VARIANT MANAGEMENT TOOLBOX

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Abstract

The approach focuses on methods in the field of product variant management. Drawn from the experience over ten years of variant management work in practice, it suggests a toolbox which improves the application of methods and tools in this area. Starting with the definition of "product variant" from the customer's and a company's internal view, a framework for variant management is outlined. The framework describes, how product features can be translated into component variants. The toolbox for variant management consists of several methods and tools. The presented framework serves as an ordering scheme for this methods and tools. The toolbox includes analytic methods, measures and design principles. To illustrate the application of the variant management toolbox a practical example is given by the concept design of axial piston pumps with a focus on a variant-reduced product structure. Particularly the architecture matrix and the variant-optimized design are carried out in the example. Finally, an outlook raises the question, how the toolbox can be subject to digital transformation.

Keywords: Design methods, Design practice, Product architecture, Innovation

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1 INTRODUCTION

Over time lots of compilations for product design methods, e.g. Pahl and Beitz (1996), as well as methods for complexity management, e.g. Lindemann et al. (2009), were published and till today brought to a wide range of practical application in industry. However, new approaches still appear. They give new insights to design methods, bring design methods into a new order for a better choice or even explain and illustrate methods in an innovative way that ensures much faster and easier practical application. E.g., the Design Thinking publication of Übernickel et al. (2015) provides innovation methods in terms of a "cookery book". "Innovation receipts" thus can be easily applied in everyday situations.

This approach focuses on methods in the field of product variant management. It suggests a toolbox which improves the application of methods and tools in this area. This approach of systematic variant management summarizes the experience of over ten years of variant management work in practice. Experiences were derived mainly in the sectors of machinery and equipment, automotive and component suppliers. Our emphasis of work was on small and medium-sized enterprises. The presented toolbox has grown steadily with every project carried out. New methods have been developed or existing methods have been adopted and/or added to the toolbox.

2 FRAMEWORK

Starting a variant management project requires to do some crucial definitions in the beginning. In the following section *product variant* is defined and the *framework* is initially outlined.

2.1 Product variants

One of most important tasks when starting variant management work in a company is to define the meaning of *product variant*. Figure 1 illustrates the definition of a product variant from two different views.

