and adaptation, of PDPs can be distinguished (cf. Figure 1) (Hollauer and Lindemann, 2017): General design methodologies are described in the literature, such as the V-Model (e.g. Vajna, 2005). They describe generic PDPs on a very abstract level and need further adjustment to specific business conditions (Gericke and Moser, 2014). Within an organization, the processes can be further divided: Reference processes (standard/canonical processes) are derived from generic design methodologies and are then adjusted to their scope of application. They represent the basis for process management and are part of a process architecture. As mentioned above, reference processes need to be further tailored to an actual projects context. The resulting project process serves as a target process, which the actual process is continuously compared to.

The focus of this paper is to investigate and support the transition from the standard process to the project process as well as to compare processes on reference process level.

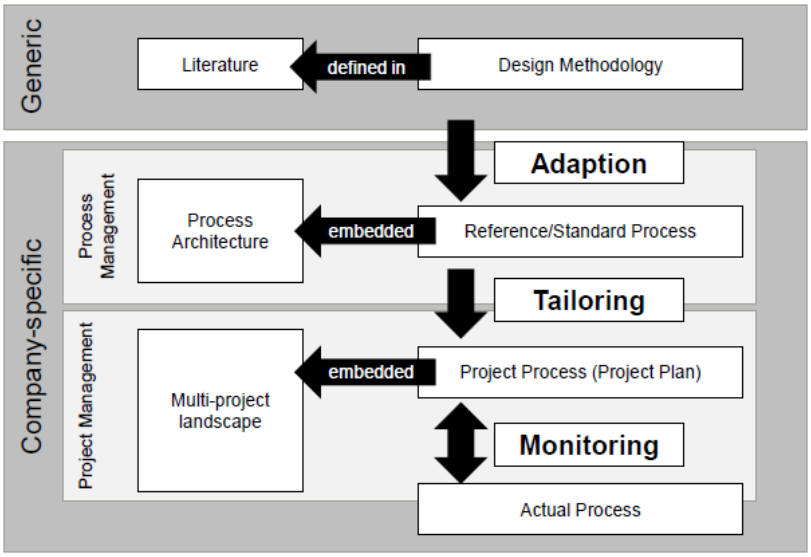

Figure 1. Levels of engineering design processes (Hollauer and Lindemann, 2017)

3.2 Standard Processes and Process Tailoring

Development processes are generally standardised, in order to always carry out work in the same way, independent from the people involved as well as time (Ungan, 2006). Therefore, standards contribute to the unification and an increase in both transparency and consistency of the processes. Consequently, the effort in training new employees can be lowered in addition to improving performance.

However, since reference processes are often too generic and extensive for the specific application in development projects, process tailoring is necessary as explained in Figure 1. Tailoring is formally defined as "the act of adjusting the definition and/or particularizing the terms of a general description to an alternate environment" (Ginsberg & Quinn, 1995). In relation to PDPs, a common interpretation of tailoring is the adaptation of a company's reference processes to specific project contexts, defined by certain context variables, such as team size, technologies and disciplines involved (Du Preez et al., 2009; Kalus and Kuhrmann, 2013). According to Vajna (2005), "a project is a process with an actual and real task to address". Tailoring standard processes to project processes is a reoccurring activity in project management (Hollauer et al., 2016).

4 RELATED WORK

4.1 Issues in EDP Modelling and Management

Even though there is a large number of process modelling approaches available in literature, only few approaches for structured process improvement and adaption to varying conditions exist (cf. Hollauer and Lindemann, 2017). Additionally, most of the relevant approaches for adaption and tailoring have been identified in the field of software engineering without an appropriate adaption to interdisciplinary product development such as mechatronics. Other issues and challenges that have been identified in regard to process modelling are (Hollauer et al., 2016; Indulska et al., 2009):

- A lack of appropriate guidance and implementation support for company-specific models.
- Insufficient consideration of process architectures and especially the interfaces between individual processes in current approaches (Lapouchnian et al., 2015).
- Lack of support regarding the tailoring of company-specific standard processes to project-specific requirements. Instead of having a clear understanding and support for repeatable and traceable tailoring activities, tailoring is instead often done by project managers on an ad-hoc basis (Kuhrmann, 2014).

