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AN APPROACH TOWARDS SITUATION SPECIFIC PLANNING OF DESIGN PROCESSES

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ABSTRACT
Today companies do not only have to be competitive regarding products and technologies, but also the handling of complex, multi-dimensional processes gains more and more importance [1]. Therefore process management tools have been established to support the designing and optimization of processes and workflows. These tools are very well applicable for business and design processes that are structured, repetitive, and can be planned in advance. But most of the existing approaches do not take into consideration the specific requirements and boundary conditions in concrete product development situations [2]. Design processes evolve in progress. Process phases and steps often can be planned only if results from previous steps are on hand. Moreover, the general conditions of a single planning situation, e.g. available capacities or specific requirements, have considerable influence on which step to take next. Therefore product development processes have to be planned and defined problem- and situation-specific.
This contribution provides an approach to situation-specific planning of design processes. The design situation will be described by means of their crucial situation-defining parameters at different degrees of process decomposition. Based on the situation analysis a suitable design process might be recommended. Since the level of planning detail of this process depends on the degree of process decomposition, it is one of the most important points of this approach to realise a crosslink between the different degrees of decomposition. Thus, a better transparency, higher value and quality of planning information shall be achieved.

Keywords: Development process, process modelling, design situation

1 INTRODUCTION
In a time of global competition, shorter time to market, and new technologies, efficient and effective business processes gain more and more importance. In this context the optimisation of product development processes attracts growing attention. Whereas numerous tools and methodologies support the planning and carrying out of, mostly, repetitive business processes, there are still no tools or modelling methods that sufficiently support the specific characteristics of design processes [2].
The complexity in planning development processes results from the evolutional characteristics of these processes and can hardly be handled with existing approaches. Process modelling methods, such as Structured Analysis and Design Technique (SADT) [3], Event-driven Process Chains (EPC) [4], critical path networks, or Process Modules as defined by Bichlmaier et al. [5], mainly support the planning and illustration of already well known and structured business and design processes. In contrast, the process design and configuration of novel, unstructured, not yet fully comprehended processes is not supported sufficiently. Here, even generic process models, such as the VDI 2221 procedural model guideline [6], fail, since these models do not have the right degree of decomposition to be used for specifically planning a design process in all of its characteristics. Again, most generic process models base on the description of already finished, successful development processes or best practices and thus may not necessarily support process planning when faced with fundamentally new problems or changing design conditions.
For that reason it is necessary to adapt these models to a specific design problem on an operational level. The main questions, however, are, what can be considered as an appropriate operational level and which parameters of the design problem and its constraints respectively have an impact on the design process thus triggering such an adaptation?

To answer these questions and eliminate the problems mentioned above regarding an adequate planning of product development processes, it is the goal of this contribution to develop a concept to support the requirement- and situation-specific planning of design processes. Different levels of process decomposition should be considered, supporting an appropriate planning detail, each based on an analysis of the specific design situation, as e.g. Maffin [7] suggests.
After defining the basic terms regarding the development process and the levels of planning to be considered in the following section, a possible outline of such a situation analysis will be given and a design process planning model will be described, which is based on that analysis. Likewise, the necessity of cross-linking the process plans on different degrees of process decomposition in order to achieve better accuracy, transparency and informational value on each level will be discussed. Finally an outlook on the verification of this model in practical use will be given.

2 PROCESSES IN PRODUCT DEVELOPMENT

2.1 Basic terms and definitions

Before focusing on different types of design processes and their situational context, the basic terms shall be clarified to provide a first understanding of the scope of this contribution. Especially, the terms *process*, *project* and *method* shall be distinguished more precisely as they are mixed up commonly.

2.1.1 Process

According to Harrington [8], a process is an activity or group of activities that takes an input, adds value to it, and provides an output to an internal or external customer. Likewise, Becker et al. [9] define a process as a closed and logical sequence of activities, which are required for the treatment of a process determining object. Coming from a more product development oriented view, Vajna [10] regards a process as a meaningful set of sub-processes and activities to solve a certain task. Here, activities are logically enclosed operations that contain at least one or more working steps. Activities are started by events, require a certain input, and produce certain events and results respectively. Blessing et al. [11] point out, that activities may have manifold interactions and that resources are required to produce an output from a given input.
In summary, a process can be regarded as the transformation of a defined input into a defined output. By looking at processes, the transformational function is given special emphasis. As many of the definitions above have shown, processes can be decomposed into nearly any number of sub-processes, activities and operations, often referred to as process modules. The appropriate degree of such decomposition is regarded in more detail later in this contribution. According to Gaitanides et al. [12], process modules can be easily described by their input and output (which concurrently represent the interfaces to suppliers and customers of that process module), a work agreement (which represents the overall objective of the process module), a processing step (which is the actual transformational operation), as well as a set of performance indicators which serve for a qualitative and quantitative evaluation of the process module execution (cp. fig. 1).

