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Finding Suitable Amount of Variety for Product Platforms

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Abstract

The development of methods to identify the optimal product variety of a product platform is an important research issue in mass customization. A product platform which includes a wide portfolio of modules or components allows customers to customize their product by expressing a lot of different requirements. However, certain requirements may be constrained each other thus bringing customers to be disappointed by unfeasible product configurations. The present article explores the possibility of using entropy-based measures for quantifying the complexity induced by product variety in the context of constrained product configuration. More specifically, this article proposes a method which uses entropy-based measures to decide the optimal variety for product platforms. This method characterises a given product platform comparing the entropy associated to the feasible product configurations with the entropy associated to the unfeasible product configurations. Computational experiments performed on two case applications show that the proposed method can be effectively used to quantify variety-induced complexity and to assist product managers to choose optimal product variety.

Key words: *complexity, customization, design, platform, product*

1. INTRODUCTION

One of the main issues in product variety management is finding a suitable variety level for a given product family. Both high variety and low variety have positive and negative implications. While designing a product family these implications should be taken into consideration and a solution that balance positive and negative effects should be found.

Higher variety allows customers to customize their product and get a higher fit with their specific needs. Consequently for a company that aims to satisfy the specific requirements of the customers the bigger the product variety, the better, and vice-versa [1-5].

However, high product variety implies high variety-induced complexity which in turn negatively affects operational performance. For example, it brings possible turbulences in the manufacturing systems, leading e.g. to higher production costs [6]. In addition, market demand for ever higher product individuality brings companies into the dilemma of being able to produce small lot sizes economically [7, 8]. Therefore, the variety extent is limited by production possibilities.

A company can improve the capability of his operations to deal with the variety-induced complexity by choosing suitable product component structure and product design architecture. An appropriately chosen wide set of modules and components can be the base to efficiently obtain an incredibly wide set of finished products able to fit specific customer needs without involving the design department in the fulfilment of a customer order. This possibility has several implications that go beyond the operations and influence the company organizational design in terms of organizational structure, information and decision processes, reward systems, and skills and mind-sets of company employees [9].

Having a product family with a wide set of modules and components a customer has the possibility to customize his product by choosing among the set of possible options for each aspect of the product. Unfortunately, due to technical, aesthetic, economic or other reasons it could be that different options conflicts and constrains each other. Customer disappointments may occur when his requirements are specified based on a wide portfolio of modules or components and not all configurations can be satisfied due to restrictions on selected components and their combinations [10]. Extent of product variety in MC environment is becoming serious problem when configuration conflicts appear [11]. Then, product designers have to consider such constraints, since they can cause serious problems.

Methods to identify and solve configuration conflicts are known also as a constraint satisfaction problem (CSP).

CSPs as mathematical-based methods of operations product variety management. In principle, constraint satisfaction methods can be effectively used in many sectors. Nevertheless, the implementation of product configurators for mass customization (MC) requires adoption of specific requirements to e.g. connection of functionally specific components together.

The present paper aims to find a method to help product designers to set a product variety that satisfy a wide set of requirements without excessively disappointing the customer with unfeasible configurations. This paper explores the possibility to solve this issue by changing the rate between infeasible product configurations and all possible product configurations when restrictions are omitted. These numbers of viable and unviable product configurations are indicators of variety-induced complexity. However, they are not optimal indicators to be used to solve the problem here considered. The ratio between the numbers of viable and unviable product configurations does not reflect assembly component composition and may provide similar variety-induced complexity. Therefore, for making decisions on variety management we propose and use entropy-based complexity metrics (Case 1).Subsequently, we present a decision-making algorithm based on these metrics and we apply it for optimal selection of a bicycle component platform (Case 2).

2. ENTROPY-BASED COMPLEXITY METRICS FOR VARIETY MANAGEMENT

2.1 Theoretical background

This sub-section analyses a relation between infeasible (non-functioning) product configurations and all possible product configurations (even the non-functioning ones) of any existing or intended product platform. Shannon defined and outlined the very first notion of complexity where so called “Information theory” was developed [12]. Few years later, information became a key element for the description and analysis of a system. Information theory over the years has been used even outside its original field of application.

It has been considered also in the product design field by several authors [13].In particular, the notion of Information Entropy has been shown to be useful in the product design process. Krus well convey its meaning and usefulness when say “the design information entropy should be seen as a measure of the design space that has been under consideration during the design process […]In order to be effective it is desirable to have a small design space, but that still contain sufficiently good designs.

A hallmark of a good design space is therefore that it is easy to assemble viable designs from a limited set of design elements, where there are ready to use sub systems and components that can be combined into new products e.g. like in a Lego set, or a good product platform” [14]. According to Krus [13] each particular design *x* with regards to its design space *D* has information entropy H_x:

research are common for their potential use also in

$$H_x = log_2 n_s, \tag{1}$$

where n_s is a number of unique design alternatives (representing so called complete design space) that are results of a combination of product options and H_x is denoted as Entropy of complete design space.

