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Validity Criteria for Need and Benefit Situations in Early Stages of Product Engineering Projects

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Abstract

To stay competitive and meet market demands, innovation is crucial. Innovation is the successful realization of a novel concept that benefits customers, users, and providers. This need and benefit situation is captured in the product profile, which describes a product's needs without specifying a solution. A valid product profile is essential for successful product development and advancing high-potential inventions. This publication presents seven validity criteria identified through two expert workshops from research and industry and evaluated through three case studies of different innovations like Apple iPhone, Amazon Fire Phone and Thermomix by assessing the deltas in benefits and use cases.

Keywords: Early Product Engineering Projects; Validation; Need and Benefits; Validity Criteria;

1. Innovation as a Driver for Society

An increasing number of consumers are supporting sustainable consumption habits, such as switching to vegetarian or vegan foods. Plant-based substitutes, particularly meat alternatives, have become increasingly popular due to the heightened awareness among consumers of the benefits of this diet for their health and the environment [1]. Innovations in the food market and technological breakthroughs in the course of Industry 4.0 have paved the way for new generations of food products and production methods [1], [2].

Given the high failure rate of newly developed products, it is important to transform the motivation for developing a product into a technical solution that meets a market need [3]. The early phase of an innovation process is particularly relevant, as the scope of decisions made early on is significant. The early phase is associated with a leverage effect that, if the right decisions are made, saves costs and resources in the later process. [4]

To support these decisions, a validated need situation is required. Therefore, the following chapter presents the state of research by introducing the product profile in the context of the innovation understanding according to Albers et al. as a modelling and representation possibility for the need situation and the challenge of validating it early on. [3]

2. Product Profiles as a Critical Part of Innovation

Albers et al. define innovation as the successful market implementation of a new idea or invention that provides additional benefits to customers, users, and providers. They highlight three elements: the product profile, the invention, and market diffusion. The invention addresses a specific need with a technical solution, while market diffusion involves the product's market presence and penetration. The product profile outlines the need and specifies the benefits for validation and design. The product profile describes the product in a solution-open manner, that means no specific solution principle is presented to solve the problem. [3] One purpose of the product profile is to validate the need and benefit situation [3]. The continuous validation of product profiles in early phases is critical in product engineering, but phases different challenges.

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Based on literature, Schwarz et al. introduce four fields of action (FoA) to meet the challenges of continuous and early product profile validation [5]: Enabling situation & need adequate stakeholder integration (I), Enabling the selection of the validation method (II), Enabling solution-open prototyping (III) and Enabling the interpretation of the validation findings (IV). Schwarz et al. point out that these fields of action need to be addressed by design support to enable the early and continuous validation of product profiles. In the last field of action in particular, it is important to assist developers in interpreting whether a product profile is valid. For this purpose, validity criteria for product profiles are needed, which developers can refer to. [5] Existing criteria for the validity of product profiles either focus on only one aspect such as innovation potential [6], future robustness [7] and risk [8] or are not applicable to early phases of development projects such as Kano [9] or maturity level [10]. Therefore, a consolidated and applicable list of validity criteria defined from practice is necessary to support developers in early phases of projects.

3. Research Profile: Goal, Question and Approach

Based on the previous chapter, the objective of this publication is to derive and evaluate validity criteria for a product profile to support and improve the assessability of the probability of the product profile's validity. To operationalize this aim, a total of three research questions have been derived, which will be answered in this publication:

- RQ1: Which statements can be derived by experts in product development and profiling regarding a valid product profile?
- RQ2: Which validity criteria can be clustered and described based on these statements?
- RQ3: How can the validity criteria be evaluated by referring to retrospective case studies?

To answer the first research question, a workshop based on the Think-Pair-Share method was conducted with two independent groups of experts from food industry and participants of the Live-Lab ProVIL [11] to identify practical statements about a valid product profile. The Think-Pair-Share method begins with the independent answering and writing down of the results regarding a defined question (Think) to then discuss them with partners (Pair). These results are then presented in plenary (Share). [12] By clustering these results, the validity criteria are synthesized for answering the second research question. The third and final research question was answered through a delta analysis, which described the deltas between 2 to 3 retrospectively modelled product profiles in three case studies. Following case studies were conducted for this purpose:

- Case Study I: Introduction of the first iPhone 1
- Case Study II: Introduction of the Amazon FirePhone
- Case Study III: Introduction of the Thermomix 6th Generation

To evaluate the criteria, the commonalities and differences of the product profiles were analyzed, specifically the deltas between the benefits and use cases.

