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# The Influence of Mass Customization Strategy on Configuration Complexity of Assembly Systems

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## Abstract

In current business environment many OEM companies are employing mass customization strategy, which has implication on the entire operations of an enterprise and especially influences the character of assembly processes. Increased product differentiation in context of customized production causes significant changes in complexity of assembly systems. Our focus in this paper is the development of methodological framework for generating all possible product configurations based on number of stable and optional components or modules from which a final product is completed. Subsequently, we propose an approach to determining so called product configuration complexity by specifying classes and sub-classes of product configurations. Then, for each sub-class of product configuration we can obtain upper bounds values of configuration complexity. Finally, configuration complexity scale based on the obtain upper bounds values is outlined and discussed.

*Keywords:* Mass customization, assembly system, product configuration, product variation

## 1. Introduction

The growing competition in the global market is always a challenge to find innovative approaches to business. The key to success in the highly competitive manufacturing environment is the firm's ability to design and develop products that can be individually tailored to customer needs. This can be achieved by employing a set of principles of mass customization. Even though mass customization is often confronted with a question of how to put the concept of Mass Customization (MC) into profit-making practice, there are many evidences that this strategy can improve, at least, product development process efficiency and reduce time and cost [1, 2] even in the design stage of a production development. Principally, Mass-Customized Production (MCP) systems can be classified into make-to-stock MCP, assemble-to-order MCP, make-to-order MCP, engineer-to-order MCP, and develop-to-order MCP [3]. Our focus in this paper will be on the issue of assembly-to-order production where we will monitor the generation of predefined product configurations and variants. In such situation, production planning and control involve not only product variety, but also process variety and therefore it is important to synchronize product and process variety in a coherent manner [4]. Usually, product variety is predominantly determined by customer needs. This approach gradually can lead to very complex assembly systems with unlimited number of product variants to choose from. The higher the number of product variants, configurations or the overall variety, the more complex difficulties in the production design and operational management of assembly systems or assembly supply chains (ASC) there are. It has already been proofed by theory, empirical data and simulations [5, 6] that variety itself has a significant impact on the performance (productivity, quality) and complexity, especially in automotive vehicle production, including assembly and parts supply. One of the major effort in the area of assembly variety induced complexity is to reveal and develop for variety-based complexity especially for assembly supply chain operations in MCP.

Our intent in this paper is to present a part of methodological framework for generating all possible product configurations and variation based on number of stable and optional components or modules from which a final product is completed. Subsequently, we propose an approach to determine so called product configuration complexity by specifying classes and sub-classes of product configurations.

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The purpose of this effort is to identify appropriate extent of product variety and complexity.

Variety of products in Mass-Customized Production is embodied in different components, modules, parameters, variations of structural relationships, and alternative configuration mechanisms. The different properties, mechanisms and/or variables of any MCP assembly operation, allow us to differ between structural, dynamic or a heuristic type of complexity. While the first one describes the state of a system in a pre-defined time point, the dynamic complexity describes and measures the change of a system in a pre-defined period of time. Any MCP layout solution consisting of numerous product configurations and variants at a certain time point allows us to sum all the product configurations and variants determining the structural complexity of the system. Dynamic complexity, on the other hand, is always linked with the size and frequency of changes in the system. The complexity, either the structural or dynamic, is even higher if a product or its configuration/variant is eliminated or newly introduced into the existing production system/layout. Today's producers have to be able to handle such a variety and conceptualize the integration between product variety and process variety. Mass-Customized Production is frequently defined as "producing goods and services to meet individual customer's needs with near mass production efficiency" [7]. The concept of Mass Customization as a theoretical and applied framework has been introduced in a research literature by Davis [8] and later presented in the book by Pine [1]. It is possible to identify two different concepts for the definition of mass customization, the broader and the narrower one. The broader concept defines mass customization as the ability to provide customers with individually designed products and services without the limitation of time, place and customer needs. The narrower concept defines mass customization as the use of flexibility processes and organization structures to provide a variety of products and services that are designed to individual customer specification [9]. Authors [10] pointed out, that success of mass customization system or MCP depends on customer demand for individualized and customized products. They explained that the demand for customized products is influenced by two main factors. The first is a degree of customer satisfaction. The second one is the firm's ability to produce products according to customer specification, with an acceptable time and reasonable costs. By them, the balance between these two factors is critical determinant for the success of the mass customization system. Product variety has been defined in several ways (see, e.g. [11, 12]). According to Ulrich [13] it is the diversity of products that a manufacturing enterprise provides to the marketplace.

