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COMPLEXITY AND PREFERENCE BASED METHODOLOGY FOR PRODUCT LINE PLANNING OF CUSTOMIZABLE PRODUCTS

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ABSTRACT
Analyses and current market development show that more customizable products are required which are competitive to mass produced products. To be competitive, the products have to be cost optimized. A methodology is presented to support the designer in the product line planning in order to achieve customizable and cost optimized products and is presented with help of a case study. The main steps of the methodology are the determination of the product attributes and characteristics which are required by the market. Subsequently, the preferences of characteristics are determined by application of conjoint analysis including 233 respondents. In a next step, the realization effort for each characteristic is assessed. The customers' preferences are clustered under consideration of the determined efforts. In the case study, three groups are found. For each group a product line is established. Analyzing these product lines, it is shown, that the number of required components can be significantly reduced, while the number of customers' requirements being fulfilled almost remains constant.

Keywords: product families, product structuring, requirements, similarity assessment

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1 INTRODUCTION

In the past, consumer products have been developed and produced for mass markets. These days, many markets are saturated and the products converge functionally. For enterprises, one way to remain competitive in these so called buyer's markets is to manufacture products in a cost-optimized way. (Baumberger, 2007)
At the same time, an increasing desire for individualization can be observed (Dye and Stephenson, 2010; Dua *et al.*, 2009). Therefore, highly customizable products are required (Ernst & Young Global Limited, 2012). Since customers are very well informed about products as a result of our change towards an information society, they are able to express their desires very specifically. Due to globalization, customers have a great deal of vendors to choose from. That strengthens the position of customers compared to enterprises. (Hippner and Wilde, 2006)
Because of the shift from a seller's to a buyer's market and the demand for customized products, enterprises are confronted with the task of fulfilling customers' wishes in the best possible way while costs need to be as low as possible. One consequence is that enterprises are forced to find the optimum between low product and process costs on the one hand and a perceived individualized design on the other hand. One strategy for enterprises is to increase the external variety without increasing the internal. Thus, enterprises are forced to offer product lines enabling the customers to customize their preferred products instead of offering mass products.
To comply, the whole product development process has to be optimized for this strategy. According to Lindemann et al., the development of customized products is split into two steps: First, the structural product line planning is carried out (2006). The results are product structures of all customizable variants. In the second step, the components are developed and designed (Lindemann *et al.*, 2006). Within the product development process a methodology for planning customized product lines taking both sides, the customers' and enterprises', into account is not known. The aim of the methodology presented here, is to find the best degree of modularization to generate optimal product lines in order to fulfil the customers' requirements based on minimum internal variety.
To achieve this aim, the enterprise has to exploit the differences among the customer requirements for identifying the varieties that are meaningful for the customers (Rungtusanatham and Salvador, 2008). These requirements have to be processed by the methodology regarding their differences and regarding the complexity they cause, in order to optimize the product lines. The outputs of the methodology are reference product structures (RPS) representing optimized product lines. Based on the RPS, the development of the components is carried out.

1.1 Existing Approaches

Existing approaches that can be used for an optimization of a product line planning either do not consider customer requirements at all, or these approaches do not identify the varieties among the customer requirements, e. g. Modular Function Deployment (MFD) (Ericsson and Erixon, 1999), Cost-and-Preference-Optimization of Variety (CPOV) (Heina, 1999), Variant Mode and Effects Analysis (VMEA) (Caesar, 1991), Design for Product Variety (DfPV) (Ishii *et al.*, 1995), and Design for Mass Customization (DfMC) (Jiao, 1998). Further, MFD, CPOV, and VMEA are only applicable with the aim of optimizing an existing variety of products. In case, an enterprise is planning to switch from mass production to customizable products, just a low variety of products is existent.
Therefore, the *methodology for planning of optimized product lines (MePoP)* is developed. The *MePoP* methodology takes the varieties of the customer requirements into account and can be applied by enterprises in the shift from being a mass producer to a provider of customized products.

2 APPROACH

The *MePoP* methodology is established enabling the engineer to define product lines prior to the product development process (Figure 1). The methodology aims for reducing the internal variety by the establishment of several product lines each having just a low variety instead of one product line fulfilling all requirements, but being very complex. These product lines have to be adapted to the determined requirements. In the following, the different steps of the methodology are presented based on a case study. The product being used is a computer mouse.