4. Workshop for Identifying Validity Criteria of Product Profiles

To answer the first research question, a workshop was designed, conducted, and the obtained results were analyzed. The workshop was conducted with two different groups of experts. Groups A and B can be distinguished by their expertise in product profile modelling and product development (see Table 1).

Table 1. Participants of the Expert Groups A (PA) and B (PB) with their relevant characteristics

Participants of the Expert Group A (Industry Experts)			
PA#	Years of Experience	Experience in Need Validation	Experience in Product Profile
PA1	10 - 15 years	Middle	Low
PA2	10 - 15 years	High	Low
PA3	10 - 15 years	Middle	Low
PA4	>15 years	Middle	Middle
PA5	10 - 15 years	High	Low
PA6	>15 years	High	Low
PA7	10 - 15 years	Middle	Low
PA8	>15 years	Middle	Low
Participants of the Expert Group B (Product Profile Experts)			
PB#	Years of Eng. Experience	Experience in Validation	Experience in Product Profile
PB1	1-3 years	Middle	High
PB2	<1 year	Low	High
PB3	1-3 years	Low	High
PB4	1-3 years	Middle	High
PB5	1-3 years	Middle	High
PB6	<1 year	Low	High
PB7	1-3 years	Middle	High
PB8	<1 year	Low	High
PB9	<1 year	Low	High

The workshop was divided into three parts: introduction, working, and conclusion phases. In the introduction phase, participants were introduced to and trained on the product profile. They were educated on the importance of the product profile in the context of innovation management and on modelling the product profile template. This ensured the participants' expertise and understanding of the product profile. In the working phase, participants were asked to use the Think-Pair-Share method to answer the following question based on their experience in product profile development: "*When is a product profile valid?*". First, participants answered the three questions individually and recorded their results on moderation cards. Then, they discussed their commonalities and

differences in tandems or triplets and presented the team results to the plenary. Initial results were clustered during the plenary session. In the conclusion phase, the results were clustered through discussion in the plenary to consolidate the identified criteria within the individual expert groups.

The following presents the two core results of the two workshops: the individual statements from the teams in the pair-share step and the final criteria within the expert group. Within the workshop with expert group A, a total of 24 validity criteria for a valid product profile were identified by the 8 experts (see Table 2). The individual statements were presented by pairs during the share part of the workshop.

Table 2. 22 Statements from expert group A regarding the question: When is a product profile valid?

Tandem #	Statements (*SA#*)
Tandem 1 (PA1 & PA4)	"Our solution solves a problem." (*SA1*)
	"Our solution excites the market." (*SA2*)
	"We can implement this." (*SA3*)
	"We understand the risks." (*SA4*)
	"It brings a sparkle to people's eyes." (*SA5*)
Tandem 2 (PA3 & PA2)	"The sources of the information are clearly documented and verifiable." (*SA6*)
	"Relevant in the future; we can assess future risks." (*SA7*)
	"There is a problem on the market." (*SA8*)
	"We use trustworthy and transparent data sources." (*SA9*)
	"The product excites our customers." (SA10)
	"The skills needed are available internally or known." (*SA11*)
Tandem 3 (PA6 & PA8)	"Positive reactions from users." (*SA12*)
	"There is an underlying problem." (*SA13*)
	"High demand." (*SA14*)
Tandem 4 (PA5 & PA7)	"The customer is willing to pay." (*SA15*)
	"Costumer: We are investing in the product." (*SA16*)
	"Customers are interested." (*SA17*)
	"We can manage the risk." (*SA18*)
	"The product improves something." (*SA19*)
	"We have the resources." (*SA20*)
	"The better benefit to the end user is clear." (*SA21*)
	"The product offers clear added value for customers." (*SA22*)

In the workshop with expert group B, a total of 17 statements regarding validity criteria were made by 9 experts (see Table 3). The individual statements were presented by triplets during the share part of the workshop.

