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FORECASTING OF FUTURE DEVELOPMENTS BASED ON HISTORIC ANALYSIS

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1. Introduction

Today, companies in the consumer industry often offer different products and numerous product variants to address the customer needs in globalized markets. The products variants can be grouped in platform-based product families [Jiao et al. 2007], for example sport cars, family cars, or vans. The product family again comprises different product variants which are distinguished by at least one variant specific characteristic [DIN199-1 2002], [Ponn and Lindemann 2011]. Many companies use product platforms to cope with the challenges of the high number of offered variants. With product platforms, comprising one or more product families, a high external variety can be offered to different markets with different needs [Baldwin and Clark 2000], [Sanchez 2004]. Different customer needs can be specific for countries or regions, for example left- or right-hand drive vehicles. Further external causes for a high product variety are legislation, customer habits, different market segments, competitive products [Pahl et al. 2007] or market strategies [Porter 2008]. On the other hand, internal triggers for product variety can be different production sites with different production technologies, raising dynamics of innovations and technology as well as shortened development and release cycles [Ponn and Lindemann 2011].

Moreover, the development, release and update cycles of technical products decrease. The reason for this arises from the required reaction to changes in the market or the environment the producing company interacts in. These reactions to external changes in terms of new product variants lead to a high workload for the company along the product lifecycle: marketing for constantly monitoring the market acceptance/success of their products, the market needs and competitors; development and production for the manufacturing of new product variants, distribution for selling and delivering the variants, and service for having more spare parts available.

Due to the high variety and the changes in the environment, many product variants emerge during a lifecycle of a product platform. Therefore, we aim at the anticipation of future trends and possible product characteristics, functions, modules and components valuable for the customers in order to plan and design product platforms. This platforms cope with both, high variety and efficient deduction of new variants, either planned or reactive. The platforms should incorporate a robust core which remains unchanged over the platform lifecycle and flexible modules for efficiently deducing the required variants [Bauer et al. 2013].

To achieve such platform concepts, this contribution focuses on the forecast of product characteristics to know the required variants in future and design the right scope of such a future-oriented platform. We developed a three-step analysis and forecast approach: the first step includes a historic analysis of offered variants. On three levels, the lifecycle of variants, changes of the characteristics describing the considered product families and changes of specific product characteristics are analysed. Based on this, a prognosis of future developments is executed by mathematical models and matched with expert

statements regarding future development and customer trends. In the last step, the previous results are compared to determine the dynamics of the characteristics for a robust product platform design.
After presenting the background of the study regarding variant management as well as analysis and forecasting methods, the approach will be presented and illustrated in a case study, followed by a discussion of both, obtained results and the presented approach. The paper is completed by a summary and future outlook.

2. Theoretical Background

2.1 Platform-based product family design

According to Meyer and Lehnerd [1997] a platform is defined as a set of common assemblies, modules and parts, which form a mutual basis. Robertson and Ulrich [1998] expand the component view by three further categories: processes, knowledge, people and relationship. The objective of incorporating a platform is to achieve synergies by using same elements (e.g. components, functions, technologies) in several products. According to the aspired commonalties and required product differentiation the product structure is divided into platform and non-platform elements [Blees 2011].
In the context of this paper, a platform is defined as a technical system composed of product characteristics which are common for all product family variants and along the product life cycle. These characteristics build the core of the product platform and remain unchanged over the platform lifecycle. The product variants themself are composed of different specifications of characteristics to meet the requested differentiation in the planning phase as well as during the life cycle due to required changes driven by the influences mentioned above. These dynamic characteristics should be incorporated in the platform architecture by a high flexibility for efficient changes and replacements.

2.2 Product family and variant structure

The entirety of all offered product of a company is called product portfolio. This product portfolio can include several product families. These "product families group related products which can be derived from a product platform to satisfy a variety of markets niches" [Simpson et al. 2006] and share similar components or functions [Meyer and Lehnerd 1997]. Product families can be further sub-divided in basic devices which serve as instance between the product family and the product variants. The basic devices are distinguished from each other by the variation of a relevant specification of characteristics, for example performance- or dimension-related. The single representatives of a product family respectively basic unit are called product variants. Product variants are referred to as products with the same purpose which are distinguished in at least one characteristic [DIN199-1 2002], [Ponn and Lindemann 2011]. Robertson and Ulrich [1998] designate them as distinguishing characteristics of a product family which have different specifications. The overview of the structuring from the product portfolio to single product variants is shown in Figure 1.

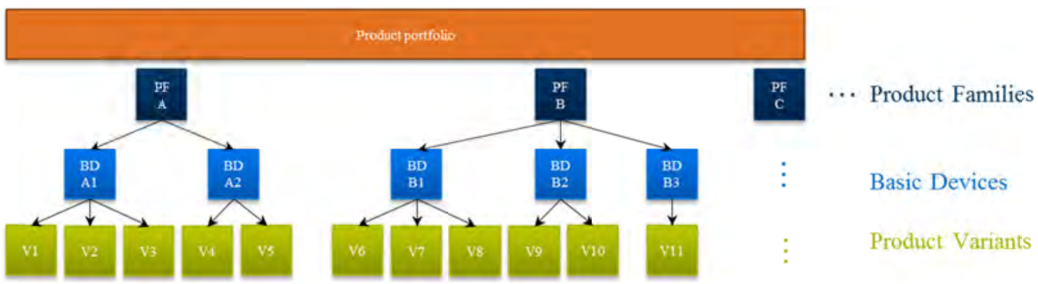

Figure 1. Decomposition of a product portfolio into variants

In summary, the different levels in Figure 1 are differentiated in some product characteristics and its specifications and are grouped together regarding their communality. From the product family level to product variant level, the products are more specified and feature a higher variety by different product characteristics and its specifications. These differences and the historic and expected development of these characteristics are the object of the developed approach. Therefore, the definition of Pahl et al.