There are many real cases, in which some product variants or configurations are impractical due to presence of constraint(s). Then, information entropy of constrained design space H_c can be enumerated as:

$$H_c = log_2 n_v, \tag{2}$$

where n_v is a number of viable design alternatives.

Since higher number of all possible design variants (complete design space) has more positive impact on satisfying consumers than smaller constrained design space, Entropy of constrained design space should be maximized [15]. In this sense, Entropy of constrained design space can be considered as positive entropy, as can be seen in the Waste entropy construct in Figure 1.

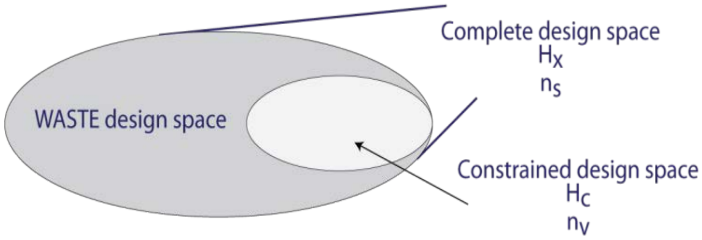


Figure 1. Waste complexity construct including all variables

Krus [13] proposed to express a quality of a modular design/platform through the rest of the design space that is outside the constrained design space by the term “waste” information entropy of design space H_w and to quantify it using the formula:

$$H_W = H_X - H_C. \tag{3}$$

In line with the logic used for the Entropy of constrained design space, Waste entropy can be considered as negative entropy. Once the background of the Waste entropy construct is outlined, we may proceed towards its application.

In order to catch the effect of product design optimization by using the concept of negative entropy, we firstly need to generate concurrent product design architectures to be mutually benchmarked. One way to do so is through a gradual elimination of selected components from the original product design architecture. Subsequently, mutual relation between so called positive entropy and negative entropy can be treated. For this purpose, numbers of all possible product configurations when restrictions are omitted, and all possible product configurations with component restrictions need to be enumerated. This procedure is presented in the following sub-section.

2.2 **Enumeration of waste entropy for concurrent product design architectures – Case 1**

To effectively present a practicability of the waste complexity concept, a realistic Case 1 is provided to motivate practitioners in product design to solve similar problems. For this reason, Case 1 as an assembly model of personal computer adopted in the form of selection algorithm has been used [16] to identify product configurations, as seen in Figure 2.

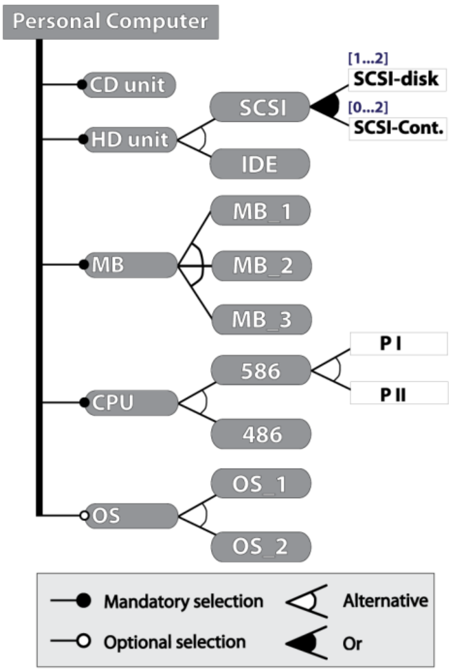


Figure 2. Personal computer case product structure

Once managers are in the early stage of product architecture design, they might decide about the most suitable product component (module) structure. Depending on the situation and the sales forecasts of the product, marketing managers strive to maximize the variety offer to satisfy a wide range of customers knowing also that some incompatible components can occur in possible product configurations. The problem is that they are not aware of the number of infeasible product configurations when designing a product platform. Moreover, it is not easy to identify those using only imagination or amateur methods as it will be shown further. Relatively high number of such infeasible product configurations, as a rule, negatively affects customer perception and buying behaviour when using catalogue or online configurator. With regards to component restrictions, there are different reasons for restriction or obligation between two or more components of any product. There may be functional, design, connectivity or other reasons for relation or for elimination of the link between any two or more components. Besides the structural, hierarchy or aggregation restrictions, four mostly used types of configuration rules may arise [16]: a) require rule, b) incompatible rule, c) port-connection rule, and d) resource balancing rule.