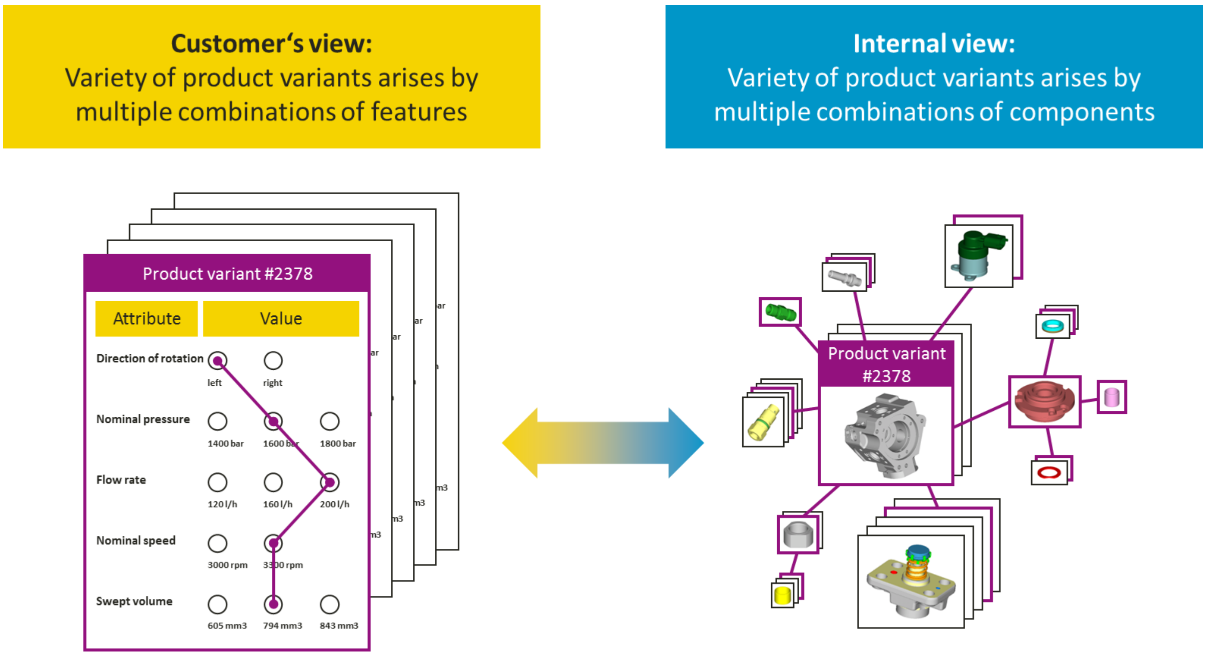

Figure 1. Definition of a product variant from different views

From the customer's point of view a product variant describes a combination of desired features. Accordingly, a huge variety of product variants arises by multiple combinations of features.

On the other hand, form the internal viewpoint of a manufacturing company, a product variant consists of a set of different components. A variety of product variants can be created by multiple combinations of component variants.

The challenge of variant management then consists in combining the two views in an efficient and economical way. The customer's individual needs represent a maximum of complexity, emerging from the high number of variants which, from an economic perspective, shouldn't be reduced. This required high complexity should be met by an internal complexity, which provides product variants in a most efficient way.

2.2 Framework

Following the definition of product variants from this different point of views, a framework was elaborated, which brings together the customer's view and the internal view. The framework as shown in Figure 2 describes in detail, how product features on the left-hand side are "translated" into component variants in a product structure on the right-hand side.

