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A NEW APPROACH ON INDUSTRY 4.0 - A PLATFORM TO INTEGRATE CUSTOMER IN THE DESIGN DECISION

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Abstract: *The paper presents a system based on the involvement of the customer in the product design, i.e., a platform where customers can configure their desired product. The study of existing configurators does not cover it and is limited to configuring modules developed by manufacturer, which means excluding the customer from product design process. This disadvantage is overcome by open platforms where customers can contribute with modules developed by themselves or third parties. The limitations of current configurators, but also the availability and accessibility of new technologies promoted by the context of the fourth industrial revolution, are the basis of the design of such a solution, and an extended proposal solution is provided to overcome the main challenges.*

Key words: *product design, design process, product configurator, mass customization, mass individualization, open architecture products*

1. INTRODUCTION

Engineering Product Configurators are increasingly being used by manufacturing companies to assist customers in specifying their requirements, and to find a product (configuration) that matches their preferences. A side effect of the high diversity of products offered by a configurator is that the complexity of alternatives can outweigh the user's ability to explore them and make a purchasing decision. Since humans have limited processing capacity, confronting consumers with too much information can lead to an information overload and, therefore, can result in decreased quality.

Engineering Product configurators are Industry 4.0 specific tools using databases, algorithms etc.

Developing smart products in the context of Industry 4.0 means adapting the way products are designed and manufactured. Intelligent design is characterized by speed, efficiency, and the elimination of errors.

Pereira Pessôa and Jauregui Becker (2020), with the help of several experts and researchers in the field, complete the set of characteristics that define Industry 4.0. Thus, 17 characteristics are identified and explained [1]:

1. Involvement of customers in the design process, thus contributing to the creative activities that take place in the product development process.

2. Design based on data collected by the product during operation, which is achieved by equipping the product with sensors that measure its operating parameters. Improvements to future products can be made on the basis of information collected by sensors.

3. Products that adapt quickly to change and must be designed to respond with a high degree of flexibility when they need to be updated or improved.

4. Design in the context of Big Data, with data collected being analyzed and used in different ways throughout the product lifecycle.

5. Design in the context of cyber security, a principle that must underpin product design so that products are able to manage the threats that come with systems communicating with each other via the Internet of Things (IoT).

6. Design that facilitates emotional interaction, beyond functionality, with products needing to trigger emotional reactions and create

connections with users. Therefore, the ability of products to communicate with other products and users in different environments is crucial.
7. Continuous engineering supported by model-based systems engineering (MBSE), aiming at change management, and bridging the gap between design patterns and requirements.
8. Systems Lifecycle Management, meaning that product decisions are made based on information collected and analyzed using Product Lifecycle Management (PLM) systems. Therefore, these systems need to be dynamic and reflect the changes that products undergo.
9. Interdisciplinarity and transdisciplinary as products increase in complexity, the participation of actors from different fields becomes inevitable.
10. Change in perception of quality, as quality requirements are no longer general, but become personalized with products.
11. Employees with knowledge access and data processing skills, as it is impossible for one person to have it all, even if it is related to a specific field, in today's context where the amount of knowledge is huge, so employees need to develop the skills to find, choose, combine knowledge to use it.
12. Low-cost open innovation; resources from outside the company can be used to reduce the costs of innovation activities. In this sense, sharing intellectual property can benefit all parties involved.
13. Designing systems with an emphasis on the human component, even if the trend towards automation is seen throughout the new product development process, and staff need to be involved in decision making to meet customer requirements and ensure that customer satisfaction is as high as possible.
14. Recognizing the importance of data, data models and information, merging it into information and modelling it so that it is easy to access, which is central to the product development process in the context of Industry 4.0.
15. Inseparability between the component and its history, the physical product being always accompanied by information about its history throughout its life cycle.
16. Flexible design for the adoption of new technologies, a feature that requires product platforms into which new technologies can be quickly and at low cost.
17. Openness to innovation, required by the rapid pace at which new technologies are emerging and posing a threat to companies if they fail to keep pace. Innovation is therefore a key point in gaining competitive advantage.

Engineering Product Configurator is a platform that integrate customer in the design decision. By involving the customer in the design process, the overall cost will be reduced, the quality and transparency will increase, as well as the satisfaction of the customer. One of the most critical aspects of each new product development is to understand and integrate all customer requirements into the new development. Usually, this process requires several loops of iterations, with impact on huge cost and time delay. The purpose of Engineering Product Configurator Platform is to ensure interactive communication between customer and product development, integrate all and even new requirements during the development process, provide a cost and timing perspective, and keep it on minimum level.

