5TH INTEGRATED PRODUCT DEVELOPMENT WORKSHOP
IPD 2004 SCHÖNEBECK/BAD SALZELMEN b. MAGDEBURG
SEPTEMBER 23-24, 2004

# SYSTEMATIC PROCESS ENGINEERING AND ITS APPLICATION IN PRODUCT PLANNING

Dipl.-Ing. M. Weigt, Dipl.-Wi.-Ing. M. Seidel
Institute for Applied Computer Science in Mechanical Engineering (RPK)
Karlsruhe University (TH), Germany

*Keywords: Process Engineering, Information Process, Systems Engineering, Cognitive Science, Process Evaluation, Process Optimisation, Innovation Management, Product Planning Methodology*

## 1 Introduction

Current industrial products are characterised by increasing complexity, quality requirements, and a high level of specialisation. To stay competitive in today's markets, a substantial improvement of the value chain is required, taking into consideration the entire product lifecycle. This leads to a rising need for adequate methods of work and the organisation of workflows in industrial practice to allow an evaluation against criteria of effectiveness and efficiency. The complexity of the underlying processes requires their definition as well as their evaluation and optimisation to be methodically supported in a comprehensible and reliable way. The success of complex processes depends on the cognitive performances of human beings and on support by information technology. This makes it advisable to regard processes as being primarily about information conversion, i.e. as information processes.

Some of the problems arising in this area are the following: The terms of method, workflow and process in this context are not consistently defined and thus inappropriately used. Existing processes often evolve instead of being defined. Furthermore, they are not considered in an integrated manner, as would be appropriate in the view of their complexity and impact. As the information conversion is not focused on, currently many processes are not sufficiently manageable. This is evident in cases of processes where the necessity arises to deal with incomplete and fuzzy information, e.g. product planning.

This work introduces *Systematic Process Engineering (SPE)* [WEI-04] as a methodical support for the development of new methods of work, their transition to executable workflows and their later implementation and optimisation as processes. The paper is organized as follows: An overview of the necessary theoretical and methodical fundamentals regarding terms and concepts is given, followed by an analysis of the currently available concepts in this area. The main focus of this paper is the concept of *SPE,* and its practical application is illustrated using the *product planning process* as an example.

# 2 Fundamentals

In this work, a *method* is defined as a set of instructions, whose execution under given conditions sufficiently ensures the achievement of an intended objective [MUE-90].

A method can be seen as an abstract model of a process: Whereas a method merely enables to achieve an objective in principle, a process actually conduces to a factual end. A *process* therefore is defined as a set of operations, whose execution under given conditions sufficiently ensures the achievement of an intended objective. As opposed to primarily stage-based methods, processes are based on milestones.

Based on this concept of processes and methods, a *workflow* is defined as a method made operational, i.e. a method which has been made ready for implementation as a process. This preparation generally includes an adaptation of its methodical content to the constraints of the implementation (corporate-specific and task-specific), and often also a further concretion and a change in formulation of the method. Workflows constitute an appropriate starting point for implementation, since they are based on deliverables, which are an essential prerequisite for manageability of milestone-based processes.

Summarising, the term *process engineering* refers to definition of new methods of work, their transition to executable workflows and their later actual execution and optimisation as processes. Activities of process engineering are generally initiated by a situation being perceived as unwanted. Such may be either of abstract or of concrete origin, but will more often be caused by existing processes than in a theoretical context. Therefore, process engineering usually starts with an existing process (see Figure 1).

