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# CLASSIFICATION OF CUSTOMISATION MEANS

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**Abstract:** *Customising products efficiently by means of development and manufacturing costs as well as attractiveness to the customer are essential factors for success in a mass customisation strategy. This paper aims at providing a classification of customisation means which can be utilised for product customisation. This is done by reviewing customisation means identified in literature and classifying them in a UML diagram. The results form the foundation for future research in product customisation including the relations to development and manufacturing processes and which are most suitable for certain product types, markets or company types.*
**Key Words:** ***Product Customisation, Product Configuration, ProductAarchitecture***

## 1. INTRODUCTION

This paper focuses on products within mass customisation (MC). Several publications discuss the definition of MC, though so far no consensus has been achieved [6, 8] on a common definition. In this context however we will adopt the definition from [11], that mass customisation is the ability to deliver individually tailored products at near the cost of mass production. Following this, mass customisation calls for customisable products which can be customised at a relatively low cost. This presents the product development process as well as the manufacturing setup with a number of challenges. One of these challenges is balancing the customisability with development and manufacturing costs since these costs, combined with the value presented to the customer, will ultimately determine the profitability of the product range. This paper focuses on the different means for creating variety in a product portfolio. The reason for this is that the means chosen for a product portfolio will drive both cost and value to the customer in terms on customisability as it will be argued in the following.

### 1.1 Product Customisation

In a mass customisation strategy, achieving the optimum degree of customisation is essential, since too high or low variety may have a significant negative impact. Too low product variety will imply that the product range is unable to satisfy each customer's individual requirements thus potentially leading to a reduced market share. Too high product variety may also negatively influence the success of a product range if the offered variety exceeds the variety required by the customer. This is due to two factors: 1) the customer may be overwhelmed by the number of choices necessary to purchase a product, which could imply that the customer gives up buying the product and chooses a competitor product instead and 2) the extra variety implies an extra cost, which will reduce the profitability of the product range. One well known example of this is the car manufacturer Nissan's car range which at one point featured 87 different steering wheels, which lead to confusion among customers who found it very difficult to choose from such vast variety [12]. Piller [9] points out the following additional costs in relation to mass customising a product: 1) increased cost in sales due to higher training of sales personnel and development of a configuration system, 2) a general loss of economies of scale, 3) higher setup costs and requirements for labour and quality control, 4) rise in component inventory and 5) increased complexity in production planning and control. It is assumed that these factors will increase as the product variety increases. Finally, higher variety usually also implies a higher cost of product development and product portfolio maintenance. Hence, there are numerous arguments why product variety should neither exceed nor be less than a certain level. The reason why this extra cost does not in general imply an unprofitable business strategy is the customers' willingness to pay a price premium for the increased variety [9]. This however is only the case if the offered variety can sufficiently meet each customer's requirements. Furthermore, the customer will be unwilling to pay an additional price premium for unnecessary variety. Hence, it can be concluded that in a mass customisation strategy, achieving the optimum variety is essential for the success of a product portfolio.

Although it is generally recognised that customizing the services related to the product can also be perceived as a means of product customisation, we shall delimit the focus in this context to customisation of the product itself. The product in this context is defined as the artefact which is sold and produced for an end customer. A useful term in this relation is "product family". Several different definitions exist for the term product family [14, 17, 2, 5]. The definitions differ slightly but generally describe a product family as a set of products that share common characteristics and will often be equal to a certain product series within a product portfolio. Although it is slightly unprecise, depending on which definition is adopted, the definition of product family used in this paper is the set of products which are to be configured using a product configurator.

Product variety can be considered from a number of different perspectives. In this context it is relevant to consider product variety from two perspectives: 1) the customer variety and 2) the internal variety. The customer variety is the product variety as perceived by the customer, i.e. the diversity of customer requirements and preferences which the product family is able to meet. The customer variety is thus defined by characteristics like product functionality, product performance and appearance. The customer variety drives the ability to satisfy customer requirements and this is ultimately what determines the success of the product family combined with the pricing strategy.

