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Categories of product innovations – A prospective categorization framework for innovation projects in early development phases based on empirical data

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Abstract

Most of the categorization frameworks for innovation projects in early development phases are not designed for supporting the product engineer in decision making and leave space for further improvement. Based on empirical data from 13 innovation projects, the authors introduce a novel categorization framework for innovation projects and discuss the relevance of identified key criteria. The focus is to provide a fundamental understanding of the varieties of product innovation projects and establish a basis for decision support frameworks regarding the adoption of tools and methods.

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Keywords: Innovation Support; Decision Support; Product Profiling; Innovation Projects; Early Development Phases; Key Criteria

1. Introduction

The product profiling approach by Albers et al. [1], which enables a systematic identification and description of potential innovation tasks and the selection of the most promising ones, supports the product engineer particularly in early development phases. The successful application of the approach depends on the specific situation and requires a profound understanding of the type of innovation project. However, the variety of innovation projects cannot be specified sufficiently by existing categorization frameworks, thus the situational adoption of such a methodical procedure cannot be explained or even optimized systematically. This matter leads to the research need for categorizing innovation projects from an application-oriented perspective, in order to support a systematic adoption of methods using the example of the product profiling approach. Due to the lack of suitable categorization frameworks in literature, a novel framework is introduced based on the data of 13 industry innovation projects.

2. State of the art

In economic sciences the concept of innovation leads back to Schumpeter [2], who evaluates innovations as necessity to be successful in the market. These innovations can be understood as successfully established inventions in the market. A general distinction of innovations can be made in product and process innovations [3]. The influence of innovations on an organizational level is discussed widely in literature [4] [5].

Further categorizations of product innovations often use the degree of change to an existing product or the newness [6] to differentiate, which often leads to a description in incremental and radical innovations [7] [8]. The underlying reason is mainly technological change [9]. This categorization of innovations is often the starting point for further detailing.

Henderson and Clark [10] promote an architectural categorization of innovations and distinguish product innovations further in incremental innovations, architectural innovations, modular innovations and radical innovations, which differ in the degree of architectural variation and the resulting economic potentials. Balachandra and Friar [11] developed a contingency framework for new product

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development and R&D projects consisting of three dimensions: innovation (incremental-radical), market (new-existing) and technology (low-high). A fourth dimension, the nature of the industry, is also discussed. In an extensive literature review Crossan and Apaydin developed a multi-dimensional framework of organizational innovations [12], in which they distinguish between determinants (leadership, managerial levers, business processes) and dimensions of innovations (process, outcome). Recent research also sets focus on service innovations. Snyder et al. give an overview of possible categories for this business sector [13].

One major problem of classifications based on the differentiation between incremental and radical innovations is that it can only be assessed retrospectively whether a product was successful on a market and therefor represents an innovation. A concept, which uses the underlying idea of planning the degree of product change, is Product Generation Engineering (PGE) as new design research perspective according to Albers et al. [14]. Following a similar understanding Shenhar et al. [15] use a two-dimensional taxonomy consisting of the system scope and the technological uncertainty. Ringen et al. [16] introduce an application-oriented approach to categorize product innovations. By the examination of automotive suppliers they differentiate between the newness to the firm and the newness to the market.

As every product development process is unique [17] one major challenge is to give methodical design support. Therefor further categorization criteria need to be taken into account. From a product engineering perspective Ehrlenspiel et al. [18] propose a much more feature-based categorization of innovations. In addition to the novelty for the user group, product life cycle terms are taken into consideration. Criteria like uncertainty and complexity are mentioned as well. In addition, a distinction between material innovations is made for processes and products as well as intangible innovations in form of software or services. Ponn and Lindemann outline development situations by using characteristics as product type, market, customer or development objectives [19].

As previously shown various aspects of describing and categorizing innovation projects are discussed in research extensively. But shortcomings need to be stated, too. Especially an applicable categorization of innovation projects in early development phases to support the product engineer in understanding the development situation and decision making show a necessity for further improvement.

The literature acknowledges the so-called early phase of innovation processes as particularly relevant [20] [21] [22]. This is mainly because the early decisions in this period have major impact on the dimensions of cost, quality and development time for the following product development project [23]. Central activities in the early phase of innovation processes are especially the elaboration and evaluation of new product ideas [24] [25] [20].