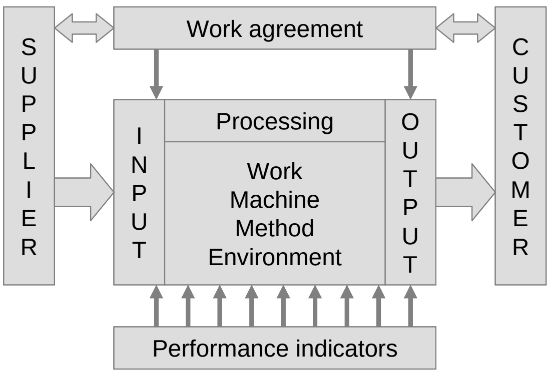

Figure 1. Process module (according to Gaitanides et al. 1994 [12])

Hemmert [13] gives an even more comprehensive definition of a process module: The process module (which is defined as “task solving situation”) is characterised by an initial object state, an intended outcome, a process operation, required means and resources, a person responsible, a defined starting time and duration as well as defined relationships with preceding, following, and simultaneous/parallel process modules. The utilisation of such process modules is also commonly suggested for the management of product development processes (e.g. see Freisleben [14], Bichlmaier et al. [5], and Meissner [15])

The relationships between the several process modules (i.e. the outcomes precisely delivered or demanded by predecessor and successor processes respectively) as well as the kind of transformation (operation) taking place within a process module shall now be of special interest, since both characteristics provide a good starting point for a process planning methodology.

For example Demers [16] has proposed an interesting method to investigate the various relationships within the design process. By looking at causes and effects of an individual process step, further process steps can be derived.

The kind of transformation, which is performed within a process, is an issue e.g. Blessing [17] is covering. She distinguishes between a more problem-oriented and a more product-oriented process concept. While stages are regarded as sub-divisions of the design process that relate to the state of the product under development (e.g. problem definition, concept design, embodiment design), activities are defined as sub-divisions of the design process that relates to the individual problem solving process (e.g. generating or evaluating solutions). A similar model is proposed by Rude [18] (fig. 2), who spans a design (process) space by the dimensions of “concretising/abstracting the design object“ (resulting in process stages), “integrating/fractionising the components of the design object“ (resulting in different product levels), and ”generating/selecting solutions” (which can be regarded as main activities within the process).

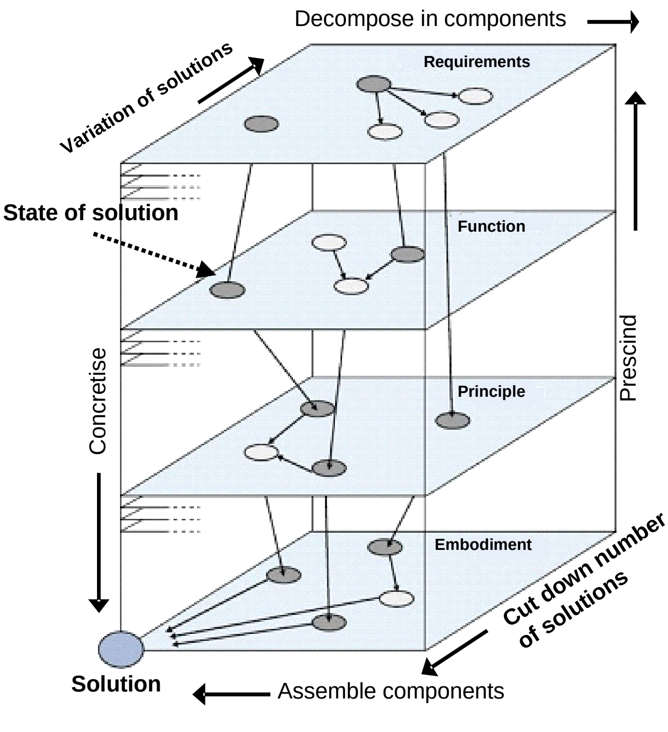

Figure 2. 3-dimensional design space (according to Rude [18])

In her further work, Blessing [17] utilises a so called design matrix with elementary stages in rows (e.g. problem definition, requirements, function, concept) and elementary activities in columns (e.g. generate, evaluate, select) to derive and document the several operations which are required in a specific design process. This design matrix can be built up on different decomposition levels of the product (product level, component level, part level). According to Blessing, this model “describes the steps that in principle serve in solving the design problem but without prescribing the course of action in a concrete case”, thus it can be regarded as some kind of universally valid design process model. However, her model is primarily meant to support a structured documentation and retrieval of project data (knowledge management) rather than to support the actual planning of design processes.