[2007] is used, where features or properties of a product are defined by its characteristics and its associated specifications. For example, one product feature can be described by its material (characteristic) and its specifications (steel, aluminium, plastic etc.) or its colour (characteristic) and its specification, such as black, white, blue.

2.3 Methods for historic analysis and forecasting

For the analysis of historic data, several methods exist within the field of statistics. For the scope of this paper, the visualization and analysis of changes happened in the past are in the focus. Time series analysis are applied for the compilation of characteristics to different points in time [Fahrmeir et al. 2009], for example stock or oil prices. This analysis is based on trends and seasons. Trends can be referred to as the search for underlying smooth time functions, whereas seasons comprise the search for seasonal patterns.

Using component models [Fahrmeir et al. 2009] can help the decomposition of time series for identifying reasonable effects such as trends or conjuncture. Moreover, global trend models can be used by known trends for a mathematical approximation by fallbacks for linear, quadratic, polynomial, or exponential trends. In contrast, local approaches use moving averages by the utilization of an arithmetic average in order to identify trends. The arithmetic average is calculated by an 2q+1 long period, whereas t is the point in time in the middle of the time period and q is smooth factor, for example in days or months.

For forecasting future developments, various qualitative and quantitative methods are available. Qualitative methods represent suitable, methodical developed forecast rules without a forecast model but by the use of experience of experts [Crone 2010]. Qualitative methods, such as presented and discussed by Lichtenthaler [2002, 2005], are not considered here as quantitative methods based on the quantitative results of the historic time series analysis should be applied. Moreover, Fye et al. [2012] have executed a detailed comparative study of noumerpous forecast methods. Qualitative method are in general less accurate but allow the possible forecast of possible , not yet existing events, whereas quantitative methods are more accurate especially by reoccurring events and shorter forecast periods.

Besides other quantitative forecast methods, such as patent and publication analysis, option assessment models, s-curves or simulation [Lichtenthaler 2002, 2005], the quantitative time series analysis is of major interest. Based on historic data, the quantitative time series analysis extrapolates these data. Quantitative time series analysis model are dependent from the type of the time series and the mathematical base frame. Crone [2010] presented twelve different patterns for time series. Dependent from this data input, the mathematical model must be chosen or adopted.

Exponential smoothing ranks among the moving-average methods. The moving average is extrapolated and damped by a historic mean value [Taylor 2003]. The ARIMA approach (Auto Regressive Integrated Moving Average) unifies the exponential smoothing and regression methods. The forecast is based on a linear combination of historic values and random error values [Mertens and Rässler 2012]. This model is based on three parameters, whereas p and d represent the order of the model and are determined by random parameter variation such as the Monte Carlo simulation [Johansen 2010]. The third parameter q is determined by precondition of the approach, for example the historic data input. Another quantitative time series analysis method is pattern recognition, which uses artificial neuronal networks which are capable of learn and reproduce functional dependencies [Mertens and Rässler 2012].

Based on an assessment of the forecast accuracy, the usability, the specific advantages and disadvantages as well as the applicability (in the context of this research) of the presented methods, the ARIMA approach coupled with a Monte Carlo simulation was chosen for the quantitative forecast of future time series based on historic time series.

3. Approach for the historic analysis and forecast of product characteristics

The developed approach for the time series analysis and forecast consist of three major steps: analysis, forecast and comparison (see Figure 2). In the following, these three steps are explained in more detail.

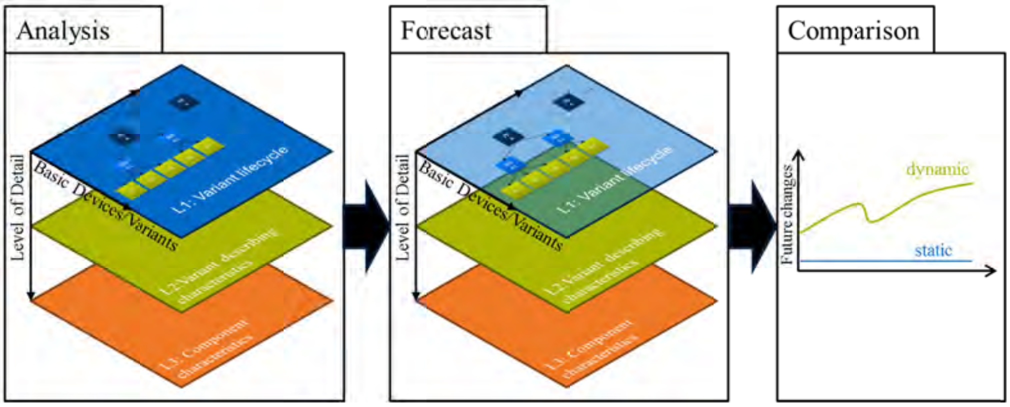

Figure 2. Approach for the historic analysis and forecast of product characteristics

3.1 Historic analysis of time series

The developed analysis method for a historic variant analysis is divided into three analysis level. With each level, the level of detail of the analysis increases. The analysis is capable of processing all variants of a portfolio, variants of one or more product families, basic devices and its deduced variants. Figure 3 shows the three analysis levels and the generated results.