The determined implementation of those activities can be supported by using product profiles. Therefore, product profile detection is one of the core activities in the integrated Product engineering Model (iPeM) [26]. Its main output object is the product profile. The product profile represents the first coherent and summarizing description of the innovation task in the early phase of product development, which serves as an evaluation and decision-making basis for innovation projects. During the activity alternative product profiles are elaborated and through several iterations one verified product profile is selected, which defines the future product in its main characteristics [26]. In this context, the estimated user benefit of the technical solution is of major importance as well as the benefit for the supplier [18]. By providing an early focus on the customer and supplier benefit for the innovation task, very iterative and thus costly product inventions are avoided. Especially the limited technical detail in the description allows a broad range of alternative product profiles without the time consuming factors of CAx-design. Based on this, the following definition for product profiles can be stated:

The product profile defines a demand situation in the market, taking into account the objectives, requirements and constraints of relevant stakeholders and emphasizes both, the anticipated customer and supplier benefits. Therefore, the product profile characterizes the future product with limited technical detail in its basic characteristics, including core functions and properties as well as associated use cases and core technologies.

3. Methodology

The overall objective is the deduction of different types of innovation projects and corresponding types of product profiles, based on empirical data. Therefore, it is necessary to introduce a suitable categorization framework for types of innovation projects first and then allocate the types of product profiles within this framework. The identification of relevant emphases between these different types of product profiles is based on the used appraisal criteria in the empirical data.

Therefore, the paper is build on the process documentations and the results of 13 innovation projects. The variety of the innovation projects corresponds to the different innovation topics and the annually changing project partners from various industries. Thus the initial system of objectives in the beginning of the project varies strongly concerning its type, range and complexity. Within the scope of the project, up to 42 students in five to seven teams work on specific innovation tasks, in the range of a search field defined by the project partner. The students are provided with reference processes including methods and tools and furthermore receive tutoring and supervising from experts. The project, with a duration of five months, breaks down into five phases. In the initial phase, the students come to grips with the topic and narrow down the search field. In the following project alignment phase, the teams have to develop several alternative product profiles within four weeks and select a range of three to five product profiles each for a quality gate with the industrial partner. For the empirical study, the projects listed in Table 1 were analyzed in detail. The listing of the projects illustrates the wide variety of project partners and topics.

Table 1. Overview of project partners and topics of the last 13 years

Partner, Year	Topic of innovation project
AVL, 2015/16	Innovative battery systems
Schaeffler, 2014/15	Systems to support mobility for elderly people
Daimler Trucks, 2013/14	Innovative driver-cabin concepts for trucks with alternative drives
Wittenstein Alpha, 2012/13	Clever integration of mechanical drive systems

Trumpf, 2011/12	Technologies for sheet metal machining
Voith, 2010/11	Innovative pulp preparation
B/S/H, 2009/10	Innovative solutions for vapor deduction for the kitchen 2020
STIHL, 2008/09	Planting, cultivating and harvesting in 2020
BLANCO, 2007/08	The washing center of the future
HILTI, 2006/07	Hammer drills of the future
Freudenberg, 2005/06	Drinking water systems of the future
LuK, 2004/05	Drivetrain 2015
STIHL, 2003/04	Innovative hand carried machines for the sector lawn and garden

During the quality gate, at the end of the project alignment phase, every team presents three to five of the self-developed product profiles to convince the project partner of their favorite innovation task. Thereby the teams utilize a variety of methods and different appraisal criteria, to substantiate the resilience of their purposes.

In total, 298 acquired product profiles out of the 13 listed projects were evaluated. The appraisal criteria, which served the selection of the three to five presented product profiles, were ascertained in detail out of the presentation documents, the appraisal tables and the project documentations of each team and were checked for consistency. In the first step, the resulting 3002 project-specific criteria were standardized based on the available context information (e.g. definitions and comments) and thus 91 specific criteria resulted. Furthermore, this standardized, yet case-specific criteria were aggregated on a generic level to 48 categorized criteria (e.g. assembling safety was assigned to Security & Safety). The categorization of the 3002 criteria, as well as the attribution of the 298 product profiles to the framework, happened within overall five workshops within the group of authors.

For the differentiation of the innovation projects, so-called key criteria were determined based on the 48 categorized criteria. At the beginning of the data collection and analysis, the following requirements were stated to ensure the resilience of the key criteria:

The key criteria have to be part of at least 10 of the 13 innovation projects and have to be covered by each category of the categorization framework for product profiles introduced in the following (Fig. 2). Accordingly, the key criteria depict must-be-criteria, which are used within all types of product profiles and are considered for planning, description and selection of innovation tasks.

