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Designing Customer Co-Creation: Business Models and Co-Design Activities

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Abstract

For nearly 30 years, mass customization as a competitive strategy has overcome the oxymoron of developing and marketing individualized products with the efficiency and at a price of mass production goods. Most authors agree that solution space development in general and product configuration in particular are two key tools for the success of this competitive strategy. Especially product configurators represent a customer co-design tool, which helps customers to express their needs and translate them into a valid technical specification. But also for product-service-systems co-design is a powerful tool to learn about customers and monitor their requirements. In this article, the relation between competitive strategy, business model, customization strategy and design solution space of mass customizers and suppliers of product-service-systems is investigated. Taking the interaction between customer and design department as a basis, templates for different co-design activities are derived that document what kind of solution space elements, knowledge and significant production strategies should be considered for different degrees of customization. This is then discussed with regard to an exemplified co-design business model for a customizable tea brewing machine.

Key words: *Business Models, Co-Creation, Mass Customization, Product-Service-Systems*

1. INTRODUCTION

Companies in various industrial sectors differentiate their offering according to a wide spectrum of customer needs, which is caused by segmentation and saturation effects in today's globalized markets [1, 2]. These tendencies, which Bliss [3] named as *new market dynamics*, show up in business-to-consumer as well as in business-to-business contexts. Hence, complexity management in all stages of the product lifecycle like order acquisition, product development, manufacturing or marketing has become a decisive success factor [4, 5]. In this context, the competitive strategy of mass customization has given proof of solving the oxymoron of manufacturing products tailored to a customer's individual needs and requirements at nearly mass production efficiency and costs [6, 7]. Many authors from academia and industry agree that solution space development and product configuration are two key tools for the success of mass customization [e.g., 5, 8, 9, 10]. Flanked by methods of variant design, such as design platforms and modular design kits used in automotive development [11], these tools allow the acquisition of customer needs as well as their translation into a valid product specification in the sense of a customer co-design tool [12].

The impact of contemporary information and communication technologies on mass customization, i.e. product configuration systems, either sales configurators or design tools in the meaning of knowledge-based-engineering systems, is generally accepted [e.g., 9, 13]. To foster these capabilities, a company has at first to define the degree of customization for the offered products, which, for one thing, depends on the different customer needs and the uncertainty in their prediction [14]. On the other hand, it also has to meet the manufacturing facilities of the company as well as its value chain [15, 16]. Then, this portfolio of capabilities has to be presented and communicated to the customer via suitable sales support systems [9, 12].

Additionally, the use of solution space development and product configuration prospers in the context of product-service-systems (PSS) [17, 18, 19]. Here, the focus shifts from a singular translation of requirements at one point in time to monitoring needs and accompanying customers during the whole product lifecycle and beyond. Likewise, it is also a prerequisite to define the degrees-of-freedom regarding product properties and

functional building blocks for all PSS-components, regardless whether hardware, software or service [e.g., 20].
Different typologies of mass customization have been discussed that are usually differentiated by extent or point in time of the possible customization [6, 21]. Single mass customization business models are discussed either on a general level or focussing on sustainability [e.g., 22, 23].
In the present article, the authors go a step further and investigate the relation between competitive strategy, business model, customization strategy and design solution space. From a product development point of view, the last two aspects determine the interaction between customer and design department in the sense of different co-design activities. Therefore, templates are derived that document what kind of solution space elements, knowledge and significant production strategies should be considered for different degrees of customization.
The remainder of this article is organized as follows. Section 2 contains a brief introduction of mass customization and PSS, which are classified into the same business typological framework. Afterwards in section 3, the setup of co-design business models is presented in general before section 4 discusses the different degrees of customization and the resulting customer co-design activities. Here, solution space elements, design tasks, relevant knowledge implementation into product models and production strategies are analysed. In section 5, the above considerations are used to derive an exemplified business model for co-creation activities. The final section 6 draws a conclusion and drafts further research questions.

2. BUSINESS TYPOLOGICAL FRAMEWORK

In this section, mass customization is derived from the product-process-change-matrix, which distinguishes different competitive strategies [24]. Afterwards, product-service-systems are characterized comparatively and integrated into an extended business typological framework.
In the context of this article, the term *business typology* is used in the meaning of Miles and Snow, who classified companies based on the relation of competitive strategy, corporate structure, business processes and management theory [25]. In contrast, a *business model* describes a distinct model that shows how benefits for customers or different corporate actors in the supply chain are generated and returned as turnover for the company [26, 27].