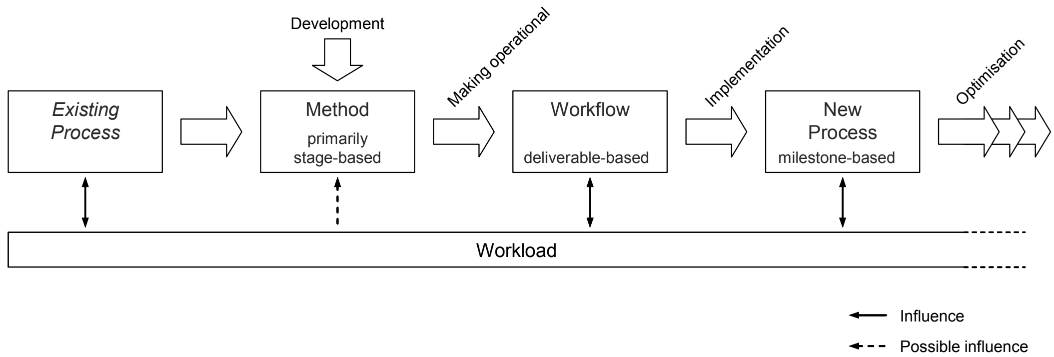


Figure 1. : Context and scope of process engineering [WEI-04]

Both existing and new processes and workflows influence and are influenced by the *workload*, i.e. the actual and planned effort of the corporate resources. On the other hand, the workload may influence the definition of abstract methods, but is not influenced by them alone.

The Systems Engineering methodology [DAE-02] provides a generic logic to be applied whenever a problem of any kind is encountered in any stage of a project. This generic problem solving cycle (see Figure 2) serves as the foundation of most engineering methodologies and is also used in management sciences and consultancy.

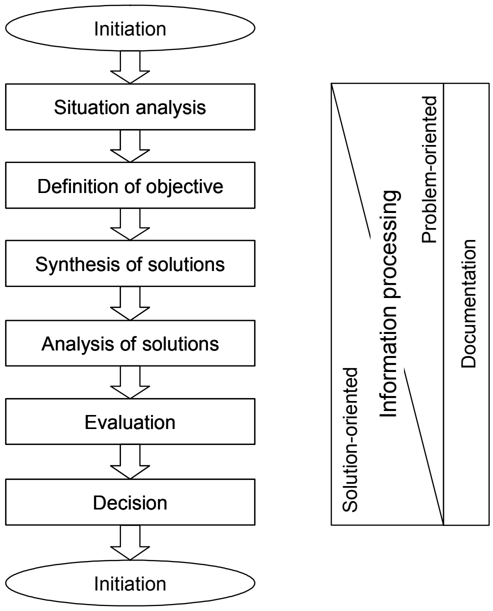


Figure 2. : Generic problem solving cycle [DAE-02]

In the context of *SPE,* this strategy is applied mainly for the following reasons: The complexity and impact of the relevant processes calls for a thorough analysis of the current unsatisfactory situation and its environment. This analysis of the initial situation is supposed to be problem-oriented to serve a demarcation and structuring of the task at hand, and a proper assessment of existing potentials for intervention and development. The development of methods and their subsequent transition to processes requires information processing to evolve from problem-orientation into solution-orientation according to the degree of concretion achieved. Finally, a well-founded choice among several alternatives is only possible based on at least a qualitative analysis of the respective options.

# 3 State of the Art

Regarding the objectives of the available concepts of process engineering in engineering and management science and practice, these approaches either focus on primarily stage-based methods (mainly engineering science, e.g. [VDI-2221]), deliverable-oriented workflows (mainly management science or consultancy, e.g. [COO-02]), or the implementation of workflows (mainly consultancy or industrial practice in general) (see Figure 3).

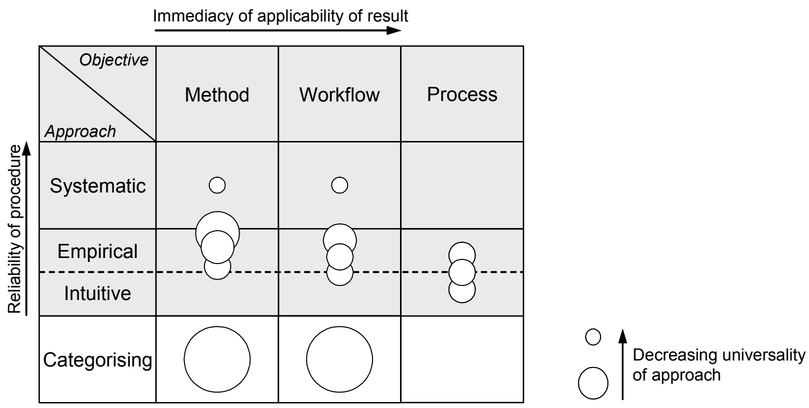


Figure 3. : State of the art of process engineering (qualitative)

The necessity of and the possibilities for the development of workflows (as defined above) as an interface function is not actively considered. A systematic transition from methods to processes therefore cannot reliably be achieved, and processes are often unsatisfactory concerning their methodical foundation.

