MANAGING UNCERTAINTIES OF REQUIREMENTS IN PRODUCT PLATFORM DEVELOPMENT

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Platforms are a common approach for achieving synergies by a standardization of components. By using a platform in several products with different customer requirements, this approach causes technical compromises. The requirements management is crucial during the development of the platform, for setting up an optimal compromise between cost saving and performance losses. One major challenge is the uncertainty of requirements, being a risk for both development time and quality of the result. This challenge is of particular importance in platform development, because the considerable time period between platform development and market launch of the derivative products. To overcome it, we present in our paper the Uncertainty Mode and Effects Analysis (UMEA). By evaluating the influence of requirements changes as well as the stability of requirements, the risk of requirements changes can be determined. This supports a targeted management of requirements uncertainty.

Keywords: Product platform, requirements management.

1. INTRODUCTION

Nowadays, product and process complexity is rising due to globalization and growing individualization. In saturated markets, customer needs have to be satisfied better, which leads to an explosion of product diversification. Due to new competitors, cost pressure is increasing. Distributing products in different markets means also that requirements, regarding amongst others cost, quality and performance of inhomogeneous customers have to be accounted for. Different regulations and laws have to be obeyed. One approach for managing complexity and increasing cost pressure are product platforms. Their application creates economies of scale by a cross-product family standardization of components and thus reduces development, manufacturing and indirect costs. Product platforms are being developed before developing the derivative products. Hence, product requirements are very vague. In this paper, we present an approach for managing that uncertainty of requirements during the early phases of the product platform development. Therefore, we attended and analyzed two platform projects within a company developing and manufacturing electrical power tools. Based on that, we identified the main challenges and developed an approach in close coordination with the developers to overcome these challenges.

2. STATE OF RESEARCH

There is a wide range of perceptions for the term “platform” in the literature. Furthermore, it has become an often used buzzword in today’s management language [1].

Research into Design — Supporting Sustainable Product Development. *Edited by* Amaresh Chakrabarti

ISBN: 978-981-08-7721-7

Ulrich & Eppinger [2] define platform as an existing technical subsystem. The derivative product is built around that. The observed development process from our case study showed that it proceeds vice versa: the platform is designed regarding the requirements of the derivative products and subsequently integrated into them. Therefore, their requirements, such as performance, functionality or manufacturing costs, have to be considered already during the definition of the platform.

Meyer *et al.* [3] define platform as a set of common modules, assemblies and parts. It forms a basis for a wide range of products. A definition from a different point of view is given by Robertson *et al.* [4]: a platform is a collection of assets that is shared by a set of products. These assets my be components, processes, knowledge as well as humans and their networks. Hölttä-Otto [5] specifies that components may be material or immaterial. An example for the latter is software.

Based on the definitions of Meyer *et al.* and Robertson *et al.*, Sekolec [5] defines platform in the context of modular products. A platform is a basis module that can be used in several product families. It is an important component of the derivative product. The platform comprises components, manufacturing processes, development know-how and manufacturing technologies.

In the context of our research, we define platform, considering the above mentioned aspects, as a technical system for standardization including both technical and organizational aspects. It is a module that can be used in a wide range of products. The platform has degrees of freedom to be adapted to application specific requirements. Hence, there are variable and fix elements within the platform. Whereas the fix elements are the enablers for synergies, the variable ones allow the specific adaption of the platform. Besides the platform, further modules of the product may be realized as a platform. For realizing synergies, it is necessary that the platform itself is developed in a dedicated project and manufactured in standardized production processes in a common assembly line.

3. PROBLEM OUTLINE

In this section, we describe the approach of requirements management and the related challenges that have been identified in a literature review and during our case study.

The demands of the end customers of the derivative products are the basis for the requirements to the derivative products. Of those, the platform requirements are deduced. This correlation is illustrated in Figure 1.