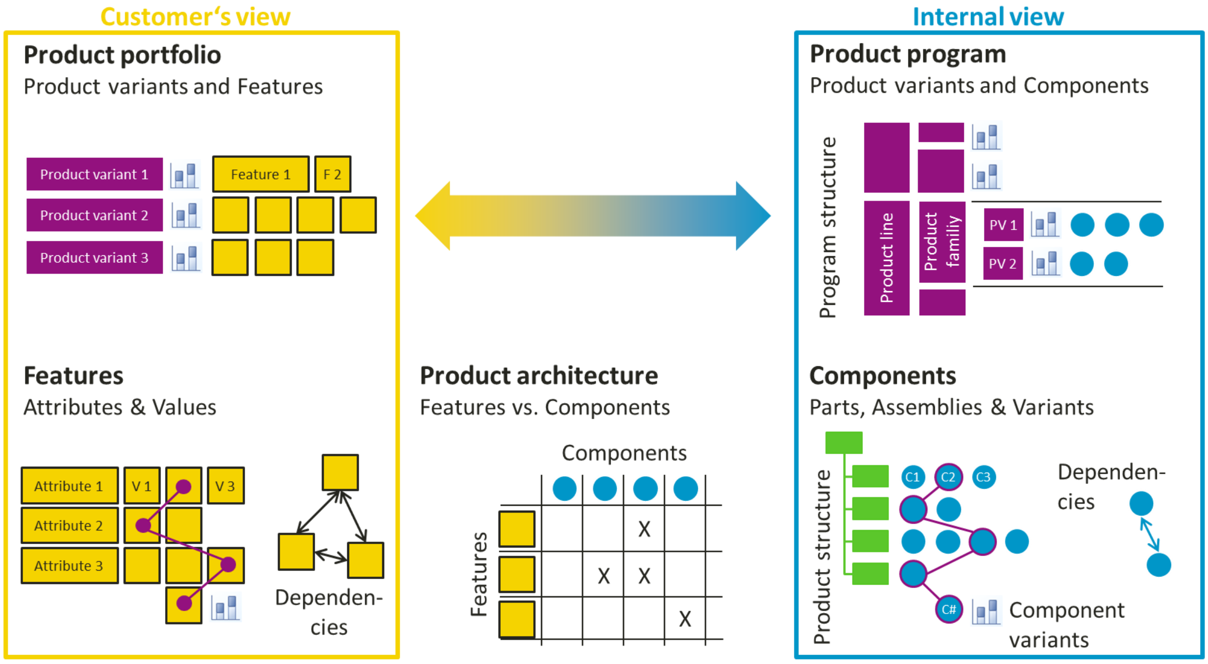

Figure 2. Framework

From the customer's view (*left-hand side*) a company offers a product portfolio, particularly an amount of product variants. The customer picks out or even configures those products that reach his needs because they provide appropriate features. In a competitive situation, the customer chooses the product of that company that provides features that are closest to his preferred features. For this reason, dealing with the product features of products in the product portfolio is a decisive task for a successful variant management.

On the other hand, a company should organize its product program in an efficient way (*right-hand side*). Hierarchical product program structures are still predominant. Product variants for example are grouped into product families and classified to product lines. They consist of components. Components can be physical parts and assemblies as well as software components. The structure of the product is more than the bill of material. The product structure describes the composition of the product. The design view on the product structure is only one view of different further views (manufacturing, sales, functional, etc.) that should be considered. On the way to mass customization (e.g. with highly individualized 3D-printed product variants) different product structure strategies are still prevalent in today's industry.

Product architecture brings together the customer's view and internal view. It defines, how product features are "translated" to product components. Product architecture management is the backbone of variant management.

3 TOOLBOX

The toolbox for variant management consists of several methods and tools. Methods and tools are sorted in the above-mentioned framework. A unique standard procedure for its application cannot be provided. But anyhow, it is possible to do a recommendation for proceeding.

3.1 Methods and tools in the framework

The presented framework serves as an ordering scheme for methods and tools for variant management as illustrated in Figure 3. In numerous industry projects over a time of ten years, we added methods and tools to the framework since they successfully have proved their application.
Various kinds of methods and tools are collected in the box. Several methods are focusing on analytical tasks. E.g. on the left-hand side the "ABC Analysis" and the "Profit margin" analysis can be applied to analyze sales frequencies of product variants and identify their profitability. Unfortunately, as experience shows, even today it is not unusual that companies don’t know their top-selling product variants (A-variants) with in addition provide best profit margins. The impact analysis is another example for an analytic method, located on the right-hand side. In the context of variant management, it is used to analyze dependencies between product components to obtain potential for an optimized product structure.
Other tools in the box provide measures for carrying out variant optimization. E.g. portfolio adjustment is applied to clear up the portfolio of product variants. Based on a thorough analysis of sales frequencies and profit margins of product variants in advance, it helps to eliminate low performing product variants in the portfolio or close gaps with missing variants.
Finally, tools are included that provide design principles for variant management. E.g. modular design is needed to build up an efficient building block system. Standardization is applied to create common parts.