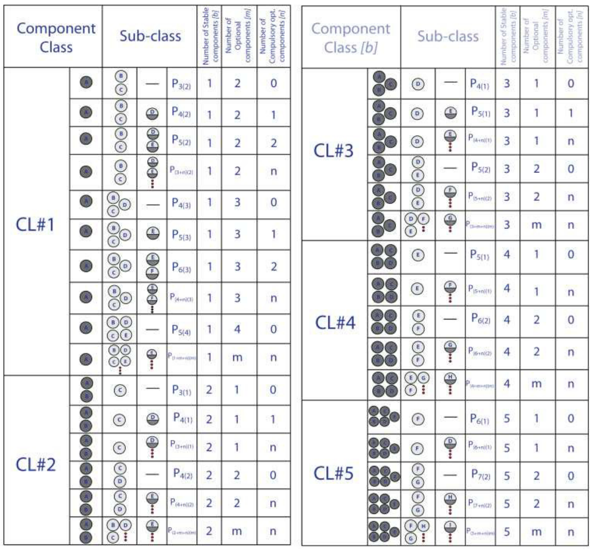
Our effort in this paper is to determine all possible product configurations based on number component types divided into three categories, namely base, optional and compulsory optional components.

## 2. Generating of product configurations

So far, the possibility of having multiple optional components or more than one type of optional component has not been considered in our research. The procedure for generating product configurations is not much different from our previous methodology [14, 15] where we dealt only with base and optional component types. We will start with the following assumptions:

1. Let`s call the product class with a number of stable components a Class of product configurations *CL#b*, where b – number of stable components on entry to assembly unit/process;
2. Each of product classes *CL* consists of sub-classes $P_{b+m+n\,(m)}$ (see Fig.1), where:

$m$ – number of optional components
$n$ – number of compulsory optional components



| Component Class | Sub-class | | | | Number of Stable components [b] | Number of Optional components [m] | Number of Compulsory opt. components [n] |
|---|---|---|---|---|---|---|---|
| CL#1 | A | B<br>C | — | $P_{3(2)}$ | 1 | 2 | 0 |
| | A | B<br>C | D | $P_{4(2)}$ | 1 | 2 | 1 |
| | A | B<br>C | D<br>E | $P_{5(2)}$ | 1 | 2 | 2 |
| | A | B<br>C | D<br>E<br>⋮ | $P_{(3+n)(2)}$ | 1 | 2 | n |
| | A | B D<br>C | — | $P_{4(3)}$ | 1 | 3 | 0 |
| | A | B D<br>C | E | $P_{5(3)}$ | 1 | 3 | 1 |
| | A | B D<br>C | E<br>F | $P_{6(3)}$ | 1 | 3 | 2 |
| | A | B D<br>C | E<br>F<br>⋮ | $P_{(4+n)(3)}$ | 1 | 3 | n |
| | A | B D<br>C E | — | $P_{5(4)}$ | 1 | 4 | 0 |
| | A | B D<br>C E<br>⋮ | F<br>⋮ | $P_{(1+m+n)(m)}$ | 1 | m | n |
| CL#2 | A<br>B | C | — | $P_{3(1)}$ | 2 | 1 | 0 |
| | A<br>B | C | D | $P_{4(1)}$ | 2 | 1 | 1 |
| | A<br>B | C | D<br>⋮ | $P_{(3+n)(1)}$ | 2 | 1 | n |
| | A<br>B | C<br>D | — | $P_{4(2)}$ | 2 | 2 | 0 |
| | A<br>B | C<br>D | E<br>⋮ | $P_{(4+n)(2)}$ | 2 | 2 | n |
| | A<br>B | B D<br>C ⋮ | E<br>⋮ | $P_{(2+m+n)(m)}$ | 2 | m | n |