4.2 Methodology draft for the acquisition of influencing factors

In order to support project leaders to adjust the standard processes to their projects, a methodology draft for the acquisition of influencing factors has been created (cf. Hollauer et al., 2016). The procedure is divided into four sections (cf. Figure 2):

1. *Preparation and planning* focusses on the identification and analysis of the company's organizational structure, previous projects and the documentation of the actual process and its objectives.
2. *Data acquisition and analysis* consists of three main parts: Project characteristics describe project-specific parameters, such as budget and team size. Context factors summarize all the other influencing factors on the PDP and can be divided into internal and external factors. Project characteristics and context factors are merged during the context analysis in order to extract underlying correlations and to cluster them accordingly.
3. *Process design* covers the design and implementation of the process. This is based on the previous context analysis. Different design options are possible and need to be evaluated per case.
4. *Evolution* covers further process development and improvement, in regard to costs, quality and time efficiency, taking the overall company strategy into account as well.

This paper focusses on the acquisition of context factors as well as their effects on the development process. In order to validate and improve the presented methodology, it is applied within a case study at an automotive OEM (section 5). Furthermore, a part of the influencing factors, which were conducted with the presented methodology, are presented in subsection 5.3 along with a categorising scheme.

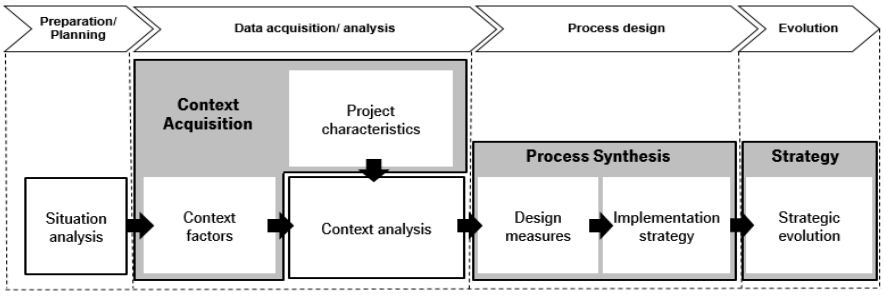

Figure 2. Methodology draft for the acquisition of processual influencing factors

5 CASE STUDY

In order to validate and improve the methodology as described in subsection 4.2, a case study at an automotive OEM has been conducted. The investigated company contains four levels of hierarchy: Top-level management is followed by the division level. Subsequently, main departments consist of departments themselves (cf. Figure 4). The case study was conducted in the area of drivetrain

development. Within subsection 5.1, the company's documentation of standard processes is presented. Afterwards, in subsection 5.2, the methodology to acquire influencing factors is applied and improved. Subsection 5.3 concludes the case study by presenting the proposed categorising scheme with one acquired example per class of context factors.
The case study is based on the following main research question: *How can project leaders be supported to implement efficient and project specific processes in order to develop successful products?* This leads to the following subquestions, which are discussed in the two next subsections: 1) How can standard processes be documented in such a flexible way that they can be used as an appropriate basis for further project specific adaption? 2) How well can the presented methodology draft for the acquisition of influencing factors be applied in practice and how can it be further detailed and improved?

5.1 Initial situation and documentation of flexible standard processes

In order to answer subquestion 1), the process documentation of the company was analysed during the case study. In this section, standard practices as well as a best practice example are presented according to how they are applied at the selected OEM.
It turned out that part of the processes in the complex company setting were either not at all or not completely documented. The other part was documented as rather abstract reference processes containing static sequences of work steps, which did not offer the flexibility needed for planning and executing product development projects with varying boundary conditions, i.e. the "tailorability" of the PDPs was insufficient. Though, in order to react to different internal and external influences such as varying stakeholders, processes need to be highly flexible (Hollauer et al., 2016). To balance the existing inflexibility, many non-standard processes were used, which were defined and known only in their respective local departments. This made company-wide standardisation and consistency of the processes and tools more difficult, decreasing efficiency in process management. Furthermore, existing tailoring approaches strongly depend on the availability of an appropriate formal model of the EDP (Hollauer and Lindemann, 2017). In summary, a lack of clearly defined, flexible and adaptable standard processes, which are needed as a basis for further project specific tailoring, was identified.
A more suitable example was found in one of the examined development departments: Instead of a static procedure, the process was documented as process modules which can be applied iteratively as necessary (cf. the concept of "building blocks" in Bichlmaier, 2000). Figure 3 shows how two different main departments (organizational hierarchy shown in Figure 4) can generate tailored processes for their respective projects, based on five basic process steps. The basic process modules can be combined as necessary. The instantiation of each module is subsequently documented in the project plan.
In order to define the building blocks, the process steps need to be generalised. As an example, product samples of different degrees of maturity (A, B, C, and D) to be produced over the development process were united to a universal module "create product sample" which itself contains several activities. In the project plan, the corresponding product sample was defined for every building block.

