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OPTIMAL INTEGRATION OF PRODUCT CONFIGURATION AND PROCESS PLANNING TO MEET INDIVIDUAL CUSTOMER REQUIREMENTS IN MASS CUSTOMIZATION

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ABSTRACT: *According to researchers and practitioners, modular products are considered as key enablers for Mass Customization (MC). Modular design is a strategy for designing products composed by many subparts (modules), which are developed separately and assembled later in different ways, enabling the configuration of several product variants. Customers do not always know how to translate their requirements into product configurations, thus an alternative could be ‘co-configuring’ the product with them. This is done by an automatic modules selection based on customer requirements to get a first product configuration, which can be subsequently adjusted by the customer, if necessary. Currently, the optimal module selection is mainly conducted without considering the process planning optimization. Nevertheless, integrating both optimizations would increase product/process flexibility and agility, reducing the overall manufacturing costs. Thereby, it is important to integrate the product configuration, driven by individual customer requirements, with the process planning for MC. This paper proposes a 0-1 integer linear programming model to optimize, in terms of cost-minimization, the integration of product configuration and process planning, for MC. Results obtained with a 2-steps approach composed by an exhaustive search algorithm (ESA) and CPLEX-solver show that total cost can be considerably minimized if both optimizations are considered together.*

KEYWORDS: *Systems optimization, Operations Research, Industry 4.0, Production systems of goods and services, Mass Customization, Co-design.*

1 INTRODUCTION

The recent technological advances provided by the Industry 4.0 together with the globalization are increasingly affecting the customer behaviors and requirements (Koren 2010; Wang et al. 2017). Currently, customers no longer want just standard products; they prefer customized and high quality products capable to satisfy their individual requirements. This new era of large variety demand and market instability, has forced companies to find innovative and viable ways of attending customer demands in relatively few time and low cost (Wang et al. 2017).

One strategy that companies have been using in order to increase their product offers to attain individual customer requirements by keeping the competitiveness is the Modular Product Design (MPD) strategy. MPD means the development of products capable to accomplish several functionalities through the combination of different modules (Pahl and Beitz 1995; Gershenson et al. 2003). According to some authors, the MPD seems to be the best product design strategy to achieve a sustainable Mass Customization (MC) (Pine 1993; Sanchez and Mahoney 1996).

Currently, the most common strategy used by companies on the configuration of modular mass-customized products is asking customers to configure their product themselves, through a configurator, in which they can choose their desired modules (Pitiot et al. 2014). Generally, customers are not assisted during the purchase process, since only options of modules are proposed (Chen and Wang 2010; Piller and Walcher 2017).

Nevertheless, customers do not always know how to translate their requirements into product configurations. Non-experts or customers new to a given product type do not have sufficient knowledge about the product and struggle to find what they want (Huffman and Kahn 1998). In MC contexts, this kind of trouble can be even worse due to the high set of choices.

Further, current configurators do not integrate production planning or supply chain issues, such as cost and time. Companies usually present a product price and delivery date calculated by standard values of duration as well as material and operation costs (Pitiot et al. 2014). Nevertheless, costs related to manufacturing are variable and can significantly affect the product price.

The several possibilities of sequencing and assigning operations, required to manufacture a product, into machines, together with the various ways of combining modules in a product configuration driven by individual customer requirements can greatly increase the system

complexity, regarding to product differentiation (Tseng et al. 1996; Koren et al. 2018). The process planning, product configuration and customer requirements are interconnected and they must be integrated in a sense that process plan decisions are also based on product configuration (i.e. the set of modules compounding the product), which in turn is oriented by individual customer requirements.

In order to achieve this integration, this paper proposes a 0-1 integer linear programming (ILP) model that integrates individual customer requirements, product configuration and process planning in order to minimize the overall manufacturing costs. For validating this model, a 2-steps approach based an exhaustive search algorithm (ESA) and CPLEX solver was applied to solve a numerical example.

This paper is organized as follows. Section 2 presents a literature review. The problem statement is in Section 3, while Section 4 brings the proposition and the numerical illustration. Finally, Section 5 presents the conclusion and research perspectives.

