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CONTROL AND INFORMATICS

Conceptualization of Industry 4.0 technology for the production of tailor-made furniture – a case study

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Abstract. Production is becoming more customer-focused as it departs from delivering standardized mass products to market segments, and the emerging Industry 4.0 technologies render this much easier than before. These technologies enable two-way information exchange with customers throughout all the steps of product development, particularly in terms of tailor-made products. This study aims at presenting proposals of implementing Industry 4.0 technologies into the process of tailored products, where the product is customized for the customer from the start and where adjustments are also made at the manufacturing stage. The study also aims to build a concept of intensification of customer contact and to improve the process flow by applying Industry 4.0 technologies. The study's subject is tailor-made furniture production, with individually designed products that are manufactured and installed at a customer's facilities. The company in the study operates on a small scale. The study employs a case study methodology that shows how the process can be improved in terms of real-time effective customer contact and process flow. The huge potential of 3D visualization as well as augmented and virtual reality technologies are also demonstrated. The study concludes with several directions for further development of existing technology solutions.

Key words: product development; Industry 4.0; customized manufacturing; furniture; conceptual study.

1. INTRODUCTION

Industry 4.0 (I4.0) is a concept describing the complex process of technological and organizational transformation of enterprises, which includes integrating the value chain, introducing new business models and digitalizing products and services. The implementation of these solutions is made possible by using new digital technologies and data resources, and by ensuring communication in the network of cooperation between machines, devices and people. The manufacturing paradigm shift refers to three key elements [1]. The first is the change in manufacturing, characterized by the introduction of physically distributed but digitally integrated systems. Features of the new systems include modularity, increasing levels of autonomy and interoperability, allowing them to be reconfigured according to current demand. The second element is new business models, i.e. ways of adapting businesses to changing market needs. Digital integration of participants in the product creation chain and the creation of flexible cooperative networks can be quoted here. The position of the customer is also changing from a passive recipient to an active participant in the product development process. The third issue is the change in the product architecture itself. In I4.0, it ceases to be a purely physical product and becomes a hybrid solution with an additional embedded service function [2–4].

The technologies in I4.0 are intertwined with digitization, which is considered by Ferreira *et al.* [5] as one of the most important business strategies to deal with competition nowadays. In terms of manufacturing activities, companies regard digitization as a promising growth strategy [6]. According to Ardolino *et al.* [7], I4.0 is formed by technologies based on and enabled by digitization, and in the scope of this concept, technologies include cloud computing, blockchain, Big Data, artificial intelligence (AI), Internet of Things (IoT) and many others. This enables strong support for integrating and connecting physical objects, production lines and processes at all stages of the product and service lifecycles [8]. These technologies are advantageous because company processes can operate more effectively and efficiently by using fewer resources, meeting market expectations, introducing new business models, winning new markets and enabling a variety of product and process innovations. In the manufacturing industry, the literature outlines several benefits of using new technologies.

Manufacturing and product development are the main interests of this study along with their connections to I4.0 technologies. Activities related to the development and improvement of manufacturing processes are perceived as crucial to a company's processes. I4.0 technologies can allow companies to obtain competitive advantage by not only offering products but also advanced product-service—software systems. This transition is referred to as digital servitization [9, 10]. According to Hsuan *et al.* [9], business organizations need to combine products, services and software into smart solutions to increase customers' perceived value as well as organizational process effi-

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ciency. Another issue for I4.0 is using flexible manufacturing processes to deliver highly customized products that allow for prompt responses to customers' needs [11, 12].

The product development process is a promising field for using I4.0 technologies. One issue in the process involves reducing the lead time of the product being sent to the market. Meißner *et al.* [13] state that one of the main challenges in implementing the smart product development process is to adapt quickly to changing conditions and requirements. It is widely known that 80% of a product's costs are established in the product development phase [14], which clearly shows the great importance of this process and how it can be improved by using new technologies. Another issue in the product development process is increasing the interdisciplinary skills of the teams responsible for product development and the multi-location of staff within a company [15], but these technologies can solve many potential obstacles and assure the smooth flow of the process. Currently, there is a strong emphasis on identifying and reducing the component costs of the entire product completion process, and thus e.g. paper [16] presents an interesting approach to identifying the prerequisites that must be met at the design development and prototype testing stage in order to reduce the total cost of a new product.