The case Model 1 has various customizable options depending on the customers' choice but with predefined restrictions in the form of rules related to incompatibility of components defined as follows:

Table 1. List of restriction rules of the Case 1

R#1 – CPU3 must not be in the same configuration with component *MB1*.
R#2 – MB_2 must not be in the same configuration with components *CPU1* and *CPU2*.
R#3– CPU3 must not be in the same configuration with component *MB_3*.
R#4 – OS1 must not be in the same configuration with component *MB_1* and *MB_3*.
R#5 – OS2 must not be in the same configuration with component *MB_2* and *MB_3*.
R#6 – MB_2 and *MB_3*must not be in the same configuration with components *HD4*, *HD5* and *HD6*.
R#7 – OS2 must not be in the same configuration with components *HD2*and *HD4*.

2.3 **Enumeration of product configurations**

Next, it is useful to transform the computer selection structure into a simplified assembly graph depicted in Figure 3. It is a representation of MC assembly of a personal computer consisting of five basic modules: CD-unit (1 option), HD-unit (6 individual customer options), Motherboard (MB) (3 options as MB1, MB2 and MB3), CPU (586_P I, 586_P II, 486), and Operating system (OS) (OS1 and OS2). Adopting the previously developed model as in e.g.: [17, 18], any such structure usually consists of number of assembly stations – nodes. These can be identified within a multi-level network. Additionally, variety of component alternatives for each assembly module can be identified in Figure 3, as seen in red rectangle.

As it is evident from Figure 3, HD unit module is represented by six alternatives, while the number of all possible component permutations is seven. One of them is omitted, namely permutation consisting of two SCSI-Controllers with single SCSI disk, as the second controller in such combination is considered to be redundant. Then, all possible product configurations without any restriction can be identified for the original product design platform D_0:

$$\sum Conf_{D0} = 1 * 6 * 3 * 3 * 2 = 108. \quad (4)$$

Subsequently, it is also necessary to determine the total number of configurations when restriction rules R#1-7 from Table 1 are considered. For this purpose, incidence matrix with component restrictions R#1-7 has been constructed (see Table 2).

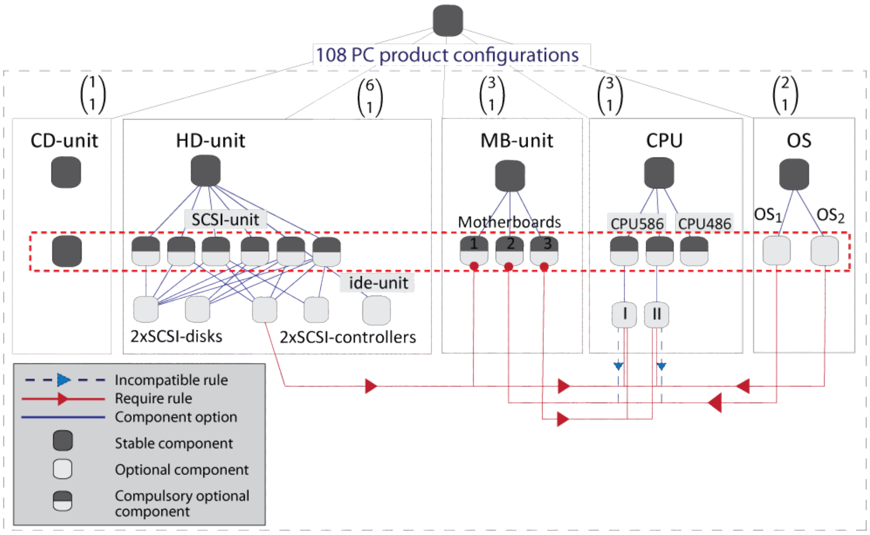


Figure 3. Case 1 assembly graph of personal computer including visualized component restrictions [16]

Table 2. Component restrictions R#1-7 in the form of incidence matrix

		Group 1 - HD						Group 2 - CPU			Group 3 - MB			Group 4 - OS	
		HD1	HD2	HD3	HD4	HD5	HD6	CPU1	CPU2	CPU3	MB1	MB2	MB3	OS1	OS2
Group 1 - HD	HD1														
	HD2														❼
	HD3														
	HD4											❻	❻		❼
	HD5											❻	❻		
	HD6											❻	❻		
Group 2 - CPU	CPU1											❷			
	CPU2											❷			
	CPU3										❶		❸		
Group 3 - MB	MB1													❹	
	MB2														❺
	MB3													❹	❺
Group 4 - OS	OS1														
	OS2														

To enumerate number of constrained (viable) product configurations, the following procedure is proposed. In the first step, let us select e.g. group of HD units. Then, we select arbitrary configuration from the group, for example HD2, which is one of the six HD unit options. Afterwards, we may construct an incidence sub-matrix for the HD2 option and the group of CPU components. As there is no restriction, HD2 as option can be combined with any CPU component (see Figure. 4).