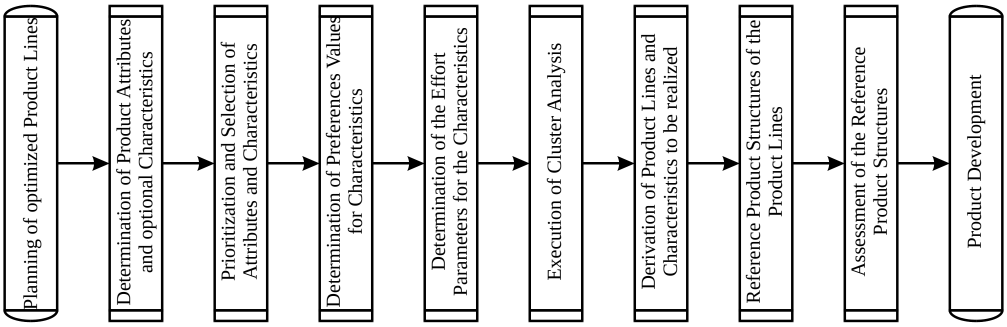

Figure 1. Steps of the methodology for planning of optimized product lines

3 DEFINITIONS

Enterprises providing consumer products execute the steps from the product idea to the product launch based on a stage-gate-process. The product development process is part of this stage-gate-process (Cooper, 1990; Kleinschmidt *et al.*, 1996). Therefore, the presented *MePoP* methodology is integrated into this stage-gate-process. In Figure 2, it is shown that the methodology is integrated into stage 2 of the process as a part of the *Detailed Investigation* prior to the stage of the *Development.* In this stage, the components are developed and designed.

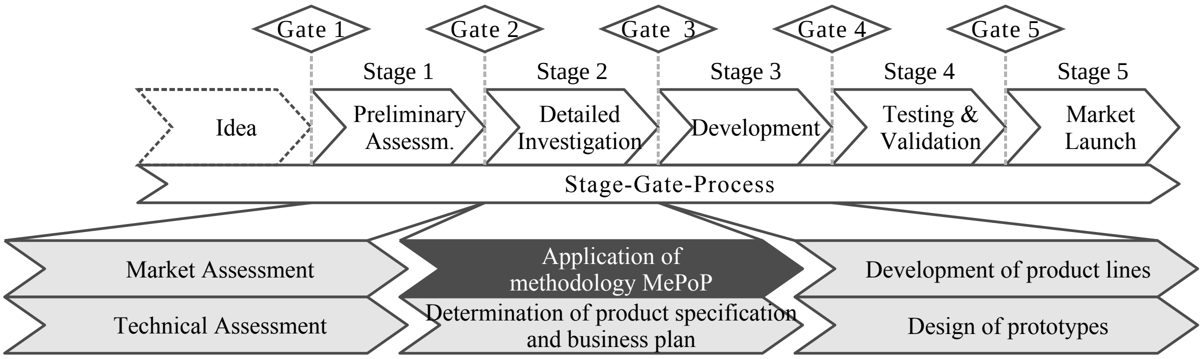

Figure 2. MePoP as a part of the stage-gate-process

3.1 Customization

According to Piller, in this paper, customization should be understood in the sense of assemble-to-order (Piller and Stotko, 2003). The development and the component manufacturing processes are executed order neutral. Therefore, a product structure is desired that enables customers to configure their preferred product based on the components provided.

3.2 Reference Product Structure and Reference Characteristic Structure

The RPS can be defined as structured representation of all components that are used to assemble all possible product variants within this product line. On the lowest level of the RPS, there are different variants of components, which are used to assemble a product variant depending on the customers' choice of characteristics. Whereas the RPS represents the enterprises' view to the product line, the customers' view is represented by a reference characteristic structure (RCS). This contains all attributes and corresponding characteristics. Depending on the orders of customers, who choose characteristics of the product, components are assembled to the product. The mapping of product characteristics to components is called reference product architecture (RPA) (Figure 3), in analogy to Ulrich's mapping of functions and components (Ulrich, 1995).

3.3 Attributes and Characteristics

Attributes and characteristics can be used to describe products. Attributes are product properties that are perceived by the customer (Weinbrenner, 1994). Attributes can take different values, so called characteristics e. g. 'red' is one characteristic for the attribute 'color' (Heina, 1999). Customers are able to describe their preferred product using the characteristics they prefer. Therefore, product variants can be described as sets of characteristics (Heina, 1999).