2.1 **Mass Customization**

Introduced as business typology that is able to describe different competitive strategies, the product-process change matrix was presented by Boynton et al. in 1993 (Figure 1.) [24].
All four possible business types are classified regarding the two dimensions product change and process change. The first stands for the demand for new products and services, whereas the latter addresses all deployed procedures and technologies for developing, marketing and manufacturing them. Both types of change can either be stable, which means slow and foreseeable, or dynamic in the sense of fast, revolutionary and generally unpredictable. Within the fields of the matrix, it is differentiated between the four basic business types of invention, mass production, continuous improvement and mass customization.

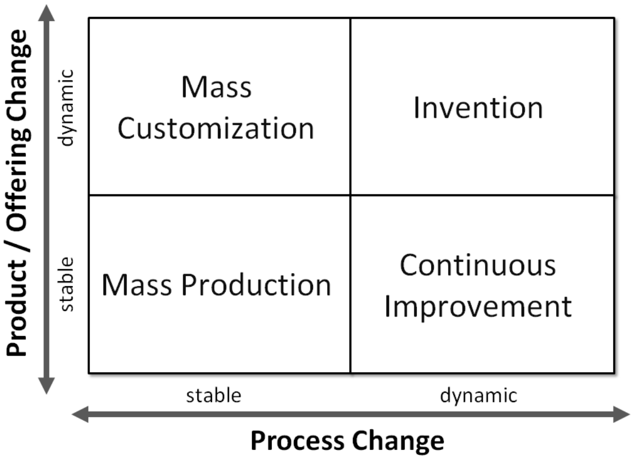


Figure 1. Product-Process-Change-Matrix (acc.to [24])

Mass Customization is the business model, in which a dynamic offering change and a stable process change come together. The idea behind this is that customer specific products can be tailor-made using flexible but stable processes in development and manufacturing with mass production efficiency. Since only the customer himself is able to formulate his specific needs and requirements, Piller [28] suggests that "MC refers to a customer co-design process of products and services, which meets the needs of each individual customer with regard to certain product features. All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes" [28]. On the other hand, the emphasis on "mass" and the coherent product development methods and manufacturing technologies clarifies the delimitation to traditional single-part production. One of the major characteristics of the MC business model is its ongoing capacity “to produce product variety rapidly and inexpensively. In direct contradiction of the assumption that cost and variety are trade-offs, mass customizers organize for efficient dynamics” [24]. In order to do this, all material and information flows have to be organized in a network structure of generic, reusable, flexible and modular units. Pine [29] points out that it is essential not to pre-engineer or pre-align those units to some single known end product but to reflect the realizable portfolio of capabilities. Ideally, all corporate processes, either administrative or related to goods and service realization, are set-up as modular design as well, which is then configured with regard to the individual customer order. In the broader sense, this comprises the aggregation of the whole supply chain [30].
For a detailed compilation of characteristics and a discussion of the success factors for mass customization refer to [6, 13, 31, 32]. The literature also

contains an overview of successful implementations in capital goods industry, mobile communications industry, food and beverages, clothing and footwear as well as financial services. A discussion of the other competitive strategies is beyond the scope of this article, for a detailed description of the other three business types refer to [24].

2.2 **Product-Service-Systems**

The core of the PSS concept is the integration of product, software and service development into one common development process. As a result, the focus shifts from selling products and / or services separately to selling functionality or corporate capabilities [20].
Some authors restrict the business case for PSS only to business-to-business applications [e.g., 33, 34]. In this case, the PSS is a result of a value co-production, which is conducted within a supply chain. It is based on a common development process of the cooperating partners. Critical success factors for developing and implementing PSS are:
1. To monitor customer requirements over the whole product life cycle,
2. The ability to adapt to consumer requirement changes rapidly and efficiently,
3. To anticipate these changes in the early phase of PSS development.
Basically, modular and parametric designs help in doing so. In the result, the PSS is altered by exchange of components or reconfiguration / re-parametrization. Mont [35] emphasizes in particular the benefits of PSS for manufacturing companies. From his point of view, additional customer value is generated since upgrade and modernization possibilities exist. Regarding the end of the lifecycle, suitable product structures provide the possibility for easy dismantling, disposal or repair and re-marketing of individual PSS components [20].

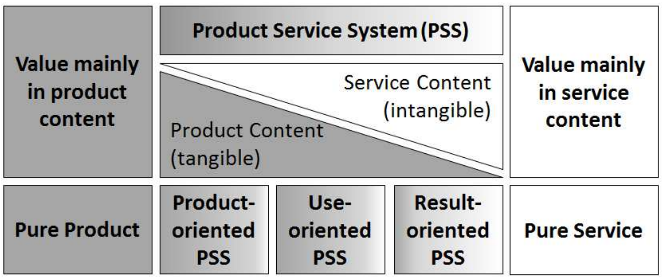


Figure 2. Main Categories of PSS (acc.to [36])

Tukker [36] set up a framework to characterize different PSS according to their different product and service content quotients. He distinguishes product-oriented, use-oriented and result-oriented PSS and the resultant business models (Figure 2.):

- **Product-oriented**: Product related services, e.g. start up and initial operation, maintenance contracts, supply of consumables, financing plans; Advice and consultancy, e.g. training, logistics optimization.
- **Use-oriented**: Product lease, product sharing, product pooling.
- **Result-oriented**: Activity management or outsourcing, pay per unit, functional result.