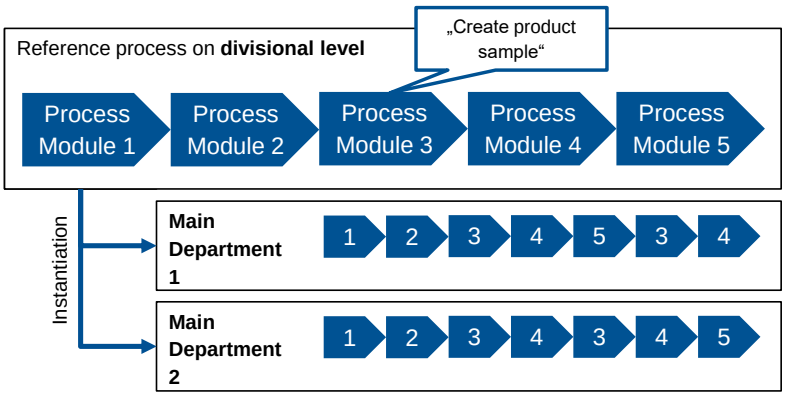

Figure 3. Process description and instantiation using building blocks

5.2 Acquisition of context factors

Adressing subquestion 2), context factors were collected using the methodology as described in subsection 4.2. Data acquisition and analysis consists of three main parts: acquisition of project characteristics, organizational context factors, and the subsequent analysis. In this subsection, the

circumstances of the examined department are briefly presented, followed by a description of the conducted acquisition and the acquired context factors as well as problems encountered during the procedure. Finally, a brief synopsis of the modifications made concerning the methodology is presented.

5.2.1 Capture and analysis of the current status

In the investigated department (development of electric engine components), project leaders were not sufficiently supported by an appropriate methodology to tailor the processes to their respective development project (compare to the results of the literature research in subsection 3.1). For example, many project leaders did not know exactly which context factors have to be considered, what kind of effects they can have on the development process and how they can change over time. In particular, inexperienced project leaders were dependent on the backflow of information gathered in former projects in order to properly asses and plan their development projects. However, the necessary backflow of information often did not happen and circumstances vary for each new project.

Before the acquisition of context factors, an acquisition and revision of the development process for electric components was already initiated on divisional level, triggered due to the insufficient applicability of the existing process. On the one hand, the objective was to describe the concrete steps of the development process on a more detailed level, in order to increase transparency and traceability. On the other hand, the adaptability of the process to the actual development projects needed to be increased. This conflict of objectives was solved by describing the process using five building blocks (cf. subsection 4.1)

After detailing the first process steps, differences between the examined department and the main departments in terms of activities and roles were investigated. Hence, the acquisition had to be extended to all main departments in order to establish general applicability. The discrepancies between the different main departments were seen as sources of context factors and were examined in more detail. Therefore, all involved main departments were questioned in depth, through personal interviews regarding the different process steps- In total, 40 qualitative, semi-structured single interviews with 34 individuals were conducted, with sessions lasting between 30 to 60 minutes each. Some individuals had to be interviewed repeatedly when new information was acquired. The interviews consisted of common parts for all interviewees as well as specific parts for certain departments or roles. With the interviews, differences between the different departments were investigated in order to elicit justified differences between the reference processes of the different departments. For this, the individual interviews were iteratively cross-referenced and compared with each other.