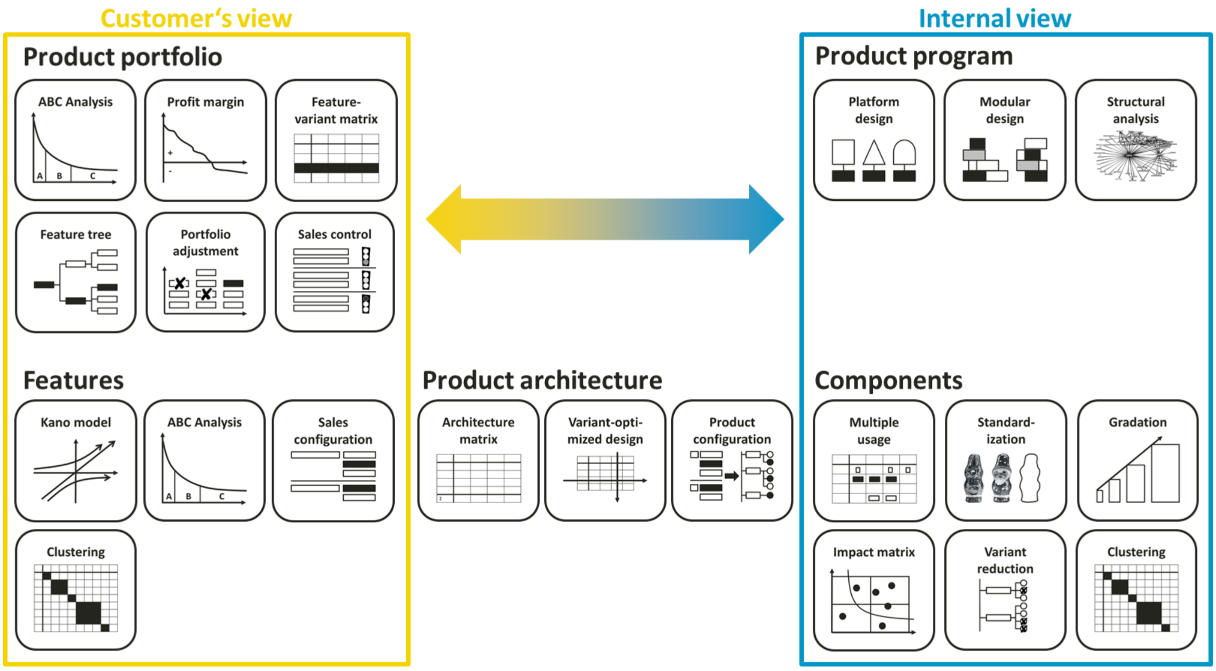

Figure 3. Toolbox: Methods and tools in the framework

3.2 Table of methods and tools

The toolbox contains several methods and tools that can be used in numerous application scenarios. However, in the following table the application of methods and tools is described in the context of variant management.

Table 1. Methods and tools

Tool	Description	Tool	Description
ABC Analysis	ABC analysis can be applied in the analysis of product variants and features. It enables to identify "top-seller" and "low-performer". Analysis should be accompanied by a profit margin analysis to investigate profitability of variants.	Platform design	A standardized core element is defined which can be combined with modules and components via standardized interfaces. Platform design reduces the number of variants and efforts regarding R&D, production and storage.
Architecture matrix	Architecture matrix visualizes the relation between the external (customer) and the internal (company) perspectives regarding the product. The product architecture "translates" the product features and functions into components.	Portfolio adjustment	A high number of products, features, components etc. are visualized clearly by using qualitative dimensions. It supports the decision-making process and provides potential for adjustments in the product portfolio.
Clustering	The objects are clustered to reduce the complexity and to make the system transparent. It is required to define the dependencies between the objects. Clustering can be useful for non-transparent or complex systems.	Product configuration	Product configuration allows to define convenient product variants for individual customer requirements. Order-related information is "translated" into production-related information. The bill of material is configured automatically.
Feature tree	The feature tree enables a systematic analysis and visualization of the product variety. In combination with an ABC-analysis the feature tree provides conclusions regarding variant-driving features.	Profit margin	The profit margins of product vatriants are calculated and the products are sorted descending according to their profit margin. Sales volumes and cumulated profit margin also have to be considered in the analysis.
Feature-variant matrix	The feature-variant matrix provides an overview for a high number of variants. The combinations of product features can be identified and planned. Similar variants can also be identified and possibly consolidated.	Sales configuration	Sales configuration is needed to create documents and to make a calculation for quotation. Starting from the customer requirements the appropriate product or product group can be identified, specified and visualized.
Gradation	Products of a type series are graded in respect to their economical value. Gradation reduces complexity and R&D efforts and increases reliability. Parametrization has to be carried out carefully in respect to functionality.	Sales control	Sales control supports sales staff by providing information in terms of preferred and not preferred variants. Variants are managed by a clearly defined classification. For example, higher prices can be charged for low sales volumes.
Impact matrix	The dependencies between the system elements are valued quantitatively in a matrix. The types and intensities of the dependencies can be identified and used to determine the potentials and measures.	Standard-ization	A standardized and simplified solution is developed for critical components. It reduces complexity, increases efficiency and saves R&D costs by multiple usage. The critical components can be identified by impact matrix.
Kano model	The Kano model can be used to analyze the product features. The dependencies between the product features and the customer satisfaction are classified and visualized. Basic, performance and delightful features are distinguished.	Structural analysis	The system elements and the dependencies between the elements are identified and visualized graphically. The impact matrix can be used as input. Structural characteristics provide measures for product optimization.
Modular design	Assemblies of components are defined which create functional and logical units with standardized interfaces. It provides flexibility and adaptability by assembling, disassembling, changing and recombining compatible modules.	Variant-opti-mized design	The product architecture is analyzed and the critical features and combinations driving the product variants are identified. Product architecture concepts are developed, evaluated and realized.
Multiple usage	The same components are assembled to different product variants or to the same variant many times. Multiple usage reduces complexity and saves costs regarding R&D, production and storage.	Variant reduction	Non-profitable product variants are removed from the product portfolio. It reduces the production and storage costs and makes the development of the next product generation easier.