This study considers the perspective of sustainable development, which is an important concept due to the global scarcity of natural resources and a fundamental criterion of new technology implementation. The literature emphasizes that sustainable development concerns the well-being of future generations, especially in terms of non-renewable natural resources, which are currently in opposition to the needs of populations [17]. There must be a compromise between these two conflicting objectives. Sustainability concerns the nature of human activities that satisfy people's needs and wants without exhausting the productive resources at their disposal [18]. It pertains to economic activities, social lives and humans' natural environment [19]. In terms of I4.0 technologies, one sustainability objective is to foster innovations and resilient infrastructure [18]. It might be expected that the development of digitization, including increasing the range and accuracy of data and its targeted analysis, must support sustainability ideas.

As stated above, the manufacturing industry is a primary field for I4.0 application, as special expectations are laid in the sphere of the product development process. Notwithstanding, new methods and developments are needed, particularly for effective and coordinated process flow when cooperating with customers. Analysis of the literature reveals a research gap regarding the problem of effective data exchange throughout the process of creating a personalized furniture product.

This study aims to present proposals of implementating I4.0 technologies into the process of tailored manufacturing, where the product is customized for the customer from the early design stage and where adjustments are also made at the manufacturing stage. This initial investigation paves the way for the second part of the study, which aims to build a concept of how to utilize I4.0 technologies for better process performance and enhanced customer satisfaction. The tailor-made furniture sector can perfectly fit this study's assumed expectations of the product design and manufacturing process.

2. CUSTOMIZED FURNITURE INDUSTRY

The furniture industry has a very specific set of business models in terms of company-customer cooperation. Fully standard products can be bought off the shelf, retailers can partially customize products, products can be self-assembled by the customer and products can be fully customized from the very first design. Different models lead to totally different characteristics of the design-manufacturing system, including the product and its design lead times, technologies, organizational systems and IT tools used in each process. Ding *et al.* [20] summarize the steps of customized furniture production processes in terms of research and development (R&D) as the first step, sales (business contracting), participatory design, production, and delivery and installation at the customers' facilities.

Tailor-made furniture production requires an individualized approach to product design and production technology design, as the product must be adapted to the customer's needs. To some extent, tailor-made furniture involves design-driven innovation, as each product is an innovative creation. As stated in the literature, design-driven innovations enable more valuable products to be designed [21], and they go beyond participatory product design towards combining product and technology design knowledge. At the same time, design-driven innovation requires relevant organization to develop the communication skills and other capabilities necessary to create and promote new products [22]. The furniture industry segment seems to acknowledge the design stage as a major factor in a company's competitiveness [23].

Product customization increases the perceived value of a product or service and supports profitability of the business [24]. Lin *et al.* [25] list three types of mass product customization: modular, adjustable and dimensional. Modular customization is a design technique in which features are designed in modules that can be combined in subsequent designs. Modular product design is often cited as a goal of good design practice in the current furniture industry [26]. Using this technique, a product can be customized by assembling several combinations of modules. Adjustable customization allows the customer to manually adjust the product to their needs; for example, the seating position of office chairs and the height and angle of a tabletop. Dimensional customization can be infinite or involve a selection of discrete options, as in the case of modular furniture composed of boxes of different dimensions. Customization performed in the manner can effectively generate large groups of different, interrelated products [24].

This individualized process of product/technology design means that manufacturing the product must meet several challenges, one of which is dealing with a large amount of data along with non-standard orders. The literature proposes several technological solutions for these challenges. Industrial IoT technologies connect industrial assets and machines to business processes and information systems, providing businesses with real-time data monitoring, collection, exchange and analytic capability [27]. The IoT, along with integrated IT systems, can effectively maintain information connectivity throughout the whole manufacturing process and integrate it with organizational processes to support the connection to customers. I4.0 technologies also respond to social responsibility and sustainability of furniture production by being environmentally friendly. The literature underlines [28] the environmental criteria of production processes and final products that must be applied to production strategies and manufacturing technology decisions employed by a company. Two advanced methods of furniture production that have gained popularity with manufacturers are 3D printing and subtractive manufacturing, and both have advantages and disadvantages [29]. The application of new techniques, mainly those referred to as I4.0, can noticeably support all tailor-made furniture products and assure effective information exchange. Generally, they are of special importance in the world of progressive product individualization.

