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Using Business Process Model and Notation 2.0 to Deploy Cobots in a Manufacturing System – Case Study

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ABSTRACT

This study examines the application of BPMN 2.0 notation within the implementation process of modern Industry 5.0 solution – cobots (collaborative robots). The research aims to compare the operational efficiencies of traditional human-only production processes with those augmented by cobots. The authors analyze two variants of furniture production processes: one involving only human workers and another combining cobots and human workers. The efficiency of these processes was assessed in terms of production time and output quantity. The investigation revealed that the production process incorporating cobots was more efficient, with a reduction in production time by 4.76% and an increase in the amount of products produced by 35.5%. The study concludes that integrating cobots into production processes can significantly enhance efficiency, reducing time and increasing output. BPMN 2.0 notation is a critical tool for modeling, automating, and monitoring these improved processes, aiding organizations in making strategic decisions towards adopting robotic solutions to boost productivity and competitive edge in the marketplace.

Keywords: cobots, BPMN 2.0, industry 5.0, process, manufacturing.

INTRODUCTION

Modern organizations are increasingly shifting towards process-based operations, where detailed analysis and mapping of tasks are integrated into comprehensive workflow systems [1]. A critical step in this process is identifying automation opportunities for efficiently managing tasks and activities. In the course of the aforementioned automation, companies are using solutions based on artificial intelligence (AI), including chatbots, image analysis systems or voice recognition, and advanced industrial machinery, including autonomous mobile robotics (AMR) [2, 3] and collaborative robotics (Cobot) [4]. Cobots, or collaborative robots, are essential to this theme. They are pivotal in facilitating collaboration between humans and machines within digitized process structures, enabling precise control over tasks and activities [1]. Approaching process management and using cobots as an integral part of the organisation is essential in modern Industry 5.0 [3]. Understanding and effectively implementing these concepts can significantly improve the efficiency and competitiveness of companies in today's dynamic and technologically advanced industrial environment.

The changing business landscape, dictated by evolving customer preferences, technological advances, and the growing range of available technologies, forces organizations to adjust their operating model constantly. These changes can be strategic, stemming from systematic analysis and planning, but often also result from executives' intuition and creativity [5]. One of the critical assets of modern organizations is the quality of the data and information collected and information and the efficiency of their processing. The quality of digital assets is directly dependent on the fulfillment of fundamental conditions such as correctness, completeness, cost-effectiveness, reliability, verifiability, accessibility, and security [6]. However, more than data correctness is needed to ensure operational success. Proper processing alignment with the organization's needs is also crucial [7].

Against the backdrop of these challenges, the digitization process of enterprises is gaining importance in various areas of business, especially where modern IT solutions allow effective cost reduction. The digitization of these areas also requires a consistent approach at the management level. In this context, electronic process management, known as workflow management, plays a unique role. When an organization does not rely on a traditional hierarchical management model but uses mapped processes, this opens up the possibility of improving coordination and supervision of activities [8].

Digitization of processes is crucial, as it forms the basis for sharing information on current activities in the organization [9]. It is worth noting that the developing systems of business management go hand in hand with advances in artificial intelligence technology and techniques. This development is no longer merely theoretical but increasingly has a practical dimension [10]. Solutions using the potential of artificial intelligence allow for the rapid analysis of large data sets, content generation, and verification. Therefore, these solutions open up the possibility of performing specific tasks within a defined process. Moreover, artificial intelligence technology is developing at the software and infrastructure levels. Artificial intelligence algorithms are already implemented within physical machines and devices [11]. In this context, collaborative robots (cobots) deserve special attention [12]. These special categories of robots can perform their tasks in a human working environment. Cobots can take over some of the manual work done by humans while maintaining safety, appropriate operating speed, and awareness of the environment. They can perform specific tasks, entering a planned process [13].

Proper operations management is critical to achieve success in the human-machine cooperation model. This management should be understandable to both humans and machines. The international notation standard BPMN 2.0 [14] is used for this purpose. This notation accurately describes and maps the business processes necessary to achieve the desired goals [15]. A business process engine plays a central role in process management, enabling digitized process handling and running and supervising the process. In such a system, all process participants are given tasks to perform or are informed of progress. Work in this system is natively assigned to people, services, or computer systems. The framework described above only exhausts some of the possibilities associated with digitized processes in the context of Industry 4.0 or 5.0 [16]. In response to new challenges, work can be assigned to cobots that can collaborate with employees on complex operations. Modern organizations are shaping a hybrid structure, integrating artificial intelligence, human capabilities, and robots to perform complex and disruptive tasks in a human environment.

The result is a plethora of information and standards that present a significant barrier to implementing sophisticated technical and IT solutions in production environments, particularly in cobots. Using graphic notations facilitates the integration of diverse data sources, offering a visual representation accessible and understandable to a diverse range of stakeholders.

In the context of these considerations, the article's primary purpose is to find an answer to the question of how the efficiency of production processes can be improved by introducing cobot using digitized process flow represented by BPMN notation. The article describes the concept of work organization based on a digitized BPMN process, enabling the creation and management of hybrid systems based on close cooperation between humans and cobots.