2 LITERATURE REVIEW

2.1 Product Configuration and Configurators for MC

MPD consists of developing modular products composed by a set of relatively autonomous modules that can be combined in several ways to accomplish various functionalities (Pahl and Beitz 1995). In many cases, modules can have variants called module instances. The combination of different module instances to create product variants takes place in the product configuration, an essential stage in MPD (Jiao and Tseng 2000; Paes et al. 2018).

The objective of MC is providing products that meet individual customer needs with mass production efficiency (Jiao and Tseng 1999). In order to enable the participation of customers into the value creation, the configuration of mass-customized products is carried out through configurators (Chen and Wang 2010; Piller and Blazek 2014). Configurator is a “co-design toolkit” that allows customers choosing and combining different product components (modules), during a purchase process, until they find a product variant that fits their needs (Piller and Blazek 2014).

Most of configurators only give choices of product components, without assisting the customer during their purchase process (Chen and Wang 2010; Piller and Walcher 2017). Nevertheless, customers do not always know how to translate their needs into product configurations. Further, as stated by Liu et al. (Liu et al. 2017), the main objective of customers when buying a product is benefiting from its functionalities rather than getting the product embodiment. Likewise, Huffman and Kahn (1998) state that presenting the product information

based on its attributes/functionalities, instead of showing product alternatives, reduces the purchasing process complexity while increases the customer satisfaction. This means that guiding customer choices through product functionalities (PFs) seems to be more appropriate than just proposing them many product alternatives.

Further, the high number of choices proposed by MC can entail customers to the “paradox of choice”, with risk of turning MC into “mass-confusion” (Piller and Walcher 2017). The large set of options proposed in an MC configurator together with the knowledge gap between customers and companies, makes the product configuration for MC being a main driver for customization complexity, from the customers’ viewpoint (Franke et al. 2004; Chen and Wang 2010).

To overcome this problem, some works have tried to optimize product configuration driven by individual customer requirements in order to increase customer satisfaction (Hong et al. 2008; Dou and Zong 2014; Zhao et al. 2020). Although these researches focused on customer needs when configuring products, they did not consider costs related to manufacturing process. However, as previously stated, a sustainable MC must provide products capable of meeting individual customer requirements while being efficiently mass-produced. Thus, it seems to be of great importance to consider manufacturing costs when configuring a product for MC, and these costs depend among others on the process planning.

2.2 Integrated product configuration and process planning driven by customer needs

Process planning is related to transcribing the product design data into a method to manufacture it, including selection of machines and operations sequencing (Mohapatra et al. 2013). This means, manufacturing costs, such as operations and material handling costs, will vary according to the process plan. In addition to the overall manufacturing costs, process planning can significantly affect the product performance, since an inappropriate process plan cannot ensure the achievement of desired PFs (Xu and Liang 2006).

On the other hand, product configuration without regard to the manufacturing system settings can imply in higher production cost and delivery time (Jiao and Tseng 2000; Xu and Liang 2005). When configuring products for MC, in addition to the manufacturing system it is important to consider specific customer requirements in order to meet their individual needs. Although product configuration and process planning are essential elements for MC, few papers addressed both subjects together by considering individual customer needs (Pine 1993; Pitiot et al. 2013).

Among them, Pitiot et al. (Pitiot et al. 2013, 2014, 2020) addressed manufacturing costs considering variable resources, but they did not precise if the same operation could be performed by different resources neither did they address material handling costs. Further, to our