| Component Class [b] | Sub-class | | | | Number of Stable components [b] | Number of Optional components [m] | Number of Compulsory opt. components [n] |
|---|---|---|---|---|---|---|---|
| CL#3 | A C<br>B | D | — | $P_{4(1)}$ | 3 | 1 | 0 |
| | A C<br>B | D | E | $P_{5(1)}$ | 3 | 1 | 1 |
| | A C<br>B | D | E<br>⋮ | $P_{(4+n)(1)}$ | 3 | 1 | n |
| | A C<br>B | D<br>E | — | $P_{5(2)}$ | 3 | 2 | 0 |
| | A C<br>B | D<br>E | F<br>⋮ | $P_{(5+n)(2)}$ | 3 | 2 | n |
| | A C<br>B | D F<br>E ⋮ | G<br>⋮ | $P_{(3+m+n)(m)}$ | 3 | m | n |
| CL#4 | A C<br>B D | E | — | $P_{5(1)}$ | 4 | 1 | 0 |
| | A C<br>B D | E | F<br>⋮ | $P_{(5+n)(1)}$ | 4 | 1 | n |
| | A C<br>B D | E<br>F | — | $P_{6(2)}$ | 4 | 2 | 0 |
| | A C<br>B D | E<br>F | G<br>⋮ | $P_{(6+n)(2)}$ | 4 | 2 | n |
| | A C<br>B D | E G<br>F ⋮ | H<br>⋮ | $P_{(4+m+n)(m)}$ | 4 | m | n |
| CL#5 | A C E<br>B D | F | — | $P_{6(1)}$ | 5 | 1 | 0 |
| | A C E<br>B D | F | D<br>⋮ | $P_{(6+n)(1)}$ | 5 | 1 | n |
| | A C E<br>B D | F<br>G | — | $P_{7(2)}$ | 5 | 2 | 0 |
| | A C E<br>B D | F<br>G | H<br>⋮ | $P_{(7+n)(2)}$ | 5 | 2 | n |
| | A C E<br>B D | F H<br>G ⋮ | I<br>⋮ | $P_{(5+m+n)(m)}$ | 5 | m | n |

Fig. 1. Component classes CL and their sub-classes $P_{b+m+n(m)}$

3. Each such Class consists of at least one stable assembly component in combination with at least two optional components (in class *CL#1*). The number of stable components is fixed throughout the whole assembly process, e.g. any assembly scheme can have pre-identified components divided into three categories, already in the assembly design stage.
   In cases when only one stable and one or two optional components enter the process, we are not talking about a customized assembly, since this operation only results in one product configuration, which is only a standard assembly process and not a customized assembly.
4. The following types of input components can be defined as follows:

(i) Stable components are those selected from among the input components of a certain assembly level and their amount is fixed through the whole assembly process. If a certain node performs the installation/assembly of optional and compulsory optional components at the same time, the previous configurations of base and optional components become fixed for further optional component level, as can be seen in Fig. 2.

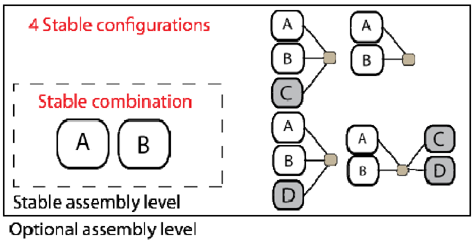


Fig. 2. Formation of stable components in stable and optional assembly levels

The two stable components A, B are further assembled/ combined with two optional components C and D. Optional component in this case means that the product configuration without any optional components is taken into account as well. We are talking about the cases, when only the stable components are assembled and no additional option has been chosen by the customer for assembly. As seen in Fig. 2, there are four product configurations available for this combination of components, so that the customer can choose at least one of them.

(ii) Stable and optional components can be further combined with compulsory optional components. In Customized assembly there is always a limitation related to the maximum or minimum required number of components that can or must be selected per assembly operation by customer. In each such instance or for each assembly unit respectively, it is also important to define whether there may be combinations of individual components or if only individual components are allowed. There are three possibilities when choosing combinations of compulsory optional components for customer:

- The definition of exact number of components to be chosen from the available compulsory optional components (individual selectivity rules from Tab. 1);
- Maximum number of components to be chosen from the available compulsory optional components (Max. selectivity rules from Tab. 1);
- Minimum number of components to be chosen from the available compulsory optional components (Min. selectivity rules from Tab. 1).

Then a summary configuration values for different rules/numbers of compulsory optional components can be determined, as can be seen in Tab. 1. It is also possible to identify the number of configurations by setting the maximum, minimum or exact rule concerning the number of components to pick for a certain assembly node/operation by customer, for example optional functions of washing machine like automatic water level, automatic temperature control, child lock, sensitive cycle or other to choose from.

Customer has to choose at least one of the mentioned functions or maximum rule depending on the number of compulsory components, and he is then offered a choice of feature combinations and of other characteristics of the assembled product.