The internal variety however is defined by the variety of physical elements which can be combined to form an end-product. Ulrich and Eppinger [17] refer to these physical elements as "chunks" to avoid the term confusion related to the term "module" which can be misleading if used in relation to a non-modular product architecture [17]. Hence the internal variety can be regarded as the number of different chunks which are included in a product portfolio. While the customer variety drives the customer satisfaction, the internal variety drives the product cost in terms of manufacturing cost as well as development cost. As stated above, it is a general assumption that higher internal variety will increase product costs due to loss of economies of scale. However, taken to extremes, a too low internal variety may also escalate product costs. One example of this could be a product platform, common to an entire product family which contains functions which are not common to all products yet expensive to produce. In this example, the commonality has become a cost driver contrary to the most common case where variety drives cost.

Ulrich and Eppinger [17] define product architecture as "the scheme by which the functional elements of the product are arranged into physical chunks and by which the chunks interact". It is thus the product architecture which will determine the relationship between the customer variety and the internal variety. This relationship is critical to the success of a product family, since it will determine the relationship between value for the customer which determines the potential sales price as well as it determines the costs associated with developing and producing the products. A well designed product family may have a vast customer variety while the internal variety is quite low, whereas a poorly designed product family may have a much higher internal variety relative to the customer variety. In general a good product architecture will produce the optimum customer variety at a minimum internal variety.

Means for product customisation and product architecture are closely related. A product architecture can be a means for achieving customisation, however product architecture considerations are also highly relevant for non customised products. Furthermore, there are a number of means for customising products which are not directly related to the product architecture. Hence, product architecture and customisation means can be related, but need to be addressed as two distinct concepts.

In the following, different means for customising products will be reviewed based on existing literature. As the review will indicate the different means for customisation are all different, however many of these have common characteristics and are in some respects similar. Some means are very similar whereas others have almost nothing in common. In order to identify the similarities a classification is performed in this paper. It is the purpose of this classification to provide researchers and practitioners with an overview of different types of customisation means as well as their relations in terms of a classification. This can be used in further research to identify which customisation means are optimal for different product types, how different means should be applied in a product development process or how different means influence the manufacturing process. The classification can be used to identify how research can be generalised or specialised, since the different means will be classified using a generalisation-specialisation hierarchy. Furthermore, the classification can be used by practitioners who need to develop a product family for mass customisation, since it will provide an overview of the different options for creating variety and their relations.

## 2 REVIEW OF CUSTOMISATION MEANS

### 2.1 Physical vs. Digital Customisation

Piller and Stotko [10] described four different categories of mass customized products according to the degree of customer integration and digitizability [10] on the basis of a survey of successful mass customisers. The degree of customer integration is not immediately relevant in this context; however, the digitizability is highly relevant. The digitizability describes "...the extent, in which functions that are relevant to a customer, can be fulfilled by the use of information technology only." Needless to say, production of purely digital products is very inexpensive, since no or very little physical operations are necessary, whereas development costs may be as high as for a physical product. However, introducing digital customisation into physical products yields an opportunity to reduce manufacturing costs, since variety which is defined by software will yield a much lower internal variety than a physical customisation. The theory about implementing functionality as software instead of physical modules is often referred to as mechatronics [4]. Mechatronic products are products which contain both mechanical and electronic and software elements.

### 2.2 Customisation of Product vs. Presentation

Gilmore and Pine [3] define four distinct approaches to delivering customised products based on whether the product itself is changed and whether the presentation of the product is changed. The four approaches are: **Collaborative customisation** implies that both product and presentation is changed. In this type of customisation the company performs a dialogue with the customer to customise a product to fit the customer's needs. **Adaptive customisation** implies that the product is sold as a standard product which the customer can alter or reconfigure. **Cosmetic customisation** is standard products which are delivered or presented differently to different customers. This implies that the product itself does not change, only the presentation does, which often implies customised packaging of the products. **Transparent customisation** happens when the product changes but the presentation does not, which is implied by the designation "transparent" since the customisation is transparent to the end customer.