3.3 Procedure

There cannot be given a standard path for passing through the framework. For different tasks with different requirements different starting points are recommended.

Our experience showed, that most of the challenges in industry concerning variant management are rather evolutionary than revolutionary. In only few cases, we were called to build up a product architecture from scratch with full freedom for designing a variant optimal product system. Of course, in this (seldom) cases it is reasonable to go through the framework form the left-hand side to the right-hand side. Nevertheless, iterations in procedure are inevitable.

Usually, variant management projects are initiated with a certain focus. This focus determines the starting point and the emphasis of work in the framework. E.g. in an advisory project for a drive technology producer the focus explicitly was set on reducing component variants. We carried out a thorough analysis to find patterns in the use of component variants - focus of work thus was on the *right-hand side*. Variants, that evolved from uncontrolled growth, could be pushed back to an economical level.

In another case, mandated by an automotive manufacturer, the perspective completely was directed to the *left-hand side*. The task was to optimize the combinatorics of equipment features. Technical feasibility and manufacturability (on the *right-hand side*) were predetermined and not in scope. We had to analyze the combinations of equipment features and could then identify potentials for building feature packages. For implementation, we used clustering methods - as listed in the toolbox.

Although we cannot provide a default guideline for going throughout the framework, a useful indication can be given: Start with creating transparency. Application of transparency methods is the first step, followed by tools for deriving measures for efficient variant management.

4 EXAMPLE OF APPLICATION: VARIANT-OPTIMIZED DESIGN

The following section gives an example for the application of the toolbox. In this case, the contract covered the concept design of a new generation of axial piston pumps with an optimized, particularly variant-reduced product structure. For the evolutionary approach, the existing product served as a starting point for optimization. Besides other methods, particularly the architecture matrix and the variant-optimized design were carried out in this case. Both methods are described exemplarily below.

4.1 Axial piston pump

To understand how methods and tools have been applied in this practical case, it is helpful to have a brief introduction to the composition and functionality of an axial piston pump as shown in Figure 4.