Furthermore, Tukker [36] evaluates eight different PSS types with respect to their influence on the market value of the offered solution, costs for the provider, use of capital and mutability.
Related to the product-process-change-matrix presented above, the previous characterization allows for the assessment of PSS regarding both change dimensions of the matrix. Regarding product or offered functionality respectively, PSS imply a change of customer needs over time. This has to be considered when developing PSS. However, nature, extent and timing of the change cannot be predicted in advance. In the model of the product-process-change-matrix, this corresponds to a dynamic product change. The company's internal processes for synthesis, production and distribution of customized solutions must be designed largely stable. This is partly due to the rapid reaction capabilities on changing customer requirements. On the other hand, lifecycle management of PSS calls for that stability, also with respect to the subsequent disposal or re-marketing of PSS components as raised by Mont [35].

2.3 **Product-Process-Baseline-Change-Matrix**

Integrating PSS in the product-process-change-matrix would thus result in no difference between mass customizers and suppliers of PSS, as both are represented by dynamic product change and stable process change. For a better differentiation, the existing typology has to be extended by another change dimension, which the authors name *baseline change* (Figure 3.). The term baseline is used in this context in the same meaning as in configuration management, where it stands for a fixed product variant. From this, subsequent product states are derived, other variants and versions are compared with the baseline and in general, changes to the baseline can be evaluated and documented [37].

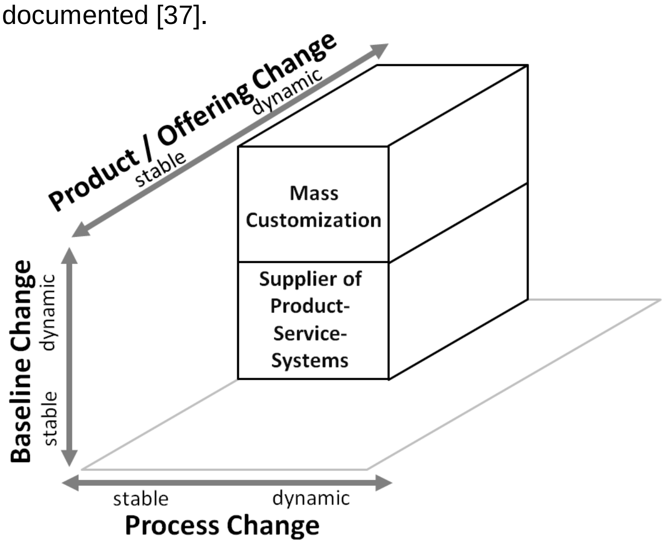


Figure 3. Product-Process-Baseline-Change-Matrix

A stable baseline change encountering a stable process change and simultaneously a dynamic offering change allows the supplier to react on changes by adaption of existing, perhaps already deployed product and service components as targeted in PSS development. On the contrary, a dynamic baseline change rather leads to substituting a solution already in use. Here, mass customizers synthetize a new best-fit solution for the actual set of customer requirements [38]. Note that from the authors' viewpoint, neither business type is restricted to business-to-business or business-to-consumer contexts. With regard to the complex market situations that correspond to the business types, such simplifications are not adequate.

3. BUSINESS MODELS FOR CO-DESIGN

In order to meet differing customer requirements, the customer co-design process synthetizes the product configuration out of the stable solution space. As Böer states, “the goal is to correctly identify the customization options and dimensions meant to satisfy the customer needs” [39]. In other words, when a business model is created, a supplier of mass customized goods and PSS as well has to answer three questions: First, what are the degrees of freedom in the offering? Second, how should they be communicated to the customer? And third, in which way can it be ensured that only valid and feasible designs may be ordered? Regarding the first question, a possible differentiation of degrees of customization can be concluded from the influence the customer co-design process takes on the manufacturer’s value chain. This is not limited to the supplier himself but also to the corresponding supply chain [12].

A way of customization that does not affect the manufacturing processes of a supplier at all is named *tuning customization*. Here, an existing standard product is taken as baseline and refined by another partner in the supply chain, which may include dismantling of parts of the existing product. That way, the offering can be adapted to special applications (e.g. police cars, outside broadcast vehicles), individual design (e.g. in the automotive sector done by companies like AMG or quatro) or in general to markets with only few customers. In this model, the customer integration can be very high since the standard product can possibly be adapted to all customer needs.