Other generic design process approaches, however, focus more on this aspect of design process management. Vajna [10] and Freisleben [14], for example, who also promote a design process module approach, develop a process planning methodology, which is also based on the concept of generic process types (so called ”therbligs”). These “therbligs” are regarded as the “atoms” of a design process [10], from which an entire process can be built up. The generic process types, which are proposed by Freisleben [14], are “searching/generating”, “evaluating”, “selecting”, “communicating”, and “documenting”.

Bichlmaier et al. [5] distinguish four types of process modules. These are “analysis”, “synthesis”, “evaluation” and” selection”, which can be further specified. This classification is also utilised to support the compilation of process chains by giving rules for reasonable combinations of modules.

Baumberger & Lindemann [19] have developed a process planning methodology that bases on the requirement oriented synthesis of process modules. Based on a standardised description of a process module, process modules are synthesised by analysing the relationships between requirements (as the goal dimension of a product development process) and product structure (as object dimension). Identified relationships are analysed whether they imply any product development processes. For that analysis Baumberger & Lindemann use the generic types of development processes “planning”, “designing”, “documenting”, “testing”, and “coordinating” (fig. 3).

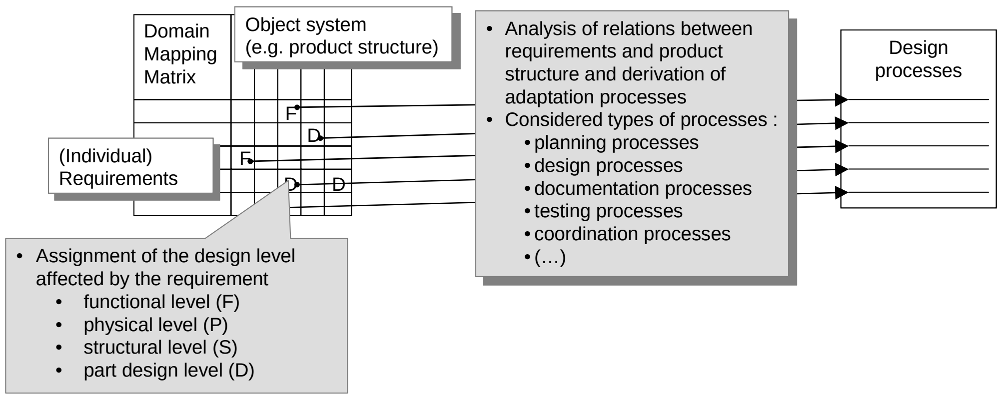

Figure 3. Requirement oriented process synthesis [19]

After giving a short overview on design process definition, projects and methods shall be distinguished from the process in the following.

2.1.2 Project

Similar to a process, a defined result shall be realised by a project. But in contrast to a process, the planning, execution and controlling of necessary activities as well as their integration into an organisational context are emphasised within the framework of a project [20]. As well, a project is characterised by singularity of its conditions, limited duration and resources as well as a project specific organisation, which does not necessarily apply for a process. However, within the framework of a project apparently one or more processes can be initiated [10]. Thus, while a process view focuses more on the part activities/transformations and their relationships within an overall process context, the project view rather keeps the entire context and organisation in mind.

2.1.3 Method

A method can be described as a planned procedure [21]. A method provides formal operational rules to handle a defined task or reach a given target. While most methods contain any kind of procedural instruction they yet cannot be regarded as processes. Methods as such do not relate to a specific object or operational context. Rather methods, especially elementary methods [22], support the execution of process operations thus serving as a process support.

2.2 A key issue: How to define the right degree of design process decomposition?

As was mentioned before the appropriate degree of process decomposition is crucial when thinking about (design) process modelling, planning and management. Generally, processes can be repeatedly decomposed into sub-processes, activities, and operations. That enables the differentiation of more defined part processes (schematically shown in figure 4) as is necessary for adequate planning and assignment of (design) processes.

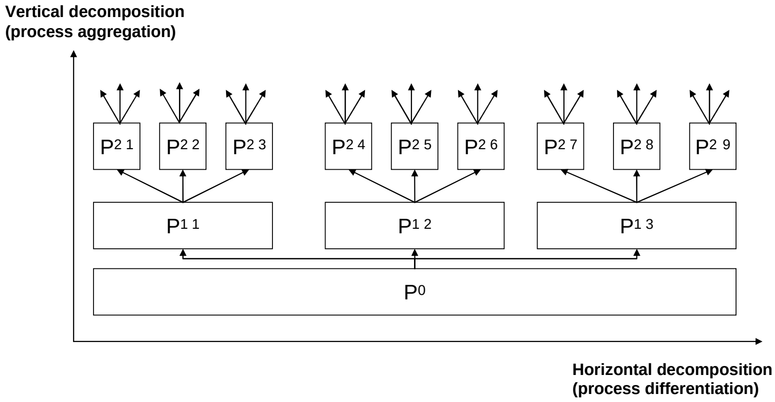

Figure 4. Horizontal and vertical decomposition of processes [23]