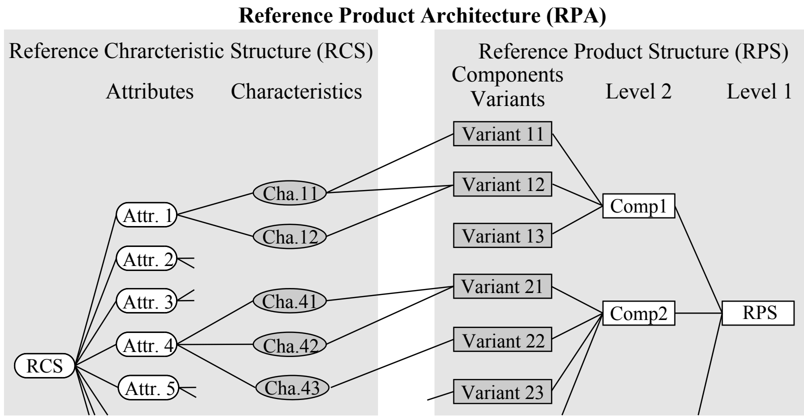

Figure 3. RPA, RCS and RPS

4 CASE STUDY

4.1 Determination of Product Attributes and optional Characteristics

A market analysis was carried out, to determine attributes and characteristics of a computer mouse which are relevant to customers. The result of the market analysis is a list with 14 attributes (Figure 4) with several characteristics each. The characteristics are not displayed in Figure 4.

Sensor	Scroll-wheel	Warranty
Signal	Number of buttons	Connection to the PC
Signal transmission	Thumb button	Plattform
Length of the cable	Shape (Usability for left-handed persons)	Color
Radio range		Surface

Figure 4. Attributes of a computer mouse which are relevant to customers

4.2 Priorization and Selection of Attributes and Characteristics

In case market analysis develops too many attributes and characteristics or it develops attributes and characteristics which cannot be realized by the enterprise due to technical reasons, selected attributes and characteristics can be discarded. An applicable procedure to prioritize attributes and characteristics is the Kano Model; an applicable procedure to eliminate attributes and characteristics is idea screening (Kano *et al*., 1984; Kotler and Armstrong, 2010). Here, the number of attributes and characteristics can be reduced applying the Kano model. In Figure 5, the remaining seven attributes and 19 characteristics to be regarded in this paper are shown.

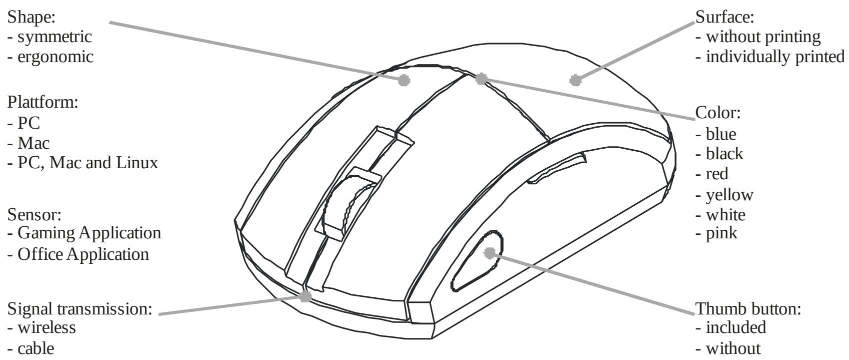

Figure 5. Computer mouse with seven attributes and 19 characteristics

4.3 Determination of Preferences Values for the Characteristics

Conjoint analysis has become a useful way to measure respondents' preferences for simple to complex offerings and predict market choices (Orme, 2010). Different types of conjoint analysis are known. The selection of the most appropriate type is based on the estimated number of respondents, the number of attributes and characteristics and the fact, whether the price is an attribute. Due to the disregard of the price and the high number of attributes and characteristics to be regarded, the

Adaptive Conjoint Analysis (ACA) is taken for determination of the preferences (Orme and Sawtooth Software, Inc., 2009).
Conjoint analysis has often been limited by the data collection methods available. In a study covering many attributes, respondents are sometimes provided with too much information to consider thoroughly. The scope of many studies has also been constrained by limitations in respondents' time and attention. ACA moves beyond those limitations by adapting the interview for each respondent. Early in the interview the computer learns enough about each respondent's values to focus on those areas of importance to that respondent. This results in broader scope, since more attributes can be tested. Even more important, the data are often of higher quality, since respondents are more interested and involved in the task. (Sawtooth Software, Inc., 2013) The study has been carried out using the Sawtooth Adaptive Conjoint Analysis software. 233 respondents participated in the study. The result of the study is a list with the individual preferences of each participant and each characteristic (Table 1). Negative values represent a low preference, positive a strong preference.