Another type of customization is *set-up customization,* which is appropriate in particular for mechatronic devices [40]. As Jørgensen [41] states, most functional issues of such devices are provided via software, e.g. the acceleration curve of a combustion engine, which is adjusted via the engine control unit. Another example is the mobile applications ecosystem. The devices’ behaviour is controlled differently by the installed apps, but the physical part of smartphones or tablets is kept the same. The process of manufacturing is not influenced and stays stable. Nevertheless, this level has an impact on product data management and configuration management since the different versions of firmware and software have to be managed as well.

With respect to *cosmetic customization*, Gilmore and Pine [42] define that a standard product is presented differently to different customers. In the original specification, this commonly addresses the packaging of a product. Some authors argue that customer value is not raised noticeably in order to realize competitive advantages. This may be especially true in the business-to-consumer context, but in business-to-business, this type of customization is widely used for the food and beverages industry (e.g. cereals or frozen food). Nevertheless, from the authors’ point of view, within cosmetic customization altering the outer appearance of the product itself is also allowed to a defined degree (e.g. painting colour). Therefore, this degree of customization only has little influence on the production process, while machining keeps stable.

The most prominent way of customization is *composition customization* since it is grounded on modularisation [29]. This corresponds to the common assemble-to-order strategy, where different sub-assemblies (in general: buildings blocks) are assembled together to a product using standardized interfaces [43]. If the building blocks are set-up as modules, their production process can be kept stable, which meets the requirements of postponement. This concept is also applicable in service engineering [44]. Due to the fact that a common parametric data model for physical, virtual and service components is still missing, this type of customization is widely used in PSS configuration [38, 45].

The type *aesthetic co-design* differs from the aforementioned. Here, the customer has an impact on product design as well as manufacturing since he is able to modify the outer appearance of a product by himself, not only regarding colour or texture but also shape (e.g. casings of white goods). Therefore, particular manufacturing processes are needed such as additive manufacturing or high speed cutting. Nevertheless, all functional building blocks are kept stable and so are their manufacturing processes.

A very far-reaching degree of customization is *function co-design*. In opposite to the aesthetic co-design, the functional building blocks are also determined by the customer. This reflects the actual discussion on open innovation [e.g., 46] and still poses a big challenge to manufacturing companies.

In addition to the aforementioned degrees of customizations, another type of co-design activity is based on the complete design automation of a product or service. In this case, customers have access to all necessary knowledge and synthesis systems to adapt a product completely to their use-case.

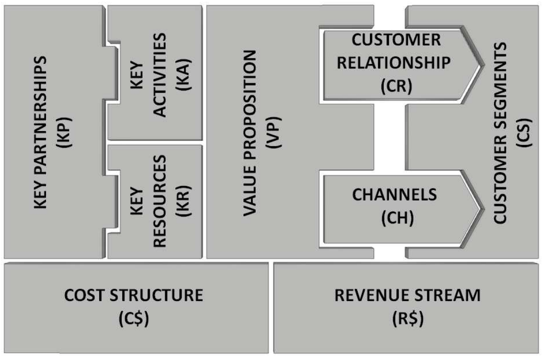


Figure 4. Business Model Canvas (acc.to [27])

Taking into account that options and the degree-of-freedom of a design may vary depending on the influence, the customer can and should take on the value chain, mass customization may not be considered as a single business model like proposed in [22]. To better understand the necessity of a more granular distinction, the Business Model Canvas (Figure 4.) developed by Osterwalder [27] can be taken as a basis.

A comparison of composition customization and aesthetic co-design e.g. shows differences in the key activities performed by the supplier. While the first focuses on developing and assembling predefined modules and standardized interfaces, the second calls for efficient manufacturing processes that enable lot size one.

Coming back to the questions of how to communicate the degrees of freedom of the offering and how to provide only feasible solutions, mainly involves the channels and the customer relationships in the business model canvas. Their formalization is realized by the definition of the design solution space and the single co-design activities the customer performs.

4. CO-DESIGN ACTIVITIES

The setup of design solution space and co-design activities are strongly intertwined. In this section, the single constituents of both are discussed and compacted into templates for co-design activities. The first step is to get aware of the necessary solution space elements and the relevant design task. Afterwards, the required knowledge that determines variant generation and that reasons about feasible and not feasible designs has to be identified and implemented. If the offer contains physical components, the last step includes the choice of a significant production strategy.

Note that the following consideration aims at both mass customization of physical products or services and product-oriented PSS. Especially result-oriented PSS need additional features because the solution space does not contain the real product [38]. Since the product is considered as tool for satisfying a customer need, it is shifted to the portfolio of capabilities or supply chain infrastructure.