During the development of a new platform, the requirements of the derivative products are collected and form the boundaries for the platform specifications. Usually a platform causes technical compromises for the derivative products [7]. It is not always possible, that the platform spans the whole bandwidth of specifications that is demanded by the derivative products. The higher the degree of commonality, the higher the technical compromises [8]. But on the other hand, a higher commonality leads to higher synergies. So during the development of a platform, a compromise between technical

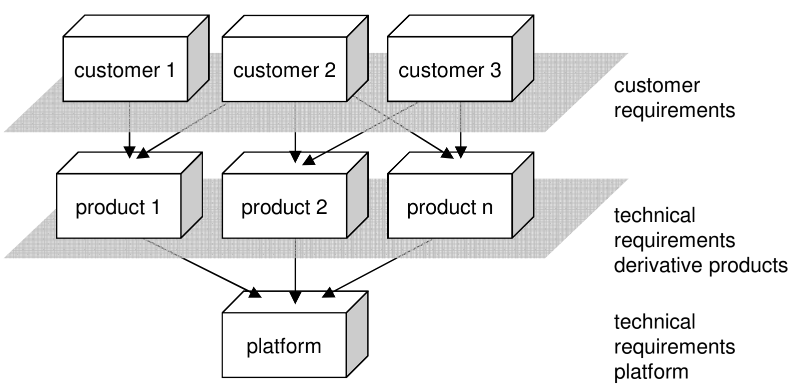

Figure 1. Derivation of platform requirements.

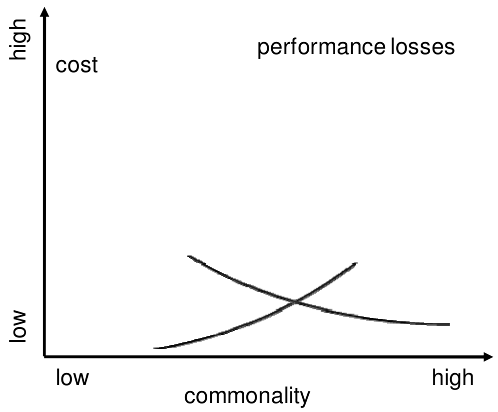

Figure 2. Effects of commonality on cost and performance according to [8, 9].

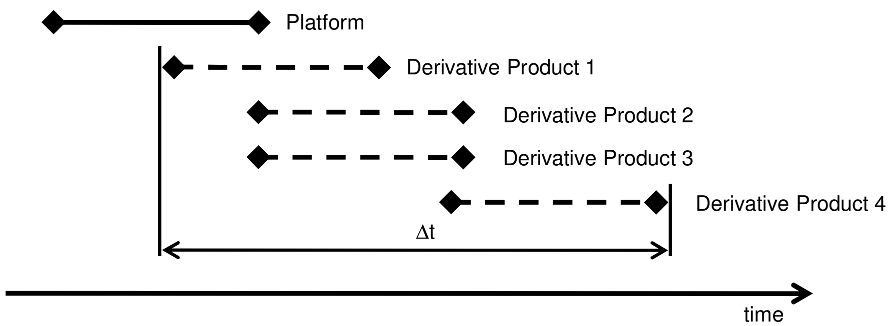

Figure 3. Development projects of platform and derivative products.

performance and costs has to be found (cp. Figure 2). This leads to a decision making process during the definition of the platform. It has to be considered whether the application of a platform within a product makes sense technically and economically. Furthermore, reasonable boundaries for the specifications of the platform have to be defined and based on that, derivative products are clustered, according to their requirements, and platform variants are derived.

During the development of product platforms, the requirements management is one of the key success factors for achieving an optimal trade-off between technical compromises and synergies.

The platform is ideally developed prior the derivative products and subsequently integrated into them (cp. Figure 3). In the worst case, the platform is developed several years prior the derivative product. This results in a high uncertainty of requirements due to changing customer requirements, competitive environment or product positioning. Furthermore, requirements are not independent, but some specifications may depend on others. On the one hand, the platform is designed to fulfil the derivative products requirements, but on the other hand, the technical possibilities of the derivative products depend on the technical capabilities of the platform.