Unfortunately, there is no one best decomposition level. Rather it depends on the specific objectives of the modelling and planning issue. While it might be necessary to look at a very detailed process level for example in cognitive design research, it is sufficient to stop decomposition on a very high (i.e. aggregated) process level with respect to multi project management. However, according to Lindemann [21], four main levels of design process decomposition shall be distinguished in the following (cp. Fig. 5):

- strategic process level (with only generic processes and roadmaps respectively)
- project level (with rough stages but a clear vision of outcome)
- operational level (with interrelated activities but vague certainty of final outcome)
- action level (with elementary processes)

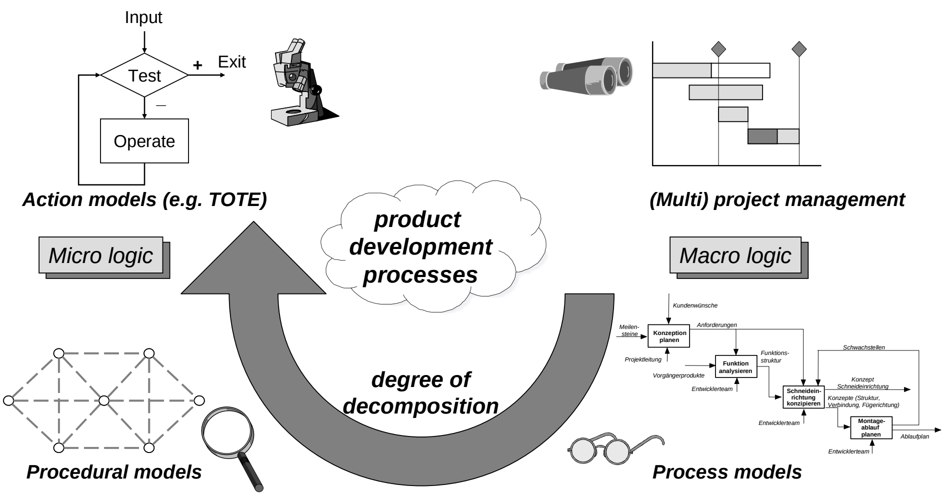

Figure 5. Design process models on different levels of decomposition [21]

For concrete planning of design processes neither the strategic nor the action level are of much interest. The strategic level does not allow any specific planning while planning on the action level will lead to overwhelming planning complexity [24]. Rather, process planning should take place on the project and the operational level. Both levels are by far more object oriented and thus enable the necessary consideration of design problem structure (as goal system), product structure (as object system), and organisational structure (as action system) [25, 26]. Here, it is necessary to switch continuously between project and operational level, especially with respect to ensuring target oriented navigation through the design process. While the project level suits better to keep the desired project output, the overall project conditions and constraints as well as pre-planned activities (e.g. work packages) in mind, the operational level is more adequate when considering steps/activities to be performed next as well as to allocate resources, means, and methods for process execution. The fact that one cannot consider the project and the operational level simultaneously can be described as some kind of *design process planning uncertainty principle*. The detailed situational conditions, which are especially relevant for design process planning at these levels, will be addressed in the following section.

3 SITUATIONAL CONDITIONS OF DESIGN PROCESSES

What makes planning of development processes so difficult is the fact that these processes are very dynamic and by no means deterministic such as other business or for example manufacturing processes. Development processes are characterised by manifold loops, step-backs, and iterations as well as strong interrelationships with other processes and interactions with various people due to strong division of labour [10, 11]. These processes are regarded to be process nets with processes that are highly interconnected, including feedback-loops and interactions on different levels [27]. In other words development processes are low-structured and hard to plan. That is one reason why formalised models of design proceeding as well as workflow management approaches yet have not been very successful with regard to the management of specific development processes. The structure of design processes strongly depends on the situational conditions of the design process in question. Thus it is obvious that one procedural model cannot fit all possible design situations.

In recent years there have been some approaches to the description of such design situations. These approaches mainly vary in granularity between a strategic and an operational level. E.g., Hales and Gooch [28] as well as Meissner & Blessing [15] cover the analysis of design situations on different levels, whereas e.g. Badke-Schaub and Frankenberger [29] focus on the design engineer’s daily work. Most approaches want to achieve a holistic picture of the design context and therefore establish many different parameters, some of which can only be analysed in hindsight and thus are not applicable for process planning.

Wallmeier [30], for example, defines the context-describing factors as: “novelty of the design task”, “number of changes in requirements”, “quality of the target analysis”, “number and duration of discussions”, “availability of information”, “communication” and some more. The number of changes of requirements and the duration of discussions belong to the factors that can only be analysed after the task is fulfilled. Communication is without a doubt an important factor in development work but hard to be measured.