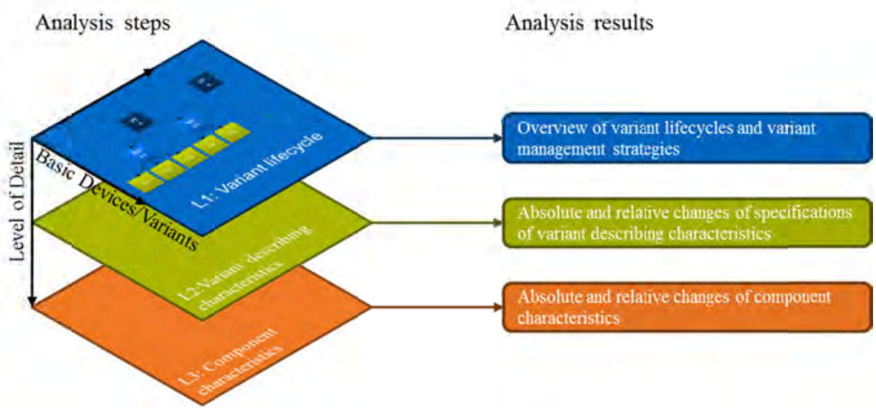

Figure 3. Procedure, level of details and results of the historic analysis of time series

First level – Variant lifecycle: On this level, the analysis procedure is independent from the choice of analysis scope. Variants of the whole product portfolio including several product families, variants of specific product families, basic devices or variants derived from basic devices can be analysed. Based on the sample extent, the temporal lifecycle of the included variants is visualized depending of their market launch date and withdrawal date (see Figure 4). Technical related variants, e.g. predecessor and successor, are grouped together in the visualization to highlight their relationships. This can result in an overlay if both variants are offered at the same timeframe. Technical non-related variants are not superimposed in the visualization. To highlight variant rollouts - identified by numerous variants launched at the same date – different colours are used.

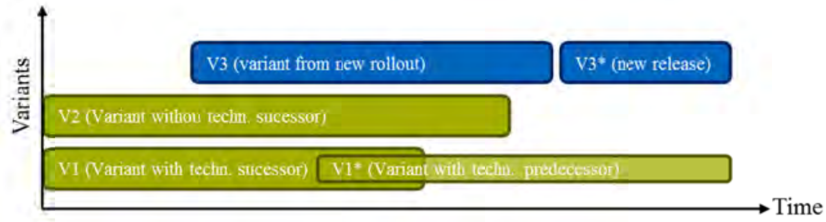

Figure 4. Exemplary visualization of the lifecycle of variants

From the visualization of the variants‘ lifecycle, two aspects can be deduced: first, the variant management strategies regarding the release management and the possible reactions to market demands and the success of the variants. The applied strategies which can be deduced from the visualization are the extension of the offered portfolio by launching new variants, introduction of variants as successors of existing variants (both variants in parallel), and substitution of an existing variant be a new variant, phasing out existing variants, upgrade and evolution of several variants. Second, a variant tree including the variation parameters of the product variants can be generated. This allows an overview over the offered range of variants and the variation of its specifications.

Second level – Analysis of characteristics describing the variant

Here, the (company-internal) coding of each single variant which includes the characteristics describing and specifying each single variant (e.g. technology, design, key performance parameters) is decoded. The specifications of these characteristics and its changes over time are analysed. The historic behaviour of these characteristics and its specifications are depicted and analysed according their change frequency and their temporal changes. Based in this, the historic development can be classified in active or inactive temporal behaviour.

Third level – Analysis of component characteristics

The third level represents the most detailed level of the analysis approach. The different specifications of the components (e.g. design, value, material of a component) are analysed according their changes. This generates more detailed information about the historic changes than level 2 and supports the analysis results of the second level by linking these changes to components. The procedure and the analysis is the same as in the second level.

The analysis of the characteristics on the second and third levels is based on their historic changes. The curve of the changes of the characteristics must be determined for further analysis and the visualization of the temporal changes. The analyzed period and the scope of the analysis (all variants within the portfolio or varaints of one product family) define the input parameters for the analysis. Based on these two parameters, the variants are first sortet according to their launch date. Then, the specifiactions of the charactersitics of level 2 and 3 are analyzed. This anaylsis is an iterative procedure for all characteristics on these both levels. Starting with the first characteristic, the algorithm looks for all sepcifications of these characteristic on each sigle day. If the characteristic is for example the colour, the possible specifications “white”, “black”, “green” etc. are examined simoultaneously for changes. If a new variant appears or disappears in this time period, the change counter is increased respectively decreased by 1. The resulting values are kept for each day. Based on this, a temporal curve for each characteristic is generated. On the second level, only the temporal behavior of the characteristics is extracted. The accordant specifiactions follow on the third level.