In an ideal case, all derivative products have a similiar project schedule and a concurrent market launch to determine all requirements with the same certainty (or uncertainty) and to rate the platform optimally. The longer the time offset Δt between the platform projects is, the more problematic it is. The requirements of the early derivative products have a higher priority than those of the utmost unclear requirements of the derivative products. In certain circumstances, later derivative products would necessitate unacceptable changes of specifications and thus cannot use the platform.

This uncertainty affects the development time as well as the quality of the result. Uncertain requirements cause higher efforts for the determination of the platform specifications as well as additional iterations. Late requirements changes lead to suboptimal technical compromises, causing suboptimal fulfillment of customer requirements as well as suboptimal synergies.

4. METHODS ADDRESSING UNCERTAINTY

In the following, we present existing methods addressing uncertainty.

The Certainty Mode and Effects Analysis (CMEA) [10] is an approach for examining the uncertainty of modules and components. By evaluation of the product's flexibility of the product, probability of changes and the organization's readiness to implement changes as well as the product flexibility can be measured. Thus, designers can be supported in understanding the effects of future changes of the product. This method has been refined by Keese *et al.* [11], who present an approach for the determination of the flexibility. Flexibility depends on the quantity of components (e.g. parts or assembly steps) that have to be replaced or changed for implementing a particular change. By applying the CMEA, the effects of possible technical changes can be evaluated.

Conrad *et al.* [12] present the Change Impact and Risk Analysis (CIRA) for determining critical properties of a product. The influences of requirements changes are evaluated by a relevance classification (Must a change request be implemented?) and analysis of the different alternatives of the change implementation as well as negative side effects.

But how can we design a higher flexibility into a platform to deal with existing uncertainty? Bischof *et al.* [13] set up design guidelines for flexible products such as buffer zones and oversizing or independent modules. In the context of product platforms, a cheaper and faster adaption of product changes would reduce the challenge of uncertain requirements. However, the authors admit, that an effect of the guidelines on the product flexibility could not be confirmed. An open question is, how much flexibility is necessary and which parameters have to be designed flexible.

In the following, we present an approach for determining the risk of requirements changes during the development of product platforms. The approach is inspired by both CMEA as well as CIRA, but adapted to the specific situation of requirements engineering in platform development.

5. APPROACH: UNCERTAINTY MODE AND EFFECTS ANALYSIS

To overcome the challenge of uncertain requirements, we have developed the Uncertainty Mode and Effects Analysis (UMEA). Based on the principle of the FMEA, our approach is adapted for the requirements management during the development of product platforms. The FMEA supports the identification of failures and quality defects of technical systems by evaluating possible failures and their causes and effects [14]. Analogously, the UMEA is a tool for evaluating the risk of requirements changes.

This risk is characterized by the two parameters "influence on the platform concept" and "stability of requirements". Whereas the criterion influence on the platform concept represents the view of the platform development, the second one brings in the perception of the developers of the derivative products.

After assessing these parameters, critical requirements can be identified and measures can be defined to handle them (cp. Figure 4).

During the development process, there are events, when the change costs escalate, e.g. after defining the platform variants, ordering manufacturing tools or determining documents like the requirements specification. At these dates, a high stability of the influenced requirements is required. The UMEA is carried out sufficiently prior to those events.

The UMEA is documented in a matrix. One row consists of the characteristics for one requirement for each considered derivative product. The requirements of a derivative product are documented in one column. An overview of the four-stepped approach is given below.

1. Assess influence on the platform concept
2. Assess stability of requirements

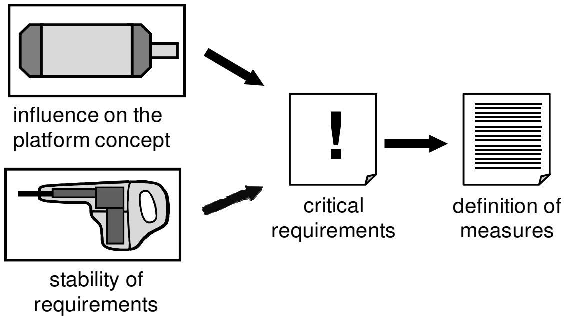

Figure 4. Principle UMEA.

