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PRODUCT CONFIGURATION FOR MASS PERSONALIZATION

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Abstract: *In the context of mass personalization, the customer is integrated into the product design process during the configuration phase. The paper presents different strategies and approaches to product configuration, the integration of product and process configurations, product configuration systems that satisfy customers, ensuring production efficiency, and mass customization. An attribute/function-based configurator is proposed that integrates process, product configuration, and process planning decisions. It was also proposed that an open architecture product configurator be developed to integrate both a customer interface and an application used by engineers involved in product design.*

Keywords: *Mass Personalization, Product Configuration, Open Architecture Products, Integrated Product Development*

1. INTRODUCTION

Businesses have shifted from producing individual products to producing product families as a result of mass personalization (MP). The goal of MP is to develop a modular product architecture that enables the generation of several variations within a single family. After accurately understanding the customer's requirements, a product variant is crafted to fulfill those needs. This is achieved through product configuration [1].

Within MP, the customer becomes part of the product design process at the configuration stage. During this phase, the customer selects their preferred options from several available product features, requiring a tool to aid in configuring the product.

In [2], Product configurators serve several essential purposes: displaying the available products, providing details on pricing, delivery times, and product specifications, and verifying that the new product variant is intact and valid.

When a customer enters their needs, a web application finds the best platform from an open-architecture product database, according to Peng et al. [3].

Wang et al. [4] aim to enhance product configurator performance by bridging the

semantic gap between customer requirements and specific design parameters, considering customers' lack of familiarity and experience with the product.

The paper presents different strategies and approaches to product configuration, the integration of product and process configurations, product configuration systems that satisfy customers, ensuring production efficiency.

2. PRODUCT CONFIGURATION STRATEGIES AND APPROACHES

2.1 Product configuration strategies

As per reference [5], there exist three strategies for solving configuration issues:

- Determining the primary product setups through the examination of historical sales data;
- Developing viable product configurations according to customer demands;
- Optimizing product configurations involves choosing the best option from available configurations based on specific criteria, such as cost, customer satisfaction, and sustainability. Typically, heuristic methods are employed to address these optimization challenges.

2.2 Product configuration approaches

To showcase product variations in a toolkit designed for mass customization, there are two methods: (1) the attribute-oriented approach and (2) the alternative-oriented approach [1].

With an alternative-oriented approach, customers are encouraged to design their product from a selection of different modules. In an attribute-oriented approach, customers provide their preferences concerning product attributes, and a complete product proposal is selected from a wide range of options based on their responses.

Organizing products based on their characteristics lessens the perceived complexity, motivates customers to make decisions, and enhances their satisfaction. Consequently,

customers favor expressing their personal needs over selecting from an extensive array of customization options.

3. INTEGRATION OF PRODUCT AND PROCESS CONFIGURATIONS

The effective manufacturing of tailored products necessitates the combination of product and process configurations. The customization process starts with the customer selecting the features they want in their desired customized product from a predefined set of options.

Various instances of accessible modules can fulfill the same product function. Figure 1 illustrates how product configuration and process planning are integrated based on specific customer needs [6].