4. Categorization framework

Based on the state of the art two dimensions for a categorization framework for innovation projects resulted as particularly relevant from the product engineer’s perspective:

The dimension Customer Relation describes the kind of relationship to the customer from the view of the individual company. The top level distinguishes between Business-to-Business (B2B) and Business-to-Consumer (B2C). There is a further separation on the next level, whether it is about a physical product or a service product. In case of a physical product, the current supply pyramid is integrated. Thus a differentiation between an original equipment manufacturer (OEM), a system supplier (Tier 1), a component supplier (Tier 2) and a part supplier (Tier 3) is built-in [27]. Ponn and Lindemann also consider this differentiation as a significant influence on the development situation [19].

The identification of the suitable technologies is an essential sub objective in early phases of innovation projects, in order to reduce technological uncertainty. Especially the so-called Core Technologies are in focus. These are technologies, which are required to realize the essential functions and properties of the product profile. This aspect of technological uncertainty, also implemented by Shenhar et al. [15], is considered in this framework through differentiating the degrees of technological mastery from the perspective of the product engineer according to Table 2.

Table 2. Characteristic degrees of mastery for Core Technologies

Degree of Mastery	Description
In Research	Potential core technologies are part of the fundamental research or applied research and have not been implemented in the market yet
In Market	Potential core technologies are commercialized in the market, but not in the same industry
In Industry	Potential core technologies are commercialized in the industry, but not in the considered company
Within the Company	Potential core technologies are already commercialized and mastered by the considered company

The categorization framework for innovation projects, shown in Fig. 1 focuses solely on the so-called System-in-Development [28], which describes the predefined design space for the development team wherein an engineering influence is possible. This System-in-Development bears interrelations to sub, as well as to super-systems according to Ropohl [29]. The resulting categorization framework covers in total 28 categories of innovation projects.

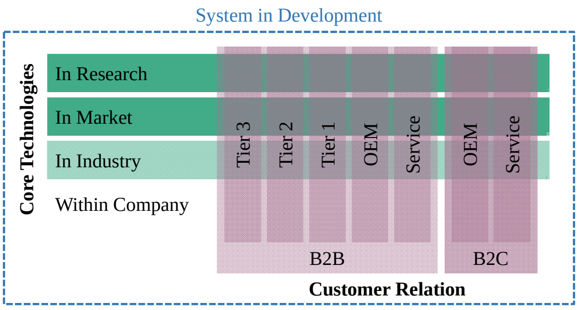

Fig. 1. Categorization framework for innovation projects

Based on the introduced empirical data and the categorization framework for innovation projects, shown in Fig. 1, corresponding types of product profiles were identified. Thus a categorization framework for product profiles results, shown in Fig. 2. Due to resolution-based restrictions of the empirical data in the course of the analysis, the identified amount of corresponding types of product profiles is limited to a total of six. This means that there is merely a differentiation between B2B and B2C along the axis Customer Relation. Furthermore, the characteristic levels In Research and In Market are consolidated along the axis Core Technologies. The resulting categorization framework for product profile types, shown in Fig. 2, serves in the following as basis for the identification of the relative emphases of each category based on the introduced key criteria.

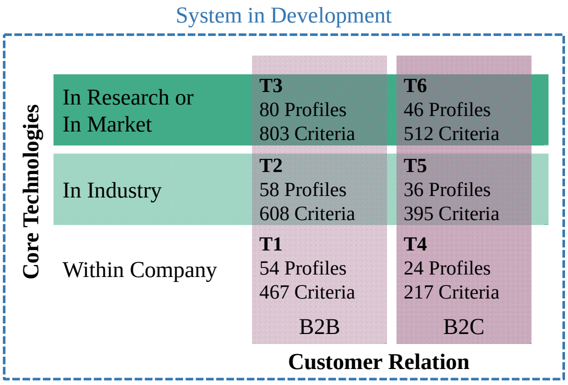

Fig. 2. Categorization framework for product profiles

5. Identification of key Criteria

Based on the assignment of the 298 product profiles to the six types of product profiles T1 to T6, as shown in Fig. 2, the corresponding key criteria are identified and analyzed in the following. In average, between eight and eleven project-specific criteria were valued for each product profile. According to the objective, to identify the most reliable key criteria, they have to be part of at least 10 of the 13 annual innovation projects and have to be covered in each type of product profile T1 to T6. Thus, the cross-influences of the initially defined system of objectives on the selection of criteria are avoided. Based on the 48 categorized criteria, 13 key criteria were ascertained. The resulting 13 key criteria are listed and explained in the following Table 3.