### 2.3 Modular Product Architecture

It is commonly acknowledged that the usage of modular product architecture is an efficient way of creating the product variety necessary in mass customisation [11, 16, 1, 17]. In this context the definition of modular product architecture defined by [17] is adopted. This definition states that products with modular architectures have the following properties: 1) One module, being a part of the product implements one or few functional elements and 2) the interactions and thereby interfaces between modules are well defined [17]. This applies to physical products and may to some extent also apply to digital products. However, digital products variety can also be implemented without usage of a physical modular architecture, since products can be customized by non-physical means. Ulrich and Eppinger [17] define three different types of modularity: 1) Slot modular architecture 2) bus modular architecture and 3) sectional modular architecture. The first two types can be characterised as sub-types of a platform architecture and will thus be addressed in the following section. In the sectional-modular architecture however all interfaces between modules are identical, implying that modules can be combined randomly and no module is common to all products in a product family. This is in contrast to platform based product families which are described in the following.

### 2.4 Product Platforms

The concept of a product platform has been defined by numerous scholars. McGrath [7] defines a product platform as: "a collection of the common elements, especially the underlying core technology, implemented across a range of products". This definition is embraced in this context since it defines very well the characteristics of a product platform related to the product itself, where other definitions also focus on processes, knowledge and organisation [13]. The usage of product platforms has proven to be a very efficient way of creating a product family with a high variety at a low cost. This is done by implementing the common functions of a product family in a platform and implementing the differentiating characteristics in modules which are combined with the platform. Simpson [15] defines two types of platform based product families; the module based platform family and the scale-based platform family. The module based product family is customised by adding or removing modules from the platform, whereas the scale-based platform is customised by stretching or shrinking the product design. However, there are also known examples of product families which embed both principles in the customisation process. The platform product architecture is a sub-type of the modular product architecture, which implies that a platform based product is also modular, however a modular product is not necessarily platform based. As mentioned above, Ulrich and Eppinger defined two modular architectures which can arguably be characterised as platform architectures. The slot-modular architecture is defined by a common module or set of modules with a number of slots in which certain module types will fit. Each slot however only fits one module type and modules can thus not be interchanged. The modules which fit in the slots are thus used for differentiating the individual products and the common modules can be considered the product platform. The bus-modular architecture also defined by Ulrich and Eppinger [17] is similar to the slot-modular architecture, however modules are interchangeable. In this architecture, a number of common modules will constitute the product platform containing the "bus", whereas the differentiating modules used for customising the product are fitted onto the bus. This implies somewhat greater flexibility compared to the slot-modular architecture, however the requirements for a common interface may render this architecture impractical in some applications.

## 3 CLASSIFICATION

The classification of the different customisation means is illustrated in figure 1. The classification is illustrated using a UML (Unified Modelling Language) class diagram, which is an object oriented analysis and design language. According to the UML standard, each box in the diagram represents a class. Each class in the diagram represents a distinct customisation means. The