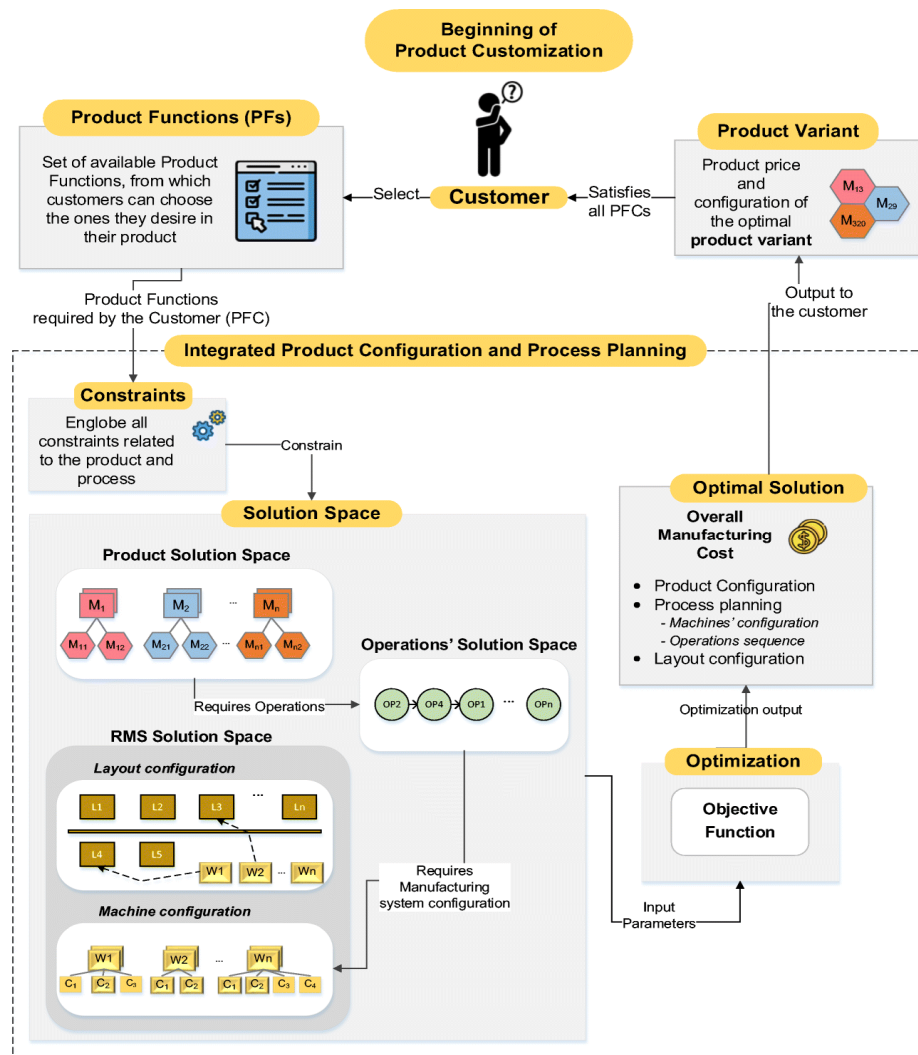


Fig. 1. Integrating product configuration with process planning [6].

Subsequently, a configurator is suggested that connects process, product configuration, and process planning decisions to fulfill customer needs while minimizing overall production expenses.

The configurator operates oriented on attributes, which means that rather than selecting a product variant for customization, the customer selects the desired features, and the configurator identifies the most appropriate product variant for customization.

Figure 2 illustrates a comprehensive suite of functions related to the product that has been developed. Each function connects to multiple modules capable of fulfilling it. Every module is linked to a series of steps required for its production. Ultimately, various combinations of machines can carry out each operation, and every machine comes with several configuration options.

The challenge is selecting the group of modules that meets all the customer's requirements while optimizing the process plans to reduce overall production expenses. These expenses include the costs of raw materials, processing operations, machine setup, and material handling.

The product configuration procedure is shown in Figure 3. From the suggested list of functions, the customer initially selects the ones he needs.

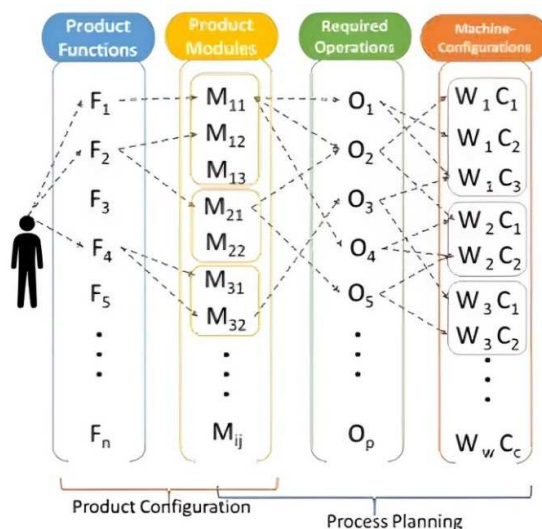


Fig. 2. Integrated product configuration with process planning.

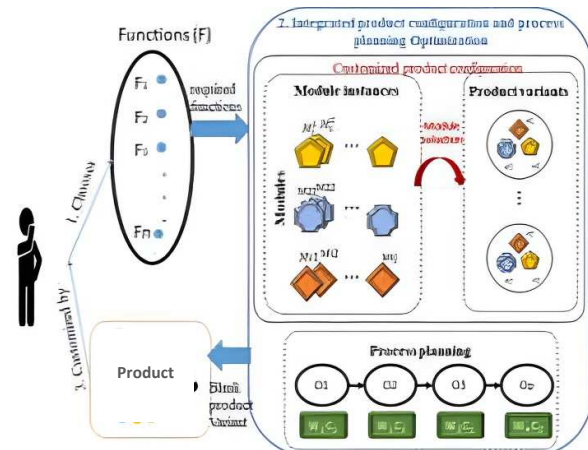


Fig. 3. The overall process of product configuration and customization.