The available procedures themselves can be classified as being mostly categorising, intuitive, empirical or systematic in nature. As an example for a widely used, intuitive/empirical procedure for the development of workflows and their subsequent implementation is Benchmarking [SAB-97]. As analytical reasoning increases with the transition from categorising to systematic procedures, so does the reliability of the respective procedures. On the other hand, the universality of an approach tends to decrease when comparing categorising to intuitive/empirical or to systematic approaches. For example, catalogues of engineering methods as categorising approaches generally cover wide areas (eventually the entire product life cycle, e.g. [EHR-03]), whereas systematically developed engineering methods are usually mathematic in nature, and as such have specific and limited purposes (for examples e.g. [PAH-03]). Besides, with the transition from method to workflow the immediacy of its applicability increases, i.e. the amount of further concretion of the objective necessary for implementation as a process decreases.

Summarising the advantages and limitations of the different types of procedures in terms of application in industrial practice, both categorising and intuitive/empirical concepts are unsatisfactory concerning their reliability and output concretion. Regarding the objectives, concepts for the development of methods provide insufficient systematisation and a limited range of applicability. For the transition of methods to workflows and their subsequent implementation, comprehensible and reliable integrated procedures do not exist.

# 4 The Systematic Process Engineering methodology

To allow a reliable transition from methods to processes, *SPE* is based on a three-stage-approach, regarding the systematic development of methods of work (1), the subsequent systematic development of workflows (2), and their systematic implementation as processes (3). Hereby, each of the later two stages is based on its respective predecessor, and every stage follows the principles of the Systems Engineering methodology (see Figure 4).

