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Analysis of existing approaches for the support of planning processes within new product development projects

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Abstract

Studies show that the deviation from the goals of industrial product development projects is mainly caused by incorrect planning at the beginning. The accuracy and reliability of the project plan depend on the available knowledge regarding the projects' outcome. But in the early planning phase this knowledge is marked with uncertainties, especially in projects with a high degree of novelty. Within this paper the uniqueness of development processes especially in the field of new product developments and the accompanying complexity and heterogeneity of planning processes are emphasized. Uncertainties in this context and phase usually result from the lack of definition by means of incomplete and not validated requirements. One option to reduce uncertainties in the planning is to rely on existing knowledge or procedures in the form of generic design methodologies. These however need to be adapted to the specific context in which they take place. Within this paper different context or rather influencing factors are consolidated and based on a literature research four different approaches for the support of planning processes in product developments are analyzed concerning their consideration of these influencing factors.

Keywords: New product development, Planning of development processes, Uncertainty

1 Introduction

In corporate environments, product development activities are usually dealt with within projects. Suitable to the characteristics of product development processes, projects are defined as unique, extensive and terminable tasks with a relatively high degree of novelty, complexity and risk (Zielasek 1995). To initiate a development project, working packages, responsibilities and deadlines are derived on the basis of existing requirements and transformed into a project plan to continually monitor the ongoing working process (Jochem et al. 2015). This is usually supported by project management tools and methods. Work breakdown structures are primarily used to depict the complete hierarchical structure of project elements (sub projects, work packages) (DIN 69901). Beyond that, schedule network analyses (e.g. critical path method, PERT, GERT, etc.) support the definition of project activities as well as the analysis of their chronological dependencies and required resources (personnel, machines, material, budget, methods) (Hering 2014). However, studies reveal that industrial development projects often deviate from the planned objectives especially in terms of time-cost-quality. The cause of these discrepancies mainly relies on inaccurate or incomplete planning activities in the beginning of the project (Bullinger et al. 2003; Engel et al. 2008; Rietiker et al. 2013; Jakoby 2015). In the short-term, the consequences are high time pressure and firefighting for single employees (Akademie 1997). But missing defined delivery dates and exceeding budgets can also have a long-term impact on the entire business processes.

The accuracy and reliability of the project plan primarily depend on the available knowledge regarding the project´s course. Since product development differs from other business processes, as e.g. production, the related processes are more difficult to anticipate, because of their increased dynamics and variability (Reinertsen 1998; O´Donovan et al. 2005; Vajna 2005). Every product development is associated with individual objectives, restrictions and activities that lead to a unique process course (Albers 2010). Moreover, real product development processes are generally characterized by an iterative process sequence. Its problems as well as its objectives are clarified successively throughout the entire development process by considering new findings that result from the solution concretization progresses (Bender 2004). These characteristics are even more distinctive in new product developments (NPD) due to the uncertainties that relate to the design objective, the design object as well as the design process (Albers 2010).

One strategy to deal with these uncertainties in project planning is to fall back onto existing knowledge. But even procedure models or reference processes (e.g. VDI 2221 or VDI 2206) that base on the experience of product designers from past or idealized development projects are far too general for transferring them to the own development project. Particularly considering the uniqueness of product developments in combination with the lack of knowledge in NPDs, their description depth is too abstract to give an indication for the right phases, activities, sequences or test cases, since every development encounters individual problems. This requires an adaption of the procedure models depending on specific influencing factors that describe the development context (Gericke 2013).

On that account the deduced research questions for this paper are: Which methodical approaches can support the early planning of development processes for technical products? And do these approaches consider the uncertainty-marked influencing factors of NPDs? Following the Design Research Methodology by Blessing and Chakrabarti the 'descriptive study I' investigates the difficulties of planning product development processes by reviewing the literature about influencing context factors and causes of uncertainties of product developments (Blessing, Chakrabarti 2009). Moreover, the research literature was screened for existing approaches that support project planning resulting in the description of four selected approaches applicable for new product developments. In the 'prescriptive study' these approaches are evaluated regarding their consideration of specific criteria that are characteristic for NPDs. Finally the results are discussed.