The chosen functions are used as input for the customization problem, which aims to simultaneously improve process planning and product configuration. The objective is to minimize total production costs while providing the customer with the best possible product variant that fulfills all required requirements.

4. PRODUCT CONFIGURATION SYSTEMS

Knowledge-based systems like product configuration systems or mass customization toolkits are tasked with adapting a product to meet individual customer requirements. [7]. During the product configuration phase, the customer and the manufacturer interact via the configuration system. This process incorporates the customer into the design process, enabling them to customize their product from preset options based on their requirements.

In the context of open architecture products, Yongliang et al. [8] group the modules that can make up such a product into common modules, customized modules, individualized modules, and unknown modules that need to be designed.

Zheng and colleagues [7] examine two phases involved in developing an open architecture product configurator (Fig. 4):

- modular design stage;
- scalable design stage.

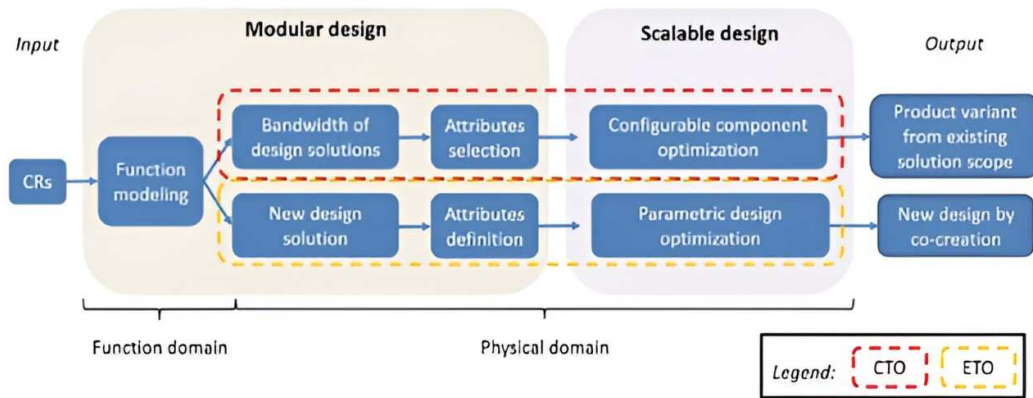


Fig. 4. Stages development a product configurator with open architecture [7].
(CTO=Configure to Order; ETO=Engineering to Order)

Modular design is described as a collection of interchangeable modules between products that belong to the same family. This is achieved through the process of correlating the functional domain with the physical domain, as illustrated in Figure 5. The Axiomatic Design model is used, in which the customer, functional, and physical domains are distinguished [9].

It is thus proposed to develop a configurator that integrates both a customer interface and an application used by engineers involved in product design, with the role of technical configurator, as illustrated in Figure 6. Integration of Configure to Order and Engineering to Order stands out in Figure 7.

The configurator is designed not to limit the choices made to pre-existing modules, but when the customer's requirements are not covered by the available modules, to have the possibility of developing one or more modules and integrating them with the existing ones, to generate a new design solution. This approach has as its central point the principle of module independence.

The constraints of existing configurators, along with the accessibility and availability of emerging technologies driven by the fourth industrial revolution, form the foundation for developing such a configurator as a combined solution of the two configuration techniques shown in Figure 8.