The curve of the characteristics (typically a step function) serves as a fundament for the determination of the changes. Therefore, two indices for characterizing the historic changes are deduced on the second and third analysis level: absolute and relative number of changes.

The absolute number of changes answers the questions which characteristics are introduced or removed since the beginning of the analysed period. This allows conclusions towards the introduction or withdrawal of characteristics and accordant technologies over time. An absolute change exists if a specification of a certain characteristic appears, which did not exist before, or an existing specification disappears. The absolute change is quantified by the sum of the appearing respectively disappearing specifications of a characteristic. The absolute changes are assigned to the point in time the change appeared and summarized in a curve over the time of the analysis.

The index of the relative change describes the progression of characteristics of variants over time. Through this view, active characteristics and its specifications with a high number of changes can be identified. A relative change exists if the specification of a characteristic changes between different variant launch dates. The reference is built by the last variant of the previous launch date respectively a technical predecessor, if existing. This reference is compared with all variants of a certain date. The relative change is quantified by the absolute value of the sum of the specification changes of a characteristic. This is based on the hypothesis that a characteristic can only be changed if a new variant is launched as a relative change reflects the change between existing and new variants. The analysis on level 3 is not executed on a daily search as only the launch dates are of interest. Moreover, there is a distinction between variants with and without a predecessor: in case of an existing predecessor, the change of the characteristic is identified and the difference is quantified. For the changed characteristics the counter is increased by 1, for the unchanged characteristic the counter remains constant. The same procedure is applied for new variants without predecessor. In this case, the comparison of the characteristics is done regarding a reference variant. If numerous variants are launched at the same time, the algorithm compares these separately with the reference variants.
The result of the level 3 analysis is relative changes to all launch dates during the considered period. The values of the relative changes can be visualized in a histogram (see Figure 5, left) or a cumulative step-function (see Figure 5, right).

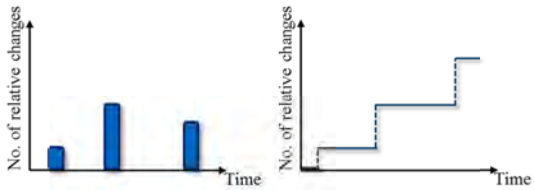

Figure 5. Histogram (left) and step function (right) for visualizing the relative changes of characteristics

The interpretation of the analysis results of level 2 and 3 is executed according to historic curves, actual trends and the variety of the specifications of characteristics. Actual trends are based on the evolution of the specifications of the characteristics by using boxplots and a trend portfolio. Boxplots provide information about the number of variants containing the considered specification. The size of the box relative to the median illustrates the amplitude of the variation and correlates with the speed of growth. Therefore, the boxplots represent the development of the whole considered period. As the number of variants with the considered specification of the characteristic at the end of the period cannot be identified in a boxplots, a histogram is used to mirror this number. Figure 6 shows the applied visualizations for further interpretation – a historic curve (a), a boxplot (b) and a histogram (c).

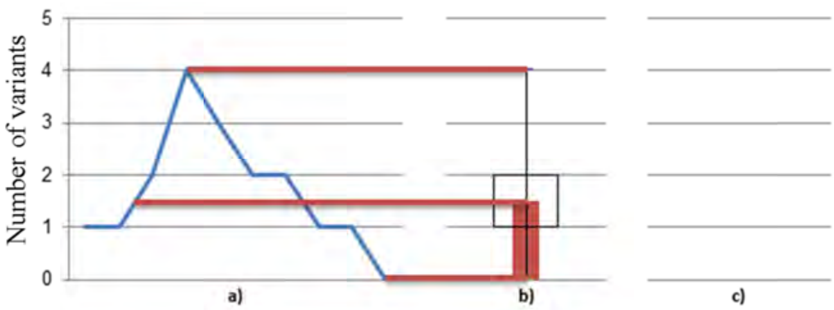

Figure 6. Development of changes: historic curve (a), boxplot (b), histogram (c)

The variance of the characteristics is determined by the analysis of absolute and relative changes of the specifications. As the relative changes increase monotonically their maximum is always reached at the end of the considered period. A histogram for showing the end value is not necessary as a boxplot is sufficient for the interpretation of the relative changes. The maximum represents a measure for the frequency of change and is used for an indication of active and passive characteristics. The distance between the upper and lower quantile represents the speed of growth v_{rel}. The relation of the values shown in the boxplot allows conclusions regarding the temporal distribution of changes (see Figure 7):

1. If all values of the boxplot are equal zero, no changes occurred.
2. If the median, the upper and the lower quantile are coextensive with each other, the characteristic is stable over time, meaning there are no changes in the middle of the considered period.
3. If the median, the upper and the lower quantile are not coextensive with each other, temporal distributed changes occurred.
4. If the median with a low value is coextensive with the lower quantile, many late changes occurred.
5. If the median with a high value is coextensive with the lower quantile, many early changes occurred.