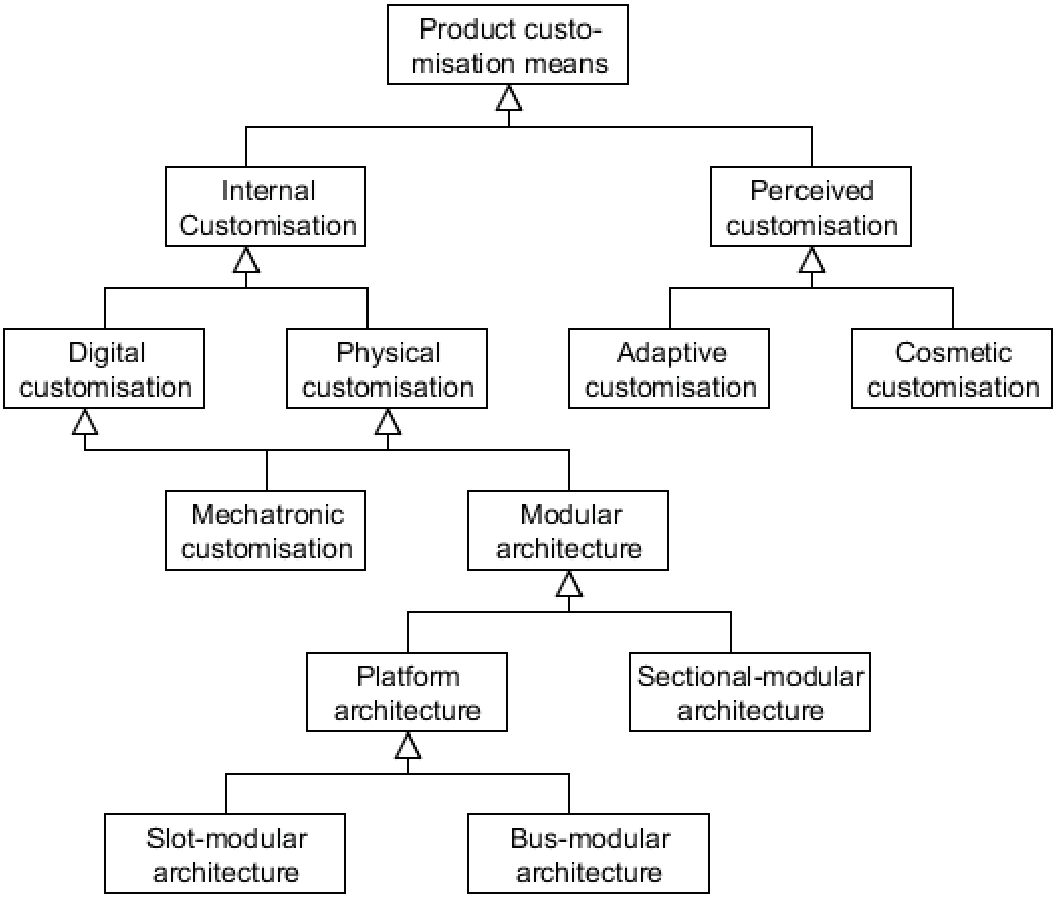


Fig. 5. *UML Class diagram of different means for customising products.*

lines connecting the classes represent a generalisation-specialisation relation, where the class at the end of the line with a triangle represents the most general class and the other end represents the most specialised class. The diagram is structured so that the most general classes (customisation means) are in the top of the diagram, and the lower in the diagram a means is shown, the more specific it is.

A number of classes have been introduced in the diagram, which have not been identified in the review above. These are classes which do not exist as a distinct customisation means and can thus not be applied in practice, but have proven necessary to create "groups" of customisation means to illustrate their similarities. These classes are argued in the following and are referred to as "abstract customisation means".

## 4. IMPLICATIONS

The classification presented above provides a number of possibilities for researchers and practitioners. This is due to a fundamental property of a classification diagram or taxonomy as the one presented in figure 5. When performing a classification, this implies that characteristics of general classes, which in this context represent customization means, will be the same for more specialized classes. This is due to the mechanism referred to as inheritance that specialized classes inherit characteristics of their super classes. An example of this from figure 5 could be that the customisation means "Slot-modular architecture", which is a sub-class of "platform architecture", will have the same characteristics as "platform architecture" only with more specialized additional properties as well. This mechanism has a number of implications for research as well as practice.