Another classification of design problems is introduced by Dylla [31]. The degree of novelty and the amount of given solution elements respectively (new design, adaptive design, variant design), the kind of design problem with respect to the main requirements to be solved, the complexity and the type of product, the manufacturing type (one off or serial production), and finally the transparency of product characteristics are supposed to be the main characteristics of a design problem here.

The situation analysis for process planning, as proposed in this contribution, will take place at two degrees of decomposition that lead to two levels of planning respectively. These are the project and the operational level as mentioned above. The interaction between these levels of planning, i.e. switching between both levels of detail while planning, is essential in order to achieve a high value of information and transparency of the process plans (the reason is the uncertainty principle of process planning described above). To achieve a context description that is feasible for process planning, we focus on factors that can be measured and at least estimated at the beginning of a process. It is important to note here, that it is not the goal to achieve a complete characterisation of the design situation, but to consider the most important parameters that allow a situation-specific configuration of the development process. It is intended to analyse as few parameters as possible but to include the crucial ones so that the ratio between effort and benefit for project planning is acceptable and a better process quality can be achieved.

The model of the design process introduced by Frankenberger [32] (see figure 6) shows the major points of interest for the situation description presented in this contribution. Those are the characterisations of the design problem and the intended output as well as of the external and internal conditions and prerequisites. Due to the different levels of detail in planning, these situational parameters have to be described specifically for both levels. Some of these parameters are only relevant for one of these levels of decomposition while others apply for both levels but regard different aspects. There are also parameters that have to be considered in general without taking a specific level of process detail into account.

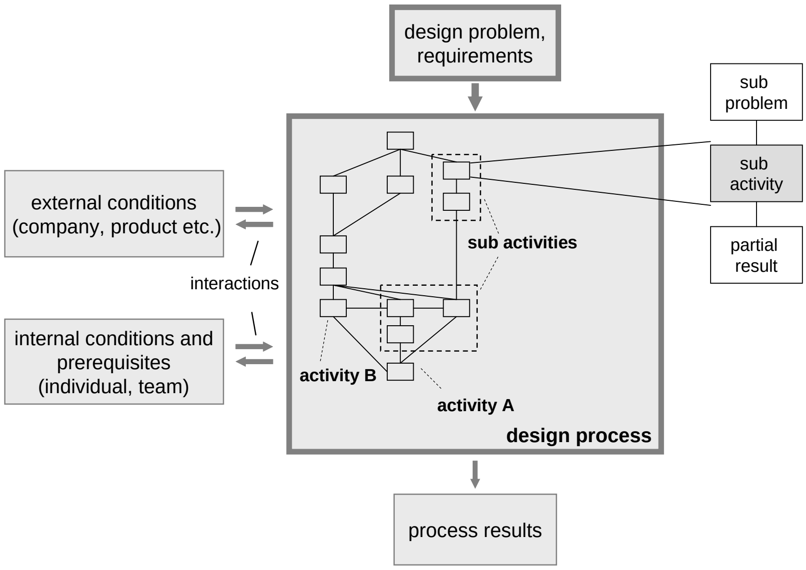

Figure 6. Model of the design process (according to Frankenberger [31])

3.1 General situational parameters

On both levels of decomposition considered here the design problem and requirements as well as the process results (i.e. the required outputs) have considerable influence on process configuration. On project level the main focus for process definition lies on external conditions, whereas on the operational level the internal conditions and prerequisites are of greater interest. Hence the parameters applied for the situation description in this approach refer to the development task and the general conditions, whereas general conditions are not organisational or individual aspects but factors like requirements, necessary competence, intermediate results etc. The parameters considered for situation description will be described exemplary in the following.

One parameter that is taken into consideration on both project and operational level is the degree of novelty. Most approaches use the distinction made by Pahl & Beitz [33] into original design, adaptive design and variant design. It is crucial for process planning whether a new, adaptive, or variant design is required for solving the design problem, because that mainly determines the scope of necessary design processes. A classification of product development projects into one of these three types is difficult, because in practice a clear differentiation is difficult. For that reason we measure the degree of novelty by a classification based on an estimation of the percentage of parts that have to be designed, adapted or can be reused respectively (on project level for the whole system, on operational level for the sub-system that is to be developed).

Another parameter often applied to describe the development task (e.g. in [15], [27], [28]) is the complexity of the task. On project level the distinction is made between high, medium and low level of complexity. The range of these classifications has to be determined company-specific, for example by the number of parts to be developed, i.e. low complexity for the development of single parts, medium complexity with sub-assemblies and high complexity if an entire system has to be developed. On the operational level, where the number of parts one engineer works on is relatively small, the complexity can be described for example by the number of neighbouring parts, the number of interfaces or the degree of collaboration with other disciplines.

3.2 Situational parameters on the project level

The situation-describing parameters that are considered on the project level are:

- Customer
- Risk
- Project constraints
- Structure of the design problem
- Number of units produced

First of all, the distinctiveness and individuality of a design problem have a dominant influence on the design process itself as well as on the planning of design processes.