Table 1. Number of product configurations in selectivity conditions

| Compulsory optional components *[n]* | Required number of n *[r]* | Different selectivity conditions | | | |
|---|---|---|---|---|---|
| | | Exact selectivity rules | | Max. selectivity rules | Min. selectivity rules |
| 1 | 1 | 1 out of 1 | 1 | 1 | 1 |
| 2 | 1 | 1 out of 2 | 2 | 2 | 3 |
| 2 | 2 | 2 out of 2 | 1 | 3 | 1 |
| 3 | 1 | 1 out of 3 | 3 | 3 | 7 |
| 3 | 2 | 2 out of 3 | 3 | 6 | 4 |
| 3 | 3 | 3 out of 3 | 1 | 7 | 1 |
| 4 | 1 | 1 out of 4 | 4 | 4 | 15 |
| 4 | 2 | 2 out of 4 | 6 | 10 | 11 |
| 4 | 3 | 3 out of 4 | 4 | 14 | 5 |
| 4 | 4 | 4 out of 4 | 1 | 15 | 1 |
| 5 | 1 | 1 out of 5 | 5 | 5 | 31 |
| 5 | 2 | 2 out of 5 | 10 | 15 | 26 |
| 5 | 3 | 3 out of 5 | 10 | 25 | 16 |
| 5 | 4 | 4 out of 5 | 5 | 30 | 6 |
| 5 | 5 | 5 out of 5 | 1 | 31 | 1 |

5. In order to generate a number of product configurations in all possible Classes of Product Variants, the following equations can be applied.

The equations for the total number of product configurations, when only two types of entry components are present, namely stable and optional, are as follows. Here the division of configurations does not matter:

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = ((2^m)-1) \text{ valid only for } CL\#1 \qquad (1)$$

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = (2^m) \text{ valid for } CL\#2 \text{ and higher} \qquad (2)$$

If the division of configurations matters, the following equations can be applied:

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = \sum_{k=1}^{m} \left( \frac{m!}{k!(m-k)!} \right) \text{ valid only for } CL\#1, \qquad (3)$$

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = \sum_{k=0}^{m} \left( \frac{m!}{k!(m-k)!} \right) \text{ valid for } CL\#2 \text{ and higher.} \quad (4)$$

The following equations can be used to calculate the number of product configurations when also compulsory optional components are present in the assembly operation. If the division of configurations is unimportant to us, the following equations can be used:

- valid only for *CL#1*:

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = ((2^m)-1) \sum_{r=1}^{n} \left( \frac{n!}{r!(n-r)!} \right), \qquad (5)$$

- valid for *CL#2* and higher:

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = (2^m) \sum_{r=1}^{n} \left( \frac{n!}{r!(n-r)!} \right). \qquad (6)$$

If the division of configurations matters, the following equations can be applied:

- valid only for *CL#1*:

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = \sum_{k=1}^{m}\left(\frac{m!}{k!(m-k)!}\right)\sum_{r=1}^{n}\left(\frac{n!}{r!(n-r)!}\right), \tag{7}$$

- valid for *CL#2* and higher:

$$\sum Conf_{CL\#bP_{b+m+n(m)}} = \sum_{k=0}^{m}\left(\frac{m!}{k!(m-k)!}\right)\sum_{r=1}^{n}\left(\frac{n!}{r!(n-r)!}\right). \tag{8}$$

where:

$m$ – total number of optional components, $m = 0, 1, 2, ..., k$

$n$ – total number of available compulsory optional components, where $n = 0, 1, 2, ..., r$

$r$ – number of required number of compulsory optional components.

The final number of product configurations is influenced by factors representing number of configurations from stable and optional and compulsory optional components separately, as can be seen from equations (5-8).

6. Similarly, we can generate product configurations of product class $CL\#2P_{8(2)}$ representing a single assembly node/station, firstly using a graphical representation in Fig. 3 and then compare the result with calculation of configurations using equation (4).