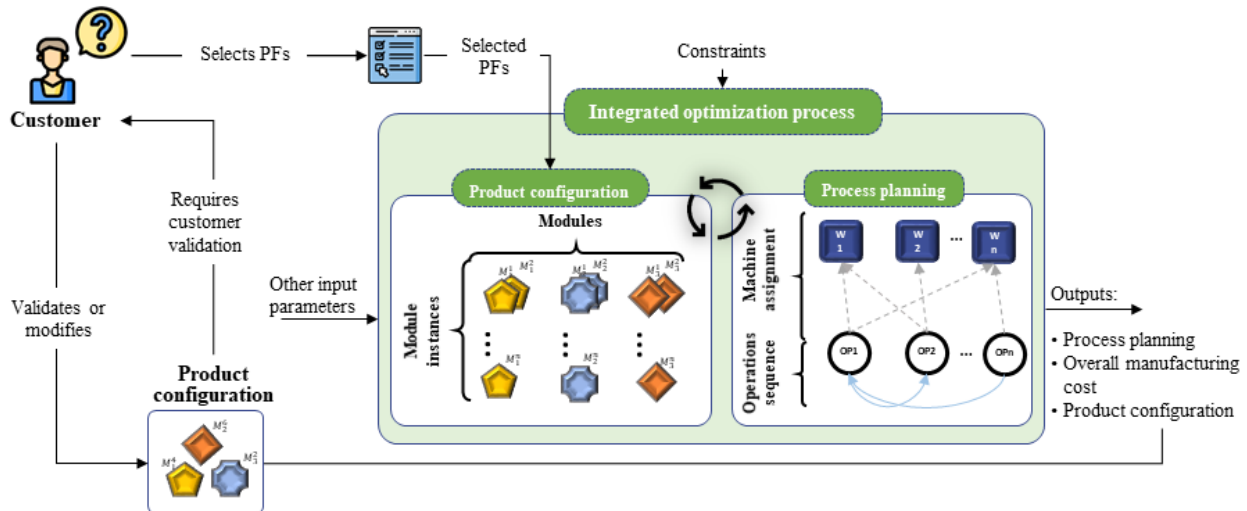


Figure 1. Proposition's illustration of the integrated modular product configuration and process planning for manufacturing mass-customized products.

best comprehension, they did not address the possibility of having different instances within the same module.

Zhou et al. (2008), Li et al. (2006) and Yang et al. (2020) tried to optimize the product configuration for mass-customizing products. They considered costs of product modules and/or module instances in their optimization problems, but they did not detail these costs in terms of manufacturing costs (material handling, operations cost, etc.) and raw material cost. Meaning each module always had the same cost, no matter the process plan.

Yigit et al. (2002) and Yigit and Allahverdi (2003), in turn, were not focused on MC, but they included individual customer requirements as input/constraints to optimize the product configuration concurrently to the process planning in a reconfigurable manufacturing system. They assumed that each type of module could have two or three module instances. However, they considered that for each type of module, there was a fixed production system configuration; consequently, manufacturing costs were considered constant according to the type of fabricated module.

The increasing globalization and demand for customized and personalized products has forced companies to be more flexible and reactive (Najid et al. 2020). This is why companies have invested in flexible manufacturing systems (FMS) and, more recently, in reconfigurable manufacturing systems (RMS) (Najid et al. 2020). In these manufacturing systems different types of machines can execute the same operation, increasing their flexibility and capacity to produce high product variety.

Nevertheless, as far as we know, there is still no work proposing to optimize the configuration of mass-customized products, driven by individual customer requirements, integrated with the process planning in FMS or RMS, with machines performing many operations,

and the same operation being performed by different machines.

Further, no papers addressing the concurrent optimization of product configuration and process planning considered material handling costs in their objective functions. However, this cost can significantly affect the overall manufacturing cost.

3 PROBLEM STATEMENT

Rather than proposing modules to the customers, here they are invited to select, among a set of options, which PFs they desire in their product. Each individual customer requirement can be translated into a PF that are represented by product modules. Each instance from a module can satisfy several PFs, while each PF can be satisfied by one or many module instances.

The set of operations required to manufacture a product variant corresponds to the combination of the operations required by each module instance chosen in the product configuration. Operations can be performed by different machines, whilst the same machine can perform several operations. In any case, each operation is performed once while the same machine can be assigned many times, but never to multiple operations simultaneously. The operation's cost can change from one machine to another and there is a cost of handling material between two machines. Therefore, manufacturing costs cannot be considered constants according to the module instance type.

Several product configurations can origin from the combination of module instances capable of satisfying PFs required by the customer, Each module instance has a raw material cost, in addition to that, costs of manufacturing, assembly and material handling are also considered. Thus, the number and types of selected module instances as well as how operations are sequenced and

assigned can affect the search for the optimal product configuration. It means a product configuration with the lowest overall manufacturing cost capable to meet all individual customer requirements (required PFs).

4 PROPOSITION

Figure 1 illustrates the proposition for integrating the product configuration with the process planning with consideration of individual customer requirements for MC.

Customers specify which PFs they want in their product. Only module instances capable to satisfy at least one PF are considered in the product configuration stage. Each product configuration will require a set of operations that must be sequenced and assigned to machines, at process level. The optimal product configuration corresponds to the one that meets all customer requirements (required PFs) and that has the lowest overall manufacturing cost, which comprises (1) costs of raw material, (2) operations and (3) material handling. Finally, the customer validates the product variant proposed and, if she/he wants, she/he can do some changes.