A distinctive customer might require the involvement of that customer into the process while development processes might be planned without specific customer consideration when those customers are anonymous. The integration of customers also influences the variability of requirements. If requirements are not changing, standardised procedures might be applicable, otherwise planning according to the specific requirements will be necessary.
Risk is a factor that is hard to measure but has considerable influence on the design process. It could be necessary to implement more steps of quality assurance or to carry out repetitive benchmarks depending on the estimation of risks. The number of values this factor can take (from low risk to high risk) depends on the company's sensitivity to this point.
Examples for the project constraints to be regarded in process planning are resources and development time. The resources are of interest according to different aspects. On the one hand the number of e.g. CAD-licences can influence the design process, on the other hand the availability of experts is essential for the development of a new product. The disposable development time has considerable influence on the combination and sequence of process steps.
Likewise, the structure of the design problem is strongly shaping the structure of the design process. If objectives and requirements respectively of the design process or possible solutions are unavailable, unknown or not transparent to a great extend the design process might involve manifold iterations, loops, and step backs. In case of a well structured design problem with clear requirements and obvious solutions the design process might be more straightforward.
As well, whether the product is one off or mass produced strongly influences the shape of the design process. E.g. while prototyping might be necessary at mass product design processes it might not be for one off products.

3.3 Situational parameters on the operational level

On the operational level the influencing factors considered are:

- Documents available/process up to the present point (Input)
- Required output/planned succeeding process steps
- Structure of partial design problem
- Operational constraints (organisational, individual, environmental prerequisites)
- Main DfX requirements
- Interdependency with other process participants (number of interfaces)

Besides the complexity of the task and the degree of novelty the input and required output of process steps are most relevant to the engineer on the operational level. Another parameter related to these is the partial design problem faced on the operational level and its structure.
The time to the next milestone or quality gate belongs to the general framework respectively the operational constraints in product development. For organisational reasons it also is relevant, whether an individual designer or a design team is working on the design problem. This also determines the necessity of any coordination or integration processes and thus belongs to the operational constraints.
The main DfX requirements, for example Design for Manufacturing or Design to Cost, also have to be regarded to be able to plan a suitable development process. The degree of interdependency with other process participants, that means the level of integration, has influence on the configuration of development processes in so far as it determines e.g. regular meetings and reviews that have to be scheduled and vary with the number of persons involved. This gains even more importance if the product developed is a mechatronic system.

4 SITUATIONAL PROCESS PLANNING

The approach to development process planning presented in this contribution follows the primary goal to enable a workflow in product development. Schmitt [24] defines workflow as getting the right data at the right time to the right tool for the right people. Thus the situation-specific planning of development processes supports an engineering workflow. By creating a better process transparency and quality, the engineer gets a better overview of who needs what information at which point of time in which form. On the other hand possible information sources become clearer too.
A situation-specific approach to development process modelling faces the main challenge of being both universally valid and applicable in specific situations. Therefore this approach presents a model which applies a situation analysis to already existing product development processes (in research and

in practical use) and gives guidelines to the adaptation of these processes in respect to the specific development situation.

Most companies nowadays use generic development processes to plan their projects or have defined milestones or quality gates around which the development process is built up. Meissner & Blessing [15] describe this as the company-specific generic framework. Based on this company-specific framework or based on a general approach as e.g. the VDI 2221 [6] respectively, the situation-specific adaptation takes place as illustrated below (cp. fig.7).

The first step in planning product development is to analyse the design situation on the project level regarding the parameters defined in chapter 3.

Depending on the situation analysis the process is adapted for the project on hand. Those project processes usually just give a rough outline of the engineer’s work. They involve information about the development task, the project milestones and the people that have to coordinate their work. The actual processes of problem solving between milestones and the structuring of work are the engineers’ main responsibility. Elements of the project-specific adaptation can be for example the determination of the length of process steps, the order of the steps or the definition of a suitable project organisation.

It is a focus of this approach to provide a tool the engineer can use for planning his project work. After an analysis of the design context on the operational level taking into consideration the factors defined in chapter 3, recommendations for potential process steps or chains will be given. At this degree of decomposition suitable process steps have to be defined in more detail than the steps applied to the project level. Even though the level of detail varies and the parameters that describe the situation on these levels differ, it is very important to establish the possibility of switching between the levels of planning in order to provide a navigation through the development process.

These smaller process steps have to be defined company-specific at best supported by engineers from all departments involved in the design process, who have experience with the company’s workflows. For both levels of planning a process knowledge base has to be implemented from which process steps can be taken in order to configurate the project processes. Depending on the context specification a search for and recommendation of process steps or process chains will be started in the knowledge base. The selection of process steps is to be done by the person planning the process. Based on the situation analysis process steps can be modified and finally put together as a complete product development process.