Table 3. Description of the key criteria

Key Criteria	Description
Technical Feasibility	Rating of the technical feasibility of the innovation task
Technical Degree of Novelty	Rating of the expected amount of novelty in comparison to the previous product generation
Future Robustness	Accordance with trend and scenario development concerning technology, market and customers
Total Cost of Ownership	Rating of the expected total operating costs, from the customer point of view
Economic Feasibility	Rating of the economic feasibility of the development project
Sales Potential	Quantitative sales, which can be achieved under favorable conditions
Differentiation Potential	Rating of unique selling propositions in comparison to competitive products
Functionality (Customer)	Satisfiability of the functional requirements (esp. Performance requirements) of the customer
Corporate Identity	Accordance with the corporate values (culture, philosophy and vision)
Schedule Feasibility	Rating of the schedule feasibility of the innovation task
Cumulated Market Volume	Rating of the expected market demand concerning the defined target group(s)
Target Group Size	Expected size of the aimed target group
Target Group Acceptance	Expected acceptance of the target group

To confirm the relevance of the key criteria for each of the analyzed development teams, an average rate of usage concerning the used key criteria per team is shown in Fig. 3.

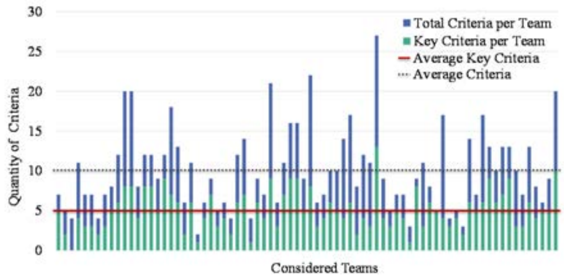

Fig. 3. Used criteria and used key criteria per team

As shown, an average quote of five used key criteria per team can be evidenced. Furthermore, it can be observed, that the coverage rate of key criteria among all the analyzed teams is relatively high. Thus, it can be concluded that the identified key criteria have an evident importance across the different innovation tasks and teams.

6. Data evaluation and implications

Based on the categorization framework of product profiles (Fig. 2) and the allocated key criteria, the emphases of each category are identified and the implications are discussed in the following. Hereby, the percentage frequency of the key criteria, shown in Fig. 4 serves as indicator for the relative relevance of the key criteria within one product profile type. The coverage of how many teams used the considered criterion is an indicator for the relative relevance of the key criteria among all teams. These cover intra-company criteria (supplier perspective) as e.g. Technical, Economic, Schedule Feasibility and Future Robustness, as well as criteria with the focus on the view of the customer and market, as e.g. Total Cost of Ownership, Functionality and Cumulated Market Volume. Through the percentage frequency of the key criteria, the emphases of the product profile types are determined in accordance to Fig. 2.

The key criteria Technical Feasibility and Technical Degree of Novelty occur at every profile type with a superior dominance. Especially in the case of the profile types T3 and T5 (cf. Fig. 2) an increasing relevance of Technical Feasibility is detected. This can be explained due to the rising uncertainty concerning the used core technologies. The Technical Degree of Novelty shows a heightened relevance in the case of T1, T4 and T6. In case of T1 and T4, this can be explained with a higher need for product differentiation. In the event of T6, the peak is attributed to a raised uncertainty.

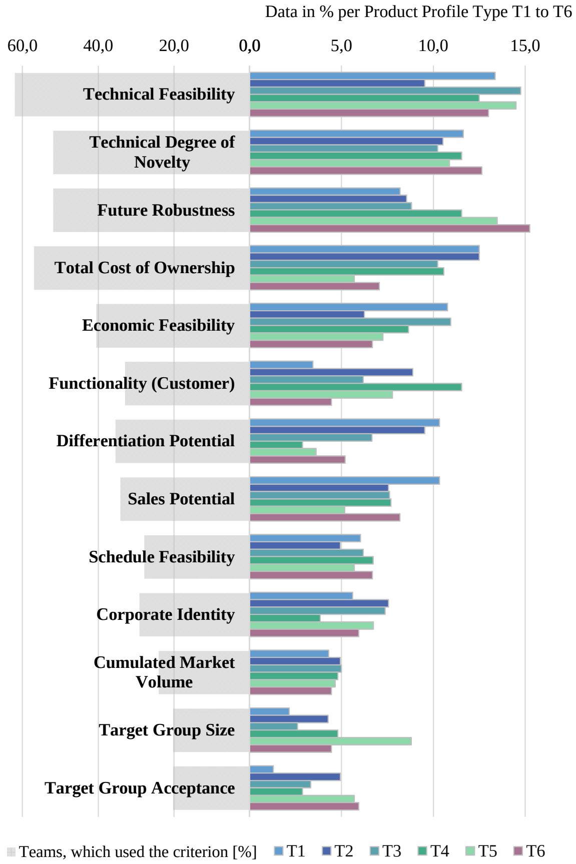

Fig. 4. Key criteria per product profile type T1 to T6

The criteria Cumulated Market Volume, Sales Potential and Schedule Feasibility show, in comparison to the previous criteria, a relatively steady frequency distribution over the several types of product profiles. However, the outliers at T1 and T5 concerning Sales Potential cannot be explained.