4.1 Mathematical model

4.1.1 Assumptions

- i. Instances from different modules cannot require the same operations;
- ii. Each machine is able to perform different operations;
- iii. The same operation can be performed by different machines.

4.1.2 Input parameters

F	= {1,2, ..., f, ..., F }, Set of all available product functionalities
D_f	=1, if functionality f is required; = 0, otherwise
M	= {1,2, ..., m, ..., M }, Set of modules
I	= {1,2, ..., i, ..., I }, Set of module instances
$G_{m,i,m',i'}$	=1, if instance i of module m is compatible with instance i' of module m'; 0, otherwise
S_{mif}	=1, if instance i of module m satisfy a functionality f; = 0, otherwise
OP	= {1,2, ..., p, ..., OP }, Set of available operations
R_{pmi}	=1, if instance i of module m requires an operation p; = 0, otherwise

$P_{pp'}$	=1, if an operation p must be processed before operation p', for $p,p' \in OP$, $p \neq p'$ =0, otherwise
W	= {1,2, ..., w, ..., W }, Set of all available machines
Q_{pw}	1, if an operation p is feasible on machine w; 0, otherwise
J	= {1,2, ..., j, ..., n}, Set of process plan positions
α_{mi}	Raw material cost of each instance i of module m
σ_{pw}	Cost per time unit of processing operation p on machine w
ψ	Cost of transporting material between two machines per distance unit
$d_{w,w'}$	Distance between machines w and w' according to their layout positions
τ_{pw}	Processing time of operation p at machine w

4.1.3 Decision variables

y_{mi}	1, if instance i of module m is selected. 0, otherwise.
x_{pwj}	1, if operation p is assigned to machine w in process plan position j. 0, otherwise.
$t_{w,w',j,j+1}$	1, if the occurrence of machine w is on the position j of process plan and the occurrence of machine w' is on the position j+1. 0, otherwise.

4.1.4 Objective function

Eq. (1) presents the objective function, which consists of the sum of raw material cost (CRM), operations cost (CP) and material handling costs (CMT):

$$Z = CRM + CP + CMT \quad (1)$$

$$\min Z$$

Where:

$$CRM = \sum_m \sum_i y_{mi} \times \alpha_{mi} \quad (2)$$

$$CP = \sum_p \sum_w \sum_j x_{pwj} \times \sigma_{pw} \times \tau_{pw} \quad (3)$$

$$CMT = \sum_{w,w' \in W} \sum_j t_{ww',j,j+1} \times \psi \times d_{w,w'} \quad (4)$$

Subject to:

$$\sum_i y_{mi} \leq 1 \quad \forall m \in M \quad (5)$$

$$y_{mi} + y_{m'vi} \leq G_{m,i,m',i'} + 1 \quad \forall m, m' \in M \quad (6)$$

$$\sum_m \sum_i y_{mi} \times S_{mif} \geq D_f \quad \forall i, i' \in I \quad \forall f \in F \quad (7)$$

$$\sum_p \sum_w x_{pwj} = 1 \quad \forall j \in J \quad (8)$$

$$\sum_w \sum_j x_{pwj} = 1 \quad \forall p \in OP \quad (9)$$

$$\sum_p \sum_m \sum_i y_{mi} \times R_{pmi} = \sum_p \sum_w \sum_j x_{pwj} \times Q_{pwc} \quad (10)$$

$$\sum_{w'} \sum_{j'=1}^{j-1} x_{p'w'j'} \geq \sum_w x_{p,w,j} \times P_{p'p} \quad (11)$$

$$\forall p, p' \in OP \quad \forall j = 1, 2, \dots, n$$

$$\sum_{w, w' \in W} t_{w, w', j, j+1} \leq 1 \quad \forall j \in J \quad (12)$$

$$t_{w, w', j, j+1} \geq x_{pwj} + x_{p'w'j+1} - 1 \quad (13)$$

$$y_{mi} \in \{0,1\} \quad \forall m \in M \quad \forall i \in I \quad (14)$$

$$x_{pwj} \in \{0,1\} \quad \forall p \in OP \quad \forall w \in W \quad \forall j \in J \quad (15)$$

$$t_{w, w', j, j+1} \in \{0,1\} \quad \forall w \in W \quad \forall w' \in W \quad \forall j \in J \quad (16)$$