The paper is divided into six chapters, with an introduction providing background information on the topic, explaining the purpose and significance of the study, and identifying the research objectives and questions. This is followed by a literature review, which summarizes existing research on BPMN 2.0 and cobots in production systems and identifies the gaps the current study aims to address. The methodology section describes the research methods, explaining how BPMN 2.0 was used to plan implementation of cobots in the case study. It covers the tools and techniques used for data collection and analysis. The case study section provides an in-depth description of the specific manufacturing system studied, detailing the implementation of cobots using BPMN 2.0 and presenting diagrams and models representing workflows and processes. The findings section presents the study's results, including data analysis and interpretation. It uses visual aids such as tables, charts, and diagrams to support the findings. This leads to a discussion section where the results are analyzed in the context of the research questions, compared with the results of other studies, and their implications for manufacturing systems and the use of cobots are explored. The conclusion section summarises the key findings, highlights the study's contribution to the field, discusses the study's limitations, and suggests areas for future research.

BACKGROUND

Business process model and notation

Business Process Model and Notation (BPMN) 2.0 is a widely adopted standard for modeling and visualizing business processes, offering a comprehensive framework for process representation. While BPMN is commonly associated with traditional process management applications such as documentation, redesign, continuous improvement, and knowledge management, its versatility extends to various other domains, broadening its applicability and impact. One significant application area of BPMN is in the context of process improvement and optimization. BPMN seamlessly integrates with various tools, enhancing process mapping and analysis capabilities, thereby providing enriched insights for process enhancement [17].

This integration allows organizations to streamline operations, identify inefficiencies, and drive continuous improvement initiatives. By leveraging BPMN with other methodologies and solutions, organizations can achieve a holistic approach to process design and optimization, leading to more efficient and effective outcomes. Additionally, BPMN is crucial in business process lifecycle management, enabling stakeholders to conceptualize and communicate process configurations [18] effectively. This aids in fostering a common understanding among relevant parties, facilitating smoother collaboration and decision-making throughout the process lifecycle. Furthermore, BPMN has been applied in various sectors, such as healthcare, where it is utilized for modeling clinical pathways and quality indicators, showcasing its adaptability across diverse domains [19, 20].

Cobots

Cobots are designed to operate safely alongside humans in work environments and facilitate realizing the vision of Industry 5.0. Integrating cobots into business processes can significantly enhance operational efficiency and workplace safety. Research has demonstrated that cobots offer flexibility for reconfiguration and configuration within processes, allowing them to be readily reprogrammed for diverse tasks [21]. The idea of collaborative robots is not new, and its roots go back more than 25 years to when Edward Colgate and a team of researchers introduced the term "cobot." Colgate's article [22] defined a robot as a passive mechanical device that aims to help humans perform industrial tasks. Cobots manipulate objects in cooperation with a human operator, creating virtual spaces that can be used to direct and constrain traffic [4].

Cobots are not fully autonomous machines, but they can "feel" and "understand" the presence of humans. Cobots excel at performing repetitive, heavy, or hazardous tasks, allowing human workers to concentrate on more intricate and creative aspects of their jobs (product creation and non-standard decisions) [23]. According to the current market standard, any robot that can operate directly alongside a human without spatial constraints is called a collaborative robot [24, 25]. This critical distinction separates cobots from traditional industrial robots. These robots are designed to automate the work of humans, performing large amounts of work with repeatable precision. They require explicit instructions on both position and movement trajectory. They are not equipped with built-in cameras and, when necessary, use external solutions. A safety barrier usually limits their area of operation. In an abnormal situation, the machine's startup must be reconfigured. Programs executed by robots are not modified, and one compilation is sufficient to handle the assumed production. The implementation of such a solution comes at a high cost.

The main advantage of cobots over traditional industrial robots is the ability to work in dynamic environments where moving parts may be present [26]. The ability to learn quickly is functional in autonomously recognizing tasks to be performed and recognizing hazardous situations and safety behaviors. This ability is the basis for using cobots [27].

The introduction of robotic systems aligns with the concept of Industry 5.0, the industrial revolution announced by the European Commission in 2021 in a document entitled "Industry 5.0: Towards a Sustainable, human-centered and Resilient European Industry". Industry 5.0 has three main features: human-centered, sustainable, and resilient. A human-centered approach puts people's basic needs and interests in production. Sustainability refers to creating closed-loop processes that enable the reuse, transformation, and recycling of natural resources, reducing the way waste is generated and the negative environmental impact. The last feature is making production more resilient, protecting against disruptions, and supporting critical infrastructure during emergencies [28].

The cobot market is increasing in Poland, from \$6.3 million in 2018 to \$45.3 million in 2022 (Fig. 1). It is projected to grow further to \$74.8 million in 2023. Projections suggest significant growth in the market in 2028, when its value is expected to reach \$212.2 million [29].

It is worth noting that in both the Polish and global markets, the main factors driving the growth of cobot deployments are the increasing need for productivity and productivity, pressure for a quick return on investment, and the continuing decline in the available workforce. The challenge remains to ensure the safety of those working near autonomous machines. Therefore, it seems to be a promising area of research.