2 Planning of the development process

To better understand the planning of development processes, it is necessary to gain an insight into its embedding in corporate processes. Within the pre-development phase, the fuzzy front end (FFE), the idea generation (customer oriented, technology oriented or cost oriented) and idea assessment (regarding attractiveness or risks), the alignment with existing projects, the project portfolio update as well as the concept development (containing market analysis, the product concept, specifications or architecture) and product planning (with product costs, timing, number of pieces and project costs) are included (Herstatt, Verworn 2001). Like illustrated in figure 1 (left), it is necessary to prove a project´s feasibility (gate 1), in order to initiate a new product development. Thereby the decision about the feasibility must include the following aspects: problem statement (why?), objectives (what?), solution approach (how?), project management (how, when, who, where?), deliverables, budget, etc.

Obviously, the planning of the development process, which means e.g. the selection of activities, the use of methods, the identification of correlating activities and the definition of test procedures, plays a critical role and greatly influences the start of the production or commercialization of the product, which is only reached by one fourth of the development projects (Booz et al. 1982, Jakoby 2015). The early phase of NPD is seen as an opportunity to enhance this quotient, because the costs of changes are still low and the influence on the project's outcomes are high (Herstatt, Verworn 2001). Uncertainties occur because the amount and certainty of the available information is very low (figure 1 right).

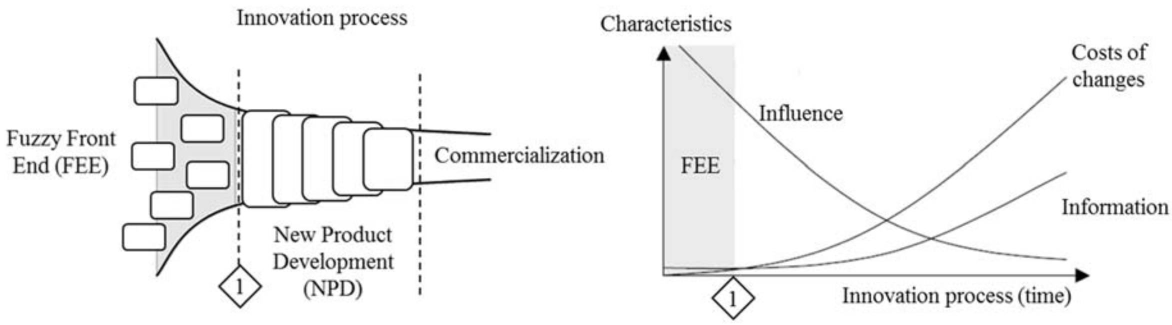

Figure 1. FFE in the innovation process (Koen et al. 2002; Herstatt, Verworn 2001)

Aside from unclear goals and market-related uncertainties, NPD are characterized through uncertainties resulting from and the degree of innovativeness of the product concept (Stockstrom, Herstatt 2008). In addition especially the development of new products is notably affected by uncertainties that are a consequence of insufficient experience and missing knowledge (Hastings, McManus 2004). Moreover, NPDs require new development activities, methods and tools that can cause additional uncertainty, which directly influences the process planning (Stockstrom, Herstatt 2008).