Constraint Eq. (5) ensures that only one instance (i) of a given module (m) can be selected each time. Eq. (6) states that only the module instance i' compatible with the module instance i can be selected to constitute a given product variant. Eq. (7) ensures that each required product functionality (f) must be satisfied by at least one selected module instance (Y_{mi}). Eq. (8) states that each operation (p) is processed at one process plan position (j) by one machine (w), whilst Eq. (9) states that each operation (p) is processed once in one machine (w). With constraints (8) and (9), the Eq. (10) ensures that each of all required operations must be performed in only one machine (w) at one stage of the process plan (j). Eq. (11) describes the precedence constraint. Constraint (12) ensures that between position j and j+1 there is at most one machine change ($t_{w, w', j, j+1}$), while the Eq. **Erreur ! Source du renvoi introuvable.** states that if two followed machines in the process plan are different, there is a material transfer between them ($t_{w, w', j, j+1} = 1$). The variable domains are described by Eq. (14), (15) and (16).

4.2 Solution approach

In this paper, a 2-step solution approach (Figure 2) based on an exhaustive search algorithm (ESA) and CPLEX solver is proposed. As previously said, in this paper each PF can be satisfied by at least one module instance.

Further, each combination of module instances corresponds to a product configuration (PC). In the first step, ESA lists all possible PCs, through the combination of all available module instances, while respecting the compatibility constraint of module instances. Then, based on the customer requirements, it means, their desired PFs, ESA filters all available PCs, to obtain only feasible product configurations (FPC). Each FPC corresponds to a PC capable to satisfy all PFs required by the customer.

Operations required by each feasible PC are inputs to the second step, in which the optimal operations sequence and machine assignment for each FPC is searched with the aid of CPLEX solver. The total cost as well as optimal process planning found for each FPC is archived. At the end, the set of optimal solutions found for all FPCs is enumerated and therefore the global optimal is selected, which corresponds to the FPC presenting the process plan and product configuration with the minimal overall manufacturing cost. Here, the minimal overall manufacturing cost includes costs of (1) raw material, (2) operations and (3) material handling.

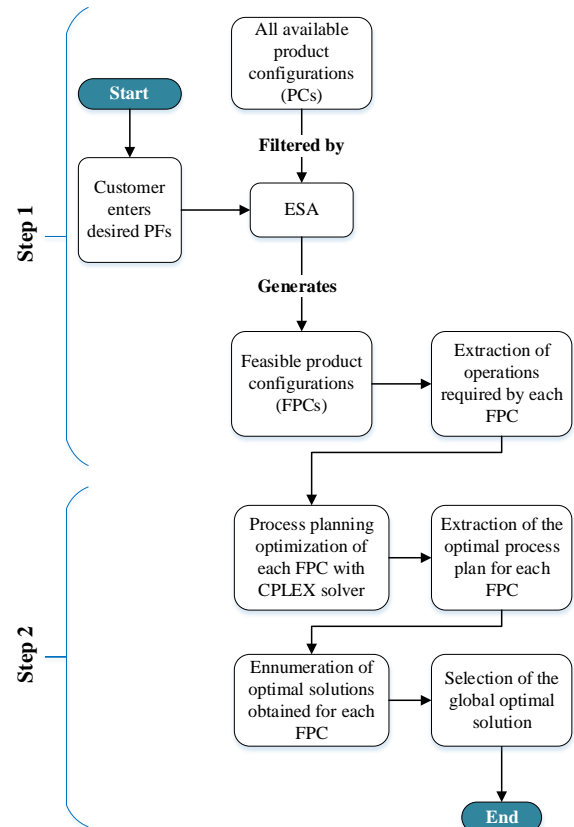


Figure 2. Framework of the 2-step solution approach to optimize the product configuration integrated with its process planning by considering individual customer requirements.

This approach allows for the simultaneous optimization of PC and process planning, while ensuring that:

- 1) The minimum cost is obtained;
- 2) All customer requirements, it means, PFs required by the customer, are attended.