In conclusion, BPMN 2.0 is a versatile and powerful tool for modeling and optimizing business processes across various application areas. Its integration with complementary methodologies and adaptability to different sectors underscore its significance in driving operational excellence, fostering innovation, and enhancing organizational performance. The combination of BPMN 2.0 with cobots presents a promising avenue for businesses seeking to improve their operational efficiency and safety standards.

This is important because integrating BPMN 2.0 with cobots in real-world production processes presents challenges often not adequately addressed. Safety and effective collaboration between humans and cobots are critical aspects that require attention. Studies like [31] emphasize the importance of recognizing collisions using machine learning algorithms to enhance safety in human-robot collaboration. Research such as [32] also calls for further technological developments to support collaborative robots in manufacturing processes, focusing on ergonomics and implementation methodologies. These studies underscore the need for more comprehensive and practical solutions when integrating BPMN 2.0 with cobots in real-world production settings.

Therefore, organizations can significantly improve productivity and workplace well-being by leveraging the strengths of BPMN for process modeling and the capabilities of cobots for safe human-robot collaboration.

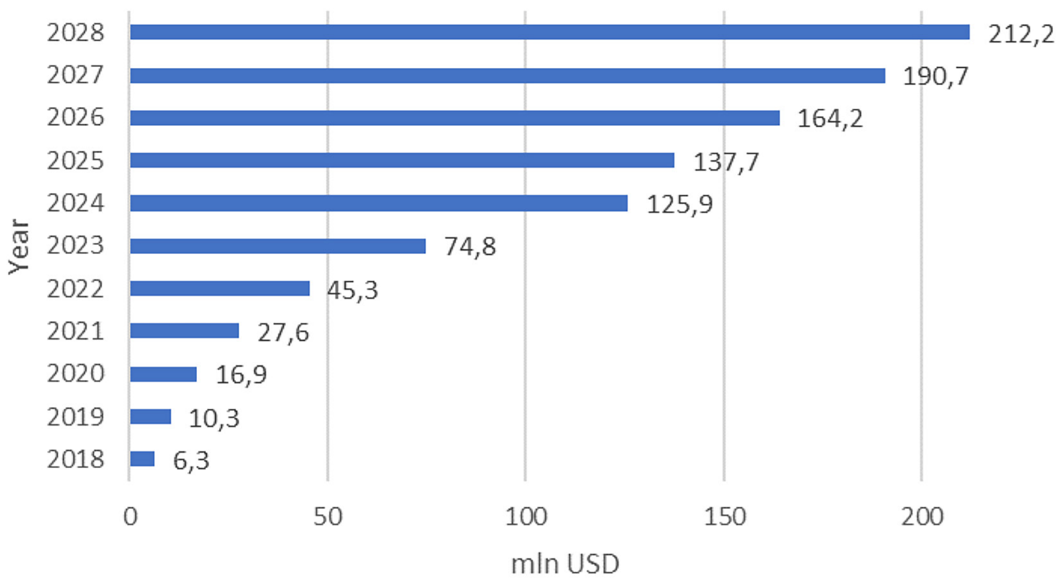

Figure 1. Value of the cobot market in Poland [30]

RESEARCH MODEL

In modern organizations, focusing on the efficiency of individual jobs is critical. However, as the scale and quality of an organization's operations grow, machines and employees coordinate and manage processes.

Frequent downtime leads to lower overall productivity, even in the presence of highly efficient machines. Therefore, it is essential to accurately record events and data on tasks performed by people and accompanying machines. The lack of clear representation and monitoring of changes at the management level hinders effective decision-making and early detection of potential risks [33]. Traditional methods, such as tabular reports, are becoming tedious and demanding, significantly when the volume and variety of production are increasing significantly, which is a challenge for today's managers. Therefore, it becomes necessary to establish a direct link between the production process and its representation at the managerial level.

To address the above problem and verify the hypothesis, a research study based on a case study was carried out, which presents an approach to managing a digitized process using modern Industry 5.0 solutions; this research used cobots, as described in the literature review. The subject of the case study is the manufacturing process of self-assembly furniture, as defined by the parameters available in the literature [33]. Due to its parameters (discrete production) and sequence (occurring bottlenecks, different workstations, low level of complexity), this process provides a suitable basis for considering the above problem. It is also essential that the analyzed process relates to the actual production being carried out.

To test the usability of BPMN 2.0 simulation, unique study variants were designed to provide a comparative basis for applying the notation. In line with the article's goal, it is to test how the implementation of cobots will affect the whole process. The research model assumed two execution variants: variant I (human-to-human) and variant II (human-to-machine), as shown in Figure 2. In the first stage, input data was obtained from the manufacturing process. These data were obtained from the available literature [33] and were identical for both variants of execution. Analyses were then conducted to identify areas for improvement. As a result of these analyses, two workstations were selected, i.e., edge banding and packaging (Fig. 3). Both options were simulated (the selected process was reflected in the notation) using BPMN 2.0 (Fig. 4).