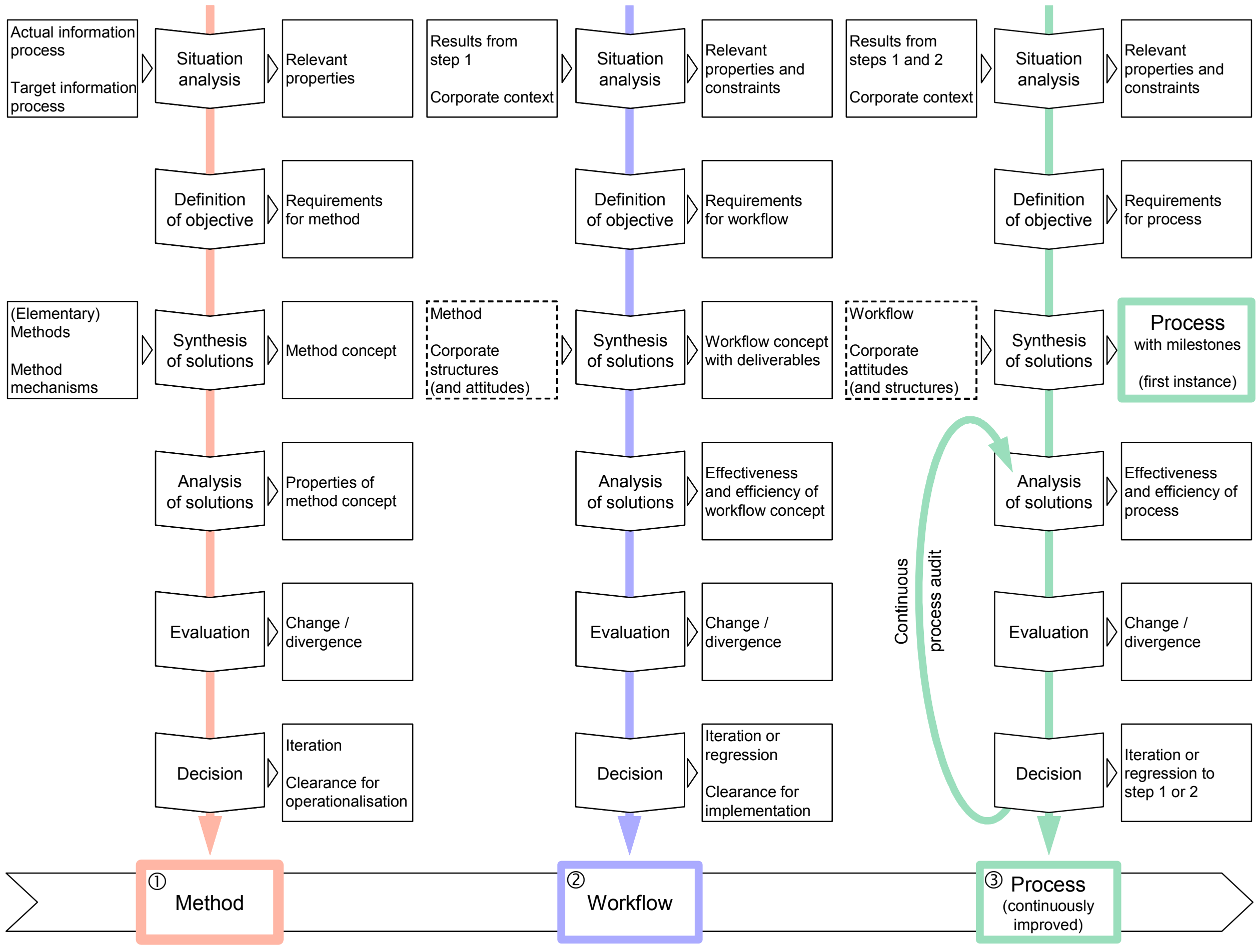


Figure 4. : Methodology of Systematic Process Engineering [WEI-04]

The definition of requirements for the development of a method requires a thorough analysis of any existing information process and especially the target information process, regarding their respective relevant properties. *SPE* does not generally postulate the development of a method (1) to be directed by constraints exceeding the generic requirements considering the immediate information process the method is supposed to support: Since no qualitative limits to information conversion do exist per se, methods generally offer a potential of universal applicability, and it is not considered advisable to early forfeit this.

When synthesising methods, certain “building blocks” may be used, depending on the granularity of the objective. These are pre-developed methods, elementary methods, or basic method mechanisms. The latter two types are identified by means of analysis of methods and their typical applications according to the guidelines of Systems Engineering and cognitive science (e.g. [DOE-87]). During this analysis, it is recommended to interpret the context of methods and tasks as a structure, i.e. as being composed of elements and their interrelations. Such are e.g. the task/problem and the methods (and possible sub-methods) themselves, their linked inputs and outputs, their users, and supporting tools (both hardware and software). The relevant environment of this context should also be considered. This structure can be analysed concerning the type and degree of e.g. its complexity (as determined by both type and number of involved elements and relations, respectively), dynamics, fuzziness and uncertainties, and inherent potentials and limitations. Such analysis provides insight both into the working mechanisms that underlie methods and the context, and therefore facilitates both the adaptation and development of methods. Similar analysis is recommended when intending to use pre-developed methods, combining or adapting them.

In (2) and (3), the corporate context (e.g. organisation – including personnel –, information technology and processes) and eventual further task-specific constraints are introduced and considered, both regarding the definition of requirements and the synthesis of solutions. Their respective relative weight depends on the stage. This is illustrated with the example of corporate structures and attitudes; the relevance of the corporate structures is generally greater in (2) than in (3), vice versa with corporate attitudes.

In (2) and (3), an evaluation of effectiveness and efficiency of workflows and processes is to take place. Effectiveness depends on the difference of the information level projected (2) or achieved (3) before and after a specific activity or the entire process. Efficiency is the ratio of effectiveness and the resources projected (2) or used (3).