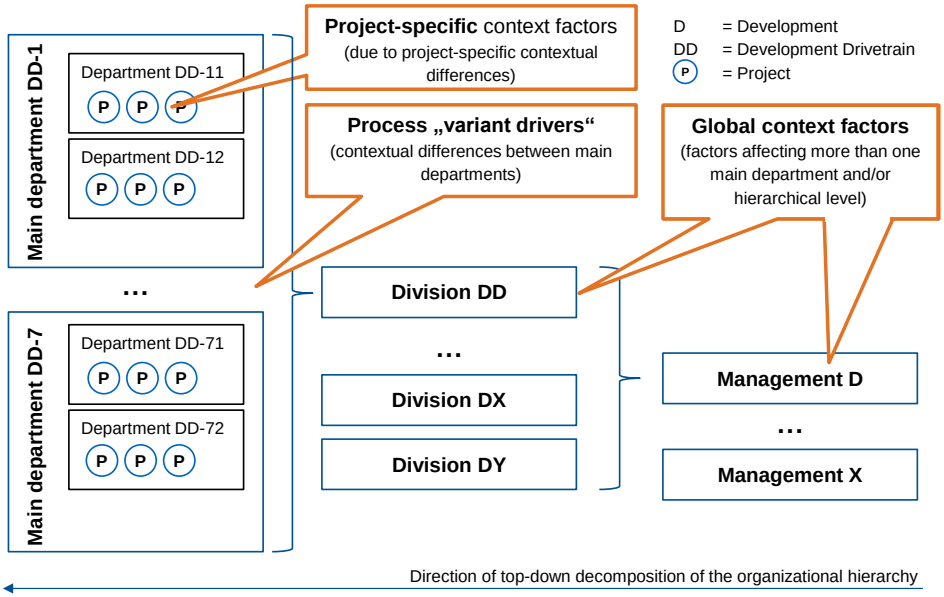

Figure 4. Different classes of influencing factors

Subsequently, three classes of influencing factors were differentiated, according to the levels of hierarchy on which they affect the organization. The factors are presented in Figure 4 and explained in more detail in the following. The context factors identified were collected and clustered at the end of

the acquisition phase (cf. Figure 5). An overview over a selection of the context factors as well as a categorising scheme are presented in subsection 4.3.

5.2.2 Variant Drivers

The discrepancies between the different main departments related to their reference processes were regarded as a source for so called "variant drivers" (cf. Figure 4) and examined by conducting personal interviews in all participating departments. Since the acquired factors were not project but department specific, “context factors” were identified corresponding to the introduced methodology (cf. Figure 2). Employees were asked which activities take place within their process steps and why there are possibly discrepancies between the departments. In this context, the following issues, which made data acquisition difficult, were identified and addressed with appropriate measures:

The first problem was a *lack of overview over the development proces*s in total. Therefore, before the conduction of the interviews, the individual process steps were described on an abstract level and used as a common basis for the further data acquisition7.

As to the employees, it was found out that they had a *different knowledge about the actual process steps depending on their role and their professional experience*. One reason for this was that some process steps had been outsourced and were therefore only known as "black boxes" with a required input and a requested output. Another reason was that everyone only had a partial and subjective view of the development process. This implied that, depending on the required information content, a sufficient number of people per department had to be interviewed in order to get a consistent general view of the departmental processes. This procedure was made difficult by the employees' fluctuation so that often the previous contact persons were not available anymore and the successors still had too little departmental knowledge. Another problem was the low availability of the employees, partly caused by their high workload or different locations.

Furthermore, the *descriptions of the activities and documents* within the process often led to misunderstandings, since each department used different terms or terms had different meanings. This problem was solved by comparing the contents of the documents and compiling a common glossary from the distinct descriptions in order to provide a basis for consensus.

The biggest obstacle regarding the acquisition of the process differences were *roles*, since they had a direct influence on the process. For instance, an identical process was described in a different way depending on the integrated roles. In order to filter out the influence of the roles and to generate comparable processes, either a specific role was agreed upon or the different department-specific roles were combined into a more general one.