The model was, in turn, digitized and transformed into an executable process running on Camunda Platform 8, version 5.12.2. In Variant

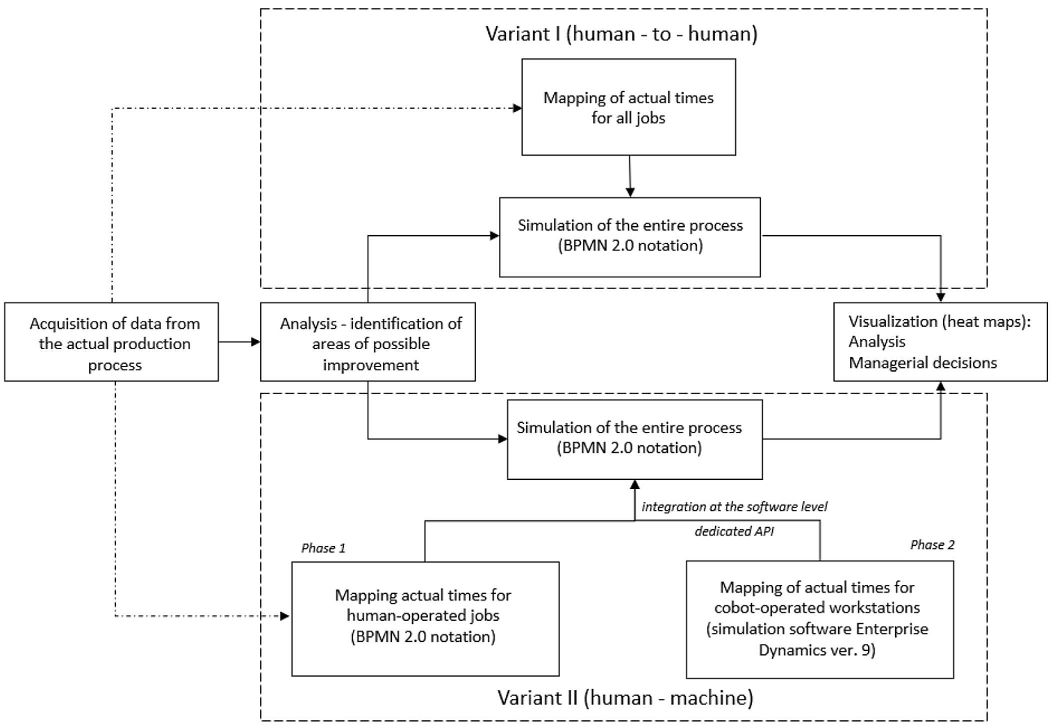

Figure 2. Research model – variant I and variant II. Source: own study

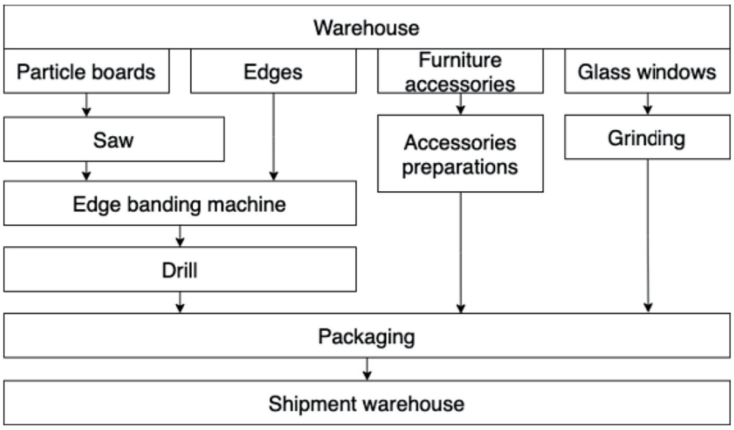

Figure 3. The manufacturing process for self-assembly furniture [33]