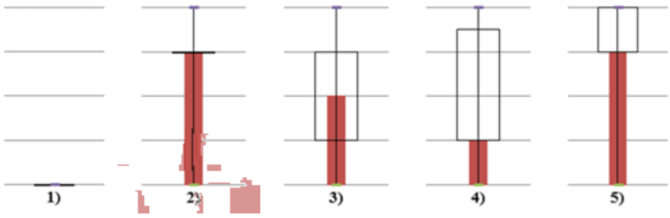

Figure 7. Interpretation of temporal distribution of changes

Moreover, a trend portfolio showing potential of growth and the number of variants (respectively the number of absolute changes) with the considered specification is generated. The potential of growth represents the potential possible increase of a specification. It considers the algebraic sign to identify both, increases and decrease in the potential of growth, and compares the first (x_1) and the last value (x_n) of the period. Moreover, the relative growing speed v_{rel} and a specification weight m are incorporated, see Formula (1). The weight m is determined by the number of variants, whereas v_{rel} represents the percentage of growth of a specification based on half of the period. In the trend portfolio, the relative growing speed is shown by the size of the bubble.

$$\text{Potential of growth} = v_{rel} * m * \text{sgn}(x_n - x_1) \quad (1)$$

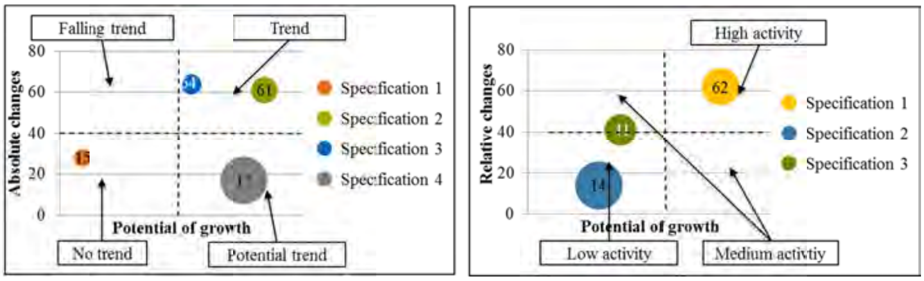

Figure 8. Trend portfolio (left) and activity portfolio (right)

The trend portfolio (see Figure 8, left) is generated for each specification of the characteristic, including the speed of growth (size of bubble) and allows following interpretation:

- Bottom left: low number of variants a low potential of growth → no trend
- Top left: high number of variants a low potential of growth → falling trend
- Bottom right: low number of variants a high potential of growth → potential trend
- Top right: high number of variants a high potential of growth → trend

The activity portfolio (see Figure 8, right) including the number of relative changes, the potential of growth and the speed of growth allows the identification of the activity of the characteristics. The activity of a characteristic is the sum of relative changes of its specifications and is calculated by the same formula as (1), whereas m represents the number of relative changes.

3.2 Forecast of future developments

In contrast to the analysis which is executed on three different levels, the forecast only focuses on characteristics and specifications and does not comprise the variant lifecycle level. But with the equivalent levels 2 and 3, the compatibility of the first and second phase of the overall approach is ensured. The scope of the forecast also can range from all variants of a portfolio to single basic devices and its derived variants.

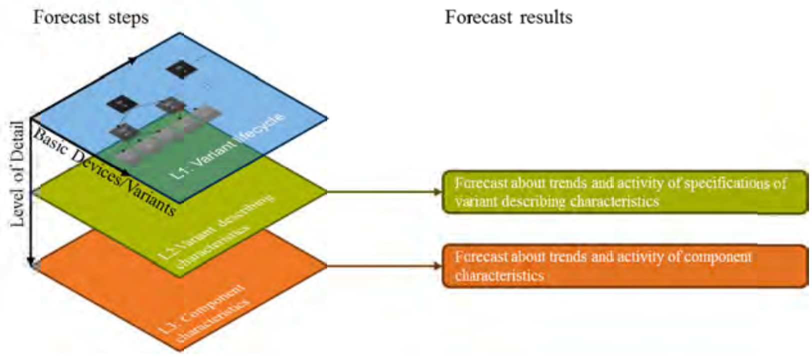

Figure 9. Procedure, level of details and results of the forecast of time series

The quantitative time series forecast method is based on the historic data as it deduce parameters from the historic analysis, such as seasonal influences and the type of curve. Every time series on level 2 and 3 is forecasted separately using ARIMA (Auto Regressive Integrated Moving Average) including Monte Carlo simulations to simulate different parameters by means of random patterns [Johansen 2010]. By this parameter variation a covering of probability of 95 % is achieved. Based on this, the medians well as the calculatory lower and upper 2, 5% boundary of probability is generated. Afterward, a linear correction of the time series progression by input of qualitative, expert-based trend analysis is integrated.

Based on the forecast scope (variant portfolio, variants of a product family or basic devices and deduced variants), the required historic data from 3.1 are used. The ARIMA procedure starts by setting following parameters: period of the forecast, number of Monte Carlo simulations and the corrective factor from the qualitative trends. For the calculation of the forecast trends, an ARIMA (p, d, and q) model is applied, whereas d represents the number of differentiation necessary to reach a constant time series; p and q are systematically varied in order to receive the values with the highest probability for an optimal model performance.