3. TRENDS IN PRODUCT DEVELOPMENT – LITERATURE REVIEW

A correctly designed product development process provides the basis for creating convenient products, and its improvement is of interest to many researchers. Ever-shorter product lead times and the uncertainty of increasingly complex markets require intelligent product design in manufacturing systems [30, 31]. Under these circumstances, simply offering basic functions without considering customer needs in product design is no longer appropriate to facilitate trade and order fulfilment across the supply chain. In addition to cost and manufacturability, market and customer prospects are the main factors for firms to gain a competitive advantage [32].

Custom furniture companies go through a longer and more complex process, including R&D, sales, participatory design, production, delivery and installation. There are several challenges throughout this process, such as handling non-standard orders, manufacturing with high precision, managing large amounts of data and requiring higher levels of computerization [20]. Processing large amounts of information during the product development process is required because activities in the process interact and are influenced by all areas of the organization [33].

In industrial production environments where manufacturing requires detailed product development, the time taken to prepare production greatly affects delivery dates. Grijota *et al.* [34] suggest there is a very high probability of reducing product delivery time by approximately 10–20% because of reduced product development process lead times. Wynn and Clarkson [35] emphasize the importance of integration, interoperability and sustainability across the product lifecycle for increasing business agility. Wang *et al.* [36] suggest using a strategic approach based on product lifecycle management (PLM), considering product data and information as part of design activities and core business processes. In the context of I4.0, processing intellectual capital is increasingly valued as the key to improving business agility and realizing the benefits of smart manufacturing. It is also the basis for product improvement and innovation. The prerequisite, of course, is appropriately selected IT solutions that play a key role in a company's operations [37]. The implementation of information-assisted design is based on the integration of 3D modelling software with parametric designs, expert systems, computer-aided analysis and knowledge management [38].

However, Iaksch and Borsato [39] highlight that current industry practices still indicate the isolation of knowledge domains, characterized by the simple transfer of information to those responsible for subsequent actions in the product development process. A prerequisite of I4.0 is that factories, workshops and all manufacturing capacities must have an informational part so that they can be integrated first to enable communication [40]. Zweber *et al.* [41] report that the intensive use of information technology in the design, detail and manufacture of products potentially allows for reusing older work, for more informed decision-making and for more reliable planning and estimation. The increase in digitization and simulation processes at every stage of production creates opportunities for organizations to achieve better productivity [42]. Thanks to the development of computer techniques that increase the efficiency of information systems, it is possible to integrate functional tasks. In other words, the quality of information improves, resulting in shorter deadlines, fewer costs and higher customer satisfaction. The prerequisite for success here is the implementation of information cooperation through connectivity at all stages of the product performance process [20].

4. STUDY METHODS

This study aims to explore the product development process in a company that delivers highly individualized custom furniture to customers. A high degree of individualization goes together with operating on a unit production scale. Case study methodology [43, 44] is one of the most adequate methods for such an explorative purpose, as it enables comprehensive investigation of a given organizational phenomenon with multi-criteria. The entire process includes product and technology design, individualized manufacturing and the product's installation at customers' properties, which involves frequent and multiple contact with customers throughout the process, from the product's conception to its installation. The subject of the study allows for in-depth and cross-sectional observation of the company's interactions with customers at all stages of product development. Following the case study methodology, all process activities are tracked and the internal process flows and interactions with customers are identified and characterized. A flowchart is used for process modelling.