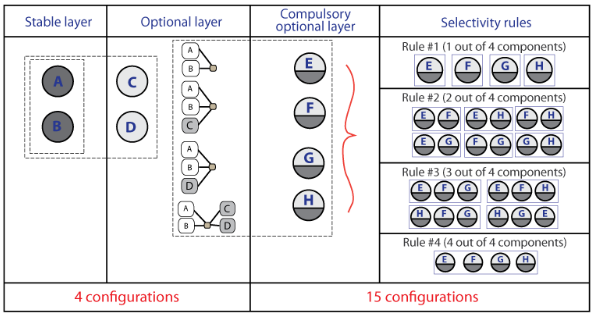


Fig. 3. Graphical explanation of configuration generation for for $CL\#2\text{-}P_{8(2)}$ resulting in 60 product configurations $b$=2, $m$=2, $n$=4

$$\sum Conf_{CL\#2-P8(2)} = \sum_{k=0}^{m}\left(\frac{m!}{k!(m-k)!}\right)\sum_{r=1}^{n}\left(\frac{n!}{r!(n-r)!}\right)$$
(9)

$$\sum Conf_{CL\#2P_{8(2)}} = \tag{10}$$
$$= \left[\left(\frac{2!}{0!(2-0)!}\right)+\left(\frac{2!}{1!(2-1)!}\right)+\left(\frac{2!}{2!(2-2)!}\right)\right]*$$
$$*\left[\left(\frac{4!}{1!(4-1)!}\right)+\left(\frac{4!}{2!(4-2)!}\right)+\left(\frac{4!}{3!(4-3)!}\right)+\left(\frac{4!}{4!(4-4)!}\right)\right]$$

$$\sum Conf_{CL\#2P_{8(2)}} = (1+2+1)*(4+6+4+1) = 60 \tag{11}$$

On the basis of the above presented methodology, our new methodological framework for creation of all possible component structures differs from previously published work as the multiple types of optional components have not yet been considered.

Theoretical assumptions of the Methodological framework for generation of all possible product configurations have been defined, while compulsory optional components were taken into account. Currently valid assumptions underplaying our previous work have been extended with new rules, which came to light during the work with the second type of component. Further research will focus on the application and verification of the methodology on the model of customized assembly structure, a case MCP assembly model in order to calculate and verify the summary numbers of product configurations and its product variants It is also essential to uncover other factors affecting the final configuration complexity.

## 3. Generating of product variations

Each sub-configuration can be assigned by a number of product variations. Product variations differ in the way the optional components are assembled to different stable components. For instance, for sub-configuration in Fig. 4 consisting of three stable and two optional components, there are 9 product variations (see Fig. 5). Optional components of a certain product configuration are assembled only to the stable components, in all different combinations and only once. It is clear, that the final number of product variants depends more on the number of „free“ optional components than on the number of stable components, so the more optional components there are, the more product variants we get in final calculation.

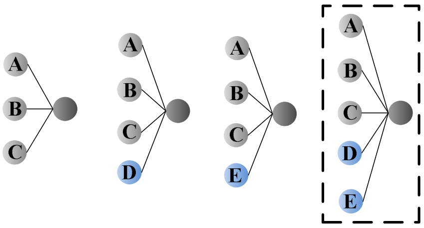


Fig. 4. All Component product configurations of *CL#3-P5*

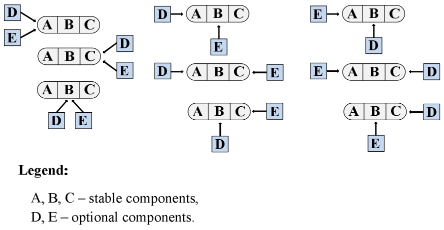


Fig. 5. Product variations of configuration where b=3, m=2

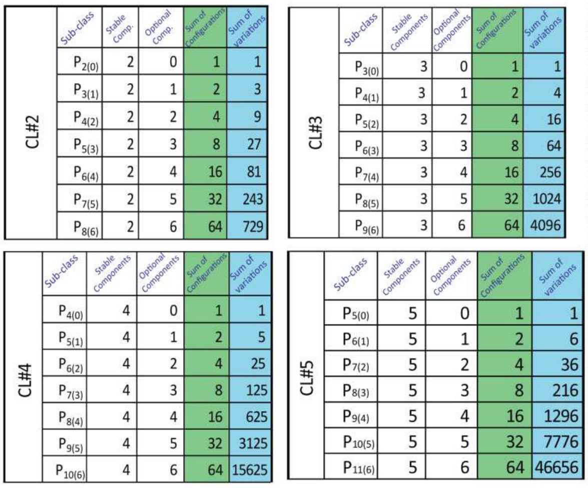
Definition of the total number of product variations of any sub-class and product class depending on the number of stable and optional components only, can be expressed as follows:

$$\sum Var_{CL\#bP_{(m)}} = \sum_{k=0}^{m}\left(\frac{m!b^k}{k!(m-k)!}\right) \tag{12}$$