Table 1. Excerpt of the Results of the Adaptive Conjoint Analysis

Internal Interview Numbers	Preferences						
	Ergonomic	Symmetric	Wireless	Cable	Including thumb button	Without thumb button	…
3	-0.189	-0.199	0.036	-0.424	-0.454	0.066	…
7	0.013	-0.362	-0.255	-0.094	0.225	-0.574	…
8	0.101	-0.284	0.240	-0.423	-0.103	-0.080	…

4.4 Determination of the Effort Parameter for the Characteristics

The main components of a computer mouse also can be determined before the product development process starts: Housing consisting of a Bottom part (C.1) and a Top part (C.2), Supporting Structure (C.3), Sensor (C.4), Printed Circuit Board (PCB) assembly (C.5), including push-buttons and mouse wheel. Depending on the type of signal transmission, the mouse has different further components: Wireless transmitter (C.6) (Signal transmission: Wireless), Battery pack (C.7) (Signal transmission: Wireless), Cable (C.8) (Signal transmission: Cable). RPA is established.
From the enterprises' view, every characteristic causes a different realization effort, because different components are affected. This has to be regarded in the step of defining the product lines. In the similarity assessment, an emphasis should be put on the more complex characteristics. This leads to a standardization of the complex characteristics and therefore the most complex components within a product line. Consequently, the characteristics have to be assessed regarding their effort: Four component-related factors are identified for this computer mouse and in a further step, for every factor the effort is converted into a characteristic-related effort using the RPA:

1. Number of components being affected by the characteristic: A higher number of components lead to a higher overhead.
2. Complexity of the components being affected: The more complex the affected components are, the higher the development effort is. The complexity of a component can be determined by the number and types of component interfaces.
3. Economies of scale: The number of units being produced affects the effort. In case another variant of a component (e.g. injection molded part) is created with high nonrecurring costs, like die costs, this causes a higher effort compared to another variant of a standard part.
4. Order Penetration Point: An order-related assembling step causes a higher effort compared to an order-neutral assembling step. Characteristics affecting sub-assemblies and therefore a high number of subsequent assembling steps have to be assessed differently compared to characteristics affecting the final assembly step (Ishii *et al.*, 1995).

First the product architecture according to Figure 3 is set up as a matrix (Table 2). Based on the product architecture, the assessment of the factors is carried out. Each connection between a characteristic and a component is expressed by a 1.
For the factor *number of parts being affected*, the sum of each row is added up. The higher the sum of the row is, the higher is the number of parts being affected by this characteristic. If the sum is low (0-1), the factor *number of parts being affected* is rated to 0; for a sum between 2 or 3, the factor is set to 0.5; for a value higher than 4, it is 1.

For the factor *complexity of components being affected*, the connections of the product architecture are weighted. To determine the weighting, a design structure matrix is set up (Table 3), which contains information about the interfaces between the components (Browning, 2001). A complex component is defined as a component, which has many complex interfaces to other components. Therefore, each interface is weighted according to Table 4.

In the product architecture shown in table 5, the connections of the product architecture are weighted by the sum which is calculated for each component in Table 3. The factor *complexity of components being affected* is also derived by calculated the sum of each row and a rating of the sum.

A similar procedure is carried out for the other two factors. Because not all factors have the same impact on the overall effort of the characteristics, the ratings of factors are weighted before being summed up (Table 6). The weighted sum is called *effort parameter*.