The next step of the study is conceptual. According to the literature [45, 46], building a conceptual framework is an important research step, as it identifies structures and relationships between components and concepts as well as objects and ideas. Previously understood and modelled processes provide a base for this conceptual work and its development by applying I4.0 technologies and other organizational changes. The elaborated concept has been assessed according to several criteria crucial for the process in terms of organizational and business viewpoints. The assessment criteria include: (1) overall process productivity; (2) product individualization; (3) process efficiency (including appearance changes and corrections); (4) user involvement in product design; (5) the degree of meeting customer expectations; (6) process implementation costs (excluding materials and overheads, etc.); (7) investment expenditure to set up the process. The study framework employed allows for relevant concepts and theoretical generalizations to be created within the given scope.

5. A CASE STUDY OF CUSTOMIZED FURNITURE PRODUCTION

This study examines the process of designing and manufacturing a furniture product as part of individual customer orders. Customized furniture production is a large and crucial area of the industry and it is often carried out by micro and small enterprises that usually operate in local markets. In one of these enterprises, the completion of an individualized furniture product was identified and thoroughly analyzed by tracking contact with customers and using IT support systems [47]. The flowchart of the product performance process in the company selected for the study is presented in Fig. 1.

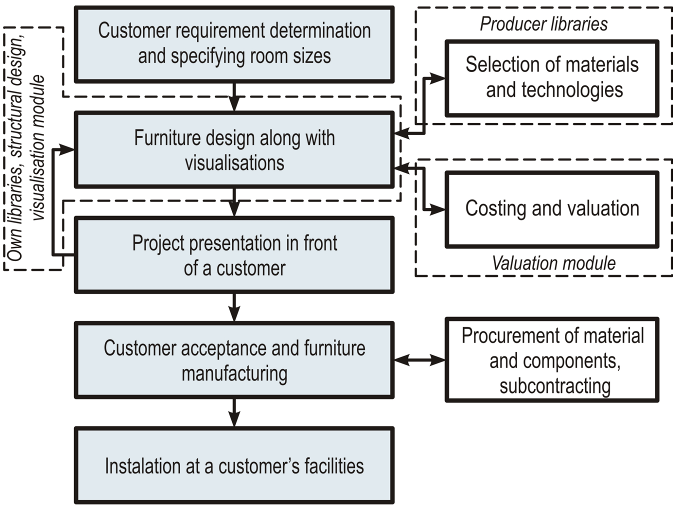

Fig. 1. Diagram of the traditional process of manufacturing a furniture product as per an individual customer's order

Initial contact between the customer and the enterprise's representative can be regarded as the first stage of the product implementation process. During this stage, an interview with the customer is conducted, which includes their vision, preferences and expectations regarding the planned furniture; then, preliminary arrangements are made concerning the date of execution of the order. Often, the specificity of the future product requires taking necessary, supplementary measurements at the customer's property. At this stage, a preliminary hand-drawn sketch, an approximate valuation and additional guidelines concerning the design of the intended furniture are all prepared.

Product design is prepared once the customer has accepted the design concept. The basic design of the product is created by the designer, who develops a model based on the presented guidelines and prepares the construction documentation. In the company surveyed, computer software (KD Max) dedicated to the furniture industry is used and is based mainly on libraries of typical and standardized elements. Many aspects related to costing, construction and manufacturing techniques must be taken into account at this stage. After obtaining general approval at the product design stage, the constructor finally prepares a visualization of the model for the customer.

The design is then transferred to the production department, and the product is presented to the customer so that it meets their expectations. In the company surveyed, 2D paper documentation is used for the technical drawings of the elements to be machined. Technologists determine the type and quantity of the semi-finished products and decide on the machining methods or subcontracting. The company uses both conventional and computer numerical control (CNC) machine tools. In the case of machining typical or simple workpieces, the numerical control program is usually created by the machine operator who creates the program directly on the machine's control panel.

The company surveyed makes extensive use of standardized or typical elements. Notable difficulties arise if non-standard elements are required, especially decorative ones such as non-standard milling patterns of fronts, brackets, handles, tabletops, etc. It has been observed that the execution of some orders at the company involves stopping the manufacturing process. This is caused by changes in customer preferences regarding the appearance or functionality of the furniture being ordered. Such interruptions are the reason for delays and extending the waiting period for the finished products.