For the acquisition of variant drivers, hence the following is necessary:

- an overview of the complete development process before conducting the interviews
- a sufficient number of interview partners
- a common glossary
- consistent process roles

5.2.3 Global Influencing Factors

During the interviews, context factors were acquired (cf. subsection 4.2.2), which had effects on several division, department, or even the whole management level. Because the scope of the context factors as described in subsection 3.2 is very broad and only provides a distinction between internal and external factors, the context factors were split into variant drivers as well as global context factors (influencing more than one units of investigation, i.e. main departments) (cf. Figure 4).

The global influencing factors which can have an effect both on management as well as division level were determined via interviews as well as further research in the corporate intranet. During the interview, the employees were asked, which factors had effects on their processes but could not be influenced. In the corporate intranet, for example, information about the strategic alignment as well as its long-term effect on the development process were collected.

5.2.4 Project Specific Influencing Factors

The third category of context factors acquired during interviews are project-specific factors. Project-specific aspects such as characteristics of the system or component in development (e.g. its complexity) and the composition of the team were queried and analysed concerning their processual effects (cf.

Figure 2). Additionally, the actual process was compared to the target process of the examined project. Thereafter, the detected deviations and their causes were analysed. As a support, pre-existing Key Performance Indicators (KPIs) were used, which had been previously developed for monitoring the existing process (cf. Figure 1). Furthermore, "lessons learned" documents of former projects were consulted to identify process-related effects of different negative influencing factors. Along with the analysis of the individual factors, the respective projects were compared to each other. The detectable differences were again correlated with the corresponding influencing factors by means of interviews and then documented.

5.2.5 Brief Synopsis of the modifications of the initial methodology

In summary, the methodology for the acquisition of influencing factors (cf. Figure 2) was revised as follows (cf. Figure 5):

- The context factors were newly divided into variant drivers and global influencing factors according to the hierarchic structure of the company. The general division of the influencing factors into project-specific and organizational context factors was maintained.
- The method was improved by adding measures of a weakness analysis (Lessons Learned and KPI). This corresponds to the initial literature research (cf. Hollauer and Lindemann 2017): The concept of process tailoring is closely related to the management of risks and challenges within engineering design projects. Furthermore, another objective of the approaches supporting process tailoring is the reuse of knowledge regarding tailoring decisions.
- The originally planned relation analysis of the influencing factors within the context analysis was not carried out, since the connections and interactions between the influencing factors were too cross-linked and complex for a general analysis. A deeper analysis of influencing factors only seems reasonable for specific factors due to the effort involved.

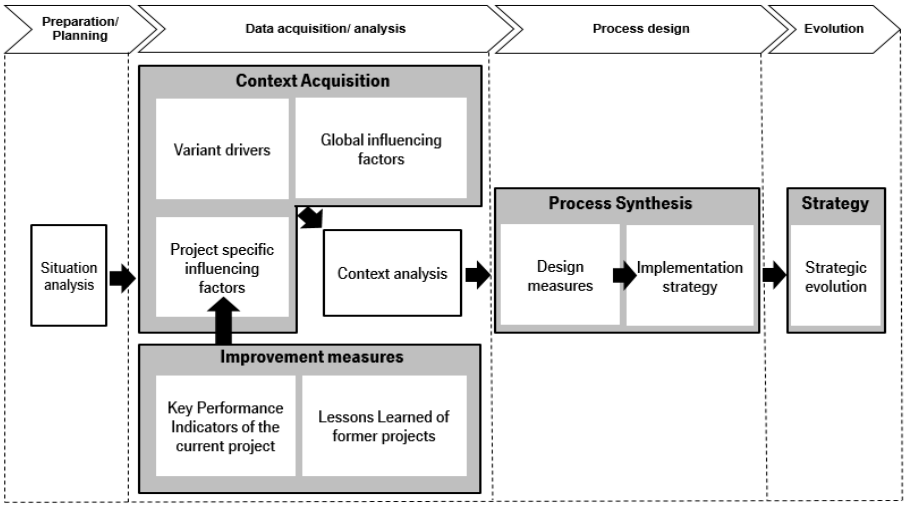

Figure 5. Methodology draft for the acquisition of processual influencing factors

5.3 Results and Scheme for Categorisation

In the case study, several influencing factors could be acquired by applying the methodology explained in figure 5. In the following, one example per type of influencing factor will be presented (cf. Table 5.1). The context factors are categorized as follows:

- *Numeration*: Necessary reference figure for a detailed explanation in text.
- *Interview partner*: To increase transparency and traceability. An accumulation of interview partners can indicate higher relevance.
- *Type of influencing factor*: Information whether the influencing factor is a project specific context factor, a variant driver, or a global context factor (cf. Figure 4 and 5).
- *Level*: Information to assign the global influencing factors to the management or division level or to assign variant drivers and project specific influencing factors to the respective main department or department (cf. Figure 4).