Next, three-dimensional matrix relations between configurations HD2, group of CPU components and a group of MB components needs to be created. Four restrictions are identified. Accordingly, CPU components can be combined with compatible MBs. Finally, four-dimensional matrix relations are constructed in Figure 4(a) and then it is possible to exactly determine five viable product configurations where HD2 is exclusively involved.

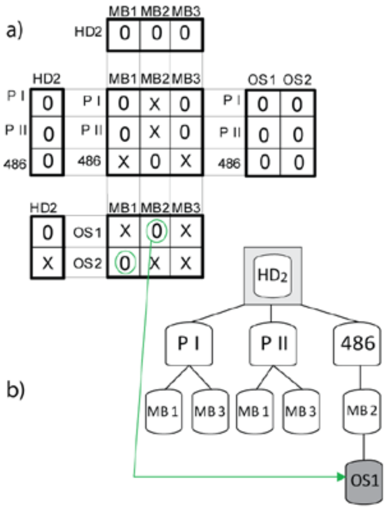


Figure 4. Proposed approach to transform incidence matrix (a) into a product configurations model (b)

Moreover, this procedure allows generating product component structure of all identified constrained (viable) product configurations, as can be seen in Figure 4(b). The sub-procedure depicted in the Figure 4 has to be repeated for the rest of the components from the Group 1. Then, the sum of only viable configurations for individual components of the Group 1 is 21, as can be seen from Figure 5.

2.4 **Proposed procedure to reduce waste entropy**

As mentioned in the introduction, the goal of the CSP solutions in terms of MC is to reduce number of waste (non-functioning) product configurations. One possible way to reach this goal is by changing the rate between waste product configurations and all possible product configurations, when restrictions are omitted. This rate can be changed through an elimination of components linked to certain restriction from an original product design platform D_0.

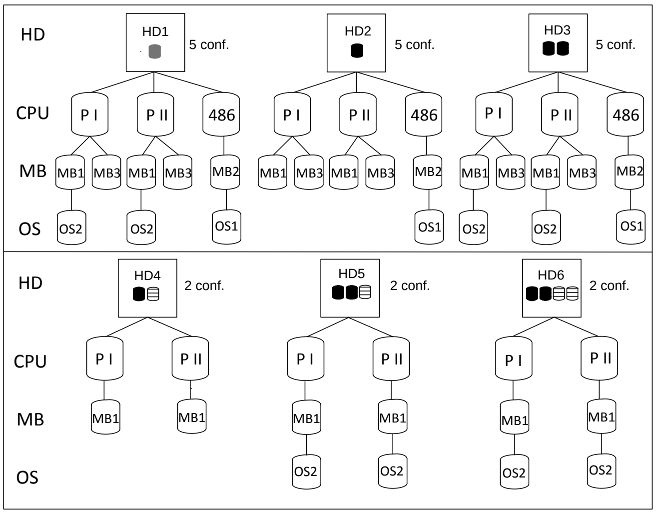


Figure 5. Model of 108 viable product configurations respecting component restrictions [19]

For this reason, a new product design platform D_1 can be obtained when e.g. one of MB, namely MB2 is selected for elimination. From here on, configurations consisting of MB_2 are not counted and therefore the total number of model configurations decreased to 72, without accepting the rules and restrictions R#1-7. The number was reached by the following multiplication:

$$\sum Conf_{D1} = 1 * 6 * 2 * 3 * 2 = 72. \quad (5)$$

Then, applying the procedure proposed in the Figure 3, the number of viable product configurations decreased to 18, as enumerated by the following formula:

$$\sum Res\_Conf_{D1} = 5 + 5 + 5 + 2 + 2 + 2 = 18. \quad (6)$$

To obtain another alternative product design platform D_2 for benchmarking purposes, we eliminate another component CPU3. Then, the number of total model configurations is calculated as follows:

$$\sum Conf_{D2} = 1 * 6 * 2 * 2 * 2 = 48. \quad (7)$$

Then, viable product configurations will also equal 18 as this elimination had no impact on the number of viable product configurations. Obtained numbers of configurations with and without restrictions are summarily depicted in the following Table 3.

Subsequently, waste entropy and waste entropy rates for each of the design platforms $D_{0\text{-}2}$ can be calculated. Table 3 shows how waste configuration ratio is changed by reducing number of restricted components.

Table 3. Computational results of numbers of product configurations

Product platforms	Number of product configurations	
	Without restrictions n_s (complete design space)	With restrictions n_v (constrained design space)
D_0	108	21
D_1	72	18
D_2	48	18

Both, the reductions from D_0 to D_1 and from D_1 to D_2 seem to be favourable in order to reduce number of waste product configurations. In such cases, decision-makers may have a dilemma on what design platform is optimal from the customer's perspective. For this purpose, the following decision-making algorithm to eliminate this dilemma is proposed.