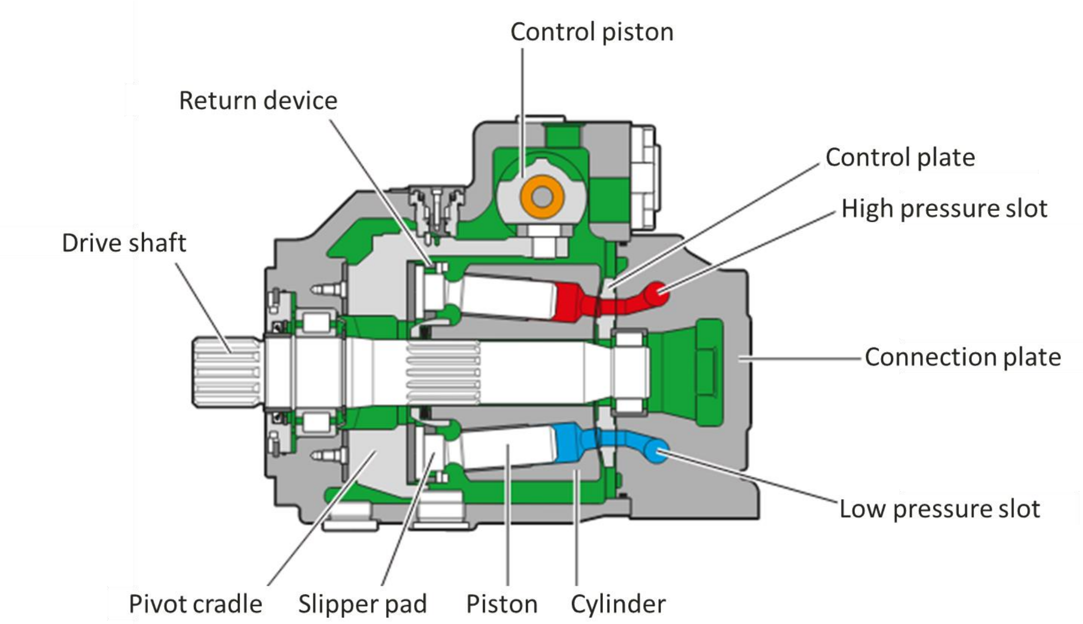

Figure 4. Composition of an axial piston pump

An axial piston pump is a positive displacement pump that has a number of pistons arranged in a circular array within a housing. Driven by a prime mover, e.g. diesel motor, the drive shaft rotates and, via the gearing, also causes the cylinder to rotate, taking with it the pistons. The pistons are held against the sliding surface of the pivot cradle by the slipper pads and carry out a stroke. The slipper pads are held against the sliding surface and guided by means of a control plate. As the cylinder rotates, each piston moves through the lower or upper dead point and back to its starting position. A movement from one dead point to the other, where the direction of movement is reversed, constitutes one complete stroke during which a volume of hydraulic fluid, corresponding to the piston area and the stroke, is either sucked in or pumped out via the two control slots in the connection plate. By adjusting the angle of the pivot cradle the it is possible to vary the displacement and thus the flow.

4.2 Architecture matrix

Product architecture management is the backbone of variant management. Therefore, as a part of this variant management project, an architecture matrix of the existing pump generation was created. The matrix brings together the customer's view and the internal view. As illustrated in Figure 5, the matrix shows, how product features of the axial piston pump are "translated" to its product components.
A selection of features is listed in the first column. For each attribute its different obtainable values are specified. The second column lists the number of values for each attribute. An excerpt of product components is listed in the top row. The entries in the fields of the matrix indicate, how many variants of a product component are caused by the values of a feature at the actual pump generation. The bottom row of the matrix calculates the amount of component variants caused by the combination of relevant features.

Features (Values)	Number of values	Components: Cylinder	Slipper pad	Return device	Pump housing	Connection plate	Pivot cradle	Control piston	Return spring	Drive shaft	Bearing shell low pressure	Bearing shell high pressure	Bearing pump housing	Bearing Connection plate	Shaft seal	Leakage oil screw plugs	Hub for drive shaft	O-Ring seal for drive schaft	Control valve
Self-suction speed (low, high)	2	2				2													
Nominal size (10, 20, 25, 30, 40)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
Controller type (pressure, power	2				2			2											
Type series (old, new)	2				2						2	2							
Sense of rotation (clockwise, counter clockwise)	2					2	2												
Sealing (FKM, NBR)	2							2							2	2		2	2
Shaft extension (geometry 1, 2, 3, 4)	4									4									
Mounting flange (DIN, SAE)	2				2														
Position of suction connection (top, back)	2					2													
Position of pressure connection (bottom, back)	2					2													
Drive shaft (none, hub, flange)	3					3				2							2		
Variety of raw parts		5			20	120	10			5	10	10							
Variety of finished parts		10	5	5	40	240	10	20	5	40	10	10	5	5	10	10	10	10	2

Figure 5. Architecture matrix (excerpt)

It is a particular advantage of the architecture matrix that drivers of variety are uncovered at best. If we have a look to the architecture matrix of the axial piston pump, we can immediately identify the worst drivers of variety. The *frame size* of the pump is the most influencing feature. It affects almost all the components. Furthermore, the *connection plate* is discovered to be the most variable product component. 240 variants result from possible combinations of impacting features.