It has also been observed that the appearance of the finished product often does not appeal to the customer. This may be due to the customer's lack of conviction about different surface textures, decorative patterns or colors that deviate from the expected appearance, which was defined at the model presentation stage. This results in customer dissatisfaction and, consequently, the need to make adjustments.

The analysis of the chosen company made it possible to assess its current processes from the point of view of the seven criteria mentioned in Section 4:

1. High time investment due to the method of information exchange used and designing custom furniture components.
2. Difficult implementation of non-standard products, e.g. ornaments, and the need to subcontract.
3. Consideration must be given to dimensional and visual changes resulting from preliminary measurements of the room and unmet customer expectations regarding the product's appearance.
4. Limited involvement, restricted to defining general assumptions and amendments to the preliminary design.
5. Fully satisfying customer expectations is difficult, especially in terms of the visual aspect of the finished product and on-time delivery.
6. Coordination of activities in the process is costly, with downtime between activities, making corrections and changes, and the installation of the product in the intended space.
7. Moderate inputs, known and widely used technologies.

Based on the assessment of the current process, it was concluded that it may be beneficial for the company to introduce modifications in line with the modern trend of I4.0.

6. TECHNOLOGY-SUPPORTED CUSTOMER PARTICIPATION

6.1. Proposed concept

Based on the analysis of the company's current product completion process, the most significant modification would be to increase the degree of digitization of the process and improve interaction between the manufacturer and the customer throughout the product creation cycle. For this purpose, a unified cooperation platform should be created, allowing for easy, effective and multi-directional data exchange. This will enable efficient exchange of information between the manufacturer and the customer, e.g. in the field of design data and rapid updating and visualization of the product. Additionally, building a collaboration platform should allow for greater integration of the furniture design, manufacturing and costing stages within the company [47]. Figure 2 visually demonstrates how the concept would replace and support the identified furniture product performance process.

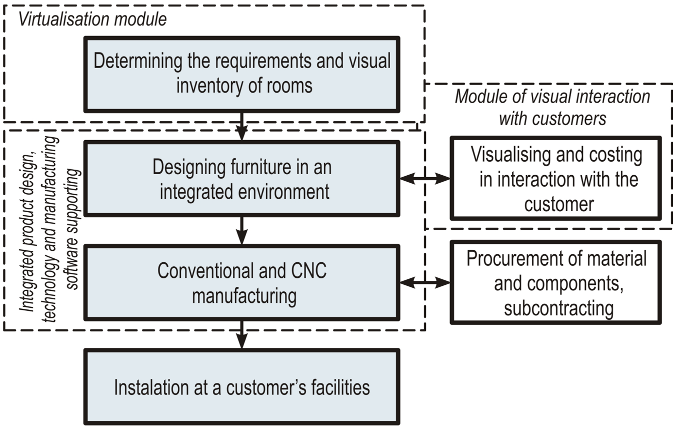

Fig. 2. Own concept of the process supported by technologies

In the proposed process concept, increasing the level of integration between the individual process stages using exclusively digital data is important. Eliminating the paper form of data transfer will present an opportunity to use a uniform digital model throughout the entire production preparation process to create an attractive visualization of the product that can be amended efficiently at each stage of the product's creation. This also applies to the initial phase of order execution, which includes measuring the target premises and determining the customer's initial requirements. Solutions for creating or supporting the construction of virtual room models or selected areas can be used here. For example, one such tool that supports the creation of digital models is an inventory software that cooperates with a rangefinder. It is also possible to use other technologies and software solutions, for example, special cameras that allow for an efficient visual inventory of rooms and effective virtualization of the project. A complete imitation of product installation should also help increase customer involvement in the product development process by making the model easier to understand.

It is proposed to supplement the currently used software environment in the enterprise with universal software that has complementary modules to ensure an appropriate level of virtualization and visualization of the product. The significant potential of the proposed solution is estimated in terms of the completion of production of non-standard furniture elements according to individual customer orders such as the decorative milling of original furniture fronts.