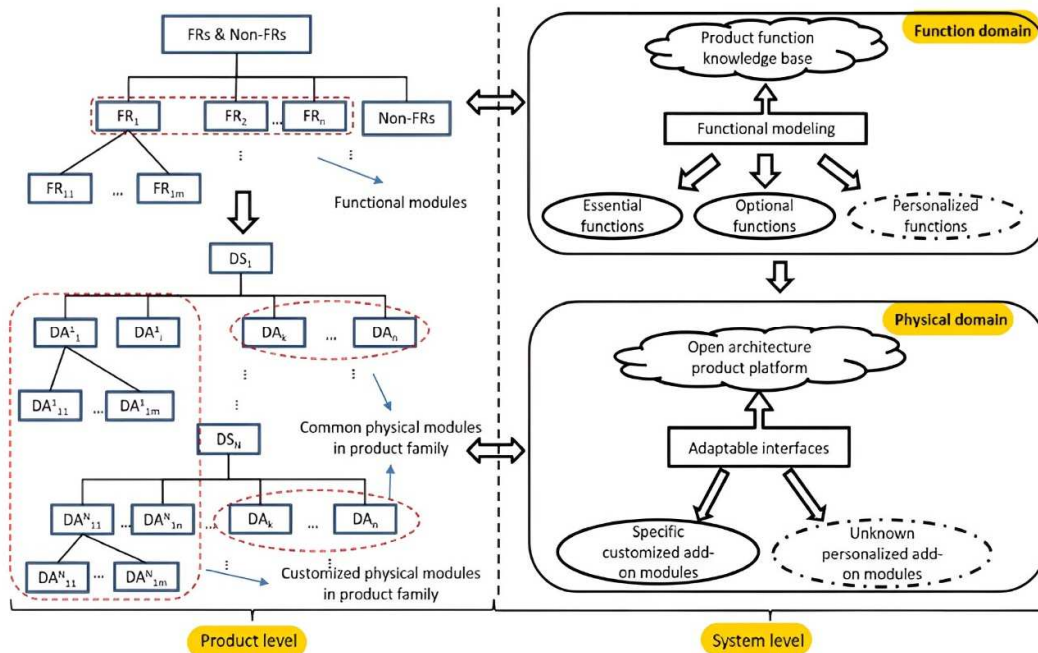


Fig. 5. Design modularity of a configurator.

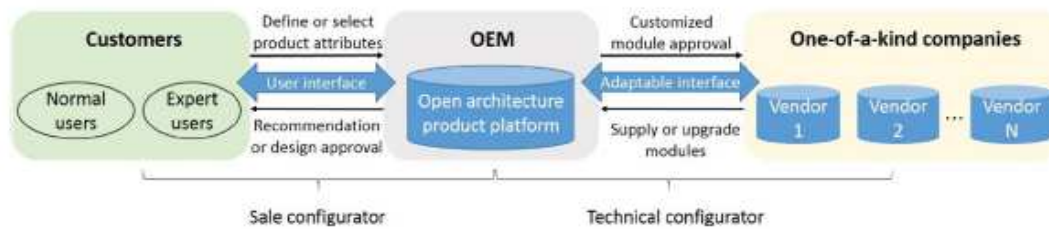


Fig. 6. The concept of configurator for products with architecture open.

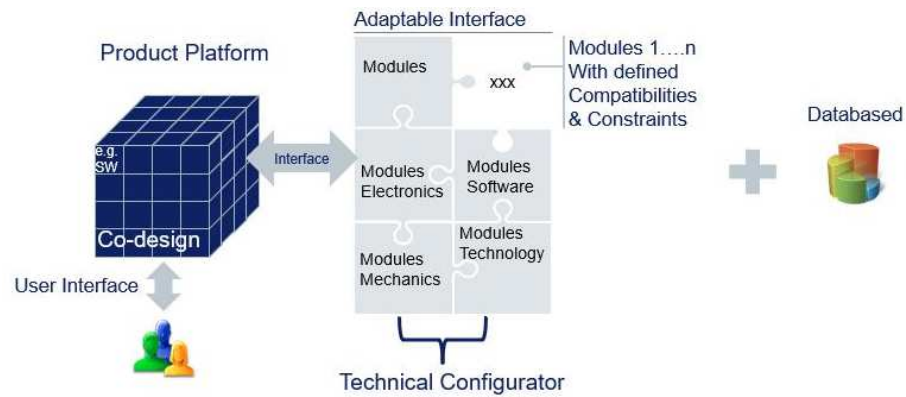


Fig. 7. Integration of configure solutions into the Configure to Order and Engineering to Order.



Fig. 8. The solution integrated of those two configuration solutions.