4.3 Variant-optimized design

The elaboration of a variant-optimized design is based on the transparency that is provided by the architecture matrix.

For a variant-optimized design we propose two different directions:

- First direction is to minimize the impact of variant-driving features. Possibilities are for example to reduce the number of values (see *Portfolio adjustment*) or to make single components independent form a feature.
- Second direction is to minimize the number of component variants. Different approaches, such as integral vs. differential design or optimization of the combinatoric of features are available.

In the present case, the architecture matrix revealed that the connection plate was the worst driver for component variety. Figure 6 illustrates a range of approaches to minimize the variety of the connection plate for a variant-optimized design.

Features (Values)	Number of values	Connection plate
Self-suction speed (low, high)	2	2
Nominal size (10, 20, 25, 30, 40)	5	5
Controller type (pressure, power	2	
Type series (old, new)	2	
Sense of rotation (clockwise, counter clockwise)	2	2
Sealing (FKM, NBR)	2	
Shaft extension (geometry 1, 2, 3, 4)	4	
Mounting flange (DIN, SAE)	2	
Position of suction connection (top, back)	2	2
Position of pressure connection (bottom, back)	2	2
Drive shaft (none, hub, flange)	3	3
Variety of raw parts		120
Variety of finished parts		240

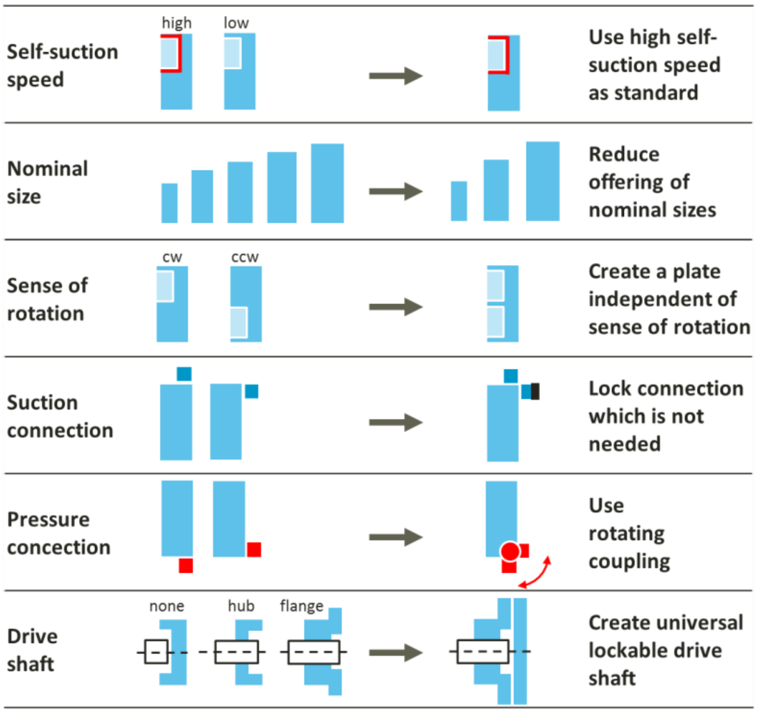

Figure 6. Variant-optimized design for a connection plate

5 OUTLOOK

The variant management toolbox and its underlying framework have served very well in numerous projects over the past ten years in the field of designing products with high variety. The gathered experience gives the impression, that most of the challenges in industry concerning variant management are rather evolutionary than revolutionary. Thus, variant management for new products usually does not start on the open countryside. In most cases, variant management focuses on certain topics, which can be very good addressed with the framework and its methods and tools.

Nevertheless, one of the most challenges - digital transformation - will also influence and reshape variant management. Therefore, the toolbox should be subject to digital transformation. Although several of above-mentioned tools of course are already realized as software tools (Excel for diagrams and portfolios, LOOMEO for structural analysis, etc.), the toolbox itself should be integrated to a digital platform. For sure, digital transformation is more than digitalizing the toolbox. For this reason, new "disruptive" methods and especially methods considering digital business models should be integrated into the toolbox.

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