The last stage (3) deals with the actual implementation of the workflow into corporate structures and processes. It is recommended to audit the resulting process continuously, starting directly after its first instantiation. This audit is to be incorporated into the workflow as developed in (2). Generally speaking, a process may either be infinite or finite. Finite processes may be executed repeatedly. An infinite process can not be reviewed by definition, but should be tracked nonetheless, for purposes of abstract learning. A finite, non-repeated process should be both tracked and reviewed, also to the end of abstract learning. A finite, repeated process should be tracked and reviewed, but as opposed to the other types, allows for concrete as well as abstract learning. Furthermore, finite or infinite processes may both directly or indirectly influence downstream or parallel processes. With such processes, a tracking of the influenced processes should be generally taken into consideration for optimisation purposes. The continuous process audit may not only make evident the need for iterations within (3), but also for regressions to (2) and (1). The improvement of the process that is facilitated by such continuous process auditing is not limited to mere incremental improvements, because the methodical foundation of the process may also be improved.

By definition, *SPE* is not limited to the engineering of sequential processes: Milestones, but also intermediate information levels, which do not constitute milestones by themselves, may be identified as appropriate starting points for parallel processes. Currently, the focus of *SPE* is on the development and making operational of industrial engineering methods, but in principle universal applicability is ensured. *SPE* is intended to be used whenever process complexity or impact calls for a systematic approach.

# 5 Product Planning: Application in Practice

Product planning projects have to cope with fuzzy and incomplete information and are essential in their consequences on company success. For these reasons, planning processes make high demands on their methodical foundation. Therefore, the product planning process is used as an example to illustrate the application of *SPE*.

The main objective of the planning process is to define the essential properties of the new product, these specifications not being contradictory to company and product strategy or result in a product being inferior concerning market needs [COO-02]. From this situation result the unique challenges of planning projects: This complex process, which has to cope with fuzzy information and dynamics of the planning situation, must appropriately consider all relevant constraints (e.g. product complexity, company and product strategy, product portfolio, competitors, customer needs, and statuses of research and advance development). This should be achieved with minimum effort and maximum revenue.

Currently available approaches supporting product planning are not satisfactory against the background of process engineering. For example, QFD-based approaches (e.g. [HOF-97], [MAI-98]) are in common use, but do not sufficiently consider the important constraints of market or strategy aspects. Primarily cataloguing approaches (e.g. [VDI-2220], [EVE-03]) are not sufficiently explicit for direct implementation in practice, though it must be accounted for this not being their immediate aim. Management science tends to focus on accounting and performance measurement and optimisation (e.g. [WAR-01], [HER-03]), but without getting at the methodical foundation of the respective processes.

Using *SPE*, a new *Product Planning Methodology* [SEI-04] to conform to the aforementioned challenges has been developed. In accordance with the information-centred view of processes, and especially to facilitate the transition to deliverable-based workflows and milestone-based processes, it focuses on how the fundamental information is linked with each other and with the respective steps of the methodology (see Figure 5).