Table 2. Product Architecture to assess the factor number of parts being affected

Attribute	Characteristic	Components								Sum	Rating
		C.1	C.2	C.3	C.4	C.5	C.6	C.7	C.8		
Sensor	Office Application				1	1				2	0.5
Sensor	Gaming Application				1	1				2	0.5
Thumb button	Included	1		1		1				3	0.5
Thumb button	Without	1		1		1				3	0.5
Signal transm.	wireless	1		1		1	1	1		5	1
Signal transm.	Cable	1		1		1			1	4	1
…	…	…	…	…	…	…	…	…	…	…	…

Table 3. Design Structure Matrix to assess the connections between the parts

	C.1	C.2	C.3	C.4	C.5	C.6	C.7	C.8
Housing bottom part (C.1)		9	3	3	3	0	0	3
Housing top part (C.2)	9		3	0	3	0	[illegible]	[illegible]
Supporting structure (C.3)	3	3		0	3	0	[illegible]	[illegible]
Sensor (C.4)	3	0	0		1	0	0	0
PCB Assembly (C.5)	3	3	3	1		3	3	1
Wireless transmitter (C.6)	0	0	0	0	3		0	0
Battery Pack (C.7)	0	0	3	0	3	0		0
Cable (C.8)	3	0	0	0	1	0	0	
Sum	**21**	**15**	**12**	**4**	**17**	**3**	**6**	**4**

Entries according to Table 4

Table 4. Types of connections

Type of connection	Assessment
Standardized interfaces, e. g. plug connectors	1
Mechanical interface, which is not visible for the customer (minor requirements for industrial design and manufacturing)	3
Mechanical interface, which is visible for the customer (high requirements for industrial design and manufacturing)	9

Table 5. Assessment of the factor complexity of components being affected

Attribute	Characteristic	Components								Sum	Rating
		C.1	C.2	C.3	C.4	C.5	C.6	C.7	C.8		
Sensor	Office Application	0	0	0	4	17	0	0	0	21	0.5
Sensor	Gaming Application	0	0	0	4	17	0	0	0	21	0.5
Thumb button	Included	21	0	12	0	17	0	0	0	50	1
Thumb button	Without	21	0	12	0	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Signal transm,	wireless	21	0	12	0	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Signal transm.	Cable	21	0	12	0	17	0	0	4	54	1
…	…	…	…	…	…	…	…	…	…	…	…

Entries according to sum of DSM (Table 3)

Table 6. Determination of the effort parameter for the Characteristics

Factor weight		0.18	0.35	0.35	0.12	**1.00**
Attribute	Characteristic	Number of components	Complexity of the components	Economies of scale	Order Penetration Point	**Effort Para-meter**
Sensor	Office Application	0.5	0.5	0	1	**0.325**
Sensor	Gaming Applic.	0.5	0.5	0	1	**0.325**
Thumb button	included	0.5	1	0.5	0.5	**0.575**
Thumb button	without	0.5	1	0.5	0.5	**0.575**
Signal transm.	wireless	1	1	1	1	**0.85**
Signal transm.	Cable	1	1	0.5	0.5	**0.65**
…	…	…	…	…	…	**…**

4.5 Execution of the Cluster Analysis

In order to validate the hypothesis, customers' requirements have to be compared to each other to identify similar sets of customers' requirements. Each set can be satisfied with one product line. As mentioned before, customers can express their requirements specifically by using characteristics of the product, leading to an unambiguous description of the preferred product. This style of description enables the application of data processing systems to cluster customers' requirements regarding their similarity (Nagarajah, 2011). Because of the typically unapparent relations between the groups of customers' requirements and a high number of datasets, that have to be compared, it is reasonable to apply data mining methods (DMM). Clustering methods like self-organizing maps (SOM) are a subgroup of DMM, which are used to identify and also to visualize complex numerical coherences. An essential feature of SOM is to map the similarity structure of a high-dimensional data space in a two-dimensional chart (Vesanto, 2000).

The first step of the mapping process is to import data vectors with the preferences of the respondents of the conjoint analysis (Table 1). Next, a nonsupervized learning procedure is carried out. The learning algorithm works in the following way: A grid with model vectors is initialized. A data vector is randomly picked out of the data set and the distance between each model vector of the grid and the data vector is calculated. The unit with the shortest distance to the data vector is called the best matching unit (BMU) and this data vector is placed on the map at this location. This operation is repeated until all data vectors have been picked out of the data set and placed on the map. Afterwards, the vectors of the model are adapted (Figure 6). The effort parameters (Table 6) are weightings for the entries of the vectors (respondents' preferences). Entries with a high weighting factor have a higher influence than entries with a low weighting factor.