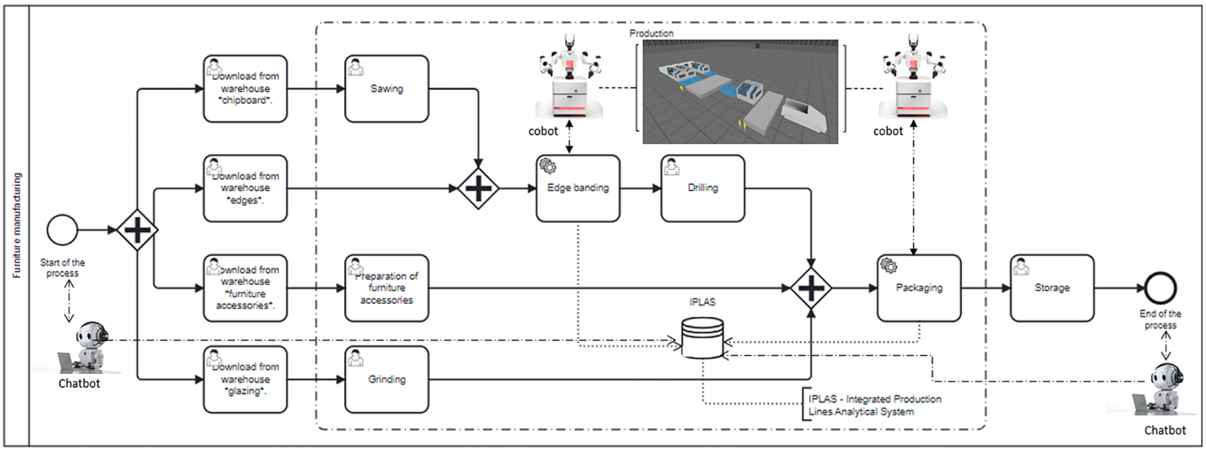

Figure 4. Digitized model of the furniture manufacturing process

I, execution times for each process step were assigned for each activity based on input data obtained from the literature. Variant II, involving using machines (cobots), included two phases. In phase one (for human-operated workstations), as in Variant I, execution times for individual activities were assigned based on input data from the literature. Phase two took into account the working time of the cobot, which was generated based on simulations using Enterprise Dynamics version 9 software.

In this way, the simulation model directly reflects the process model. It is worth noting that the working times of the human-operated workstations, which were adopted in the simulation software, were identical for variants I and II. The only differences were in the operating times of the cobot-operated stations (edge banding and packaging), which were generated by the simulation software. This approach ensured the impartiality and reliability of the obtained cobot operating times. Then, using a dedicated API (Application Programming Interface), the cobots's working times were passed to the business process engine for further analysis (feedback). The final step, common to both variants, was analyzing process execution times for the human-to-human and human-to-machine variants. In summary, the difference in execution times in the two variants is related to the different execution times of operations at the wrapping and packaging stations, where in variant I, the work was performed by humans, and in variant II, by robots. It is important to note that all times assumed in the simulations are actual. To illustrate the differences, heat maps were developed as a management visualization tool for the analysis, and simulation results were obtained for both variants.

The manufacturing process of self-assembly furniture is initiated from the moment the supplied material is received and continues until the final phase of releasing the finished product to the shipping warehouse (Fig. 3). Analysis of the process indicates that a critical operation is edge banding. This operation involves the implementation of several subsequent operations. In contrast, single operations are carried out for the other stations. In the process, between successive operations, the breakaway fields are located. The final product is the result of packaging operations. Therefore, the wrapping and packaging are critical stages in the production process. The two workstations where these operations are performed are operated by two workers simultaneously. For this reason, they were considered essential where potential bottlenecks could occur [33]. As a result, it was decided to include them in the cobot implementation area (Fig 4.).

The challenge was to model the following process and its technical configuration in an executable environment (Camunda). It was necessary to model the process using the symbols and rules available within BPMN 2.0. In addition, a particular challenge was configuring the digital process and analyzing the process in terms of critical operations. Representation in the form of BPMN 2.0 allowed all the necessary data to be collected so that individual simulations could be carried out. Thus, the process is analyzed holistically - unlike in the traditional approach, where individual elements are separately analyzed.

Variant I

Each activity was performed manually in the first variant of the process implementation, so the workstations handling the edge banding and packaging operations were designated tasks with user participation. The simulation experiment involved five working shifts that started on consecutive days. Each shift lasted 8 hours and was not interrupted. The start of production occurred with the change, which involved taking materials and zero production. A heat map was developed for such assumptions, as shown in Figure 5. The map illustrates the load on the various components of the production system in the simulation under analysis. Areas marked in red indicate significant workload and an increased risk of downtime, resulting in decreased process efficiency. Workload means that the duration of successive tasks (operations) increases, which translates into an increase in the waiting time for an operation at a given and, consequently, the next. Therefore, the red areas are those areas of the process where queues (flow lines) appear because successive process operations do not provide adequate capacity. This means the process does not balance against demand and, therefore, does not run smoothly. This is caused by delays at the edge banding station (re-cladding required, quality control required) and packaging (access needed for all parts). These translate into significant delays in the initial part of the process. For this reason, cobots were proposed to be implemented in these areas – as approximated in Variant II.

Variant II

In the second variant, the activities performed at the BPMN notation's edge banding and packaging stations were designated as a service. This service was integrated into the simulation software, enabling work on these stations with a virtual cobot using a dedicated API.