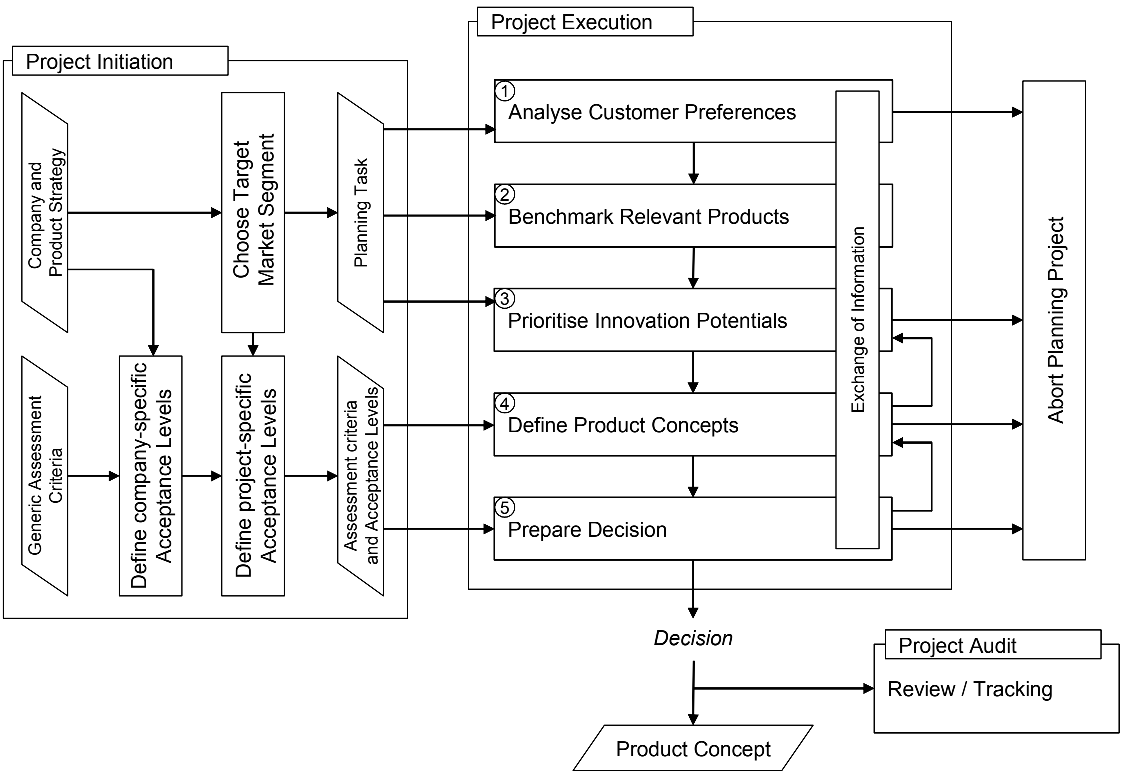


Figure 5. : Product Planning Methodology [SEI-04]

The methodology distinguishes between Project Initiation, Project Execution and Project Audit: *Project Initiation* includes the definition of the planning task based on the demands of both company and product strategy, and also the project-specific determination of the acceptance levels of a set of generic assessment criteria. *Project Execution* comprises the main steps necessary to define product concepts and to prepare management decisions concerning the further advancement of the innovation project. A concluding *Project Audit* ensures further improvement of methodology, workflow and process using both review and tracking measures. The emphasis on tracking measures exceeding the process itself accounts for the fact that the product planning process constitutes the beginning of the new product's life, and that conclusions about the effectiveness of planning decisions also have to be drawn from the results of parallel processes, processes in downstream departments or in stages later in the product life cycle.

To exemplarily explain the practical application of *SPE*, this paper focuses on the most fundamental constraints of the product planning process – market fit, strategy fit, and coping with both process and product complexity and dynamics – and their effect on both the resulting methodology and the measures taken for its being made operational.

Most importantly, the aforementioned constraints are monitored not selectively, but continuously during the entire project, accounting for their potential dynamics. For example, market and strategy fit are incorporated not only when initially defining the planning task. This is repeated during step 3, when defining and reconsidering the essential product properties in accordance with strategical and competition aspects.

In step 1 and step 2, the use of a Kano-based classification and a *Deviation Benchmark method* helps identifying and focusing on the most relevant characteristics of the new product. This makes product complexity manageable in accordance to the planning task. A prioritisation of these essential properties furthermore helps to reduce process complexity during step 3 and in preparation of step 4. During this step 4, an *Innovation Planning Matrix method* reduces product complexity and supports the development of concept variants to aid concept optimisation. To meet dynamics, it is recommended using this matrix method to define fall-back- and step-ahead-strategies. Both the Deviation Benchmark method and the Innovation planning matrix methods were also developed using *SPE*.