3. Identify critical requirements
4. Define measures

In the following, the approach is described in detail.

1. Assess influence on the platform concept
The platform concept defines, which elements of the platform are fix and which are variable. The evaluation of the influence on the platform concept describes the impact of requirements changes. This includes, whether a change affects fix or variable elements of the platform and which effort is caused by possible additional variants of the fix element. This criterion is the same for all derivative products.

The evaluation scale is as simple as possible to reduce barriers to entry for method application. The more complex methods get, the less likely they are used [15]. For assessing the influence on the platform concept, we introduce a three stepped scale, which is described below:

- High
  Requirements changes may risk an economically or technically reasonable application of the platform within the contemplated product.
- Medium
  An individual variant due to requirements changes is still reasonable.
- Low
  Requirements changes are generally uncritical.

2. Assess stability of requirements
The criterion stability reveals whether a requirement is committed by the developers of the derivative products. The stability has to be evaluated for every derivative product individually.

For assessing the stability of requirements, it is only checked whether there is a commitment by the derivative product development team. If a requirement is not committed, the platform developers have to anticipate moving targets.

3. Identify critical requirements
Critical requirements are in general those with a high influence on the platform concept and a low stability. Those with a medium influence and a low stability must be discussed in detail whether they are critical.

4. Define measures
In this last step, suitable measures to lower risk of requirements changes are defined. There are two main strategies: lowering the influence on the platform concept or increasing the stability of the critical requirements.

Important measures are presented below:

- Concretize requirements
  selective efforts on increasing the stability of critical requirements, e.g. by intensive discussions between development and marketing
- Design for Flexibility
  lower influence by designing a punctual more flexible platform, e.g. by designing buffer zones
- Scheduling review
  schedule review of requirements for detecting critical requirements changes as soon as possible
- Revise platform applicability
  If a high risk is caused by single derivative products and other measures are not applicable, it has to be discussed whether the product's requirements are considered furthermore.

6. EXAMPLE: DRIVE PLATFORM FOR ELECTRIC POWER TOOLS

For an evaluation, the UMEA method has been applied to a drive platform for electric power tools. In the scope of consideration were power tools for various applications: screw driving, drilling, chiseling, grinding, cutting etc. The applications are characterized by a large diversity considering the user profiles, e.g. with respect to the intensity of use, the performance level required, feature content, size and weight etc. The differences in the profiles are caused, amongst other factors, by the type of user (standard user vs. heavy user), the intended market (e.g. Europe, Asia, North America) and the intended trade (building construction, civil engineering, interior finishing etc.).

A major component of all power tools in consideration is the electric drive, which is developed as a platform. The requirements on the drive show a huge diversity originating from the variety of applications. In order to develop an optimum platform scenario, the requirements from each platform customer project were collected. The relevant criteria in this context are (amongst others): starting behavior, overload capability, performance (torque, rotational speed), geometrical dimensions (maximum diameter, maximum length) and robustness concerning vibrations.

An UMEA matrix was generated with the requirements in rows and the platform customer projects in columns. The matrix was filled by the project manager of the platform project in interviews with representatives from the platform customer projects. The UMEA procedure was carried out in a common workshop with representatives from the platform project, all platform customer projects and a workshop moderator. An excerpt of the workshop results are displayed (in a generalized form) in Figure 5. There exist about 15 potential derivative product projects, of which two projects (screw driver, rotary hammer) are exemplary displayed.