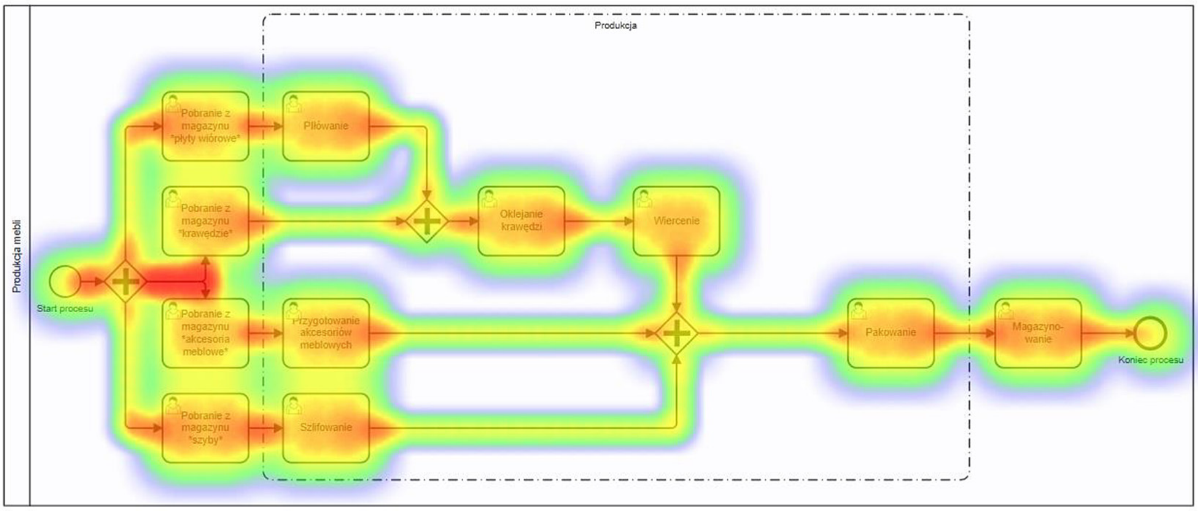

Figure 5. Heat map of the process for the human-to-human variant

The simulation software made analogous assumptions about the number of shifts, the duration of one shift, and the initial inventory for Variant I. The parameters of the operation times for the various activities performed by the cobots were calculated and determined based on the cited literature sources [34, 35]. These times were simulated using a negative exponential probability distribution, typical for simulating continuous and independent events with a specified constant average speed [36]. In the simulation software, the simulation's source (source) atoms were used to retrieve materials from the warehouse. The processing (server) atoms represent the machines and equipment that comprise the process. In addition, an atom (assembler) was used to simulate the work of the wrapping machine and the packaging station. An output atom (sink) was used as a transfer store. It should be noted that the described process was supplemented with atom queue fields, which are buffers within the implemented production [34, 37]. The assumptions made in this way became the basis for running simulations and acquiring cobot runtimes. The running time of the cobots, in turn, was passed back via a dedicated API to the Camunda business process engine. Consequently, a process heat map was developed for Variant II (Fig. 6). Comparing the results obtained for the two variants in Figure 6, brighter areas at the edge banding and packaging workstations are compared to the data shown in Figure 5.

In the context of the analyzed process, the heat maps indicate which workstations are less efficient (darker areas) than others (lighter areas). More delicate areas on the heat map indicate increased activity and faster task completion, while darker regions suggest less activity and slower work. The heat map makes it easier to understand patterns and performance in the analyzed process. The introduction of cobots significantly reduced the duration of individual process instances in the human-robot variant compared to the human-to-human variant. Thanks to their support and the possibility to work among people, the efficiency of operation (edge balding, packaging) dramatically increased. A lower workload for employees ensures better quality and, thus, fewer mistakes, which translates into efficient process operation and shorter unit times. It's possible to observe that there are no queues, and the efficiency of all processes is only regulated by the efficiency of the warehouse supplying semi-finished products. This representation is an appropriate justification for those implementing a cobot solution or making business decisions in this area.

RESULTS

A detailed analysis of the production process results was carried out using the BPMN 2.0 notation and the business process engine. During the experiment, it was possible to visually verify the impact of the choice of technology from the field of Industry 5.0 on the implementation of the process. To compare the variants, the production of self-assembly furniture during one eight-hour shift was assumed, as well as the assumption that the delay in the realization of the output of one piece of the product will be less than three