4.1 **Solutions Space Elements**

A solution space element is a more or less predefined artefact or template the customer can choose or start detailing from.

Product / service baselines are used in the meaning of predefined feasible variants, which may exist virtually or as deployed artefact. As solution space element, a baseline sets up a starting point for the individualization, an initial design or a reference configuration for changes, alterations and (pricing) calculations. The more complex the artefact to be configured and the more options can be chosen, the more appropriate is the use of an initial baseline.

Building blocks may be used in various ways. On the one hand, they represent modules for product assembly and related services. Especially for composition customization, all building blocks must have known standardized interfaces to use all benefits of modularization. On the other hand, several building blocks may be linked to packages or a design platform so that the solution space is structured and not all possible combinations of building blocks may be addressed. With regard to mechatronic devices, software, either as firmware or applications, is treated as functional building block as well.

Set-up customization, aesthetic co-design and design automation call for parametrization. The characteristic value ranges have to be defined before the customer can choose his parameter set. In simple cases, this refers to minimum and maximum limits, in case of more complex relations it has to be considered how different parameters influence each other in sense of a simulation or constraint model, so that only suitable solutions are presented.

4.2 **Design Tasks**

Just as the solution space, its exploration has to be structured so that requirements can be efficiently transferred into the technical specification, which leads to a feasible individual solution. Automation potentials should be exploited wherever possible, i.e. by application of the principles of knowledge-based-engineering (KBE). These range from parametric CAD models with implemented mathematical and logical constraints to interactive technical product configurators [47]. Before such a KBE-system is modelled, it has to be defined what type of tasks the system has to perform, what user input is needed and in which way knowledge has to be applied in order to create feasible solutions to the given design problem [48].

Basically, there are two major groups of design tasks. Analysis refers to all activities, where a system or product already exists (to a certain extent) and its behaviour or properties are examined by predefined methods. In contrast, synthesis corresponds to all activities, where a system has to be constructed according to some given requirements [49]. Regarding the possible automation of relevant design tasks in product and service engineering, or more general the support of a human designer by a knowledge-based system, a further differentiation of synthesis tasks can be made with respect to the particular problem solving methods which are addressed. To those belong [48]:

- **(Synthetic) Design:** Designing a structure that fulfils certain requirements – result: artefact description.
- **Configuration Design:** A subset of synthetic design, where all components are fully predefined. Another known label of this task is composition – result: artefact description.
- **Assignment:** Creating relations between two groups of objects – result: mapping set 1 on set 2.
- **Planning:** Generating an ordered set of single activities to meet certain goals – result: action plan.
- **Scheduling:** Creating a schedule of temporally sequenced activities – result: mapping activities on timeline and resources.

Parametric CAD offers another type of synthetic task, which is parametrization [50]. Here, degrees-of-freedom regarding dimensions and topological constraints are implemented into a given design. These degrees-of-freedom have to be eliminated according to given requirements and constraints. Figure 5. shows a base frame that can be varied within certain lengths and heights. The design systems then reasons about necessary corner stiffenings and chooses the applicable set of forklift pads.

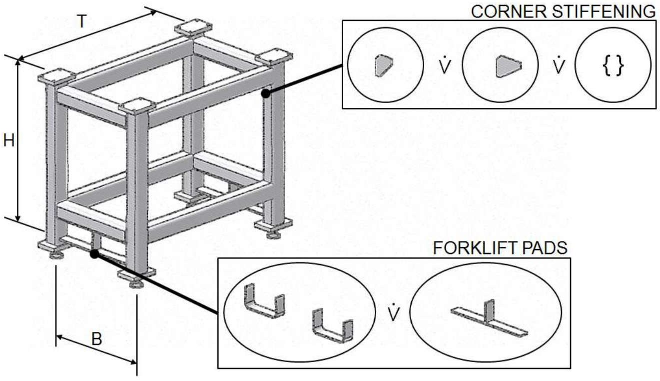


Figure 5. Parametric Base Frame

From a point of view of software engineering, parametrization corresponds to the solution of a constraint-satisfaction-problem [51].

4.3 **Knowledge Implementation**

When solution space and design tasks are defined, the next step is the implementation of the relevant knowledge in both the overall KBE-system and the solution space elements:

- **Functions:** Especially regarding synthetic design and configuration design, descriptions about functions, their in- and outputs as well as knowledge about resource consumption and allocation.
- **Components:** Same as functions but linked to the building blocks of an offering. May contain hard- and software elements.
- **Constraints:** Mathematical, logical or physical relation between two functions or components and mapping of functions and components.
- **Restrictions:** Sub-group of constraints, defines areas in the solution space, which are permitted due to manufacturability, design interfaces or strategic issues (e.g. product family planning, etc.).
- **Interfaces:** Sub-group of constraints, which define physical or logical interfaces between two functions or components as well as the possible information, energy and material flows.