To identify the accuracy of the forecast, a part of the time series is used for testing. The historic data comprises two third and the last third represents the forecast period. This means the forecast period is half the time as the historic analysis. The deviation of the forecast is identified by the Root Mean Spare Error, RMSE [Crone 2010, S. 134]. The RMSE allows conclusions about the forecast accuracy and the quality of the results.

3.3 Comparison of historic and forecasted changes

Based on the trends and activity of the characteristics derived from the historic and the forecasted changes, the characteristics are compared in order to classify them into static and dynamic ones.

Static characteristics delineate the ones which have not been subject of many changes in the past and are expected to be stable within the forecast period. Such characteristics and their realizing components or modules should be integrated into a product platform. This platform should be stable and unchanged during its lifecycle.

Dynamic characteristics have been changed a lot in the considered past and also are expected to change often in the future. Such characteristics should be used to differentiate the variants among each other, towards competitors' products and can be matter of innovations during a product platform lifecycle. This knowledge about dynamic characteristics is important to design these characteristics

respectively their realizing components or modules in a flexible way and not including them in a product platform, e.g. by standardization.
Table 1 shows the possible combinations of the activity of the characteristics and the resulting classification into static and dynamic ones.

Table 1. Classification of characteristics based on the historic and forecasted activity

Activity historic analysis	Activity forecast	Clasification
low	low	static
middle	low	static
high	low	static
low	middle	static
middle	middle	static
high	middle	dynamic
low	high	dynamic
middle	high	dynamic
high	high	dynamic

4. Case-Study

The developed two-step approach for historic analysis and forecast shown in the previous section was applied using two different product families projects of the white good industry (see Table 2). The analysis and forecast included all possible information which could be extracted from the provided data base. In this paper, we will present only an excerpt of the case study on the three analysis levels and the two forecast levels.

Table 2. Overview over the scope of the case study

	Product Familiy Project 1	Product Familiy Project 2
Number of product families	1	11
Number of basic devices	8	2
Total number of Variants	200	638
Time period	03.2011 to 11.2013	03.2006 to 11.2013

4.1 Historic analysis of time series

On *the first analysis level*, the overview of the lifecycle of the considered variants is generated. Figure 10 shows the lifecycle overview for the product family project 1. It can be seen that the number of variants increased steadily: 70 at the start of the product family to 169 at the end of the considered time period (+141% variants). Also the basic devices increased from 5 to 8. In total, there were several small continuous waves of variants' introduction, maximum all 3 to 4 months, leading to a constant market penetration. Moreover, one substitution wave can be identified, replacing 10 variants by new ones. Another interesting aspect is that two variants only have been at the market for about nine months. The average market availability of the variants was around 550 days, minimum 150 days, and maximum 700 days.
In total, 130 new variants were introduced after the launch, 118 of them were newly added,
12 were replaced, and 31 were completely removed.

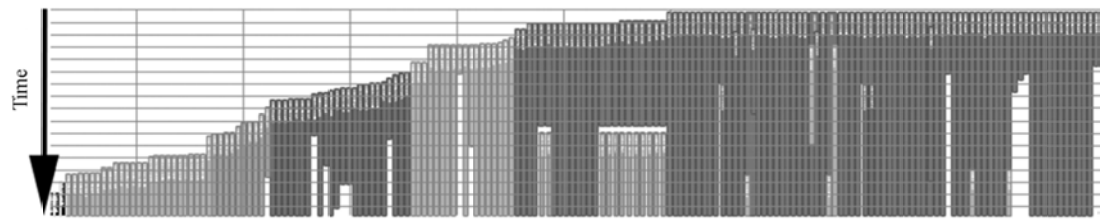

Figure 10. Overview of the variants' lifecycle of product family project 1

As the second and third analysis level use the same procedure and interpretations but on a different level of hierarchy, only an example of the *second analysis level* is given here. One exemplary characteristic, describing the range of features, and its specification is presented. The characteristc has five different specifications. Figure 11 (left) shows the absolute changes of these sepcifiactions in a step function over time. Spec. 1 and spec. 4 are constantly increasing up to 60 absolute changes. Spec.3 was removed and introduced again.

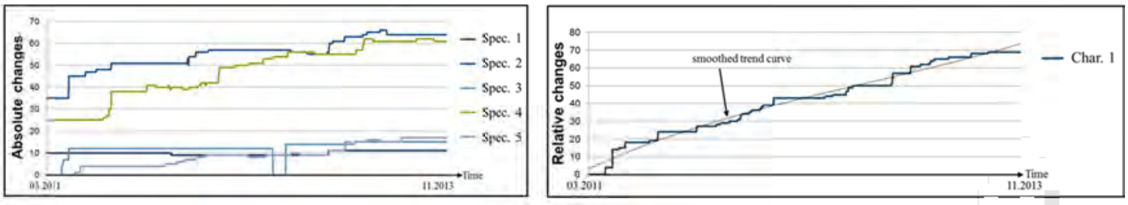

Figure 11. Absolute (left) and relatives (right) changes

Moreover, the number of relative changes of this characteristic was added up of the absolute changes of its specifications. The result can be seen in Figure 11 (right). As defined in 3.1, the curve is increasing over time and averaged with a smoothed trend curve.