The criterion Total Cost of Ownership shows especially in the B2B-section of the categorization framework an above-average frequency. This can be explained with the high focus on cost saving in the B2B-industry. In the B2C-section, the criterion is used more often concerning established technologies (T4). This can be attributed to the higher price sensitivity of the customer target group in this product profile type. In contrast to that, the profile types T5 and T6 tend to address the Early-Adopter, thus the criterion becomes less important.

The frequency distribution of the criterion Future Robustness demonstrates an increasing emphasis in the B2C-section T4 to T6, especially for the types T5 and T6 (concerning in the company unknown core technologies) a superior importance can be recognized.

Particularly in the case of service providers and suppliers (in the B2B-section), the criterion Economic Feasibility gains in importance concerning T1 (established technologies with a very low target of manufacturing costs) and concerning T3 (novel technologies with a high economic uncertainty).

The criterion Functionality (Customer) becomes significantly less important for the product profile types T1 and T6. In the case of T1, the emphasis changes from performance requirements towards basic requirements. This leads possibly to a decreasing importance of Functionality and an increasing importance of Economic Feasibility. Whereas in case of the product profile type T6, a displacement to the excitement requirements takes place.

The Differentiation Potential towards competition plays as criterion a superior role especially for T1 to T3 in the B2B-section. Here it appears very dominant particularly at core technologies, which are mastered in the company (T1) resp. mastered in the industry (T2), due to a high intensity of competition.

The criterion Corporate Identity is informative about whether an innovation task is compatible with the corporate values as culture, philosophy and vision. At this, it is obvious that the criterion gains consistently in importance, just as technologies are used, which are new to the company.

The criterion Target Group Size exhibits in the B2C-section a slight higher frequency, especially concerning known core technologies (T5) in industry it is with utmost importance. Analogous to that, a similar constellation with a local maximum at T2 can be regarded in the B2B-section. In both cases, the market is characterized by an intense competition in industry, which is made difficult through the technological advantage of the competitors.

The Target Group Acceptance plays as criterion especially in the B2C-section T5 and T6 a greater role. This is possibly attributed to a higher uncertainty in regards to the technology diffusion within the target group.

Based on this empirical data and qualitative analysis it can be stated that the relevance of many key criteria is corresponding to the product profile type and thus correlates with the kind of the innovation project. Furthermore, the reasons for these correlations can be explained on basis of the categorization framework for most cases and thus the applicability of the presented model is confirmed. Based on this empirical study, first implications for innovation projects and corresponding product profile types can already be deduced. At first, the generic definition of product profiles should be extended by the aspects of product costs and prizing, as well as technical, economic and schedule feasibility. Additionally, it can be determined that criteria with a constant distribution, e.g. Schedule and Technical Feasibility demonstrate the necessity for appropriate process standards in the reference process. Whereas the distribution of criteria, e.g. Total Cost of Ownership or Future Robustness implicate a much more focused use of methods. The necessity of related methods and tools should be carefully reviewed.

Before this data can be implemented in a specific support framework, further validation based on industry processes is necessary. The insights can be used for the optimization of process and resource control in the early development phases, as well as the linkage to suitable methods and tools in general.

7. Conclusion and outlook

The introduced approach of product profiling by Albers et al. [1], which enables a systematic identification and description of potential innovation tasks and the selection of the most promising ones in early development phases, has been developed continuously over the years. However, the successful application of the approach depends on the specific situation and requires a profound understanding of the type of innovation project. This matter leads to the research need for categorizing innovation projects from an application-oriented perspective. Therefore, the aim of this contribution is a categorization framework, which provides, through the determination of the innovation project types from the product engineer's perspective, an adoption of tools and methods. Due to the variety of innovation projects, which could not be specified sufficiently through existing categorization models, a novel categorization model with a total of 28 categories is introduced as part of this contribution. This categorization framework is applied to the introduced product profiling approach. The resulting categorization framework for product profiles covers six categories, which were identified and analyzed on the database of 13 industry innovation projects. Through the evaluation of the percentage frequency of the used key criteria in all of the 13 projects, the different emphases of innovation project types and their corresponding product profiles were demonstrated. The resulting implications for the product profiling approach will be validated in the upcoming industry projects in 2016/17. The medium-term aim is to use the empirical data and implications for the product profiling approach for the advancement of an already-existing software-application for decision support [30] in the product development process. Apart from that, this paper provides points of reference for further research based on the applied methodology and the identified criteria.

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