Therefore, three different reasoning techniques may be used [52, 53]:

- **Rule-based reasoning:** The knowledge representation relies on design rules, i.e. IF-THEN-ELSE-statements. Rules are fired procedurally and can execute subordinate rules or delete them from the working memory in order to realize more complex tasks. A major disadvantage of this kind of system is their lack of separating between domain knowledge and control strategy. This results in bad maintainability, when the system exceeds a certain amountnumber of rules.
- **Model-based reasoning:** The possible solution space is described as physical and/or logical model (constraint-based) or by representation of resource consumption and allocation (resource-based).
- **Case-based reasoning:** In this approach, the knowledge is not explicitly modelled as rules or constraints. The knowledge necessary for reasoning is stored in cases that represent former approved configurations. Depending on the degree of maturity of the inference engine, the system either is limited to search for existing solutions, which match exactly to a given requirements profile, or the system is able to assort a set of existing cases, which represent the best-fit. Highly developed case-based systems are able of mixing or altering exiting cases in order to adapt them to new situations.

4.4 **Order-Fulfillment Strategies**

Regarding the manufacture of the customized artefacts, various order-fulfillment strategies as well as combinations of them are suitable [e.g, 54]. Nevertheless, in most contexts a significant strategy can be found.

- **MTS:** Make-to-Stock, prefabrication of the whole end product based on demand predictions.
- **ATO:** Assemble-to-Order, prefabrication of standard modules, which are assembled to the customer end product when the customer order is processed.
- **MTO:** Make-to-Order, all components are manufactured when the customer order is processed, no prefabrication.
- **ETO:** Engineer-to-Order, customized components are designed when the customer order is processed.

4.5 **Intermediate Result**

Considering different business models for the different degrees of customization, we formulated templates for the single preferred co-design activities. Refer to Table 1. for an overview.

For *tuning customization*, a baseline for an existing product or for parts of it must be known, which may be customized. This includes knowledge about interfaces, so that the exchanged components match the baseline. Basically, the co-design process is of the type configuration design, because in the majority of cases, the building blocks for exchange are already predeveloped. There are multiple examples in automotive engineering. For configuration, knowledge about realized or modified functions and components has to be formalized as well as knowledge about constraints (assignment of tuned parts to multiple baselines) and restrictions. The predominant production strategy is MTO, unless market potential is high enough to switch to MTS on a module level.

Looking at *set-up customization*, the foundation for all customization activities is also a product baseline. In addition, as solution space elements, parameter value ranges and software building blocks need to be defined. The co-design task corresponds to parametrization with knowledge about functions, constraints and restrictions. As production strategy MTS is advisable. Examples can be found in electrical engineering.

Table 1. Templates for Co-Design Activities related to the Degree of Customization

Degree of customization	Solution Space Elements	Significant Co-Design Task	Implemented Knowledge	Significant Production Strategy	Comment
Tuning Customization	Product Baseline and Building Blocks with known Interfaces	Configuration Design	Functions, Components, Constraints, Restrictions	MTO	Requires disassembly of prefabricated products.
Set-Up Customization	Product Baseline and Parameter Value Ranges, Software Building Blocks	Parametrization	Functions, Constraints, Restrictions	MTS	Software applications may offer new functionalities, software itself is not co-designed.
Cosmetic Customization	Product Baseline, Painting and Textures, Packaging	Configuration Design	Constraints, Restrictions	MTS	May target only on packaging.
Composition Customization	Building Blocks with standardized Interfaces, (Product Baseline)	Configuration Design	Functions, Components, Constraints, Restrictions	ATO	All components fully predefined.
Aesthetic Co-Design	Baseline for Targeted Functions, Baseline for initial Design and Parameter Value Ranges	Parametrization	Components, Constraints, Restrictions	MTO	Restricted due to design interfaces or manufacturability.
Function Co-Design	Building Blocks with standardized Interfaces	Synthetic Design	Functions, Components, Interfaces, Constraints, Restrictions	ETO	Includes creative design of new components.
Design Automation	Product Baseline and Parameter Value Ranges	Parametrization	Functions, Components, Interfaces, Constraints, Restrictions	MTO	Requires implementation of all available engineering knowledge.

Cosmetic customization likewise uses product baselines. When considered as predefined building block, the assignment of colour and packaging can also be done via configuration design under consideration of constraints and restrictions. Since all machining is the same for each product, the prevailing production strategy is MTS.

For the classical *composition customization,* all suitable building blocks including their interfaces have to be set up as solution space elements. If a design platform is the basis for configuration, it may be defined as baseline. In automotive engineering, it is a common approach to define style editions and packages, which also may be understood as baselines [11]. The resulting configuration co-design task uses functions or components, which are assembled-to-order, as well as their constraints and restrictions.