Table 3. 17 Statements from expert group B regarding the question: When is a product profile valid?

Triplet #	Statements (*SB#*)
Triplet 1 (PB1, PB2, PB3)	"It has added value." (*SB1*)
	"We can implement a product solution in the project." (*SB2*)
	"Excitement among project partner." (SB3)
	"The solution is accepted." (*SB4*)
Triplet 2 (PB4 & PB5 & PB6)	"Show where the information comes from." (*SB5*)
	"Interest from customers and users." (*SB6*)
	"We comprehensively document our methods and data." (*SB7*)
	"We highlight where the risks are." (*SB8*)
	"We show where the problem lies." (*SB9*)
	"Our results demonstrate the added value." (*SB10*)
	"Transparency in the product profile contents." (*SB11*)
Triplet 3 (PB7 & PB8 & PB9)	"Able to assess the changes and derive the risk." (*SB12*)
	"It is better and we make it better." (*SB13*)
	"Our team is qualified for this." (*SB14*)
	"Future relevance." (*SB15*)
	"There is somebody who buys it." (*SB16*)
	"Technical feasibility and team capability are suitable." (*SB17*)

The statements from the individual workshops and experts were subsequently clustered into a total of seven categories, which correspond to the validity criteria. The clustering of the individual statements can be found in Table 4.

Table 4. Seven identified validity criteria by clustering of the statements from expert group A and B

Statements (SA# & SB#)	Clustered Validity Criteria
SA6, SA9, SB5, SB7, SB11	Traceable information basis
SA1, SA8, SA13, SA19, SB9	Underlying problem
SA14, SA15, SA16, SA17, SB4, SB6, SB16	Confirmed demand and willingness to invest
SA3, SA11, SA20, SB2, SB14, SB17	Capabilities
SA4, SA7, SA18, SB8, SB12, SB15	Assessable development risk
SA21, SA22, SB1, SB10, SB13	Added value
SA2, SA5, SA12, SB3	Triggering enthusiasm

The identified validity criteria will be described in more detail in the following chapter to answer the second research question.

5. Describing Validation Criteria of Product Profiles

Based on the clustering, a total of seven validity criteria were identified. These validity criteria can be divided into three overarching categories: descriptive, qualitative, and affective.

In the descriptive validity criteria, the validity of the product profile is defined by the description and summary of information. The validity criterion of traceable information

examines the source of the individual pieces of information in the product profile. The information included in the product profile must be accompanied by its origin to ensure traceability. The criterion underlying problem requires checking whether a problem is described in the product profile. This refers to Dörner's problem description, where a problem is defined by a delta between the actual and target state, with a barrier preventing the transition [13]. Additionally, the product profile must verify confirmed demand and willingness to invest, where the target market and a possible price must be confirmed by the customer.

Qualitative validity criteria determine validity through expert evaluations. One qualitative criterion is the necessary capabilities within the company, which examines whether the necessary capabilities currently exist and are substantiated. Capabilities describe the competencies, personnel, and capacities that exist within the company. The criterion measurable development risk assesses the level of risk concerning change and future. Change risk describes the extent of necessary changes [8] to fulfil the product profile, while future risk describes the future robustness of the product profile [7]. The final qualitative validity criterion, existing added value, examines whether the product profile stands out from current products on the market in both vertical and horizontal markets. It describes a benchmarking of the references regarding the benefits for provider, costumer and user.

Affective validity criteria correspond to criteria determined by customer perception. This includes the criterion of triggering enthusiasm, which describes whether the benefits in the product profile, prioritizing value-adding benefits, trigger enthusiasm in the customer or user. This can be achieved through indirect and direct stakeholder integration.

These seven validity criteria support product developers in assessing the validity of the product profile and can be iteratively and continuously referenced in the product profile creation process. Since these criteria were developed from a workshop and defined by the participants' expertise, they need to be further evaluated. The following chapter evaluates the criteria based on four case studies, analysing the product profiles of successful and failed inventions concerning the product profile of the status quo in the market.