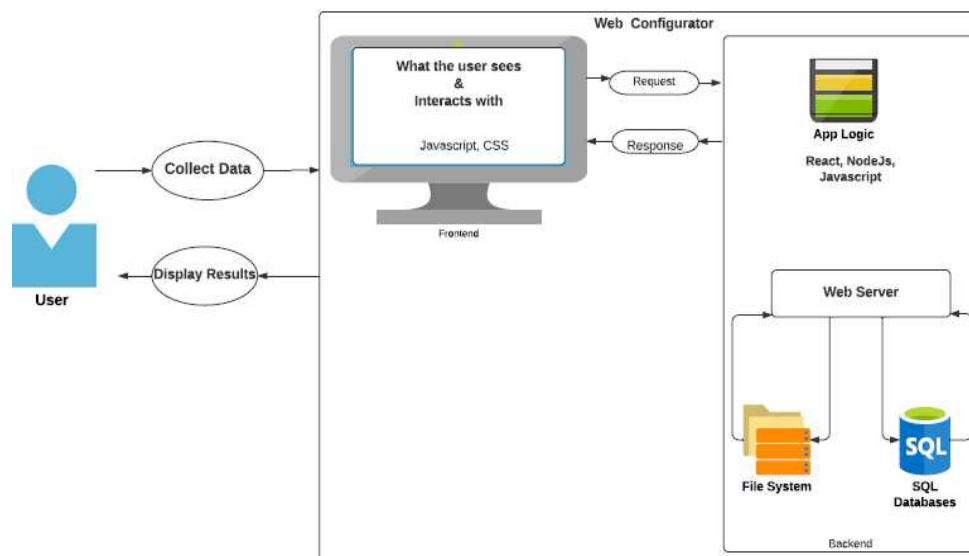


Fig. 9. Configurator architecture.

The configurator architecture (Fig. 9) consists of a user interface and a back-end application (technical configurator). The technical configurator is connected to a database containing information about existing components, modules, and finished products. The web interface offers customers the possibility to register their functional, non-functional, and legal requirements.

7. CASE STUDY: WORK LAMP

To illustrate the above, a case study regarding Work Lamp is presented.

Customers use the configurator to enter the necessary details for the task light they need. These include specifications such as voltage, required luminous flux, color temperature, CRI, impact resistance and overall dimensions. The configuration tool allows customers to configure task lights in a dedicated interface. The configurator is connected to databases and algorithms, to perform calculations.

Based on customer input and using formulas and databases, the configuration tool performs calculations to generate multiple configuration options. These options are based on different materials, light source types, or prices. The results are then presented with the advantages and disadvantages of each option.

Design parameters for the three design sub-domains (optical design, mechanical design and electronic design) are considered. Electronic and mechanical Bill of Materials are used to calculate the cost of materials for the desired lamp.

The configurator tool helps save design time by providing initial steps for choosing LED types, number of LEDs, currents, electronic modules, components and material types. These steps are usually required during the quotation phase, when a customer requests information about a specific lamp. The configurator model allows for quick and accurate responses to customer requests, providing technical details and price indications with just a few clicks.

The Work Lamp product configurator is based on the model shown in Figure 4, which

delineates two stages of the development of the open architecture product configurator:

- Modular design stage, with macro-level impact on the performance of an entire product family;
- Scalable design stage, which focuses at the micro level on optimizing design specifications.

The open architecture product configurator Work Lamp (Fig. 10) was created utilizing the Axiomatic Design Theory [9] as a combined solution of the two configuration methodologies depicted in Figure 8 in order to facilitate the transition from requirements to actual products.

The initial step will involve gathering the needs and requirements of the industrial environment from the standpoint of Industry 4.0. Functional Requirements (FRs) and Constraints (Cs) will be derived from Customer Attributes (CAs). The degree of automation and digitization needed throughout the product life cycle will depend on how FRs are defined.

The design parameters (DPs), which help to fulfill the functional requirements, shall be nominated for each FR. In the event of limited production runs or custom-made items, the design parameters will specify the flexibility, the integration of the design process with the manufacturing process variables (PVs), and the new stages of design and development of the new product. This will also guarantee that the modules are interchangeable.

Customer interaction, engineering, application, and production are the model's three vertical tiers. The design parameters, which are divided into optical, electrical, and mechanical modules, provide additional information about functional, non-functional, and legal requirements. These parameters are then gradually improved to the level of detail needed to bring the product's optimized solutions to life and move on to the developed product (production). Together with the collection needs module, the optical, electronic, mechanical, non-functional, and legal modules are the primary design modules for this product. Figure 11 illustrates the introduced design parameters for each of these modules.