The variance and speed of growth of the specifications of the considered characteristics is determined by the analysis of the relative changes with boxplots. The maximum of the boxplot represents the measure for the frequency of change and is used for an indication of active and passive characteristics. The distance between the upper and lower quantile represents the speed of changes. This information is then transferred into the trend and activity portfolio. The results for the trends of the specifications as well as the activity of the considered characteristic are shown in Figure 12 (left).

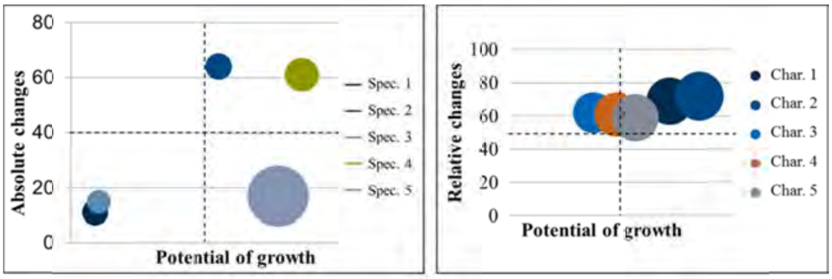

Figure 12. Historic trend and activity portfolio

The specification 2 and 4 are assigned trends as they have a high potential of growth, a high number of different variants, and especially Spec.4 shows a high speed of growth. Spec. 5 has the highest speed of growth and a high potential of growth. But as this is based on less absolute changes, Spec.5 is characterized as a potential trend.

The trend analysis and classifications was done for all specifications of all characteristics. On the right side of Figure 12, the deduced activity portfolio of five variant describing characteristics is shown. All of them had many relative changes and their potential of growth range in the upper two-thirds. Char.1, which specifications are shown in detail, as well as Char. 2 and Char. 5 is classified as active due to their high number of relative changes and their potential of growth in the analyzed historic time period. Char. 2 represents a design characteristic of the product and has the highest activity. Char. 3 and Char. 4 are classified as middle active characteristics but it is hard to classify definitively in this case.

4.2 Forecast of future developments

For the forecasting of the time series, the historic time series built the basis for the ARIMA-method. For the systematic parameter variation required by ARIMA, 50 Monte Carlo simulations were run through for each time series. The chosen forecast period was ten years. The presented forecast results

of the time series of the specifications are shown for the same characteristic and its specifications as above.
In the expected trend portfolio, Figure 13 left, shows the forecasted absolute changes, potential of growth and speed of growth. Spec. 2 and 4 are classified as trends, mirroring the result of the historic-based time series analysis. The potential of growth of Spec. 3 and 5 decreased respectively increased, meeting on the border of no trend and potential trend. Spec. 1 is still classified as no trend.

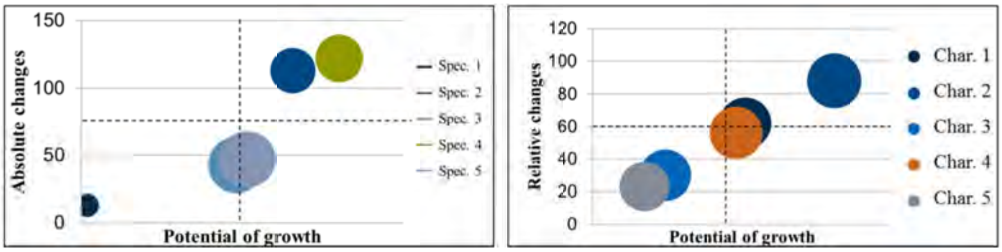

Figure 13. Historic trend (left) and activity (right) portfolio

Again, the five variant describing characteristics were transferred into the activity portfolio, see Figure 13 (right). Char. 2 is categorized as a very active characteristic whereas Char. 3 and Char. 5 have a low activity. Char. 1, which specifications are shown in the trend portfolio in detail, and Char. 4 moved towards the middle of the portfolio and range between middle and high future change activity.

4.3 Comparison of historic and forecasted changes

In the comparison, the trends and activities of the specifications respectively characteristics are compared to categorize them according their dynamic properties for future platform design. As the trends for the specifications of the presented characteristics feature differences between the historic and forecasted trends, this characteristic is instable towards its trend. The result of the classification of the five characteristics towards their expected dynamic is shown in Table 3. In total, two characteristics show a robust respectively not dynamic behaviour regarding future changes. These can be integrated into a product platform for a change perspective. The other three characteristics show a high dynamic and should be kept flexible, for example in exchangeable and efficient-to-change modules.

Table 3. Classification of characteristics based on the historic and forecasted activity

Characteristics	Activity historic analysis	Activity forecast	Classification
Characteristic 1	high	high	dynamic
Characteristic 2	high	high	dynamic
Characteristic 3	high	low	robust
Characteristic 4	high	high	dynamic
Characteristic 5	high	low	robust

5. Discussion of the results

The presented method for analysis and forecasting characteristics of multi-variant portfolios allows a representation of both, the current and the future state. One the one hand, this can improve the planning and design of new platform-based product families. Based on the historic and forecasted data, characteristics with dynamic and robust behaviour regarding future changes are identified. Temporal robust characteristics and its fulfilling components can be implemented in the platform from the change perspective as no change is expected over the platform lifecycle. Dynamic characteristics should be designed as flexible, encapsulated modules to allow frequent changes, for example driven by changed market demands. By the means of standardized interfaces the characteristics respectively their fulfilling components can be changed fast, allowing fast responses by lower costs and efforts.