One strategy to deal with uncertainties in project planning is to fall back onto existing knowledge. Design methodologies like VDI-guideline 2221 or 2206 are therefore often used as the basis for the design planning of development processes (Albers, Meboldt 2007). In order to cover a wide range of different contexts, the process models proposed in the design methodologies became rather abstract, which in turn reduce their applicability (Clarkson, Eckert 2005). An approach suggested by different authors is to start with an abstract, context-independent approach and adapt it to the specific context (Gericke et al. 2013). Hales and Gooch developed a model to analyze the context based on checklists to assist the developers and to reduce the risk of project failures. Altogether they proposed five levels of resolution (macroeconomic, microeconomic, corporate, project and personal) for the design process according to Pahl and Beitz and provide checklists with influencing factors (Pahl, Beitz 1977; Hales, Gooch 2004). There are numerous further research or empirical studies that identify deficits and insufficiencies of the adaption of methodologies to the context in which they are applied (Gericke et al. 2013). Meißner et al. for example analyze the influence of different context factors (in this regard factors that have an influence on the course of a design project) on the selection of design methodologies on the basis of a literature study in which they identified factors that describe the product development context (Meißner et al. 2005). They were able to prove a direct relation between the context of product developments and the activities carried out during the development, which indicates that companies who operate in different contexts also possess different product development processes (Meißner et al. 2005). Hence there needs to be an adaption between the abstract methods and processes towards precise planning situations in companies. Meißner et al. suggest to adapt the product development process on different abstraction levels with regards to the attributive contexts factors (figure 2).

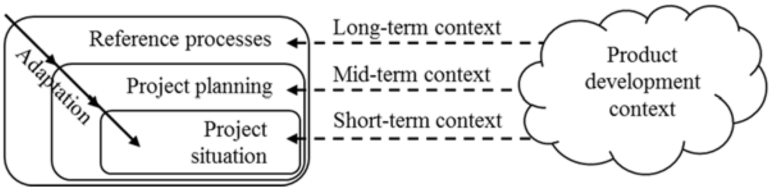

Figure 2. Different levels of context factors (Meißner et al. 2005)

Context factors that remain stable over a period of several years should be strategically incorporated in the planning of the product development. Whereas the project specific designing of the product development process needs to include project specific as well as in the medium term changeable factors that vary with the project duration. Dynamic, short-term part of the context can only be considered in case of a predictable variation at the beginning of the project in the project planning (Meißner et al. 2005; Ponn, Lindemann 2006; Ponn 2007). Based on the definitions above, Gericke et al. provided a list of 239 influencing factors extracted from a comprehensive literature research that included empirical studies from different disciplines (product development, design management, project management, general management, organizational theory and psychology) (Gericke et al. 2013). They organized the factors on a first level (Level 1) according to Hales' levels of resolution and further specified them on two more detailed levels (Level 2 and Level 3) within a scheme, which also includes important characteristics of the influencing factors, interdependencies between them and an estimation of their relevance (Hales, Gooch 2004; Gericke et al. 2013). In correspondence with the above mentioned levels of context factors, the relevance of a factor may affect one or several of the following levels of adaption (Gericke et al. 2013):

- Strategical relevance: adaption of a design methodology to a specific corporate context i.e. creating a reference process
- Operational relevance: adaption of a company's approach to a project's context i.e. planning a project
- Situational relevance: response to specific situations within a project

In summary, it can be noted that it is indispensable for both the initial design of a new development process and the adaption of generic design methodologies (both understood here as planning of development processes) to incorporate the specific context, described by the context factors. Therefore, it can be conducted that methodical approaches that support the planning activity also need to consider these requirements.

3 State of the art: Methodical support of planning processes

In order to assess the methodical approaches for the support of the process planning in terms of the fulfilment of the defined requirements, we follow a three-stage procedure. At first (chapter 3.1 and 3.2) a comprehensive literature study is conducted to identify the relevant methodical approaches. Afterwards the specific context factors are narrowed towards the scope of NPD (chapter 3.3). At last the identified approaches are analyzed regarding their incorporation of the selected influencing factors (chapter 3.4).