4.3 Results and discussion

In order to verify the model and the solution approach, a numerical illustration with 7 available PFs, 4 modules (with module instances varying from 2 to 5 per module), 13 operations, 10 machines, positioned in different layout positions with known distances, was used.

The algorithm was implemented in Python 3.7 language and all tests were conducted in a laptop computer powered by an Intel core i7-7600U CPU (2.80 GHz) and 16 GB of RAM.

In this problem, the optimal solution will always depend on the PFs required by the customer. Since in the example 7 PFs are available, there are 127 different ways of requiring these PFs (e.g. PF1+PF2, PF2+PF4+PF5, etc.), consequently there is a global optimum for each case. However, no matter which PFs customer requires, the proposed solution approach follows the same steps. Due to that, only one example is presented in this paper for detailing the obtained results.

The optimal solution found for the example considering the selection of PFs 1, 4, 5, and 7 is presented in Table 1. The best product configuration is composed by the module instances M1I3, M3I1 and M4I1 (M1I3 is instance 3 of module 1), with an overall manufacturing cost of 43.52 €. The CPU time required was 60.96 s.

Table 1. Results found for the example considering the following selected PFs: 1, 4, 5, and 7.

Step 1 – Filtering all FPCs							
Selected PFs	1, 4, 5, 7			Number of FPCs	5		
Step 2 – Finding the global optimum							
The best FPC is composed by :				Overall production cost is:			
M1I3, M3I1 and M4I1				43.52 €			
The best process planning is:							
Process position:	j1	j2	j3	j4	j5	j6	j7
Machine	W1	W10	W6	W6	W6	W4	W7
Operation:	OP 1	OP 11	OP 8	OP 2	OP 12	OP 7	OP 10

5 CONCLUSION

This paper proposed an approach to reduce “mass confusion” through customer guidance at the product configuration stage, while integrating the latter with the process planning in order to minimize overall manufacturing cost. This cost is composed of (1) raw material of

module instances, (2) process operations and (3) material handling. This optimization was modeled as an ILP problem and a 2-steps approach was used to solve it.

In this model, the product configuration was optimized in terms of PFs required by customers, proving that it is possible to integrate customer requirements while optimizing the product configuration integrated to the process planning. Results found have proven that considering manufacturing costs when configuring a product for MC is relevant, because a product with a more expensive raw material cost does not always mean a higher overall manufacturing cost. Therefore, this approach can be used as an alternative to help customer during their decision making process in order to reduce the “mass confusion” caused by the too many available choices in MC contexts.

Further, the exact solution approach presented in this paper has proven its ability to find rapidly and efficiently a global optimum, for a relatively complex problem that integrate two combinatorial problems: the product configuration and process planning.

For future researches, we want to evaluate the integration of product configuration and process planning in a RMS, by exploring its ability to reconfigure at machine and layout levels simultaneously. Further, we want to test this solution approach with a real product, and therefore with higher instances.

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REFERENCES

- Chen Z, Wang L (2010) Personalized product configuration rules with dual formulations: A method to proactively leverage mass confusion. *Expert Systems with Applications*
- Dou R, Zong C (2014) Application of Interactive Genetic Algorithm based on hesitancy degree in product configuration for customer requirement. *International Journal of Computational Intelligence Systems* 7:74–84
- Franke N, Piller F, Piller FT (2004) Toolkits for User Innovation and Design: an Exploration of User Interaction and Value Creation in the Watch Market. *Journal of Product Innovation Management* 21:401–415
- Gershenson JK, Prasad GJ, Zhang Y (2003) Product modularity: Definitions and benefits. *Journal of Engineering Design* 14:295–313
- Hong G, Hu L, Xue D, et al (2008) Identification of the optimal product configuration and parameters based on individual customer requirements on