The process planning support will provide the documentation of the actions taken during the design processes. This documentation is implemented in order to be able to reuse best practice processes and to evaluate which order of process steps maybe did not lead to the designated target and therefore should not be recommended the next time. Moreover the possibility of defining and registering new process steps in the knowledge base will be established in case new situations arise, which cannot be met with already documented process steps. After finishing a development project its process quality is evaluated and thus further information about best practices can be gained and reused over time.

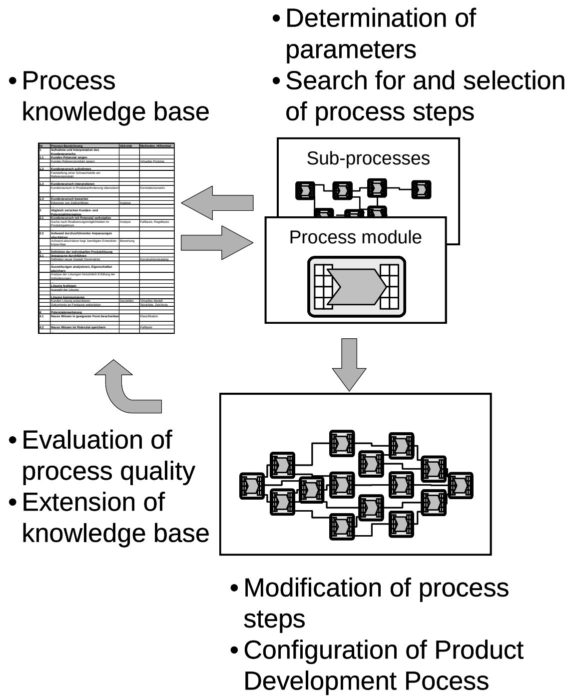

Figure 7: Situation-specific process modelling

5 FUTURE WORK

The approach presented in this contribution will be applied and evaluated in an industrial context.

One point of interest here is to evaluate if the parameters proposed for the situation description suffice, which means to analyse whether the parameters chosen are the right ones or have to be replaced by different ones. Furthermore it is possible, that more parameters have to be added in order to obtain an adequate situation description for process planning. It is not the goal to provide a holistic analysis of the design situation, which would result in a complexity far too high to be manageable. The goal is rather to take into consideration the main influences that cause the need for adaptation of the generic processes.

Another focus is to define a guideline to determining the values the parameters can take. The process of value determination will be planned and recorded, best practices derived and finally a guideline documented.

The adaptations of the generic processes will be analysed in each collaborating company using the documentation of past projects, information about current projects and interviews with engineers. The combination of these data shall provide a picture about the situation that led to the adaptation, i.e. the influencing parameters and their respective values. The process adaptations analysed will be evaluated regarding their improvement or worsening of process efficiency so that first conclusions can be drawn concerning best practices.

After the determination of the company-specific values of the parameters and the changes they cause in the project processes, the findings will be applied to actual projects in order to test the applicability of the approach.

During the research at the companies the model will be implemented prototypically in collaboration with computer scientists. Besides the implementation of the process knowledge base, the user interface, a methodology to recommend process steps or chains it will be an important step to realise the constant recording and analysis of processes so that best practices can be identified and reused. The prototype is intended to meet among others the requirements of

- being as simple as possible,
- being easily and intuitively useable,
- improving the reusability of processes and
- informing about possible process support.

The tool developed prototypically is intended to support especially small and medium-sized companies in development process planning.

6 SUMMARY

This contribution provides an approach towards situation-specific product development process planning. It is illustrated, that the planning of development processes at two degrees of process decomposition is a promising approach to increase transparency and quality of process information. Moreover it is made clear, that it is not possible to regard both degrees of decomposition at the same time due to the differing influencing parameters. Thus it is pointed out, that providing the possibility of switching between the levels (navigation) during process configuration is necessary and can effectively better the overview and transparency of development processes. Furthermore an outline of a situation analysis is given, that takes into consideration the specific characteristics of the different levels. The parameters applied for situation description at both degrees of decomposition are defined regarding the different levels of detail necessary in planning project and operational processes. Herein it is noted, that it is not the goal to provide a complete situation analysis, but to consider the factors that show the widest influence on development process planning. Based on the situation analysis a knowledge based approach to development process planning is applied. The system supporting process planning will recommend best practice processes based on the documentation of past processes and will include the possibility of adding new processes so that unknown design situations can be faced as well.