Aesthetic co-design is based upon a parametrization process. The customer uses an initial design, which is altered according to predefined value ranges. Relevant connection points to a carrier or other design interfaces are defined as constraints. The definition of restrictions includes e.g. machining spaces or minimal wall thicknesses. Components are MTO.

With respect to *function co-creation*, an ETO-strategy is set up, customer and supplier design functions together under consideration of interfaces, constraints and restrictions. The sophistication of this model is very high when the customer shall be able to perform designs without or with only little assistance of the supplier, since all relevant engineering knowledge has to be formulated in the corresponding design system.

In *design automation,* the solution space element is again a product baseline with a physical or logical model in the background. Ranges for all adjustable parameters must be defined as well as their constraints and restrictions. The design task is of type parametrization.

5. SET-UP OF A CO-DESIGN BUSINESS MODEL

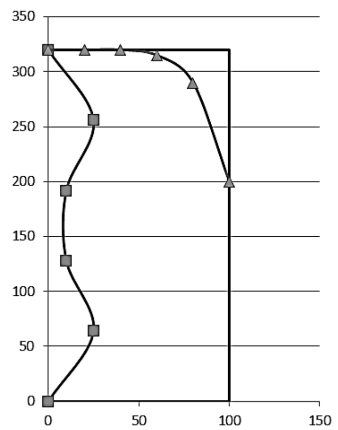
Figure 6. Tea brewing machine with customizable covers and cover variations

This section describes the business model for a customizable tea brewing machine (Figure 6.). The particular feature is the adaptability to the kitchen or room furniture, which is achieved by co-designable covers. Since functionalities and basic design of the machine remain the same, the degree of customization corresponds to aesthetic co-design. The value proposition in context of the business model canvas refers largely to design.

There are two customer segments: The first is hoteliers, who want to distinguish themselves from competitors by integrating also electrical devices into the room concept for the single categories they provide. The second is consumers who are willing to pay premium prices for a customized tea brewing machine. With regard to the first segment, a nearly constant demand and lot sizes with up to 500 pieces is estimated, while the latter has an inconstant demand and predicted lot sizes in the range of 1 to 5 pairs of covers.

In order to have efficient operations, the key resource is a laser-sintering machine, which allows production at lot size one without tooling or jigs. The covers will be manufactured in ABS plastics, so no additional support structures have to be manufactured that would boost build time and processing efforts. The corps of the tea brewing machine is the design baseline, which ensures the functionalities and defines the interfaces to the covers as relevant constraint. Other restrictions result from the manufacturing process, e.g. minimal wall thicknesses or the dimensions of the process chamber.

Aesthetic co-design calls for parametrization as design activity for the modifiable covers. The solution space contains various initial designs for the covers, which may be altered through the use of a design configurator (Figure 7.). In Addition to the shape, the colour can be chosen from a given list since the processed parts are dip-coated.



Configuration		
Design Space	Height	Width
	320	100
	max. 320	max. 100
	x	y
Left Cut	0	0
	25	64
	10	128
	10	192
	25	256
	0	320
Upper Cut	0	320
	20	320
	40	320
	60	315
	80	290
	100	200
Embossed Text	IPeG	
Color	yellow	

Figure 7. Cover Configurator

According to the maximum dimensions of the coverings, which are restricted due to the limitations of the process chamber, a maximum count of 60 pieces can be manufactured in one job. The build time is approx. 30 hours including cooling, cleaning and dip-coating. Switching to a SLS machine with a bigger process chamber would allow a parallel production of 320 pieces in one job at duration of 90 hours.

The sales department focuses on three different scenarios of how the configurator can be used. The classic way a design configurator is used within the company's product development department leads to the manufacturer producing a limited number of different cover configurations in different colours in large quantities. In this business model, the end user is not involved in the design process, but rather acquires existing, predefined screens for his device. The form of individualization thus corresponds to *composition customization*.

In the second scenario, the end user has access to the configurator. The form of the individualization thus changes to *aesthetic co-design*.

The third scenario extends this application. Here, the customer is not only able to configure his own covers, but he can share his designs on the manufacturer's internet platform with other users. There, designs may be evaluated or altered by others.

Figure 8. shows parts of the relevant business model canvas focusing on value proposition, customer relation, customer segments and channels.