The first section describes in more details what are the benefits to integrate the customer into design process. Next, a case study is presented, showing a practical example on how to involve a customer on new product development and advantage of flexibility, especially when requirements are changed during development process.

Conclusions are summaries of what can be achieved with a simplify tool on the most creative part of product development and open the perspective of further develop this area.

2. CUSTOMER INVOLVEMENT IN PRODUCT DESIGN PLATFORM

Customer involvement in the product design process should not be seen in terms of cost minimization, but rather as an opportunity to create more value. In this respect, mass production, custom production, personalized production, and handcrafted production are essentially concerned with the strategies: 'Design of Customers', 'Design with Customers', 'Design by Customers', and 'Design for Customers' (Fig. 1) [2].

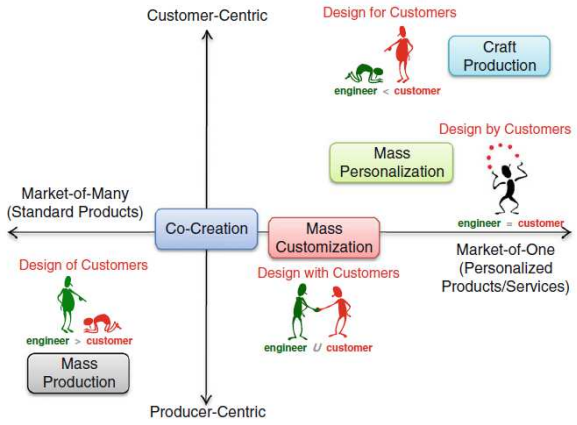

Fig. 1. Strategies for customer involvement in the product design process [2].

So, while artisanal production may allow customization up to Market-of-One level, the cost of making the product is high. In the mass-production paradigm, products are standardized by designers without any customer involvement. Mass customization presents a passive customer choice process from standard offerings, where customers are led by designers with limited participation, i.e., configuration based on a predefined product family.

Mass customization involves intense customer interactions and pro-active customer integration, and the product creation horizon should be shifted from a physical product perspective to a total lifecycle experience. The process is oriented towards a "customer design" or "customer-centric co-creation" strategy.

Over the last few years there has been a shift from mass and customized production to personalization production [3]. Complex products with multiple and individualized functions require a high degree of innovation in the design phase and a high degree of flexibility in production.

In mass production, the product architecture is homogenized. In mass customization the product architecture is modular and in mass individualization the sequence of the three operations is more complex, these are shown in figure 2 [3].

As opposed to customized products, individualized products aim to satisfy a single customer.

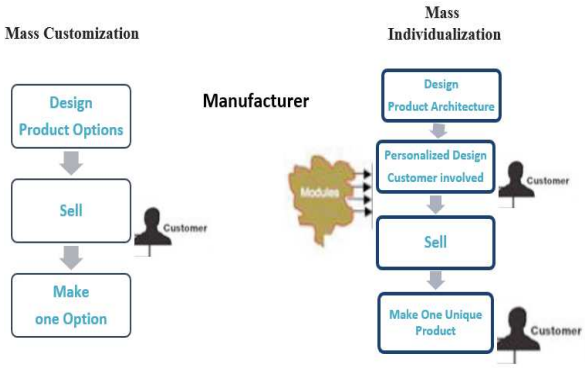

Fig. 2. The mass customization and individualization organizational chart [3].

Therefore, it is a customer-centric approach. The customer has the power to radically change the product design or even create new products within budget and lead time.

Custom mass production is based on modules that can be configured to achieve the final product. This mechanism allows the reuse of basic design parameters within a product family [4]. However, the ability to adapt even the entire design of a product to meet customer needs is essential in the manufacture of individualized products.

In the current economic scenario, it has been repeatedly demonstrated that a company's performance is directly proportional to the satisfaction of its customers. As a result, there is a migration towards individualized products.

The individualization strategy chosen by each company aims to strike a balance between increasing the variety of its products and the costs of a higher degree of complexity.

The perspective presented by Kuhl and Krause (2019) states that there are 3 possible product individualization strategies from which a company can choose [5]:

- The manufacturer tailors the product for a specific customer. In this case the manufacturer offers an individualized product that meets the needs of a single customer. The degree of individualization is limited by manufacturing processes, cost, time, but also by the type of product and its lifetime.