6. Evaluating the Validation Criteria Using Case Studies

The content of the case studies involves elaborating on the deltas and commonalities between the product profiles to evaluate the validity criteria. The four case studies were selected to analyze, on the one hand, a disruptive innovation, incremental and technological innovation, and on the other hand, a failed innovation. The following chapter briefly introduces the case studies and then presents the deltas and commonalities in the product profiles. Finally, the case studies are used to evaluate the validity criteria. The approach is described in figure 1 based on the first case study.

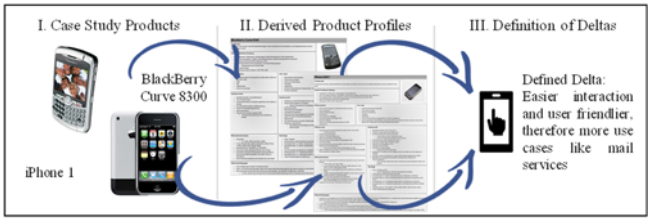

Fig. 1. Approach to the description of the deltas using the example of Case Study I. iPhone image derived from [14] and BlackBerry Curve 8300 image derived from [15]

6.1. Case Study: Black Berry and Apple iPhone

Within 74 days, 1 million units were sold, and by January 2008, 4 million units had been sold [16]. It made Apple one of the most profitable companies and fundamentally changed the smartphone industry [17]. The BlackBerry Curve 8300, also introduced in 2007, was popular among business customers due to its keyboard and email functions [18]. However, RIM failed to transition to touchscreen devices in time, leading to a decline in sales from 2011 onwards. BlackBerry could not compete with the iPhone and Android devices [19]. Therefore, this case study is seen as a disruptive innovation because the mobile phone market was revolutionized by the introduction of the smartphone.

Both the iPhone and BlackBerry enabled phone calls and offered multimedia functions. Both devices were, in a way, status symbols at the time and allowed for photography. The iPhone had the following deltas compared to the BlackBerry. The iPhone offered full web browsing and a significantly better internet experience than the BlackBerry, whose internet usage was rather rudimentary. Both devices offered multimedia functions, but the iPhone presented these in higher quality and a more intuitive form. It was more user-friendly and intuitive than the BlackBerry and was perceived as something new and exclusive, making it a status symbol. The iPhone facilitated access to information through its user-friendly interface and capacitive touchscreen, while the BlackBerry had a QWERTY keyboard. The iPhone was a mass-market device, while the BlackBerry was more targeted at business people and companies. Conversely, the BlackBerry also had deltas in the product profile compared to the iPhone. The BlackBerry focused on messaging and emails, making these functions more pronounced. It enabled better productivity and communication than the iPhone and offered high security standards and enterprise-specific functions.

Compared to the BlackBerry, the iPhone offered enhanced benefits and added value by better optimising functions and making usage easier for many customers. The BlackBerry could not equally convince in this area. Nevertheless, the BlackBerry generated added value through its messaging functions and high security, which kept it on the market longer and distinguished it from quickly displaced competitors.

6.2. Case Study II: Amazon Fire Phone, Apple iPhone 6 and Samsung Galaxy S5

The Amazon Fire Phone, Amazon's first smartphone, was sold from mid-2014 to mid-2015 [20]. The iPhone 6 and iPhone 6 Plus, the eighth model in the iPhone series, were launched in September 2014. They offered larger screens, slimmer designs, and improved technical specifications. Within 24 hours, four million devices were pre-ordered, and 13 million were sold worldwide in the first three days. [21] The Samsung Galaxy S5, the successor to the Galaxy S4, was launched in April 2014. It offered innovations such as water and dust resistance (IP67) and fingerprint unlocking. [22], [23] This case study deals with a failed innovation.

The Amazon Fire Phone, the iPhone 6, and the Samsung Galaxy S5 share several commonalities. All three devices enable phone calls, offer internet access, multimedia functions, media playback, communication and messaging, as well as photography. They provide network effects, particularly the AFP and the iPhone, through strong integration into their respective ecosystems. Additionally, all three devices are in the high price segment.