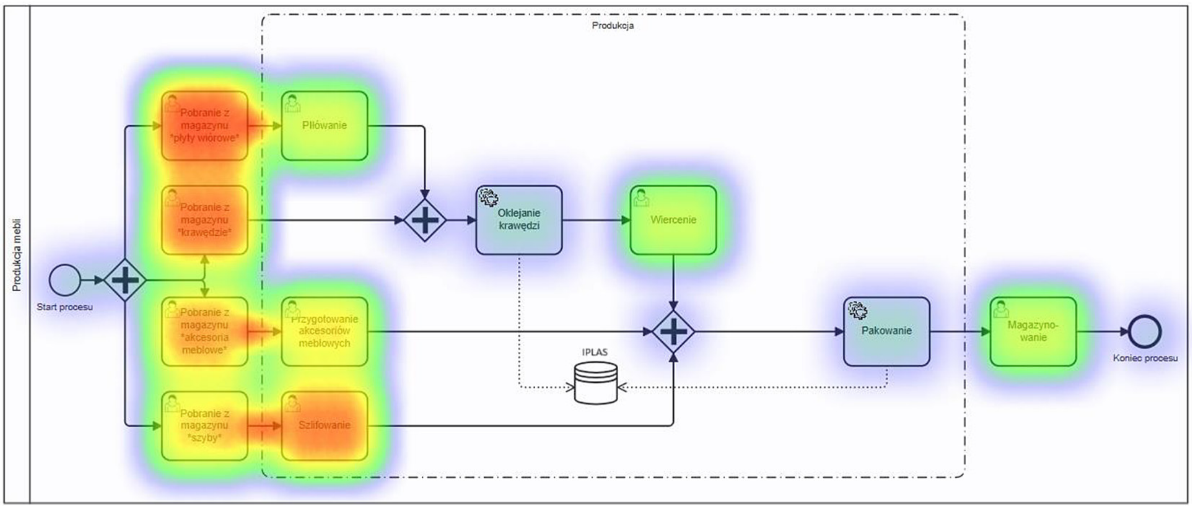

Figure 6. Heat map of the process for the human-robot variant

minutes for the 99th percentile [Fig. 7, y-axis – delay time for the production of one piece of the product in minutes, x-axis – elapsed time for an eight-hour shift in hours (from 0 to 8h)]. "P99" means that 99% of all process instance executions [one process instance = correct (with a delay of less than 3 minutes) production of one piece of product] should be completed in less than one eight-hour shift. Analogous simulations were performed for assumptions of 90%, 75%, and 50% execution of process instances during one eight-hour shift. For each of these simulations, times were recorded based on results obtained from the Camunda business process engine.

As a complement to the analyses conducted further (after the implementation of the cobot), an increase in correctly executed process instances during one eight-hour shift was recorded [Fig. 8, y-axis – bars indicate the number of correctly executed process instances, solid line indicates the average duration of process instance execution, x-axis – elapsed time for an eight-hour shift in hours (from 0 to 8 h)]. For each simulation, data was acquired based on the indications of the Camunda business process engine.

To quantify the results obtained, formulas were developed to illustrate the analyses carried out:

1. Time saving:

$$S[\%] = \frac{T_{hh} - T_{hm}}{T_{hh}} \times 100\% \quad (1)$$

where: S[%] – time saving, T_h – human-to-human variant, T_{hm} – human-machine variant.

2. Change in average production volume

$$C[\%] = \frac{(Q_{hm} - Q_{hh})}{Q_{hm}} \times 100\% \quad (2)$$

where: C[%] – change in average production volume, Q_{hm} – average quantity of products for the human-machine variant, Q_h – average quantity of products for the human-to-human variant.

Based on the data extracted from the business process engine and formula 1 and formula 2, it is also possible to quantify the results obtained. For the human-machine variant, there is an increase in the average amount of finished products going to the shipping warehouse by almost 35.5% compared to the human-to-human variant. Similarly,

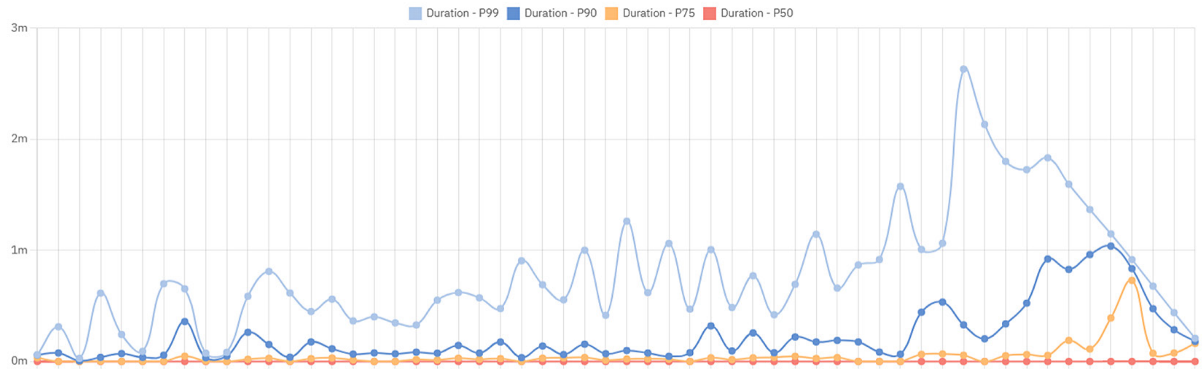

Figure 7. Duration of individual process instances for the 99th, 90th, 70th, and 50th percentiles

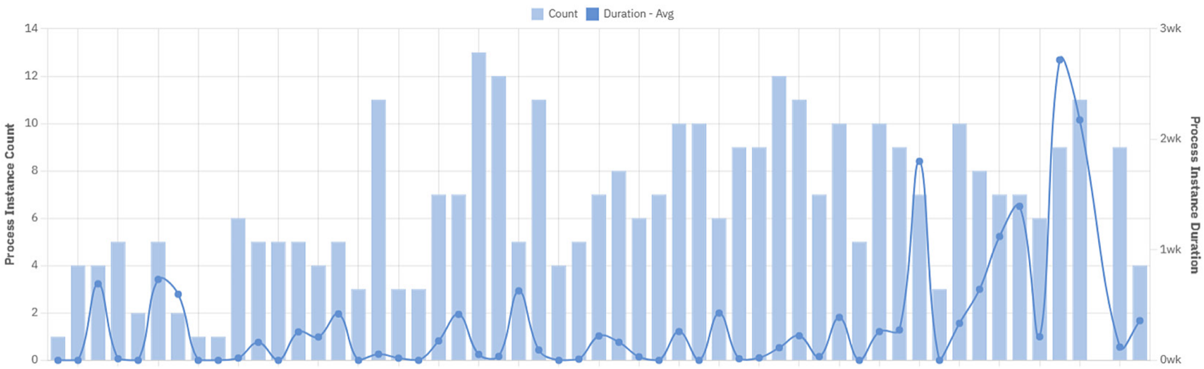

Figure 8. Increase in correctly executed process instances for one eight-hour shift due to cobot implementation

for the average work-in-progress, the amount of semi-finished products going out increased by 4% for the edge banding station and by as much as 30% for the packaging station. Achieving these results, which translate into time savings of 4.76% and an increase in the average quantity of products produced by 35.5% for the whole process, makes cooperation between humans and cobots possible.