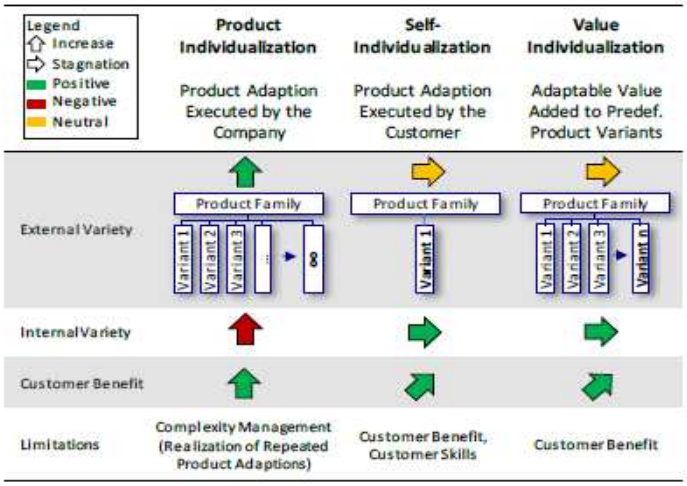

Fig. 3. Differences and limitations of individualization strategies given the diversity of products and benefits to customers [5].

- Products are tailored to the customer or self-individualized. This strategy involves the development of the same product for several customers, but which can be tailored to the needs of each customer by the customer himself. In this way, the company can easily manage internal product variety. However, both the development process and the product itself must be carefully planned and designed to consider the individualization capabilities of potential customers.
- Individualization strategy without tailoring individualized products or services. This

refers to offering a standard product but with individualized services, such as delivery or tailoring services at the point of sale.

Considering the advantages and disadvantages of each strategy, as well as the customers and the type of product offered, companies need to choose the individualization strategy that is most effective and will bring the most benefits (Fig. 3.). The following figure shows the differences and limitations of individualization strategies.

A key factor in custom mass production is the ability to adapt a product design to new requirements or circumstances by replacing or adding modules using a predefined adaptable interface [6].

Levandowski et al. used the principles of adaptability to develop a product configuration platform [7]. Other researchers, such as Koren et al., have also adopted the concept of adaptive design to achieve an open product configuration platform and define the steps required in open architecture product development [8]:

- Product makers develop the core platform with the basic functions.
- Original Equipment Manufacturers (OEMs) define interface communication standards, which allow integration of innovative modules designed by different developers; interfaces can be mechanical, electrical, and computational.
- Although modules are developed by different companies, the OEM has the final say on the approval of each module, although it is not the OEM that develops these modules.
- Customers personalize their product according to their needs, choosing modules from different suppliers.
- The integration of the modules is done in the central platform to adapt the product to the customer's wishes. Final assembly can be done by the customer himself, if the products are not subject to safety regulations. This is not currently applicable in the automotive industry due to the complexity of the products.

Zhou et al. address affective and cognitive design methodologies for mass customization [2].

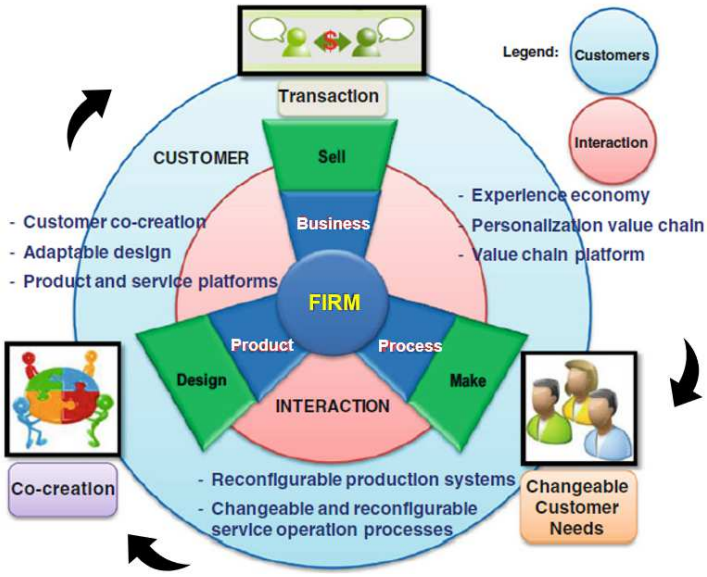

Fig. 4. Mass customization through customer interactions with the enterprise system [2].

The prevailing design practice for mass customization manifests itself through a configure-to-order paradigm, which means meeting explicit customer needs (CNs) and built on legacy design. Mass customization involves a strategy of producing goods and services to meet the latent needs of the individual customer, with values that outweigh costs for both customers and manufacturers. Valuing the user experience, affective and cognitive design for mass customization is expected to address the latent CNs of the individual customer. Decisions in affective and cognitive design, which involve eliciting affective and cognitive needs, affective and cognitive analysis, and affective and cognitive fulfillment, are reviewed with a wide range of interests, including engineering design, human factors and ergonomics, engineering psychology, marketing, and human-computer interaction [2,11].