Considering the uniqueness of planning situations in general, companies need to redefine their goals with every new project. To provide an adequate assessment method to evaluate the new product concepts, the acceptance levels of a set of generic criteria are recommended to be defined specifically for every project. Quantitative acceptance levels are used whenever possible, but qualitative properties are also being accounted for. In addition to these rateable criteria, a process-accompanying documentation of the information generated and the decisions made provides the foundation and transparency needed for a comprehensible decision in step 5, which may be examined and understood in later stages of product development as well, if need arises.

Based on this universally applicable methodology, customized workflows have been defined and prototypically implemented as processes in cooperation with the automotive supply industry, whose company specific constraints have been analysed and incorporated into the workflows and processes. During the ensuing planning projects, resource consumption was assessed to be significantly reduced as compared to earlier projects.

# 6 Conclusion

The concept of *SPE*, as introduced in this paper, allows defining methods of work, workflows and processes in a comprehensible and reliable way. This helps process engineering in its entirety. Processes, including the relevant constraints, become transparent; therefore they can be better understood, re-defined, rated and optimised. As a result, technical and management decisions related to process engineering get substantiated, and can be justified, documented and communicated.

The current focus of *SPE* is on industrial engineering methods and processes. For explanation purposes, this paper demonstrates the application of *SPE* to the development of a *Product Planning Methodology*. The validation of the practical applicability of this methodology was the subject-matter of several co-operations with the automotive supply industry.

Future work in this area will address the further identification and systematisation of corporate constraints and measures for their consideration. Based on the experiences of the practical applications so far, methodologies to support additional product life phases will be developed in close cooperation with industrial partners. Finally, further research will be carried out considering the "building blocks" for method synthesis, especially elementary methods and method mechanisms.

## References


[COO-02] Cooper, R. G.: Top oder Flop in der Produktentwicklung. Weinheim: Wiley-VCH

[DAE-02] Daenzer, W. F. & Huber, F. (eds.): Systems Engineering. Zurich: Industrial Organisation

[DOE-87] Doerner, D.: Problemlösen als Informationsverarbeitung. Stuttgart: Kohlhammer

[EHR-03] Ehrlenspiel, K.: Integrierte Produktentwicklung. Munich: Hanser

[EVE-03] Eversheim, W.: Innovationsmanagement für technische Produkte. Berlin: Springer

[HER-03] Herstatt, C. & Verworn, B. (eds.): Management der frühen Innovationsphasen. Wiesbaden: Gabler

[HOF-97] Hoffmann, J.: Entwicklung eines QFD-gestützten Verfahrens zur Produktplanung und -entwicklung für kleine und mittlere Unternehmen. PhD thesis. Berlin: Springer

[MAI-98] Mai, C.: Effiziente Produktplanung mit Quality Function Deployment. PhD thesis. Berlin: Springer

[MUE-90] Mueller, J.: Arbeitsmethoden der Technikwissenschaften. Berlin: Springer

[PAH-03] Pahl, G., Beitz, W., Feldhusen, J. & Grote, K. H.: Konstruktionslehre. Berlin: Springer

[SAB-97] Sabisch, H. & Tintelnot, C.: Integriertes Benchmarking für Produkte und Produktentwicklungsprozesse. Berlin: Springer

[SEI-04] Seidel, M.: Systematische Produktplanung. PhD thesis manuscript. Karlsruhe University (TH).

[VDI-2220] VDI 2220: Produktplanung. (May 1980)

[VDI-2221] VDI 2221: Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte. (May 1993)

[WAR-01] Wartzack, S.: Predictive Engineering. PhD thesis. Dusseldorf: VDI

[WEI-04] Weigt, M.: Systematische Prozessentwicklung. PhD thesis manuscript. Karlsruhe University (TH).



Dipl.-Ing. Markus Weigt / Dipl.-Wi.-Ing. Michael Seidel
Institute for Applied Computer Science in Mechanical Engineering (RPK)
Karlsruhe University (TH)
D-76128 Karlsruhe
Phone: +49 721 608-7958 / +49 721 608-8145
Fax: +49 721 661138
E-mail: weigt@rpk.uni-karlsruhe.de / seidel@rpk.uni-karlsruhe.de