3.1 Literature research and proceedings

To understand the current trends and situation in the support of process planning within product development projects, a literature research has been conducted. Journal articles, papers and books were obtained from Springer Link, Web of Knowledge, Google Scholar and Google. The investigation concentrated on publications not older than 15 years that included at least one of the following key words “project planning”, “process design”, new product development”, “innovation process”, “fuzzy front end” as well as “requirements conform planning” in English and in German. In a first screening 106 publications were identified and sighted. They focused the following topics (multiple selections were possible): project planning (32 publications), new product development (26 publications), requirements (22 publications), uncertainties (16 publications) and fuzzy front end (11 publications). Full text files of all publications were downloaded for a further analysis. The files were scanned, classified according to the kind of publication (paper, dissertation, etc.), summarized, grouped (NPD, Uncertainty, etc.) and rated by the authors according to their relevance. Altogether 21 approaches for the support of planning processes within new product development projects could be identified. Within a second review, these were again classified this time according to the kind of support (methodology, procedure model etc.), their focus (strategical, situational support etc.) and their subject (innovations, technical products, mechatronic systems etc.). Based on their content, their engineering reference and current relevance (published in the years 2004-2013), four approaches were selected (chapter 3.2).

3.2 Description of selected approaches for the support of planning processes

The planning of product development processes is a current subject of discussion in many scientific publications especially in the field of engineering. The following chapter describes four different approaches for the planning of product developments, which were found in the course of the literature study (chapter 3.1).

3.2.1 A hierarchical product development planning framework (Anderson, Joglekar 2005)

Anderson and Joglekar propose a framework, which describes a top-down procedure to plan new product developments in four levels of hierarchy. Because of the influence of uncertainties on development decisions they state that on each level the three uncertainty-dimensions market, creativity and processes have to be taken into account. The first level focuses on strategic aspects for the selection of NPD projects considering the enterprise’s market environment, its own technological base and available design resources. Also the timing and budgeting for the selected project are determined from a strategic point of view. The second level comprises a tactical planning of the capacities and resources for this project (acquisition, allocation and outsourcing). Starting from that basis, it then has to be decided if the standard timing and budget will be used. On the next level, the project’s execution is scheduled according to the available capacities and resources. Considering possible uncertainties (e.g. iterations due to changes) the single tasks have to be defined and sequenced. The planning infrastructure is the level on which assumptions are made for the other levels as e.g. technological forecasts, coordination overhead for outsourcing, rework percentage or allowed overtime.

3.2.2 Transdisciplinary planning and synchronization of mechatronic product development processes (Hellenbrand 2013)

For planning product development processes, Hellenbrand differentiates two types in practice: the development of a target process based on the product model and the adaption of an existing or the current project’s process. While the planning of NPD usually starts with the first type, the second type can be seen as its adjustment in later phases. However, Hellenbrand proposes a function-oriented approach, following established procedure models. Essential for this approach is the integrated consideration of the product and process structure. So the product's technical architecture is analyzed from a transdisciplinary view to develop a rough structure of the process. The resulting abstract process plan is analyzed regarding inconsistency and optimization potential to specify the process plan more precisely. The definition of mile stones, in combination with the functional structure, helps to determine sequential dependencies and eventually detailed process steps.

3.2.3 Situational support of the methodical concept development of technical products (Ponn 2007)

Ponn develops an approach to situationally support product development engineers with their daily work, especially with the methodical development of technical product concepts. Thereby the support focuses on the determination of adequate tasks and the determination of adequate methods for their execution. A description model, the fundamental part of his approach consists of four components: a development situation, a description model for the tasks of the development process, a description model for product development methods and a total model that interrelates the other components. Furthermore, Ponn also generates an information library (consisting of a morphology of the development situation, a process toolbox, a method tool box and a correlation matrix), an application method (to describe the usage of the information library for the support of the operative development processes) and a computer embedded tool. The direct context of the development situation describes criteria to differentiate the existing from the target situation. Indirect context factors are taken into account in combination with possible occurrences to select appropriate methods. This enables a user to have an integrated view on the development situation, the tasks and methods.