- *Concerned process steps*: Based on the process building blocks (cf. section 5.1), information about the process steps, which are affected by the described influencing factor.
- *Content categorisation of the influencing factor*: Necessary for clustering of the acquired influencing factors. Different categories are possible, e.g. tool and component.
- *Specification of the influencing factor*: More detailed description of the influencing factor.
- *Processual effects of the influencing factor*: Description, which effects the influencing factor has on the mentioned process steps in the specific case.
- *Reasons*: Short description, why the influencing factor has the mentioned processual effect.
- *Measures* (not presented in the table due to lack of space): Solution approach to prevent negative influencing factors or their negative effects.

Table 5.1. Categorising scheme for the acquisition of influencing factors (abstracted and anonymised due to confidentiality reasons)

Framework		Classification of the influencing factor			Characteristics of the influencing factor			
No.	Interview Partner(s)	Type	Level	Concerned Process Step(s)	Content Categori-sation	Specification	Processual Effect(s)	Reason(s)
1	A,B	project specific influencing factor	DD-12	1,2	component	new complex component concept	increased risk of late changes	delayed breakdown of the requirements to component level
2	A, C, D	variant driver	DD-1, DD-2	all	location	location S	less iterations	well-integrated structure => faster communication => better coordinated processes
3	E,F	global influencing factor	Division D	4	tool	automation of software test and validation	shortening of the testing cycles, less iterations	less mistakes, possibility of testing overnight
4	G	global influencing factor	Manage-ment D	all	law	requirements concerning ISO or functional safety	increased risk of late changes	they can take effect during the development cycle
..	..	..	..	..	..	..	..	..

6 CONCLUSION & OUTLOOK

In order to successfully develop innovative products, companies are in need of structured, flexible, and tailorable standard processes which contain relevant activities, roles and supporting measures without being bloated or confusing. However, project leaders are often not sufficiently supported to adapt reference processes to their specific projects, due to two major issues: Either reference processes are documented in an inadequately or they lack a detailed overview of contextual factors and their impacts on the respective processes regarding adaptation and tailoring. We intend to close that gap by developing a methodology which supports the systematic analysis of a processes application context and the subsequent methodical design of variant-rich PDPs in the form of modular process kits consisting of individual process modules, as well as configuration rules and further necessary information (process and context scope and overview etc.).

To evaluate the preliminary methodology, a case study was carried out. The procedure for acquiring context factors regarding the application context of PDPs was applied and improved based on the case study results (DS II). Among the improvements, a scheme for categorizing context factors was developed. With the approach, project leaders are given a tool to establish more efficient project specific processes.

The presented categorisation scheme can be expanded in a number of ways. For example, the context factors can be attributed in more detail for a more precise classification. For this, we are investigating feature models from the field of domain engineering (cf. Czarnecki and Eisenecker 2000) for their applicability to capture complex and diverse process application contexts. Combined with the virtual nature of PDPs which requires the use of modelling in order to design and visualize PDPs as artefacts, we are currently developing a modelling framework to support the developed methodology. The

framework comprises the necessary meta-models as well as rich modelling views for different concerns addressed in the methodology.
Regarding strategic aspects, an estimation of future changes of context factors can be taken into consideration. Furthermore, a way to systematically examine the relations and interactions of context factors and their impact on the PDP is necessary, e.g. using matrix-based approaches. Finally, a tool in the form of a software assistant would lower the barrier of implementation and guide the user.

REFERENCES

Bichlmaier, C. (2000), *Methoden zur flexiblen Gestaltung von integrierten Entwicklungsprozessen*, Herbert Utz Verlag.