- performance and costs in one-of-a-kind production. *International Journal of Production Research* 46:3297–3326
- Huffman C, Kahn BE (1998) Variety for sale: Mass customization or mass confusion? *Journal of Retailing* 74:491–513
- Jiao J, Tseng MM (1999) Methodology of developing product family architecture for mass customization. *Journal of Intelligent Manufacturing* 10:3–20
- Jiao J, Tseng MM (2000) Fundamentals of product family architecture. *Integrated Manufacturing Systems* 11:469–483
- Koren Y (2010) *The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems*. John Wiley & Sons, Inc.
- Koren Y, Gu X, Guo W (2018) Choosing the system configuration for high-volume manufacturing. *International Journal of Production Research* 56:476–490
- Li B, Chen L, Huang Z, Zhong Y (2006) Product configuration optimization using a multiobjective genetic algorithm. *International Journal of Advanced Manufacturing Technology* 30:20–29
- Liu A, Lu S, Zhang Z, et al (2017) Function recommender system for product planning and design. *CIRP Annals - Manufacturing Technology* 66:181–184
- Mohapatra P, Benyoucef L, Tiwari MK (2013) Integration of process planning and scheduling through adaptive setup planning: a multi-objective approach. *International Journal of Production Research* 51:7190–7280
- Najid N-M, Castagna P, Kouiss K (2020) System Engineering-Based Methodology to Design Reconfigurable Manufacturing Systems. In: Benyoucef L (ed) *Reconfigurable Manufacturing Systems: From Design to Implementation*. Springer Nature Switzerland AG, p 258
- Paes IF, Sabioni RC, Daaboul J, Duigou J Le (2018) Product and Process Modular Design: a Review. In: 8th International Conference on Mass Customization and Personalization – Community of Europe, MCP-CE 2018. University of Novi Sad – Faculty of Technical Sciences Department of Industrial Engineering and Management 21000, Novi Sad, Trg Dositeja Obradovića 6, Serbia, pp 97–106
- Pahl G, Beitz W (1995) *Engineering Design: a systematic approach*. Springer Science & Business Media
- Piller F, Walcher D (2017) Leading Mass Customization and Personalization: How to profit from service and product customization in e-commerce and beyond
- Piller FT, Blazek P (2014) Core Capabilities of Sustainable Mass Customization. In: *Knowledge-Based Configuration: From Research to Business Cases*. Morgan Kaufmann Publishers, Waltham, MA, pp 107–120
- Pine BJ (1993) *Mass customization: The new frontier in business competition*. Harvard Business School Press
- Pitiot P, Aldanondo M, Vareilles E (2014) Concurrent product configuration and process planning: Some optimization experimental results. *Computers in Industry* 65:610–621
- Pitiot P, Aldanondo M, Vareilles E, et al (2013) Concurrent product configuration and process planning, towards an approach combining interactivity and optimality. *International Journal of Production Research* 51:524–541
- Pitiot P, Monge LG, Aldanondo M, et al (2020) Optimisation of the concurrent product and process configuration: an approach to reduce computation time with an experimental evaluation. *International Journal of Production Research* 58:631–647
- Sanchez R, Mahoney JT (1996) Modularity, Flexibility, and Knowledge Management in Product and Organization Design. *Strategic Management Journal* 17:63–76
- Tseng MM, Jiao J, Merchant ME (1996) Design for Mass Customization. *CIRP Annals* 45:153–156
- Wang Y, Ma HS, Yang JH, Wang KS (2017) Industry 4.0: a way from mass customization to mass personalization production. *Advances in Manufacturing* 5:311–320
- Xu Z, Liang M (2006) Integrated planning for product module selection and assembly line design/reconfiguration. *International Journal of Production Research* 44:39–65
- Xu Z, Liang M (2005) Concurrent Optimization of Product Module Selection and Assembly Line Configuration: A Multi-Objective Approach. *Journal of Manufacturing Science and Engineering* 127:875–884
- Yang D, Li J, Wang B, Jia YJ (2020) Module-Based product configuration decisions considering both economical and carbon emission-related environmental factors. *Sustainability (Switzerland)* 12:
- Yigit AS, Allahverdi A (2003) Optimal selection of module instances for modular products in reconfigurable manufacturing systems. *International Journal of Production Research* 41:4063–4074
- Yigit AS, Ulsoy AG, Allahverdi A (2002) Optimizing modular product design for reconfigurable manufacturing. *Journal of Intelligent Manufacturing* 13:309–316
- Zhao S, Zhang Q, Peng Z, Fan Y (2020) Integrating customer requirements into customized product configuration design based on Kano's model. *Journal of Intelligent Manufacturing* 31:597–613
- Zhou C, Lin Z, Liu C (2008) Customer-driven product configuration optimization for assemble-to-order manufacturing enterprises. *International Journal of Advanced Manufacturing Technology* 38:185–194