The realization of mass customization through customer interactions with the enterprise system is illustrated in figure 4.

3. CASE STUDY. A PLATFORM BUILT BASED ON CUSTOMER INVOLVEMENT

3.1 Open architecture products

In our days the products become more complex and in most of the cases there are fulfil more than a simple function. The product that fulfills multiple functions or is able to change information with other systems is called intelligent product. The intelligent products are made up of mechanical, electronics, and software components and require a lot of effort and many engineers involved from the first stage of development.

In the traditional product development process, the industry allocates a huge amount of money and involves many engineers from different domains.

The communication between different domain is always an issue and the only way to ensure the progress is to defined milestones for checking the stages.

In case the customer needs to change the initial requirements, the change management process is very complicated and costly.

However, all this limitation makes the product development process unfeasible for many of small and medium companies.

To improve the actual status, a new way of product development is necessary. The first role of a product configurator is to reduce repetitive tasks and provide solutions, based on database of knowledge. The purpose of product configurator is not to replace the flexibility of human brain, but to support the process development with data driven and speed of decision for complex algorithms.

The role of open architecture products is to create a bridge between developers and users of the product. The three elements that make up a modular structure are: architecture, modules, and interfaces [9,10]. The authors conclude that, depending on how modules are connected, the most common structures are the following.

- Fully modular structure in which each module relates to directly neighboring modules.
- A platform-based structure, to which modules are connected.

Open architecture products and adaptable module-based design sustain and stimulate innovation in integration technologies. Peng et al, discuss the benefits of open architecture product development [9]:

- Improved functionality by incorporating new advanced technologies into product design.
- High-quality standards, such as validated modules, are used, as well as the knowledge and processes associated with them.
- Reduced costs because it relies on the reuse of common modules and components.
- Fast delivery times, due to reuse of design elements and manufacturing processes.
- Individualization, using customized modules to meet changing requirements.
- Environmentally friendly products are better for the environment as their useful life is increased, reducing waste.

As the same authors conclude, open architecture products have net advantages, and this model is already being used in the development of new products. From a theoretical point of view, the need to find scientific foundations to support this method was identified, as well as the need to develop a tool to serve engineers in their daily design activities.

The need is for a platform built based on customer involvement that uses an open architecture to be built on.

The (back-end) of the application is based on Structured Query Language (SQL) and connects to the database and processes the information to achieve all technical options to fulfil the customer requirements.

3.2 Engineering Product Configurator LED Working Lamp

The *configuratordb* database contains information about different types of LEDs, electronic modules, and mechanical materials. In the open architecture approach a large amount of information can be integrated into LED databases, from all suppliers in the world. In the traditional product development process, the choice of suitable LED is engineering responsibility, based on technical know-how and different criteria. No matter how experienced one person is, to verify a big quantity of information in a short time is impossible; therefore, usually companies limit the options of choice from beginning on (Fig. 5.).

The software (back-end) of the application connects to the database and processes the

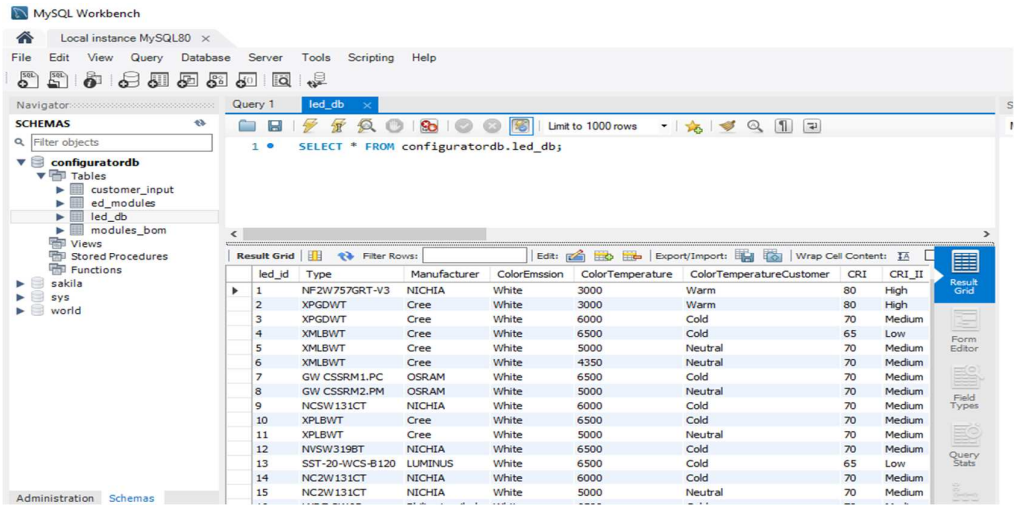

Fig. 5. Interface in MySQL.

information to achieve all technical options to fulfill the customer requirements.