In the **first UMEA step**, the requirements were assessed concerning their influence on the platform concept. Requirements with high impact are e.g. starting behavior and overload capability. Changes concerning these requirements may cause severe changes in the platform concept (basic motor type, lamination) and are therefore critical. These changes would endanger the use of the platform drive and would require the use of a specific drive. Requirements with medium influence on the platform concept are e.g. performance and geometrical dimensions. Here, the platform shows a certain flexibility within certain boundaries. Requirements with low impact are e.g. the robustness concerning vibrations. A change concerning this requirement would necessitate additional design measures (e.g. potting or molded magnets) with no major influences on the platform concept. These changes would, however, lead to higher manufacturing costs.

In the **second UMEA step**, the requirements were evaluated concerning their stability respectively their status of commitment. This assessment was carried out for each platform customer project separately. Requirements with high stability are e.g. geometrical dimensions and robustness concerning vibrations. Requirements with low stability in at least one customer project are e.g. starting behavior, overload capability and performance. Here, information concerning the applications, the competitor situation etc. is still missing. Therefore statements concerning these requirements are tentative, and changes are highly probable.

UMEA Matrix for Electric Drive Platform			Platform customer projects			
Requirements			#1 Screw Driver		#2 Rotary Hammer	
Criteria	Influence	Comment	Stability	Comment	Stability	Comment
Starting behavior	high	Changes in requirements have strong impact on choice of basic motor type	low	120% starting torque (tentative); significant differences in application compared to predecessor; still in discussion with marketing	high	150% starting torque; application similar to predecessor tool
Overload capability	high	Changes in requirements have strong impact on lamination > tooling costs	low	150% (tentative); value depending on applications and competitor tools > info still missing	low	120% (tentative); value depending on applications and competitor tools > info still missing
Performance (torque, rotational speed)	medium	Flexibility for changes in requirements up to 10%	high	10% higher performance than predessor tool	low	10% higher performance than predecessor tool; still in discussion with marketing
Geometrical dimensions (max. diameter, max. length)	medium	Diameter: flexibility for changes up to 10%; length: flexibility for changes up to 20%	high	same dimensions as predecessor tool	high	10% smaller than predecessor tool
Robustness concerning vibrations	low	Changes in requirements can be adressed by additional design measures	high	medium vibration robustness required	high	high vibration robustness required

Figure 5. UMEA matrix for electric drive platform (excerpt).

In the **third UMEA step**, the critical requirements were identified. In the example, the starting behavior and the overload capacity are critical because of a high influence on the platform concept and a low stability in at least one customer project. In addition, performance is critical due to a medium influence on the platform concept and a low stability in at least one platform customer project.

Based on the evaluation of requirements concerning their criticality, measures were defined in the **fourth UMEA** step. To deal with the uncertain performance requirements of the rotary hammer as well as the requirement starting behavior of the screw driver, detailed market research activities were planned in order to increase the stability of these requirements. Due to an uncertain competitive environment, increasing the stability of the requirement overload capability was not possible. Therefore design measures for a higher flexibility of the platform have been undertaken.

7. DISCUSSION & OUTLOOK

Based on the results of our case study, we discuss in the following the advances and limits of the presented approach. These reflections base on the results of a discussion with the project manager of the platform project after the evaluation of the approach.

The main benefit of the UMEA is the analysis, communication and explicit documentation of uncertainties of requirements and the related risk for the platform success. Thereby, measures for requirements changes, often hard to predict in time of occurrence, can be taken.

By evaluating the influence on the platform concept of the requirements, awareness is created about the impact of a certain change at a certain moment. An additional benefit is an intensified communication and collaboration between the development teams of the platform and the derivative products. By discussing the requirements in a team of both stakeholders, incorrect estimations of one department can be identified and if applicable corrected.

The result of the UMEA is a prioritization of requirements regarding importance by evaluating their influence, urgency and commitment. Due to critical issues getting transparent, a more targeted and quicker reaction on changing boundary conditions is possible.

One challenge of the approach is to get all relevant parties involved and motivated. During the application, there is the need of workshops with developers of the platform as well as the derivative products. This interrupts their day-to-day business and thus may be given a low priority. Another challenge for the platform designers is to get an understanding of the interdependencies between requirements and design parameters of the platform. This knowledge is necessary to determine the influence on the platform concept as well as the influence of defined measures on the platform specifications.