Technical parameters																																	
Nominal current												Maximum current																					
Optics						Electronics						Mechanical						Costing															
LED No.	Current/Temp	LEDs Rows	LEDs Rows	Supply current	Supply voltage	Supply Power	Electro Pins	Module Area	Housing Material	PCBA Area	LEDs Rows	Current/Temp	LEDs Rows	Supply current	Supply voltage	Supply Power	Electro Pins	Module Area	Housing Material	PCBA Area	LEDs Rows	Current/Temp	LEDs Rows	Supply current	Supply voltage	Supply Power	Electro Pins	Module Area	Housing Material	PCBA Area			
1	700	0.64	1	700	12	8	M32	3.00	Aluminum	3.64	0.571	1	1200	0.64	1	1200	12	M32	3.00	Aluminum	3.64	0.571	1	1200	0.64	1	1200	12	M32	3.00	Aluminum	3.64	0.571
1	700	0.64	1	700	6	4	M31	8.85	Aluminum mastic resin	9.49	0.671	1	1200	0.64	1	1200	6	M31	8.85	Aluminum	9.49	0.671	1	1200	0.64	1	1200	6	M31	8.85	Aluminum	9.49	0.671
1	700	0.64	1	700	6	4	M31	8.85	Aluminum mastic resin	9.49	0.671	1	1200	0.64	1	1200	6	M31	8.85	Aluminum	9.49	0.671	1	1200	0.64	1	1200	6	M31	8.85	Aluminum	9.49	0.671

[illegible]

The “Overview_results” sheet displays the design options (Fig. 12). The score is calculated using design matrices. The maximum score is assigned to results that meet the conditions of a decoupled design, in which each FR is satisfied by a single DP and there is no interaction between FRs. Results based on a coupled design, i.e. each FR is influenced by multiple DPs, are evaluated with lower scores.

8. CONCLUSION

The aim of the paper was to present different strategies and approaches to product configuration, integration of product and process configurations, product configuration systems that satisfy customers, ensuring production efficiency, up to mass customization.

An attribute/function-based configurator is proposed, which integrates processes, product configuration and process planning decisions.

An open architecture product configurator was developed, which integrates both a customer interface and an application used by engineers involved in product design, exemplified in a Work Lamp product.

The results are applicable in the industry and allow adaptation to other products.

9. REFERENCES

- [1] Sabioni, R., Wartelle, L., Daaboul, J., Le Duigou, J. *Attribute-based integrated product process configurator for mass customization*, Procedia CIRP, 103, pp. 140-145, ISSN 2212-8271, 2021.
- [2] Trentin, A., Perin, E., Forza, C. *Product configurator impact on product quality*. International Journal of Production Economics 135(2), 2012, pp. 850-859, ISSN 0925-5273, 2012.
- [3] Peng, Q.J., Liu, Y.H., Zhang, J., Gu, P. *Personalization for Massive Product Innovation Using Open Architecture*. Chinese Journal of Mechanical Engineering. 31, 2018.
- [4] Wang, Y., Y. Mo, D.Y., Tseng, M.M. *Relative preference-based product configurator design*, Procedia CIRP, 83, pp. 575-578, ISSN 2212-8271, 2019.
- [5] Zhang, L.L. *Product configuration: A review of state-of-the-art and future research*. International Journal of Production Research, 52(21), pp. 6381-6398, 2014.
- [6] Sabioni, R.C., Daaboul, J., Le Duigou, J. *An integrated approach to optimize the configuration of mass-customized products and reconfigurable manufacturing systems*. International Journal of Advanced Manufacturing Technology, 115, pp. 141-163, 2021.
- [7] Zheng, P., Xu, X., Yu, S., Liu, C. *Personalized product configuration framework in an adaptable open architecture product platform*. Journal of Manufacturing Systems, 43, pp. 422-435, 2017.
- [8] Yongliang, C., Hengli, L., Deshuai, L. *Optimal Configuration Design of Open Architecture Products Considering Product Adaptability and Diversity of Modules*. CIRP Proceedings, 76. pp. 73-78, 2018.
- [9] Suh, N.P. *Axiomatic Design: Advances and Applications*. Oxford University Press, Oxford, ISBN 0-19-513466-4, 2001.

Configurarea produsului la personalizarea în masă

În contextul personalizării în masă, clientul este integrat în procesul de concepție a produsului în timpul fazei de configurare. Lucrarea prezintă diferite strategii și abordări de configurare a produsului, integrarea configurațiilor de produs și proces, sisteme de configurare a produsului, care să satisfacă clienții, asigurând eficiența producției, la personalizarea în masă. Se propune un configurator bazat pe atribute/funcții, care integrează deciziile de proces, de configurare a produsului și de planificare a proceselor. De asemenea, a fost propusă dezvoltarea unui configurator pentru produse cu arhitectură deschisă, care să integreze atât o interfață pentru client cât și o aplicație folosită de inginerii implicați în concepția produsului.

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