3. DECISION-MAKING ALGORITHM

In this section, we describe the decision-making algorithm to select optimal platform of product variants by using mutual relations between waste entropy H_w and constrained design space entropy H_c in cases with multiple product platforms to be decided and with complex product platforms with high number of available product configurations.

We start by taking so called draft design platform D_0, representing an existing product design platform generating both, all possible and waste product configurations for customers, where n_{s0} presents a number of unique product design configurations as results of a combination of product components and n_{v0} is a number of viable product design configurations.

Let us further assume that we remove single component from the platform D_0, which is in conflict with other component(s). Then, D_0 can be transformed into a new state with n_{s1} for all unique product design configurations and nv1 for viable product configurations, denoted as platform D_1. If we would continue in such a reduction of components, the design platform D_1 is modified into D_2. Obviously, we may continue in the reduction of system component depending on specific conditions.

To compare exactly two arbitrary design platforms against each other, e.g. D_0 and D_1, the following two measures are proposed:

$$\Delta H_{w_{0,1}} = \left| \frac{H_{w_1}}{H_{w_0}} - 1 \right|, \quad (8)$$

$$\Delta H_{c_{0,1}} = \left| \frac{H_{c_1}}{H_{c_0}} - 1 \right|. \quad (9)$$

Applying the above measures for the decision, e.g. between platforms D_0 and D_2, if $\Delta H_{w0,2} > \Delta H_{c0,2}$ => design platform D_2 is more preferable product architecture in terms of waste complexity than D_0, as graphically depicted in Figure 6.

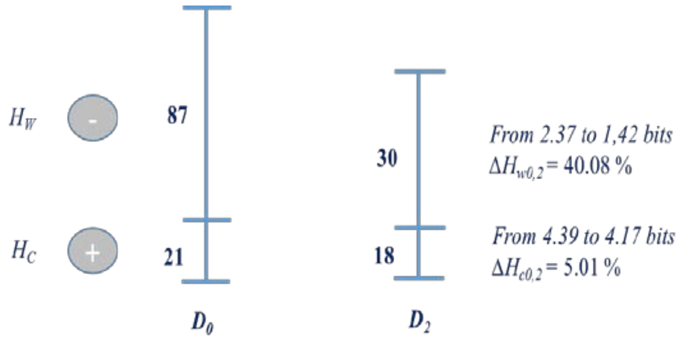


Figure 6. Enumeration of waste complexity for two concurrent platforms D_0 and D_2

To select among three alternative design platforms of Case 1, the following sub-procedure can be used. Let us suppose that design platforms D_1 and D_2 are more preferable for MC than D_0, based on the criteria:

$\Delta H_{w0,1} > \Delta H_{c0,1}$,

$\Delta H_{w0,2} > \Delta H_{c0,1}$.

Then, one can select more preferable design platform between D_1 and D_2 using these three criteria:

I. If $\Delta H_{w0,1} - \Delta H_{c0,1} > \Delta H_{w0,2} - \Delta H_{c0,2}$ => design platform D_1, is more suitable than D_2.

II. If $\Delta H_{w0,1} - \Delta H_{c0,1} < \Delta H_{w0,2} - \Delta H_{c0,2}$ => design platform D2, is more suitable than D_1.

III. If $\Delta H_{w0,1} - \Delta H_{c0,1} = \Delta H_{w0,2} - \Delta H_{c0,2}$ => both design platforms D_1, and D_2 are equally preferable for buyers.

The above proposed procedure for the selection of optimal design platform is graphically depicted in Figure 7 in the form of algorithm flow-chart. Similarly, a procedure to select optimal product design platform for the consideration of three or more platforms at once can be developed.

4. WASTE ENTROPY OF CONCURRENT PRODUCT DESIGN ARCHITECTURES – CASE 2

In order to show the relevance of the proposed algorithm to select the optimal product design platform, the following realistic case from the Shimano compatibility catalogue is used [20].

The case application in this section is represented by restrictions between the two inter-operating component modules of the bicycle drive train, which can be found in every bicycle model. The original platform D_0 consists of 12 groups (nine for gears and three for chain stay angle (CSA)). Each of the nine groups has a specific number of alternative components to be combined with a front drive train (FD), e.g. gear 42-32-24T can be combined with six Front Crank sets (FC): M980, M780, M670, M610, M552, M522. To compose the platform D_0, a non-symmetric matrix consisting of 38 rows and 19 columns has been used. In Figure 8, elements of the matrix noted with “X” stand for incompatible combinations.