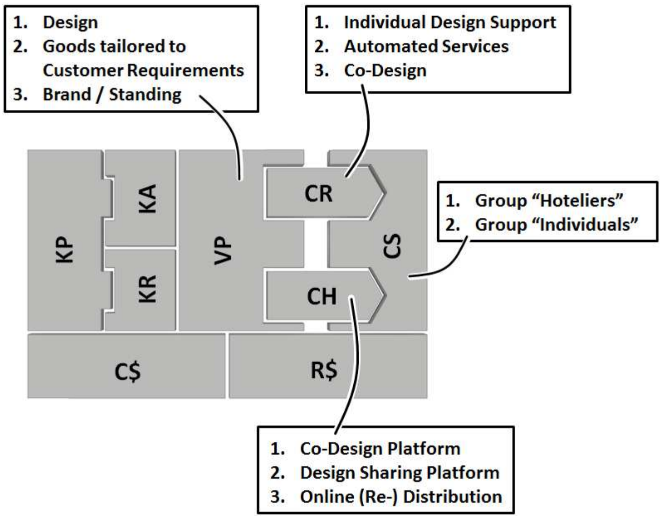


Figure 8. Exemplified Business Model Canvas

Considering a PSS, the tea brewing machine can be used as product-oriented PSS as well. Like inkjet printers today, the tea machine can be used to get a foot into the door of especially hoteliers or bigger restaurants. While the costs for renting or buying the machines would be low, the supply with consumables would be the real revenue stream. Furthermore, analysing the consumption of these consumables over time offers valuable data for marketing, product management and production management.

6. CONCLUSION

In the present paper, the relation between competitive strategy, business model, customization strategy and design solution space of both mass customizers and suppliers of product-service-systems was investigated. Focussing on the co-design activities a company offers its customers we presented templates for seven different degrees of customization.

The templates show the complexity of the co-design activities. The more influence the customer has on the product definition, the more knowledge has to be implemented in the tools for solution space development. Only in that way may a company assure that the customer is able to define exclusively valid product variants. For practitioners, such a template may serve as a starting point, when a business model has to be formulated that involves customer co-creation in product development. Nonetheless, this research concentrates on offerings, where lot size one corresponds to single-piece production. An open point remains at the inclusion of chemical and process industry. Here, e.g. the concept of modularity is also applicable [28], so solution space modelling is in principle feasible. But there are two key differences. First, the end product usually has known and unavoidable tolerances with respect to its characteristics, e.g. the colour of wall paint. These tolerances have to be considered, while setting up the design solution space. Furthermore, the portfolio of capabilities of the supply chain may be more complicated to model. The influences of production facilities and environmental conditions on batch size and the quality of the single batches have a different significance and complexity than in single-piece production.

Another field of interest targets the solution space for result-oriented PSS. Here, a product or service baseline is not part of the solution space itself but of the portfolio of capabilities. The solution space then contains a model of customer benefits.

From an academic point of view, future research should focus on concretising the templates regarding data models and knowledge implementation. The single co-design tasks call for different reasoning techniques, so one possible issue is the search for significant mechanisms. Here, PSS call for a particular key aspect: The lack of a common parametric data model for product and service constituents currently limits the applicability of some reasoning techniques and parametrization. The integration of e.g. mechanical CAD and service CAD including parametric, feature-based and knowledge-based design is worth examining. PSS development would highly benefit from such an engineering environment.

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Projektovanje kokreacije sa potrošačima: Poslovni modeli i aktivnosti kodizajniranja

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Apstrakt

Već skoro 30 godina, kastomizovana industrijska prouizvodnja je kao konkuretna strategija prevazišla oksimoron razvoja i marketinga personolizovanih proizvoda sa cenom i efikasnošću koja odgovara masovno proizvedenoj robi. Većina autora se slaže da su dva ključna alata za uspeh ove konkurentne strategije razvoj prostora rešenja i konfiguratori proizvoda. Posebno konfiguratori proizvoda predstavljaju alat za kodizajniranje, koji potrošačima omogućava da izraze svoje potrebe i predstave ih kroz validnu tehničku specifikaciju. Isto tako, kodizajniranje pretstavlja veoma moćan alat za proizvodne i uslužne sisteme, pomoću kog se može dosta naučiti o potrošačima, a mogu se pratiti i njihovi zahtevi. Ovaj rad istražuje odnos između konkurentne strategije, poslovnog modela, strategije kastomizacije i projektovanja prostora rešenja kastomizovanih industrijskih proizvođača i dobavljača za proizvodne i uslužne sisteme. Uzimajući interakciju između potrošača i sektora za projektovanje kao osnovu, izrađeni su šabloni za različite aktivnosti kodizajniranja koji dokumentuju koje vrste elemenata prostora rešenja, znanja i proizvodnih strategija treba uzeti u obzir za različite nivoe kastomizacije. Ovo se nakon toga diskutuje na ilustrativnom primeru poslovnog modela kodizajniranja za kastomizovanu mašinu za pripremu čaja.

Ključne reči: *poslovni model, kokreacija, kastomizovana industrijska proizvodnja, proizvodni i uslužni sistemi*