Applying the UMEA supports the identification of requirements with a high change risk. One possible measure for reducing this risk is a more flexible design of the platform. The UMEA supports the designers in the determination of requirements (and thus the specifications to be developed) that should be designed flexible. The remaining question is how to implement this flexibility in an optimal way. The usual approach is the definition of buffer areas and an oversizing or overstressing of components. These lead to worse specifications and thus a deterioration of the customer satisfaction. Our case study showed that the developers wish for specific guidelines that support them in designing more flexible platforms or in postponing the dates, when certain specifications have to be determined.

ACKNOWLEDGEMENTS

We would like to thank Josef Obermeier, Jens Frenzel, Martin Lammerskötter Walter Wissmach, Bernhard Bohnenberger and Matthias Paetow from Hilti Entwicklungsgesellschaft mbH for their willingness to give us insight into the development of drive platforms as well as Katharina Eben and Sebastian Kortler from the Institute of Product Development, Technische Universität München for their methodical support and all of them for stimulating discussion.

REFERENCES

1. Sanchez, R., "Creating Modular Platforms for Strategic Flexibility", *Design Management Review*, 15(1), pp 58–67, 2004.
2. Ulrich, K. T. and Eppinger, S. D., "Product Design and Development", 4th ed. McGraw-Hill/Irwin, 2007.
3. Meyer, M. H. and Lehnerd, A. P., "The Power of Product Platforms", The Free Press, 1997.
4. Robertson, D. and Ulrich, K., "Planning for Product Platforms", MIT Sloan Management Review 39(4), pp. 19–31, 1998.
5. Hölttä-Otto, K., "Modular Product Platform Design", Ph.D. Thesis, Helsinki University of Technology, 2005.
6. Sekolec, R., "Produktstrukturierung als Instrument des Variantenmanagements in der methodischen Entwicklung modularer Produktfamilien", VDI-Press, 2005.
7. Simpson, T. W., Supersad, C. C. and Mistree, F., "Balancing Commonality and Performance within the Concurrent Design of Multiple Products in a Product Family", Concurrent Engineering 9(1), pp. 177–190, 2001.
8. Fellini, R., Kokkolaras, M., Papalambros, P. Y. and Perez-Duarte, A., "Platform Selection and Performance Loss Constraints in Optimal Design of Product Families", Proceedings of DETC'02. ASME 2002 Design Engineering Technical Conferences, 2002.
9. Ehrlenspiel, K., Kiewert, A., Lindemann, U. and Hundal, M. S., "Cost-efficient Design", Springer-Verlag, 2007.
10. Palani Rajan, P.K., Van Wie, M., Campbell, M., Otto, K. and Wood, K., "Design for Flexibility — Measures and Guidelines", International Conference on Engineering Design (ICED '03), 2003.
11. Keese D. A., Takawale N. P., Seepersad, C. C. and Wood, K.L., "An Enhanced Change Modes and Effects Analysis (CMEA) Tool for Measuring Product Flexibility with Applications to Consumer Products", Proceedings of ASME 2006 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, 2006.
12. Conrad, J., Deubel, T., Köhler, C., Wanke, S. and Weber, C., "Change impact and risk analysis (CIRA) — combining the CPM/PDD theory and FMEA-methodology for an improved engineering change management", International Conference on Engineering Design (ICED'07), 2007.
13. Bischof, A. and Blessing, L., "Design for Flexibility: Making Provisions for Requirements Changes", International Conference on Engineering Design (ICED'07), 2007.
14. Pahl, G., Beitz, W., Feldhusen, J., Grote, K. H., Wallace, K. and Blessing, L., "Engineering design: A systematic approach", 3rd ed. Springer-Verlag, 2007.
15. Sadek, T., Meuris, D. and Wendland, M., "An experimental study on comprehending heterogeneous modeling", NordDesign 2010, 2010.