For the design platform D_0, complete design space is defined by n_{s0}=722 product configurations and constrained design space expressed by n_{v0}=239 product configurations. Using this matrix, it is possible to gradually and randomly remove selected components with restrictions to obtain alternative platforms and to benchmark various concurrent SHIMANO product platforms against each other. Firstly, gears 48-36-26T including eight crank sets (M610, T780, M670, T781, T671, T611, T551 and T521) have been selected for an elimination into the platform D_1 (see Figure 8). This group of components was selected for an elimination based on the criterion of the highest density of restrictions. Subsequently, we obtain compatibility table of the platform D_1. The number of rows in this table was reduced from 38 to 30. This way we obtained platform D_1 defined by n_{s1}=570 drivetrain configurations and n_{v1}=215 constrained (viable) product configurations.

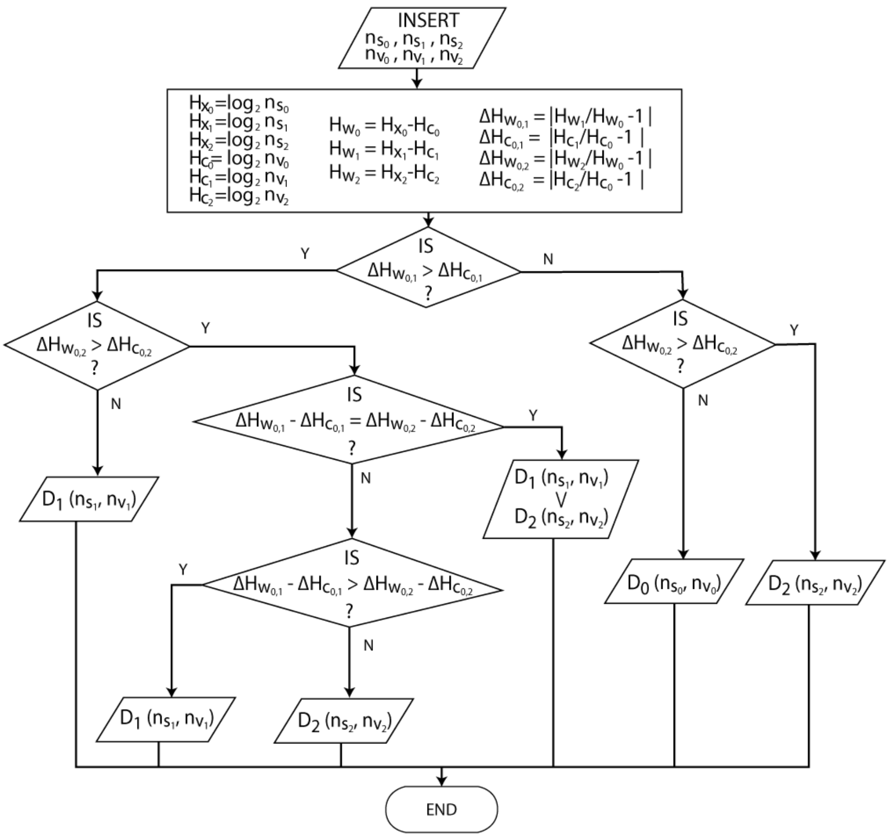


Figure 7. Algorithm to select optimal product design platform based on waste entropy complexity construct [19]