The iPhone 6 and Samsung Galaxy S5 had the following deltas compared to the AFP. The iPhone 6 enables mobile payments and offers special security features. Both devices, the iPhone and the Samsung Galaxy, offer a larger app store and differ in smartphone operation. The Samsung Galaxy offers greater expandability, for example, in terms of storage, and protective measures that the iPhone and AFP do not offer. However, the AFP also had deltas compared to the other two smartphones. The AFP enables the Amazon shopping experience in a new and simplified way. It offers 3D and recognition technology that the iPhone and Samsung Galaxy do not provide. Additionally, Amazon offered unlimited photo storage with Amazon Cloud.

6.3. Case Study III: Thermomix 5th and 6th Generation

The final case study is the introduction of the sixth generation of the Thermomix following the fifth, describing incremental innovation aimed at maintaining or improving competitiveness [24].

The Thermomix 5 was launched in September 2014, and the Thermomix 6 in March 2019. The TM5 is known for its versatility and multifunctionality, capable of replacing numerous kitchen appliances. The TM5 and TM6 are visually similar. Since the TM5, the Thermomix has featured a touchscreen display, which was enlarged in the TM6. The TM6 has integrated Wi-Fi and Bluetooth. In addition to the functions of the TM5, it offers a range of new features such as slow cooking, fermentation, vacuum cooking, sautéing, caramelizing, and the maximum cooking temperature has been increased from 120°C to 160°C. [25], [26]

The Thermomix 5 and Thermomix 6 share many commonalities. Both models offer numerous cooking functions and feature a screen that facilitates cooking and preparation tasks. They are multifunctional and user-friendly, provide internet access, and are part of a comprehensive ecosystem. Both devices are considered status symbols, save time, and are highly versatile. Additionally, they benefit from strong brand recognition. However, the Thermomix 6 differs in several key aspects from the Thermomix 5. It is customizable and offers integrated Wi-Fi, whereas the Thermomix 5 requires an additional part for Wi-Fi. Furthermore, the Thermomix 6 has several new and improved cooking functions, making it even more versatile.

6.4. Evaluation of the Validation Criteria

Based on the described deltas, the validity criteria could be evaluated. This evaluation is shown in Table 5.

Table 5. Overview of the Evaluation of the Validity Criteria based on the Case Studies

Validity Criteria	CS I	CS II	CS III
Traceable information basis	○	○	○
Underlying problem	●	●	◑
Confirmed demand & willingsness to invest	○	○	○
Capabilities	○	○	○
Assessable develop-ment risk	◑	◔	◔
Added Value	●	◑	◔
Triggering enthusiasm	●	●	◑

With the help of the case studies, three criteria (underlying problem, added value, triggering enthusiasm) could be fully evaluated, and one criterion (assessable development risk) could only be partially evaluated. Three criteria (traceable information basis, capabilities) could not be evaluated because the case studies describe retrospective successes, and the criteria focus on the process of product profile creation, with information such as capabilities not being accessible.

7. Summary and Outlook

In summary, all three research questions could be answered. Through the same workshop with two different expert groups, statements could be made regarding when a product profile is valid. This resulted in 38 statements, which could be clustered into a total of seven validity criteria, thus answering the second research question. Based on three case studies with well-known innovations and failed inventions, the case studies showed through the identified deltas that four validity criteria are evaluated, but three relate to the product profile process and internal information not accessible in a case study. This answered the third research question.

The latter highlights further potential for future research. Firstly, a holistic evaluation should be conducted through a survey with experts to confirm the criteria. Seconldy, it must be investigated in which types of product development processes these criteria can be applied, as the workshops only

mentioned new developments or developments with a long horizon or time-to-market as possible application cases. This application of the validity criteria poses challenges related to the product to be developed, the organizational structure, and the process organization. Within the product, different industry-specific requirements and framework conditions can be a hindrance. On one hand, regulatory requirements, such as in medical technology, can restrict their use. On the other hand, suppliers often have to comply with the specifications of customers and their customers, leading to differences compared to the B2C market. Within the organizational structure of a company, the availability of necessary resources and data is challenging, as these are often scarce or difficult to obtain within the team, department, or similar, making their use more difficult. In terms of process organization, integrating the criteria is more difficult because existing processes in validation and product planning are already established and hard to change. Additionally, early product development in many companies is technology-driven.

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