Such thoughs can also be integrated by the re-design of an existing product family, e.g. a new generation.
On the other hand, the variant management strategy can be supported by the presented approach. The implementation of the current strategy can be reviewed and possible deviations can be identified and link to causes. In the presented case study, a shift from a continuous market launch can be shifted to planned and defined launch waves (with more time in between the waves) together with an accompanied marketing strategy. Also, the average lifecycle of variants can be analysed and deviation can be identified.
Of course, it must be noticed that the recommendations for a platform design are partially based on a mathematical forecast model. Such a forecast cannot represented the reality but constitute possible future developments. Especially with an increasing forecast period, the influence of external influences and its uncertainties arise which cannot be eliminated totally with the applied ARIMA approach. Moreover, the mutual influences of the forecasted time series are currently not considered.
In summary, the approach can exactly depict and visualize the historic development of a portfolio on different levels of details and with different analysis scopes. This improves the transparency about the development in an easy visual way in contrary to lists available in data bases. The forecast gives indication for the trends and activity of the characteristics and it specifications on two different levels. This can serve as a basis by the re-design or the design of a completely new platform-based product family. The forecast data should support the data acquired by the marketing, for example from market studies and customer surveys.

6. Discussion of the approach

The approach for the historic analysis of a portfolio fulfilled the set objectives and delivered the expected results. By the analysis of a second product family project including more product families and variants the robustness of the analysis towards large data sets could be shown. Moreover, the absolute and relative changes of characteristics could be analyzed and therefore historic trends, the growth potential and the dynamic activity of the characteristics could be identified. The classifications of trends are not always very clear due to the set boundary values. The relative consideration of the changes is sensitive allows a comparison but always has to be set into the analysis context and the number of changes of other characteristics.
One of the biggest strengths is the efficiency of the analysis regarding trends and the dynamic activity. It is expected that the analysis can be also expanded to other products and therefore is generalizable. The only boundary condition is set by the structure of the data to be analyzed. For example, the search algorithm for the second analysis level must be adopted if products are coded in a different way.
The forecast method also reached the set objectives as a forecast of the expected changes of variant describing characteristics and its specifications is possible. The stability of the forecast tool has to be improved in the future as for some time series the tool crashed and could not deliver results. In these cases, no trends from the analysis were available for the forecast but should be considered in the future for a more comprehensive view. Moreover, the forecast method should be enhanced by generic trend in order to consider the supervention of new trends. A very interesting results is that the forecast of the relative changes correlate with the s-curve theory. After a steady increase of some characteristics a parabolic curve including a maximum resulted which can be an indicator for saturation in the development and can serve as an indicator for a technology change. Another already mentioned aspect is the accuracy of the forecast with an increasing forecast period.
The whole approach shows a good applicability as only historic data sets are required for an analysis and the forecast. Also the approach is quite flexible as the different analysis levels can be chosen as wanted and are not inevitably dependent from each other.

7. Outlook

Future research concerning this approach entail following aspects: first, the causes of changes should be identified by the visualization of the historic analysis. By knowing these change causes, the strategy for reaction towards external and internal driven changes should be evaluated critically. Second,

popularity trends by the use of sales figures of all variants will be analysed and compared to the historic developments. With this, it can be seen to which degree introduced variants were successful in the market and how the market success steered the variant management strategy. A pilot study is already on-going at the moment.
Regarding the forecast method, generic trends will be included in order to allow the introduction of new possible trends in the forecast. Moreover, the tool will be overworked to achieve a better robustness for the deduction of possible forecast of all time series.
Moreover, the results presented in the paper will be used to plan and design a platform which includes – besides other perspectives – the temporal activity of the characteristics, its probability and its frequency of change. With this dynamic perspective, a platform should be developed which is capable of future changes in an efficient way and avoids changes to the constant platform core during the lifecycle of the platform.

8. Summary

This paper presents a three-step approach for a historic analysis of a variant portfolio and a forecast of the development of specific characteristics of variants and their specifications. The historic analysis comprises variant portfolios, product families, basic devices and all derived variants. The analysis is conducted on three different levels: in the first levels, the lifecycle of the variants is visualized according their launch and end date and is analyzed according the variant management strategy. On the second level, the bsolute and relative changes of specifications of variant describing characteristics are analyzed over time. The third level includes the absolute and relative changes of component characteristics. Based on the second and third levels, trends and the activity of these characteristics are deduced.
The forecast method includes a mathematical model using the ARIMA approach and systematic parameter variation by a Monte Carlo simulation. The forecast is limited to the second and third level to forecast trends and the expected activity of both, the specification of variant describing characteristics and component characteristics. In the last step, the trends as well as the activities of the analyzed characteristics are compared in order to classify them towards their dynamics. This classification gives an indication of such a characteristic should be kept robust or flexible in designing or re-designing platform-based product families.
The approach is validated by a case study, analyzing two different product family projects. In this paper, only examples are shown. The results as well as the approach are discussed towards their strengths and limitations, before giving directions for future research regarding the presented approach.

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