The *configuratordb* – an open architecture product configure is developed on a platform-based structure, in which modules are connected, the configurator database contains information about different types of LEDs, electronics module, mechanical materials.

3.3 Customer Input

In the case of this configurator, the opinion, involvement, and feedback of the customers were very important.

First, based on the light output requirement, the Product Configurator selects all LEDs capable of fulfilling the light and determines the necessary number of LEDs with defined supply current. Based on the number of LEDs and supply voltage required, the Product Configurator proposed all possible electronic architecture, in nominal and maximum current, to maximize the light output.

Customer Input zone (Fig. 6.):

- In the INPUT page, the customer requirements are introduced, on dedicated field.
- After saving it, based on algorithms with constraints and compatibilities already defined, the Product Configurator can generate the result.

The result consists of all technical options, based on databased information, to achieve the requirements for different stages during the development process (optics, electronics, and mechanics).

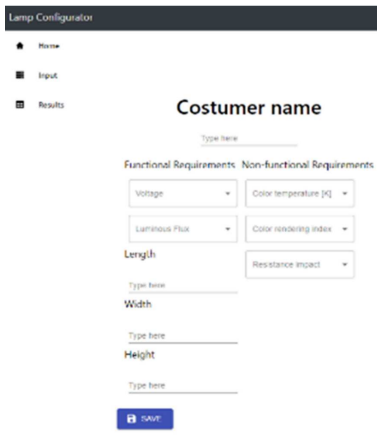

Fig. 6. Lamp configurator interface - customer zone

The product configurator and data driven approach solves such topics in real time and moreover provides a more technical solution for comparison purposes. In that way, the engineering team just decide the best fit for customer need in short time. In addition, the possibility of human error is significantly reduced.

Thermal management is an important topic in such applications; therefore, power dissipation is calculated automatically to define the size of the electronic PCB (Printed Circuit Board). From a mechanical perspective, it is important to define a list of materials and assembly processes, based on available technology. Raw materials of different components are selected on the basis of function play in the system (ex. Lens: transparent polymethacrylate PMMA or PC), but also based on system requirements defined in the specification.

4. CONCLUSION

The limitations of existing configurators and the new requirements of Industry 4.0 used today, the following conclusions can be drawn:

1. A more technical solution is proposed by Engineering Product Configurator in a very short time (compare with traditional manual engineering approach).
2. Using databased, all available information is used in a new way to generate innovations
3. Comparison between all options / technical solutions is possible, in order to decide for one which fits better for the customer's need or expectation.
4. Involving the customer in the decision process, with explanation and arguments between different options, during different stages of development, encourages co-creation approach and increases customer satisfaction.

Further research could focus more on product development digitalization or even integrate artificial intelligence on creative process. The possibility to define the best technical solution in a limited time, to involve the customer in the development process, to integrate new technologies. requirement without additional effort during the development process, change

the perspective of product development process and bring significant benefits in terms of quality, cost, and timing. The Big Data concept helps to store a huge amount of information and the data-driven approach makes it possible to process a large amount of information.

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O NOUĂ ABORDARE PRIVIND INDUSTRIA 4.0 - O PLATFORMĂ DE INTEGRARE A CLIENTULUI ÎN DECIZIA DE PROIECTARE

Lucrarea prezintă un concept bazat pe implicarea clientului în proiectarea produsului, și anume o platformă în care clienții pot configura produsul dorit. Studiul configuratorilor existenți nu acoperă acest aspect și se limitează la configurarea modulelor dezvoltate de producător, ceea ce înseamnă excluderea clientului din procesul de proiectare a produsului. Acest dezavantaj este depășit de platformele deschise, în care clienții pot contribui cu module dezvoltate de ei înșiși/ terți. Limitările configuratoarelor actuale, dar și disponibilitatea și accesibilitatea noilor tehnologii promovate de contextul celei de-a patra revoluții industriale, stau la baza conceperii unei astfel de soluții și se oferă o propunere de soluție extinsă pentru a depăși principalele provocări.

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