Similarly we can calculate product variations of product class representing a single assembly node/station, while b=3, m=3. Calculation of product variations when coping with Compulsory optional components has not been defined for their low practical relevance.

$$\sum Var_{CL\#3P_3} = $$
$$= \left[\left(\frac{3!.3^0}{0!(3-0)!}\right)+\left(\frac{3!.3^1}{1!(3-1)!}\right)+\left(\frac{3!.3^2}{2!(3-2)!}\right)+\left(\frac{3!.3^3}{3!(3-3)!}\right)\right] \tag{13}$$
$$= (1+9+27+27) = 64$$

Furthermore, it can be proven that from a practical standpoint, product configurations are much more important than product variations. To prove the practical relevance of product configurations, it is necessary to investigate their dependence on the number of stable and optional components. For this purpose, summary fragment tables of product configurations and variations of product classes *CL#2* to *CL#5* can be used, as can be seen in Fig. 6.



| CL#2 | Sub-class | Stable Comp. | Optional Comp. | Sum of configurations | Sum of variations |
|---|---|---|---|---|---|
| | $P_{2(0)}$ | 2 | 0 | 1 | 1 |
| | $P_{3(1)}$ | 2 | 1 | 2 | 3 |
| | $P_{4(2)}$ | 2 | 2 | 4 | 9 |
| | $P_{5(3)}$ | 2 | 3 | 8 | 27 |
| | $P_{6(4)}$ | 2 | 4 | 16 | 81 |
| | $P_{7(5)}$ | 2 | 5 | 32 | 243 |
| | $P_{8(6)}$ | 2 | 6 | 64 | 729 |

| CL#3 | Sub-class | Stable Components | Optional Components | Sum of configurations | Sum of variations |
|---|---|---|---|---|---|
| | $P_{3(0)}$ | 3 | 0 | 1 | 1 |
| | $P_{4(1)}$ | 3 | 1 | 2 | 4 |
| | $P_{5(2)}$ | 3 | 2 | 4 | 16 |
| | $P_{6(3)}$ | 3 | 3 | 8 | 64 |
| | $P_{7(4)}$ | 3 | 4 | 16 | 256 |
| | $P_{8(5)}$ | 3 | 5 | 32 | 1024 |
| | $P_{9(6)}$ | 3 | 6 | 64 | 4096 |

| CL#4 | Sub-class | Stable Components | Optional Components | Sum of configurations | Sum of variations |
|---|---|---|---|---|---|
| | $P_{4(0)}$ | 4 | 0 | 1 | 1 |
| | $P_{5(1)}$ | 4 | 1 | 2 | 5 |
| | $P_{6(2)}$ | 4 | 2 | 4 | 25 |
| | $P_{7(3)}$ | 4 | 3 | 8 | 125 |
| | $P_{8(4)}$ | 4 | 4 | 16 | 625 |
| | $P_{9(5)}$ | 4 | 5 | 32 | 3125 |
| | $P_{10(6)}$ | 4 | 6 | 64 | 15625 |

| CL#5 | Sub-class | Stable Components | Optional Components | Sum of configurations | Sum of variations |
|---|---|---|---|---|---|
| | $P_{5(0)}$ | 5 | 0 | 1 | 1 |
| | $P_{6(1)}$ | 5 | 1 | 2 | 6 |
| | $P_{7(2)}$ | 5 | 2 | 4 | 36 |
| | $P_{8(3)}$ | 5 | 3 | 8 | 216 |
| | $P_{9(4)}$ | 5 | 4 | 16 | 1296 |
| | $P_{10(5)}$ | 5 | 5 | 32 | 7776 |
| | $P_{11(6)}$ | 5 | 6 | 64 | 46656 |

Fig. 6. Summary fragment tables of product classes *CL#2* to *CL#5*

Based on the summary tables of classes *CL#2* to *CL#5* it is evident, that the number of product variations is substantially larger than the number of product configurations with growing number of input components or for a certain sub-class.

It can be further stated that the number of product variations depends on the number of stable as well as on optional components. On the other hand, the number of product configurations varies/grows only depending on the number of optional components.