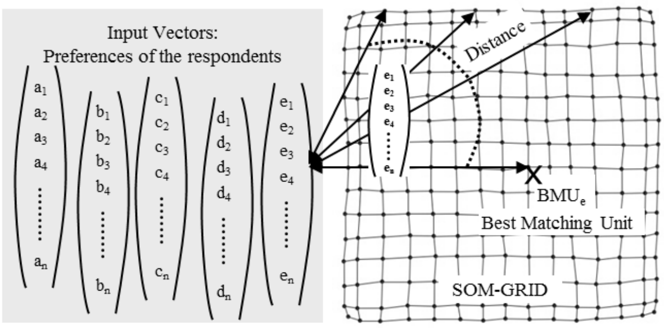

Figure 6. Training process for SOM (Feldhusen et al., 2012)

4.6 Derivation of Product Lines and Characteristics to be realized

Furthermore a clustering is carried out by the aforementioned procedure. Similar vectors are clustered and therefore the corresponding respondents are grouped (Otte, 2004). In the case study, three groups each with a different number of respondents are established (Group 1: 95 respondents, Group 2: 87 res., Group 3: 51 res.). In the next step, it is analysed, which characteristics are required in each of the three groups: For each respondent, the preferences of all characteristics of one attribute are compared to each other. The preference with the highest value belongs to the preferred characteristic. Doing this

for all attributes, it is possible to derive the optimal mouse for each respondent (set of characteristics with the highest preference values). Analysing the optimal mice of all respondents, it is possible to set up the RCS according to Figure 3 for each group (Table 7). The RCS contains all characteristics which are required in each group.
Based on Table 7, it is obvious that the sensor for office application is not needed in any of the groups. In group 1, no cable-based signal transmission is needed; in group 3 no wireless-based signal transmission is required. For each of the groups, a product line with the related characteristics can be established.

Table 7. Reference Characteristic Structures for each group

Attribute	Characteristic	Group 1	Group 2	Group 3	**Sum**
Number of respondents		95	87	51	
Sensor	Office Application	**0**	**0**	**0**	**0**
Sensor	Gaming Application	95	87	51	**233**
Thumb button	included	60	77	29	**166**
Thumb button	without	35	10	22	**67**
Signal transm,	wireless	93	14	**2**	**109**
Signal transm.	Cable	**2**	73	49	**124**
…	…	…	…	…	**…**

4.7 Reference Product Structures of the Product Lines

Based on the gained information, the RPS for each product line can be determined: For group 1, the product architecture shown in Figure 3 is taken. First all characteristics are eliminated which are not required in Group 1 according to the RCS (Table 7). Further, all variants of the components are removed, which are connected to those erased characteristics (Figure 7). All remaining components represent the RPS for this particular group. This procedure is repeated for the other two groups. As a result, three different RPS are established.

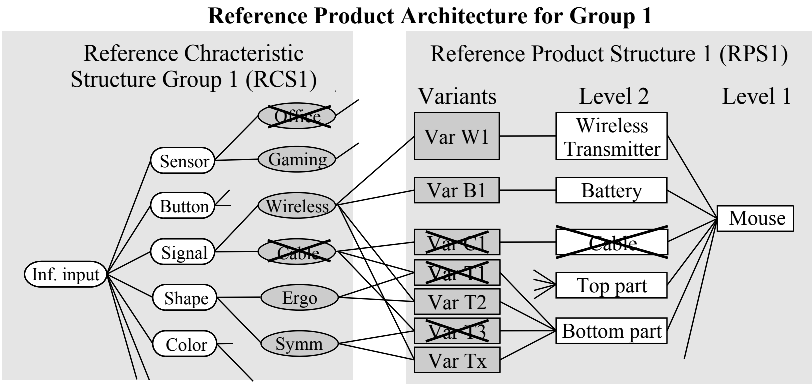

Figure 7. Reference Product Architecture for Group 1

4.8 Assessment of the Reference Product Structures

To assess the methodology, the result of the methodology is compared to other procedures in planning product lines. Taking all characteristics according to Figure 5 into account, 576 different variant configurations of the computer mouse are realizable. To realize these variants, 81 different components are needed. These variants cover obviously all variants, which are preferred by the 233 respondents (Figure 8).
In case the executed conjoint analysis is used just for market research, all characteristics with low preference values in all groups would be eliminated, e. g. the sensor for office application (Table 7). Eliminating just these characteristics, the overall number of required components can be reduced to 52 (64 % of 81), still fulfilling 99 % of all respondents preferred mouse configurations.
Applying the presented MePoP methodology, the required number of components can be reduced to 43 (53 % of 81) in order to fulfil 97 % of all respondents' mouse configurations. The number of product variants which theoretically can be realized by the provided product lines is reduced from 192 (33 % of 576) to 120 (21 % of 576). The fitting of the provided product variants (external variety) to

the required variants (internal variety) is improved by application of the MePoP methodology. Thus, applying this methodology the number of required components can be significantly reduced without neglecting the respondents’ requirements.