3.2.4 An instrument for the planning of product development processes (Redenius, Steffen 2004)

Taking the increasing complexity and intelligence of mechatronic systems as well as the numerous dependencies in the product and in the development process itself into account, Redenius and Steffen propose an approach to support the planning of product development processes in this environment based on a case basis and a method tool box with a corresponding software model. The case basis contains detailed descriptions of beforehand successfully realized processes and supplies the developer with know-how and a process template for similar development processes. Design objects (documents to be generated) and elementary actions (to model, to search, to combine etc.) were assigned to established methods and complemented by further attributes (qualification, time, costs, input, tools etc.). Through the usage of this method tool box, the potential developer can choose the exact method that supports his task in the best possible way. The method selection can be specified in the course of the process planning, when more information is available.

3.3 Selection of influencing factors

With regards to the explanation of new product development projects in chapter 2 and the previously described augmented levels of uncertainty during the planning of such projects, the 239 influencing context factors identified by Gericke et al. were at this point limited to 85 factors (table 1) (Gericke et al. 2013).
Uncertainties that are inherent in these context factors have an impact on the planning of NPD processes. For example the "understanding of [customer] need" is marked with a high uncertainty regarding the requirements (design objectives). That has an immediate effect on the certainty of the design object and of the design process. The "qualification of product partners"

on the other hand is marked with uncertainties in the design process and affects the design object and objectives.

Table 1. Selected influencing factors on three levels (Gericke et al. 2013)

Level 1		**Level 2**	**Level 3**
Microeconomic (Market)		Customer	Understanding of Need, Urgency of Need, Expectations, Involvement
Corporate	**a) Company**	Corporate strategy	Clarity of goals, Dynamics of corporate goals, Scope of planning/strategy, Level of risk taking/innovation, R&D/Product development strategy
		Corporate culture	Responsibility, Politics between departments, Cooperation between departments
		Stakeholder	Stakeholder
	b) Management	Management skill	Quality of planning/coordination
Project		NPD	NPD culture, NPD strategy, NPD organization,
		Project management	Project motive, Project boundary, Restrictions, Feasibility of technical requirements, Forecast reliability, Information basis for decision making, Feasibility of schedule, Permitted product cost, Adequacy of organization, Quality of process description, Adequacy of project resources, Qualification of project partners
		Design team	Expertise, Experience, User involvement, Cross-functional interaction
		Design task	Quality of task clarification, Level of constraints/flexibility of requirements, Interdependency/contradiction of goals/requirements, Dynamics of requirements, Complexity, Required knowledge, Available information, Availability of required information, Novelty, Innovativeness, Required quality, Technical risk, Project risk, Knowledge
		Use of design tools and methods	Systematic approach, Flexible approach to change, Formal design methods, Intuitive design methods, Effort related to methods, Sharing of methods across departments, Open-mindedness regarding new methods, Support of communication, Project control, Support of collaboration, Computer design methods, IT support, Codes and standards
		Production	Manufacturing technologies, Batch size - level of standardization of job execution
Personnel		Knowledge	Knowledge base, Experience, Facts, Methods, Heuristic competence, Knowledge applicability
		Skills, competencies	Perception, Use of knowledge, Communication, Creativity, Versatility, Negotiation, Spatial thinking, Analyzing, Synthesizing, Problem solving competencies, Social competencies,
		Individual styles (ways) of thinking and acting	Individual styles of thinking and acting

3.4 Synoptic evaluation of the approaches

Within this chapter the previously described approaches were analyzed regarding their consideration of the selected influencing factors listed in table 1. This comparison is specified in table 2.
Anderson and Jogeklar provide a framework, which addresses fundamental but only generic factors that have to be considered for the planning of NPD. The main strength of this approach is the analysis on the highest hierarchical level, which ensures that the goals of the planned new product are compliant with the corporate strategy (e.g. clarity of goals, dynamics of corporate goals, R&D/product development strategy) and goals. Also the strategic and organizational boundaries of the NPD project (e.g. NPD strategy and organization) are determined by the higher management. So uncertainties regarding these high level decisions are minimized. But this framework does not contain detailed support for determining and planning the project's process steps and their outcomes. Especially the estimation of uncertainties occurring at the operational level, caused by the individual's knowledge and experience, which has a high impact on the overall performance, is not supported adequately.