## 4. Concept of configuration complexity scale

On the base of the above-described methodology it is possible to identify an important attribute of the class *CL#2* regarding the number of product configurations, where an important fact has been uncovered (see Fig. 7).

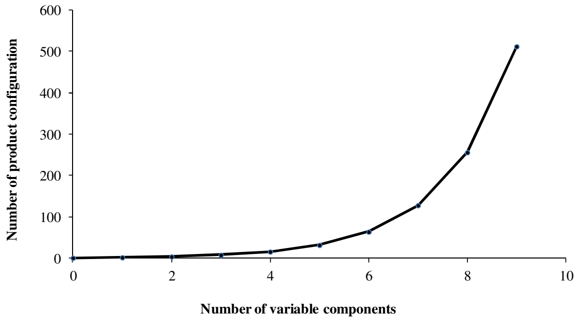


Fig. 7. Graphical representation of configuration complexity of class *CL#2*

As seen from Fig. 7, the class *CL#2* reaches the highest values of product configurations among all classes for the given number of input components (for example; *CL#2*$P_8$ with 2 stable and 6 optional components gives 64 product configurations while *CL#2*$P_8$ to *CL#∞*$P_8$ gives also 64 product configurations). The values of product configurations from *CL#2* are then considered to be the upper bound values of the scale concept. In order to define a degree of complexity, a concept of configuration complexity scale is defined, as can be seen in Fig. 8.

Procedure for creation of configuration scale concept consisted of the following steps:

- Generation of all possible component (product) ASC configurations based on the number of base, optional and compulsory optional components and their graphical representation;
- Defining the number of product configurations and product variations for every component class *CL* and their appropriate sub-classes;
- Analysis of the final values of configurations and the definition of upper bound value of the scale concept according to number of product configurations of product class *CL#2;*
- Obtaining the upper bound values defined by “degrees of product configuration complexity” of configuration complexity scale.

Complexity degrees based on total number of product configurations in case of two base components entering the process - *CL#2*:

- 1st degree: from $P_3$ (2) to $P_4$ (4)
- 2nd degree: more than $P_4$ to $P_5$ (8)
- 3rd degree: more than $P_5$ to $P_6$ (16), etc.

Numbers in brackets are the values of product configurations for a certain number of stable and optional components. Then it is possible to identify any MCP assembly operation and assign it a configuration complexity degree. Our aim in future research to define the optimal configuration complexity level, so called optimal configuration complexity so that a MCP designer can take the optimal complexity level account even in the design stage or in the decision-making process.

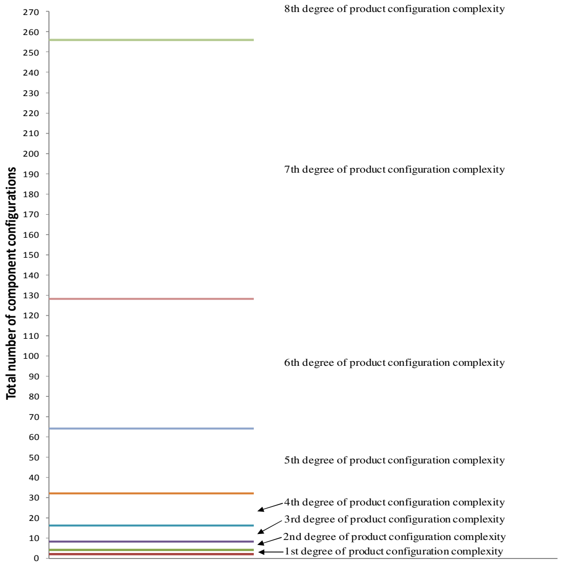


Fig. 8. Graphical representation of configuration complexity scale with defined upper bounds

## 5. Conclusions

This work follows our previous research activities focused on assembly supply chain structure generations and development of structural complexity metrics for assembly processes [16, 17, 18].

In this paper our first intention was to define basic rules for methodological framework of product configuration generation. Based on the verification of presented theoretical example, its usability has been shown. In order to determine all possible product configurations, we subsequently established computational formulas for this purpose. Such generation of number of product configurations can be considered as the supplementary tool for determination of product structure complexity. Proposed scale to categorize product configuration complexity to certain levels, as shown in Fig. 8, can be useful to analyze differences in product complexity in terms of MCP.

In our future works we would like to verify more complex mass-customized product representations and also apply presented approach to Cladograms to proof the relevance and usability of the concept and therefore on the definition of product configuration complexity.

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