Elimination for D_3

Elimination for D_1

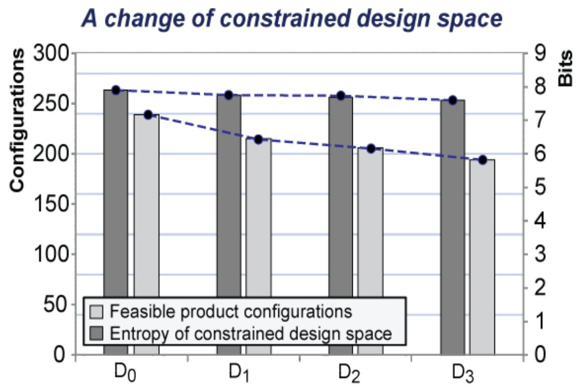
Elimination for D_2

Platform D_0		Front drivetrain (FD)																		
							For triple						For double							
CSA		66° - 69°								63° - 66°			66° - 69°							
Gears	Front crankset (FC)	M981	M781-A	M671-A	M611	M981-D	M781-A-D	M671-A-D	M611-D	T781-3	T671-3	T611-3	M986	M786	M676	M616	M986-D	M786-D	M676-D	M616-D
42-32-24T	M980									X	X	X	X	X	X	X	X	X	X	X
	M780									X	X	X	X	X	X	X	X	X	X	X
	M670									X	X	X	X	X	X	X	X	X	X	X
	M610									X	X	X	X	X	X	X	X	X	X	X
	M552									X	X	X	X	X	X	X	X	X	X	X
	M522									X	X	X	X	X	X	X	X	X	X	X
40-30-22T	M782	X				X				X	X	X	X	X	X	X	X	X	X	X
	M672	X				X				X	X	X	X	X	X	X	X	X	X	X
	M622	X				X				X	X	X	X	X	X	X	X	X	X	X
	M612	X				X				X	X	X	X	X	X	X	X	X	X	X
	M523	X				X				X	X	X	X	X	X	X	X	X	X	X
48-36-26T	M610	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T780	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	M670	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T781	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T671	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T611	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T551	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T521	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
44-32-24T	T611	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T551	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	T521	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
44-30T	M985	X	X	X	X	X	X	X	X	X	X	X								
42-30T	M985	X	X	X	X	X	X	X	X	X	X	X								
40-28T	M985	X	X	X	X	X	X	X	X	X	X	X								
	M785	X	X	X	X	X	X	X	X	X	X	X								
	M675	X	X	X	X	X	X	X	X	X	X	X								
	M625	X	X	X	X	X	X	X	X	X	X	X								
	M615	X	X	X	X	X	X	X	X	X	X	X								
38-26T	M980	X	X	X	X	X	X	X	X	X	X	X								
	M785	X	X	X	X	X	X	X	X	X	X	X								
	M675	X	X	X	X	X	X	X	X	X	X	X								
	M625	X	X	X	X	X	X	X	X	X	X	X								
	M615	X	X	X	X	X	X	X	X	X	X	X								
38-24T	M785	X	X	X	X	X	X	X	X	X	X	X								
	M675	X	X	X	X	X	X	X	X	X	X	X								
	M625	X	X	X	X	X	X	X	X	X	X	X								
	M615	X	X	X	X	X	X	X	X	X	X	X								

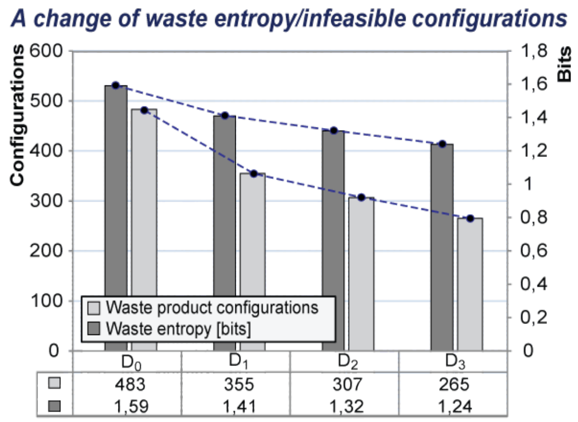
Figure 8. SHIMANO compatibility table with Platforms $D_{0\text{-}3}$ for gears and front derailleur [20]

Afterwards, for determination of the platform D_2, we proceed towards elimination of gear type 44-32-24T (including three crank sets T611, T551 and T521), as can be seen in Figure 8. The number of rows in this table was reduced from 30 to 27. We obtained platform D_2 defined by n_{s2}=513 drivetrain configurations and n_{v2}=206 constrained (viable) product configurations. In order to provide other alternative product platform D_3 for the benchmarking study, two FDs M981 and M981-D have been eliminated due to the high number of restrictions related to these two components. Then, we obtained platform D_3 defined by n_{s3}=459 drivetrain configurations and n_{v3}=194 constrained product configurations, while the number of columns decreased from 19 to 17.

Obtained numbers of drive train configurations and related values of waste entropy H_w and constrained design space H_c are summarily depicted in the following Table 4. Subsequently, as can be seen from Figure 9(a), values of constrained product configurations as well as related constrained design space have decreasing character starting from the Platform D_0 to D_3. Another logical objective of the methodology - decreasing waste (infeasible) configurations - has been satisfied as well, as confirmed by the Figure 9(b).



a)



b)

Figure 9. Graphical interpretation of constrained (feasible) design space (a), and waste entropy/configurations (b) within Platforms $D_{0\text{-}3}$

In the following step, the decision-making algorithm to determine suitable extent of product variety for different platforms has been applied. Since algorithm in Figure 7 is dedicated for the decision on maximum three alternative design platforms, an extension of this algorithm for maximum four design platforms has been constructed. After using the algorithm and the procedure proposed, we obtain a decision for Platform D_3 as the most suitable with respect to the amount of the waste entropy, as evident from Table 4.