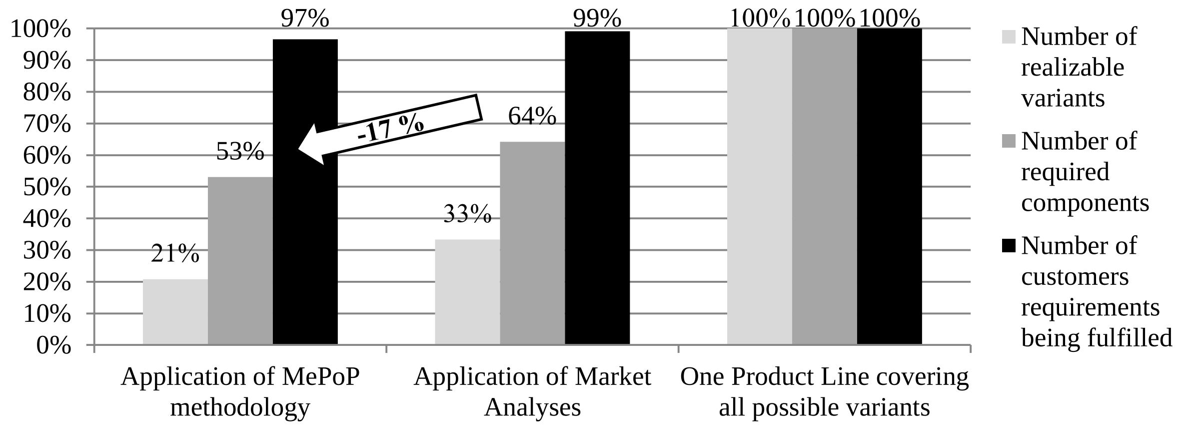

Figure 8. Assessment of the Reference Product Structures

5 CONCLUSION

A methodology is presented that enhances the product planning process and thus supports the engineer while planning customizable products. Figure 1 shows the steps of the methodology which have to be executed in order to find the optimal product lines that fulfil customers’ requirements (external variety) based on a minimum internal complexity (internal variety). A case study is presented, where this methodology is applied and it is shown, that the number of required components can be significantly reduced, while the number of customers’ requirements being fulfilled almost remains constant. Thus, the application of the methodology is reasonable. Instead of providing just one product line fulfilling all customer requirements, it is reasonable to provide more product lines with a reduced variety in order to decrease the internal variety.

In a next step, this methodology should now be tested using a commercial case study, in order to proof the validity. This includes the assessment of the methodology regarding cost savings.

REFERENCES

Baumberger, G.C. (2007), *Methoden zur kundenspezifischen Produktdefinition bei individualisierten Produkten,* 1st ed., Verl. Dr. Hut, München.

Browning, T. (2001), “Applying the design structure matrix to system decomposition and integration problems: a review and new directions”, *IEEE Transactions on Engineering Management*, Vol. 48 No. 3, pp. 292–306.

Caesar, C. (1991), *Kostenorientierte Gestaltungsmethodik für variantenreiche Serienprodukte: Variant mode and effects analysis (VMEA),* Als Ms. gedr., VDI-Verl., Düsseldorf.

Cooper, R.G. (1990), “Stage-gate systems: A new tool for managing new products”, *Business Horizons*, Vol. 33 No. 3, pp. 44–54.

Dua, A., Hersch, L. and Sivanandam, S. (2009), “Consumer electronics gets back to basics”, available at: https://www.mckinseyquarterly.com/Retail_Consumer_Goods/Strategy_Analysis/Consumer_electronics_gets_back_to_basics_2454 (accessed 26 July 2012).