7 ACKNOWLEDGEMENTS

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REFERENCES

[1] Clarkson, P. J., Eckert, C. M., *Design Process Improvement*, Springer, Berlin, 2005

[2] Wynn, D. C., Eckert, C. M., Clarkson, P. J., *Modelling and simulating iterative development processes*, Proceedings of the 15th International Conference on Engineering Design 2005 (ICED2005), Melbourne 15.-18.08.2005

[3] Marca, D. A., McGowan, C. L., *SADT – Structured Analysis and Design Technique*, McGraw-Hill, New York, 1989

[4] Scheer, A.-W., *Prozessorientierte Unternehmensmodellierung*, Gabler, Wiesbaden, 1994

[5] Bichlmaier, C., Grundwald, S., Lindemann, U., Reinhart, G., *PMM – Process module methodology for integrated design and assembly planning*, In: Proceedings of 1999 ASME International Design Engineering Technical Conference, September 12-15, 1999, Las Vegas, New York, ASME, 1999

[6] Verein Deutscher Ingenieure (Hrsg.), *VDI-Richtlinie 2221 – Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte*, VDI-Verlag, Düsseldorf, 1993

[7] Maffin, D., *Engineering Design Models: Context, Theory and Practice*, Journal of Engineering Design 1998, Vol. 9 Issue 1

[8] Harrington, H. J., *Business process improvement*, McGraw-Hill, New York, 1991

[9] Becker, J., Kugeler, M., Rosemann, M., *Prozessmanagement*, Springer, Berlin, 2002

[10] Vajna, S., Workflow for design, In: Clarkson, J., Eckert, C. (eds.), Design process improvement, Springer, London, 2005

[11] Blessing, L. T. M., Lindemann, U., Meissner, M., *Gestaltung von Entwicklungsprozessen*, In: Krause, F.-L., Franke, H.-J., Gausemeier, J.: Innovationspotenziale in der Produktentwicklung, Hanser, München, 2007

[12] Gaitanides, M., Scholz, R., Vrohlings, A., Raster, M., *Prozessmanagement*, Hanser, München, 1994

[13] Hemmert, U., *Entwicklung ablauforganisatorischer Sollkonzepte*, TU, PhD Thesis, Aachen, 1985

[14] Freisleben, D., *Gestaltung und Optimierung von Produktentwicklungsprozessen mit einem wissensbasierten Vorgehensmodell*, Magdeburg, Univ., PhD Thesis, 2001

[15] Meissner, M., Blessing, L. T. M., *Defining an adaptive product development methodology*, In: Proceedings of International Design Conference 2006, Dubrovnik, 15.-18.05.2006

[16] Demers, M., *Methoden zur dynamischen Planung und Steuerung von Produktentwicklungsprozessen*, Dr. Hut, München, 2000
[17] Blessing, L T. M., *A process-based approach to computer-supported engineering design*, Cambridge, Black bear Press, 1994
[18] Rude, S., *Wissensbasiertes Konstruieren*, Shaker, Aachen, 1998
[19] Baumberger, C., Lindemann, U., *Requirement oriented process planning and configuration*, In: Proceedings of NordDesign 2006, 16.-18.08.2006, Reykjavik, pp. 244-254
[20] Platz, J., Schmelzer, H. J., *Projektmanagement in der industriellen Forschung und Entwicklung*, Springer, Berlin, 1986
[21] Lindemann, U., *Methodische Entwicklung technischer Produkte*, Springer, Berlin, 2007
[22] Zanker, W., *Situative Anpassung und Neukombination von Entwicklungsmethoden*, Shaker, Aachen, 1999
[23] Gaitanides, M., *Prozessorganisation*, Vahlen, München, 1983
[24] Schmitt, R., *Unternehmensübergreifender Engineering Workflow*, Clausthal, Univ., PhD Thesis, 2000
[25] Ropohl, G., *Allgemeine Technologie - Eine Systemtheorie der Technik*, Hanser, München, 1999
[26] Beneke, F., *Konzeptionelle Ansätze einer prozessorientierten Produktentwicklung*, Essen, Univ., PhD Thesis, 2003
[27] Fricke, E., Negele, H.; Schrepfer, L., Dick, A, Gebhard, B.; Härtlein, N., *Modelling of concurrent engineering processes for integrated systems development*, In: Proceedings of the 17th digital Avionics Conference 1998, 31.10.-07.11.1998, Bellevue, pp. B13/3-B13/8 vol.1
[28] Hales, C., Gooch, S., *Managing Engineering Design*, Springer, London, 2004
[29] Badke-Schaub, P., Frankenberger, E., *Management Kritischer Situationen*, Springer, Berlin, 2004
[30] Wallmeier, S., *Potenziale in der Produktentwicklung – Möglichkeiten und Grenzen von Tätigkeitsanalyse und Reflexion*, VDI-Verlag, Düsseldorf, 2001
[31] Dylla, N., *Denk- und Handlungsabläufe beim Konstruieren*, Hanser, München, 1990
[32] Frankenberger, E., *Arbeitsteilige Produktentwicklung*, VDI-Verlag, Düsseldorf, 1997
[33] Pahl, G., Beitz, W., *Engineering design*, Springer, London, 1996

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