Table 4. Computational results of entropy and number of product configurations

Approach	Indicator	Platform D_0	Platform D_1	Platform D_2	Platform D_3
Design space-based approach	Entropy of design space	$E_x=\log_2 n_s$ [bit] $n_s=722$ $E_x=9.50$ bits	$E_x=\log_2 n_s$ [bit] $n_s=570$ $E_x=9.15$ bits	$E_x=\log_2 n_s$ [bit] $n_s=513$ $E_x=9.00$ bits	$E_x=\log_2 n_s$ [bit] $n_s=459$ $E_x=8.84$ bits
	Entropy of constrained design space	$E_C=\log_2 n_v$ [bit] $n_v=239$ $E_C=7.90$ bits	$E_C=\log_2 n_v$ [bit] $n_v=215$ $E_C=7.75$ bits	$E_C=\log_2 n_v$ [bit] $n_v=206$ $E_C=7.69$ bits	$E_C=\log_2 n_v$ [bit] $n_v=194$ $E_C=7.60$ bits
	Waste entropy ratio	$E_w/E_x=16.7\%$	$E_w/E_x=15.4\%$	$E_w/E_x=14.7\%$	$E_w/E_x=14.0\%$
Abosolute NPC-based approach	Number of all possible configurations	*722 conf.*	*570 conf.*	*513 conf.*	*459 conf.*
	Feasible product configurations	*239 conf.*	*215 conf.*	*206 conf.*	*194 conf.*
	Relative number of infeasible configurations	67%	62,3%	59,8%	57,7%

5. DISCUSSION AND CONCLUSION

The present paper considered product platforms which include a wide portfolio of modules or components and proposed an approach to identify the optimal product variety that satisfies more customer requirements without excessively disturbing customers with unfeasible configurations. The proposed approach is based on the comparison of the entropy associated to the feasible product configurations with the entropy associated to the unfeasible product configurations. This approach is operationalized through a proposed algorithm that guides the product designer step by step towards the identification of the optimal variety.

The proposed approach can be employed to assist product managers to independently assess competing product variety platforms against each other and to evaluate their customization characteristics quantitatively and without any additional costs for the company. As it was shown and proven on multiple case models and platforms, proposed approach leads to decision for optimal product platform.

Some authors (e.g. [17, 21-27]) argue that infeasible configurations might be hidden to improve “configuration experience” by using sophisticated product configurators. It was also proven in psycho-social domain (e.g. [28]) that any changes of long-term accepted rules in human behaviour initiate disappointments or frustrations. Obviously, it is evident that one of configurator types is developed especially for options that include also waste (infeasible) component combinations and they simply cannot be hidden [29]. On the other hand, a necessary development trend within corporations requires the change of “internal complexity” thinking which will definitely bring new possibilities and remove production barriers [30].The approach here proposed complements these positions. In fact, it implicitly accepts that conflicting requirements, if they are not too frequent, may be hidden. At the same time implicitly recognises that if these conflicts are discovered by the customer they can be disappoint him. And finally,the proposed approach pragmatically accepts that until engineers do not remove the technological limits that cause some of the conflicts, these conflicts are present and have to be managed in some way.

Limitations of the paper are in the method itself, as it only considers number of product configurations (in numerical and entropic forms), not looking at the demand side – external/customer view. Thus, the problem treated in this paper opens new research perspectives because each different sector of mass customization requires effective approach to solve CSPs.

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Pronalažanje odgovarajućeg nivoa varijantnosti platformi proizvoda

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Apstrakt

Razvoj metoda za utvrđivanje optimalnog nivoa varijanti proizvoda, neke platforme proizvoda, predstavlja važnu istraživačku temu u oblasti kastomizovane industrijske proizvodnje.Platforma proizvoda, koja uključuje širok spektar modula ili komponenti, omogućava potrošačima da kastomizuju proizvode izražavajući veliki broj različitih zahteva. Međutim, određeni zahtevi mogu biti međusobno ograničavajući, što može dovesti do nezadovoljstva potrošača zbog neizvodljive konfiguracije proizvoda. Ovaj rad istražuje mogućnost korišćenja mera zasnovanih na entropiji, kako bi se kvantifikovala složenost izazvana raznovrsnošću proizvoda, u kontekstu ograničenja pri konfiguraciji proizvoda. Preciznije, u ovom radu se predlaže metod koji koristi mere zasnovane na entropiji sa svrhom donošenja odluke o optimalnom nivou raznovrsnosti platforme proizvoda.Ovaj metod opisuje svojstva određene platforme proizvoda poređenjem entropije povezane sa izvodljivim konfiguracijama proizvoda i entropije povezane sa neizvodljivim konfiguracijama proizvoda. Računski eksperimenti koji su primenjeni na dva različita slučaja pokazuju da predloženi model može efektivno da se koristi radi kvantitativnog prikazivanja složenosti izazvane raznovrsnošću. Takođe, ovaj metod može služiti kao pomoćni alat menadžerima pri izboru optimalne raznovrsnosti proizvoda.

Ključne reči: *Složenost, kastomizacija, projektovanje, platforma, proizvod*