A centralized database and product data management (PDM) can be used for effectively managing technical documentation. The PDM environment will store project data in a secure space and eliminate problems with managing file references, versioning and revising documentation. Thanks to the application of a systematic method of cataloguing and a clearly defined workflow, constructors and technologists can cooperate effectively in real time. In parallel with the development of the structural form of the product and checking its compliance with the technological process, activities in the computer-aided manufacturing (CAM) environment can be performed. Using direct numerical control capabilities, the generated program can be sent from the computer directly to the CNC machines.

An example of streamlining the design data exchange process could be to create an active creator, link it to the design software and make it available to the customer. Such a solution enables partial automation of the process of creating a uniform digital model. To some extent, the presented concept reduces the number of product completion stages in relation to those carried out traditionally. Showing the progress of work to the customer on an ongoing basis and increasing their level of interaction in the design and valuation process moves the design approval stage closer to the beginning of the process when there is more freedom to make changes.

6.2. Software

The market for computer programs in the furniture industry has expanded steadily in recent years, and some general-purpose applications have already been used successfully after appropriate adaptation. In practice, the use of software usually comes down to supporting interior design by using product libraries, project valuation, optimizing cutting board materials and preparing programs for processing elements on CNC machine tools. Currently, cloud-based CAx environments are gaining popularity, as they provide a certain set of tools for online collaboration between the company and the customer, real-time design, instant access to technical and production engineering and software, unlimited data storage and flexible production planning regardless of the device and location.

As a result of constant pressure to meet individual customer needs, an increase in the proportion of non-standard products has been observed in the furniture industry. General-purpose software is often used to manufacture such products. Users seeking to integrate support for the entire product life cycle from concept through design and production to service and disposal opt for PLM software. Such systems are designed to communicate engineering changes throughout the manufacturing and supply chain in real time.

On the one hand, it has been observed that small and medium-sized enterprises (SMEs) are often uninterested in implementing PLM software because of the high investment costs. On the other hand, universal programs with average modelling capabilities are popular in SMEs. Popular software products in this environment include Inventor, Solid Edge and Solid Works. For the concept in this study, these three universal software systems have been taken into account, and each offers basic CAx functions such as 3D modelling, 2D drawing documentation, support for material selection, handling sheet metal and welded structures, performing simple simulations and integrating machining processes.

Due to the comparable capabilities of the software mentioned above, it is difficult to unequivocally identify the right one. Choosing a specific solution is determined by the characteristics of the product itself, temporary needs and the specifics of the company in general. It can be stated that in terms of the product development process in this case study, the Inventor software is worth paying attention to, as it enables the parameterization of models and allows for the easy exchange of components, which predisposes it to designing non-standard furniture that are variants of typical products. An additional software module called Eco Materials Adviser is also worth noting. This tool allows designers to optimize material selection based on information regarding their effect on the environment and production costs. The use of this module can be one of the elements to orient production towards sustainability, especially in the aspect of eco-efficiency of the processes being implemented.

6.3. Expected effects

The classic process used at the company for creating individualized orders is time-consuming. Lead time is significantly extended due to using traditional methods of furniture design and the associated method of creating quotations. Making some changes to the design requires repeating almost the entire loop of the process, thereby practically creating a new design variant. Documentation in paper form limits and hinders the transfer of adequate information to the customer and workers in the production process in terms of quality and quantity.

Many of the tasks carried out during the furniture development process can be considered routine. For such tasks, software specially dedicated to the furniture industry works well in practice. However, there are some elements for which the design process is carried out from scratch, taking into account specific assumptions and sometimes complex design requirements. The use of universal software in such cases is considered to be more effective, as it creates an opportunity to make some products within the company, which may lead to a reduction in the number of subcontractors.

Ding *et al.* [20] state that mass personalization is difficult to achieve on a large scale, as fulfilment of individual customer orders can affect production costs and overall complexity. Tuncel and Kayan [48] state that, from the customer's perspective, the perceived added value from customized manufacturing can outweigh the losses due to product customization time, delivery time and increased product price. These are the challenges associated with manufacturers' shifting towards mass customization.