Hellenbrand's approach, on the other hand, offers a very detailed determination of the product's functional structure and consequently of the development process steps. So the identification and estimation of uncertainties regarding the design task (e.g. functional requirements and their interdependencies, complexity of the product structure, required information) is very well supported. Although general strategies for determining a risk reduced sequence of the development activities is proposed, required information for a detailed prescheduling about the probability and consequences of risks as well as alternatives cannot be derived. Also, the derivations for the individuals' context and tasks at the operational level are only insufficiently supported. Furthermore the project's scheduling cannot be generated with this approach but has to be made separately.
Ponn's description model and its corresponding information library, application method and IT tool take almost all influencing factors into account. His approach focuses on the support of product developers in their daily work. So, he explicitly considers the factors that influence the actual realization of the project. However, the approach regards the specific development situation, in which the projects take place and with that also the know-how, skills, competences and thinking of the individuals working on the project. Thus, he focuses on the short- and mid-term context. The influencing factors resulting from the customers, stakeholders or the management are only marginally dealt with.

Table 2. Comparison of selected influencing factors with research approaches

	Author	**Anderson/ Joglekar (2005)**	**Hellenbrand (2013)**	**Ponn (2007)**	**Redenius/ Steffen (2004)**
	Approach	A hierarchical product development planning framework	Transdisciplinary planning and synchronization of mechatronic product development processes	Situative support of methodical concept development of technical products	Instrument for the planning of product development processes
	Category	Framework	Procedure	Methodology	Instrument
	Additions	-	Function-oriented process modell	Method and process tool box	Method tool box and case basis with processes
View	**Product type** / **Level 2**	Technical products	Batch produced mechatronic systems	Technical products	Mechatronic systems
Macro	Customer	◑	○	○	○
	Corporate strategy	●	○	◑	○
	Corporate culture	○	○	◑	○
	Stakeholder	○	○	○	○
	Management skill	○	○	○	○
Meso	NPD	●	○	◑	◑
	Project management	◑	◑	◑	◑
	Design team	○	◑	●	◑
	Design task	○	●	●	◑
	Use of design tools and methods	◑	◑	●	●
	Production	○	○	◑	●
Micro	Knowledge	◑	◑	●	◑
	Skills, competencies	○	○	◑	○
	Individual styles (ways) of thinking and acting	○	○	◑	◑

○ = not considered ◑ = partially considered ● = fully considered

To reduce the degree of uncertainty in the product development, companies are ambitious to rely on familiar definitions and familiar knowledge (Lohmeyer 2013). Redenius and Steffen use this idea within their practical planning instrument by incorporating a case basis with know-how from previously realized processes. Their approach focuses on the project itself and how it can be handled. The individual skills of employees are considered but not holistically incorporated. The macro view onto a development project regarding the company's corporate strategy, culture or the customer requirements is not regarded at all in contrast to Anderson's and Joglekar's framework.

4 Discussion and Outlook

Based on an extensive literature review, the complexity and heterogeneity of planning processes within product development projects is shown. Four selected methods and approaches supporting planning processes for technical products are analyzed and compared with a list of relevant influencing factors, identified in previous studies. The results demonstrate that the existing approaches only cover specific areas whereby two trends can be observed. On the one hand, there are approaches that mainly consider strategical factors (e.g. project objectives) while excluding the operational level (e.g. design task, dynamic of product requirements). On the other hand, some approaches are doing precisely the opposite. Only Ponn rudimentarily manages to combine these two dimensions. Within his planning approach uncertainties resulting from personal experiences and know-how are considered sufficiently, but it is only possible to choose between "no/yes" answers regarding the knowledge about certain other factors. Depending on the answer, process steps or methods are suggested, without analyzing their impact on the project objectives (schedule, cost, quality). However this connection has to be established in further researches, in order to minimize uncertainties in NPD effectively. Several uncertainty response options are conceivable, which result in different development processes and in turn will influence the risk of not achieving the project' objectives.

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