Blessing, L. and Chakrabarti, A. (2009), *DRM, a design research methodology*, 1. Aufl., Springer, Dordrecht.

Cooper, R. G. and Edgett, S. J., *Lean, rapid, and profitable new product development*. [Ancaster, Ont.]: Product development Institute, 2005.

Czarnecki, K. and Eisenecker, U.W. (2005*), Generative programming: Methods, tools, and applications*, 6. print, Addison Wesley, Boston [u.a.].

Du Preez, N. et al. Nieberding, H. (2009), "Tailoring the development process according to the context of the project", *CIRP Journal of Manufacturing Science and Technology*, 1(3), 191–198. doi:10.1016/j.cirpj.2008.10.003

Ginsberg, M. P. and Quinn, L. H. (1995), *Process Tailoring and the the Software Capability Maturity Model Process Tailoring and the Software Capability Maturity Model*. (November)

Gericke, K., Meißner, M. and Paetzold, K. (2013), "Understanding the context of product development", *In Proccedings of the International Conference on Engineering Design*, ICED (Vol. 13).

Gericke, K. and Moser, H. A. (2014), "Adapting a Design Approach: A Case Study in a Small Space Company", In P. Heisig (Ed.), *Modelling and management of engineering processes* (pp. 101–114). Engineering Design Centre, University of Cambridge.

Hollauer, C.and Lindemann, U. (2017), "Design process tailoring: A review and perspective on the literature", *6th International Conference on Research into Design 2017 (ICoRD 17)*, Guwahati, India (accepted for publication)

Hollauer, C., Kattner, N. and Lindemann, U. (2016), "Towards a methodolgoy to support the development of flexible company-specific engineering design processes", (accepted for publication), paper presented at *PICMET '16 Conference*, 04.-08.09., Honolulu, Hawaii.

Indulska, M., Recker, J., Rosemann, M. and Green, P. (2009), "Business Process Modeling: Current Issues and Future Challenges," in *Advanced Information Systems Engineering: 21st International Conference*, CAiSE 2009, Berlin: Springer, pp. 501–514.

Kalus, G. and Kuhrmann, M. (2013), "Criteria for software process tailoring: a systematic review", *Proceedings of the 2013 International Conference on Software and System Process - ICSSP 2013, 171*. doi:10.1145/2486046.2486078

Kuhrmann, M. (2014), "You can't tailor what you haven't modeled," in *ICPS: ACM international conference proceeding series, 2014 International Conference on Software and Systems Process (ICSSP)*: Proceedings: May 26-28, 2014, Nanjing, China, H. Zhang, L. Huang, and I. Richardson, Eds, New York: Association for Computing Machinery, Inc, pp. 189–190.

Lapouchnian, A., Yu, E. and Sturm, A. (2015), "Re-Designing Process Architectures", in *2015 IEEE 9th International Conference on Research Challenges in Information Science (RCIS):* 13 - 15 May 2015, Athens, Greece, C. Rolland, Ed, Piscataway, NJ: IEEE, 2015.

Lindemann, U., Maurer, M. and Braun, T. (2009), *Structural complexity management: An approach for the field of product design*. Berlin: Springer.

Markham, S. K. and Lee, H. (2013), "Product Development and Management Association's 2012 Comparative Performance Assessment Study," (en), *J Prod Innov Manag*, vol. 30, no. 3, pp. 408–429.

Qureshi, A. J., Gericke, K. and Blessing, L. T. M. (2013), "Design Process Commonalities in transdisciplinary Design", In: *The 19th International Conference on Engineering Design - ICED'13*.

Ungan, M. C. (2006), "Standardization through process documentation", In: *Business Process Management Journal* 12 (2), S. 135–148.

Vajna, S. (2005), "Workflow for Design," in *Design process improvement: A review of current practice*, J. Clarkson and C. Eckert, Eds, London [U.K.]: Springer.

ACKNOWLEDGEMENTS

We thank the German Research Foundation (Deutsche Forschungsgemeinschaft – DFG) for funding this project as part of the collaborative research center 'Sonderforschungsbereich 768 – Managing cycles in innovation processes – Integrated development of product-service systems based on technical products'.