Increasing the customer's involvement in the product creation process can reduce the number of major adjustments to a furniture design by increasing the speed of the customer's response. Generally, using software options can be challenging for the customer as they require specialist knowledge and skills as well as high-quality equipment. Falheiro *et al.* [24] suggest that using flexible software tools, e.g. in the form of smart configurators, can solve this problem, yielding time and cost savings as well as improving the reporting of customer-specific design requirements. A certain opportunity is also attributed to generative design with the support of cloud environments and AI systems.

The presented concept of process modification in this study attaches great importance to the visualization of the product, which is attractive to the customer. Analysis of the scientific literature identifies proposed methods for accurate representation of objects in virtual space. Virtual reality (VR) and augmented reality (AR) technologies seem to show massive potential here. For example, [49] presents a solution for the problem of efficient simulation of various interior designs and establishes a coherent vision of the designer and the customer thanks to the use of VR technology. Furthermore, [50] uses the rather popular Matterport software to evaluate the effects of 3D room scanning. It should be emphasized that the Matterport system is not yet used in furniture design on a large scale, but it is a leader in building virtual twins of architectural objects. An interesting solution is Canvas software, which is used to create a 3D model using a smartphone or a camera connected to a tablet.

In a case study on using VR/AR technology with employees to select new office furniture, [51] concludes that using the technology is becoming increasingly crucial for manufacturing companies as it helps reduce the market risk and increase customer interaction in the product development process. These studies indicate that VR/AR technology is not yet a fully stable and widespread solution. However, it is likely that the development of technological solutions that meet the assumptions set out here and that are ready for mass use will appear soon.

In conclusion, from the viewpoint of the seven criteria that have been consistently adopted in this study (mentioned in Section 4), it is possible to evaluate the process of preparing an individualized furniture product, namely:

1. Reduced time spent on customer contact and designing custom furniture components.
2. Capability of manufacturing products that satisfy all customer requirements.
3. Reduction in the number of changes and corrections in the final version of the product because of ongoing implementation and better visualization of the product.
4. High level of involvement, with the ability to suggest changes at any stage of the process.
5. Fully satisfying customer expectations is easier, including on-time delivery and better customer involvement.
6. More efficient coordination ensures lower ongoing process costs and reduces rework.

7. Advanced software requires more resources, and although selected module functions are not yet available, high acquisition costs are to be expected.

7. CONCLUSIONS

Currently, I4.0 is revolutionizing how companies do business and create relationships with consumers, suppliers and other stakeholders. Small furniture companies are also participating in this revolution, supporting the existing demand for customized products to a large extent. At the same time, these small businesses face difficulties in implementing new technologies due to a lack of the necessary resources, skills, commitment and proper understanding of digital opportunities. Filling these gaps is significant because digital technologies are important competitive tools. Neglecting them can be risky and may seriously threaten a company's survival in the current market. Digitization can provide support for added value creation and customer involvement, which are key success factors for small businesses. It should, however, be noted that increasing the degree of digitization implies changes in existing product fulfilment processes.

In the concept presented in this study, it is essential to increase customer interaction and improve data exchange in the product development process. This will enable rapid identification of design requirements, allowing for corrections that will speed up the process, reducing delays and enhancing customer satisfaction. However, increasing customer interaction requires the development of IT solutions that are more accessible to the ordinary user without special training in software operation and advanced skills in engineering design.

The presented concept allows for effective creation of non-standard products that also use typical elements. The direction of development seems to be in ensuring full integration of universal software with currently used software dedicated to the furniture industry, thus maximizing the use of unified elements as well as typical materials and technological processes. The practical introduction of universal software with additional modules that are adaptable to the needs of the furniture industry may ensure significant facilitation and better synchronization of the product completion process. The implementation of solutions related to generative design as an element facilitating co-design with the customer may also be of great significance.

In the future, more emphasis should be placed on the development of methods for more accurate representation of the model in the space of the existing room, for example, using AR/VR techniques. The combination of individualized manufacturing with interactive 3D media that provide customers with real-time 3D interactive virtual space and alternative product compositions seems to show massive potential in this context.

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