### 4.1 Research implications

In research, the classification can be used to generalise research results. Since sub-classes of customisation means are in fact also "members" of their super classes, research findings for more generalised classes can also be applied to their sub-classes. For example, research findings for platform architecture products should be applicable for e.g. slot-modular products as well. This however cannot be said to be true generalisation of research findings, since sub-classes will be more specialised which is the opposite of generalised. Generalisation of research findings would be performing the opposite operation, which is investigating if research findings of a sub-class are also applicable for its super-class. This cannot however be deducted directly from the taxonomy in figure 5, since the properties of a customisation means which have influenced the research findings may be different than for the super-class. However, since the characteristics of the super- and sub-class are in nature similar, there is some probability that research findings for a sub-class can also be applied to it super class. For example would research findings for mechatronic customisation might be applicable to digital customisation as well. This solely relies on whether the research is based on characteristics which are specific to the sub-class or characteristics which are specified for the super class as well. If the latter is the case, the research findings should be generalisable. It should however be noted that this classification cannot be used as an argument alone for generalisability of research findings, but rather as a guideline for generalisability which should be evaluated accordingly.

### 4.2 Implications in practice

Besides providing an overview of different possibilities for creating variety in a customisable product family, the taxonomy can provide a number of other possibilities for practitioners. Following the same principles as described for researchers above, practitioners will be able to apply principles, tools and methods developed for a certain customisation means to its sub- or super-class. For example, methods for developing products with a modular architecture may also be applied to products utilising a platform architecture. It could be argued that this could just as well be applied without using this classification, which is true. However, this classification formalises the relationships between the different customisation means which can make it clearer for practitioners what the possibilities are for adapting tools and methods for their particular application.

### 4.3 Potential future applications

It is the intention that the classification means should be extended further by identifying additional and more specific customisation means, which would increase the applicability.

It is furthermore that a similar classification should be performed for different customised product types, e.g. automobiles, cell phones, computers, kitchen appliances etc. This classification combined with the classification in this paper would provide the basis for investigating further the relationship between different types of customisation means and specific product types. This would allow analysing which customisation means are the most appropriate for certain product types with respect to e.g. customisability, product development cost and production costs.

## 5. DISCUSSION

A recurring and essential issue when performing a classification is which criteria to perform the classification by. In this context it has been chosen to classify the customisation means by how the customisation is performed. The classification could very well have been performed using other criteria. However, in this context it has been emphasised to establish a classification which presents the best possible overview and introduces as few abstract customisation means as possible.

The review and following classification could have included numerous other types of customisation means. In this relation, much research has been conducted focusing on modularity and thus many other types of modularity have been defined, however including more of these would not improve the overview of different classification means since this would emphasise modular architectures over non-modular means. The classification does not address the issue of the stability of solution space. This issue refers to whether the components of a customised product are predefined by the manufacturer, or customers are able to design new components themselves, sometimes referred to as customer co-design. It could be argued that this is also a means for customisation, however since this can be a part of nearly any means of customisation included in the classification it was chosen not to include this for simplicity.

It should also be emphasised that the different means of customisation are not mutually exclusive. This implies that different means can be applied to achieve the optimum customisation of a product. Examples of this could be mechatronic products which are based on a product platform or adaptively customised products which are customised by the customer using digital customisation.

## 6. CONCLUSION

This paper has presented a review of different customisation means, of which some are different product architectures which are efficient means for achieving customisation. These different means are classified using object oriented analysis presented in a UML class diagram.

The intention of performing this classification has been to provide a foundation for further research rather than an industrially applicable tool. The research which will succeed this classification will relate the means of customisation to different product types, which will ultimately enable practitioners to choose the right customisation means for a specific product type. Furthermore it is the intention to relate different customization means to the product development process as well as manufacturing, so that it will be possible to identify specific issues for certain customisation means which require special attention or provide recommendations depending on customisation means. As a part of this it will also be investigated which benefits and disadvantages each customization means implies during product development as well as manufacturing. The research will be further extended to also relate product configuration processes and product family modelling methods to product types and types of customisation means.

Hence this research serves primarily as a foundation for future research; however it may also be useful for practitioners who wish to gain an overview of different means for customising products as a part of a product development project, redesign or product portfolio planning.

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