Dye, R. and Stephenson, E. (2010), “Five forces reshaping the global economy”, available at: https://www.mckinseyquarterly.com/Five_forces_reshaping_the_global_economy_McKinsey_Global_Survey_results_2581?pagenum=4 (accessed 26 July 2012).

Ericsson, A. and Erixon, G. (1999), *Controlling design variants: Modular product platforms,* Society of Manufacturing Engineers, Dearborn, MI.

Ernst & Young Global Limited (2012), “This time it’s personal: from consumer to co-creator”, available at: http://www.ey.com/Publication/vwLUAssets/This_time_it_is_personal_-_from_consumer_to_co-creator_2012/$FILE/Consumer%20barometer_V9a.pdf (accessed 19 November 2012).

Feldhusen, J., Milonia, E., Nagarajah, A., Neis, J. and Schubert, S. (2012), “Enhancement of adaptable product development by computerised comparison of requirement lists”, *International Journal of Product Lifecycle Management*, Vol. 6 No. 1, p. 20.
Heina, J. (1999), *Variantenmanagement: Kosten-Nutzen-Bewertung zur Optimierung der Variantenvielfalt,* Dt. Univ.-Vlg; Gabler, Wiesbaden, Wiesbaden.
Hippner, H. and Wilde, K.D. (Eds.) (2006), *Grundlagen des CRM,* Gabler, Wiesbaden.
Ishii, K., Juengel, C. and Eubanks, C.F. (1995), “Design for Product Variety: Key to product line structuring”, in Inman, D.J. and Jadaan, O.M. (Eds.), *Presented at the 1995 ASME Design Engineering Technical Conferences*, American Society of Mechanical Engineers, New York, pp. 499–506.
Jiao, J. (1998), *Design for mass customization by developing product family architecture*, Proquest Information and Learning, Ann Arbor.
Kano, N., Seraku, N., Takahashi, F. and Tsuji, S.-i. (1984), “Attractive Quality and Must-be Quality”, *The Journal of the Japanese Society for Quality Control*, Vol. 14 No. 2, pp. 39–48.
Kleinschmidt, E.J., Geschka, H. and Cooper, R.G. (1996), *Erfolgsfaktor Markt: Kundenorientierte Produktinnovation*, *Marktorientiertes F-&-E-Management*, Springer, Berlin.
Kotler, P. and Armstrong, G. (2010), *Principles of marketing,* 13th ed., Pearson, Upper Saddle River, NJ.
Lindemann, U., Reichwald, R. and Zäh, M.F. (2006), *Individualisierte Produkte-Komplexität beherrschen in Entwicklung und Produktion,* 1st ed., Springer, Berlin.
Nagarajah, A. (2011), *Selbstorganisierende Merkmalskarten für eine anforderungsbasierte Produktvariantenauswahl*, Shaker, Aachen.
Orme, B.K. (2010), *Getting started with conjoint analysis: Strategies for product design and pricing research,* 2nd ed., Research Publishers, Madison, WI.
Orme, B.K. and Sawtooth Software, Inc. (2009), “Which Conjoint Method Should I Use?”, available at: http://www.sawtoothsoftware.com/download/techpap/whichmth.pdf (accessed 3 April 2013).
Otte, R. (2004), *Data Mining für die industrielle Praxis,* 1st ed., Hanser, München.
Piller, F.T. and Stotko, C.M. (2003), *Mass Customization und Kundenintegration: Neue Wege zum innovativen Produkt,* 1st ed., Symposion-Verl., Düsseldorf.
Rungtusanatham, M.J. and Salvador, F. (2008), “From Mass Production to Mass Customization: Hindrance Factors, Structural Inertia, and Transition Hazard”, *Production and Operations Management*, Vol. 17 No. 3, pp. 385–396.
Sawtooth Software, Inc. (2013), “Which Preference Modeling Method should you use?”, available at: http://www.sawtoothsoftware.com/products/advisor/ (accessed 3 April 2013).
Ulrich, K. (1995), “The role of product architecture in the manufacturing firm”, *Research Policy,* Vol. 24 No. 3, pp. 419–440.
Vesanto, J. (2000), “Using SOM in Data Mining”, available at: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.33.942 (accessed 24 September 2012).
Weinbrenner, V. (1994), *Produktlogik als Hilfsmittel zum Automatisieren von Varianten- und Anpassungskonstruktionen,* Hanser, München, Wien.