The result of the analyses of the collected research material confirms the original thesis and the possibility of concluding that the introduction of the cobot has significantly improved the efficiency of the production process implementation. It is worth noting that this improvement and its control became possible due to the use of BPMN notation.

The simulations and the analyses of feasibility and economic aspects form the basis for strategic management decisions on whether or not to implement a robotic system. The monetary value is considered a reduction in the production process time at stations using cobots and a reduction in the number of defects. Reduced labor time translates directly into increased production and indirectly into higher revenues. The scale of production plays a vital role in the implementation of robotic solutions, opening up the prospects for the company's development by increasing the quality of products and attracting new, regular customers.

It should be noted that the above activities are only possible with the right management approach and the use of dedicated tools. The authors chose the BPMN 2.0 notation for this purpose. The tool enabled the automation of the process and allowed the development of process heat maps and the implementation of control tasks.

DISCUSSION

The realized activities were made possible by understanding the novelty of robotic systems technology and advanced techniques for using BPMN notation in business processes, which is well established in the literature and practice. The authors successfully attempted to implement the BPMN 2.0 notation in manufacturing processes, which is a definite novelty. They used the Camunda business process modeler and engine, which worked in a PaaS model (Camunda Platform, year 8). In addition, the authors used the Camunda Optimizer based on Zeebe's native design (version 1.2) to develop heat maps, which provided efficiency, resilience, and security for process orchestration and enabled the development of heat maps for processes. These tools offered transparent data for further calculations. The authors also proved that it is feasible to integrate simulation software (in this case, Enterprise Dynamics ver. 9) with the notation above and, consequently, any component (including an actual cobot) using a dedicated interface (API).

The study confirms that a digitized process represented using BPMN 2.0 and cobots has an impact and can improve the efficiency of the production process. A comparison of the two variants, human-to-human and human-to-machine, showed that the human-to-machine variant gained a significant advantage. The results suggest that using BPMN 2.0 for cobot deployment can significantly improve manufacturing processes. This includes reduced cycle times, minimized human error, and enhanced consistency in manufacturing operations.

Moreover, it points out potential cost savings from the deployment of cobots. These savings stem from increased automation, reduced labor costs, and improved resource utilization within the manufacturing system. The findings emphasize the importance of human-cobot collaboration. BPMN 2.0 facilitates the design of manufacturing processes where humans and cobots can work together seamlessly, enhancing safety, productivity, and job satisfaction.

The results of the simulations and feasibility and economic analyses form the basis for strategic management decisions to implement or abandon robotic solutions. Correct process automation and management of programmable robots support workers where necessary, especially when performing routine, forceful, or potentially dangerous work [38]. Process management techniques combined with advanced simulation are practiced in business and supported by scientific publications [39]. Nevertheless, the use of BPMN notation in combination with cobots seems to be an innovation, opening up the perspective for further research.

It should be noted that the study presented only answers some questions and concerns. The interdisciplinary nature of the management and technical issues posed a challenge, and further research is needed to accurately analyze the costs and choose a method for implementing robotic solutions in large-scale production. Developing a universal model for implementing the proposed solutions in an organization would be interesting. Despite these limitations, the case study simulations appear promising and could inspire further research and attempts at implementation in business practice. The long-term implementation of collaborative robots (cobots) in production systems presents several potential limitations and challenges that must be carefully addressed to ensure successful integration and sustained performance. One critical challenge highlighted in the literature is the need for a highly skilled workforce to program cobots for complex tasks and integrate robotic systems with other smart devices in the factory [40]. This skill gap can hinder the seamless operation and optimization of cobots within production systems, emphasizing the importance of training and upskilling initiatives to support long-term cobot utilization. Moreover, the alignment between automation decisions and the company's strategic objectives is crucial for the sustained success of cobot implementation in manufacturing processes [41]. Additionally, the lack of significant modifications in existing systems when implementing cobots can pose challenges in achieving optimal performance and scalability over time [33]. Balancing the integration of cobots with minimal disruptions to the existing production setup requires careful planning and consideration of long-term implications for system adaptability and flexibility.

CONCLUSIONS

This article discusses the possibility of implementing BPMN and cobot solutions that contribute to the productivity and efficiency of the organization. The perspective presented results from understanding the synergy between modern Industry 5.0 technology and organizational and management techniques.

It should be emphasized that organizations operating in a specific industry and using particular technologies and organizational methods must carefully consider which robotic solutions best fit into its ecosystem. Implementing such solutions must align with the organization's operating strategy. This may include implementing Industry 5.0 solutions, adapting to a holding organization model, or applying lean management principles.

The integration of BPMN 2.0 notation into actual production processes with the inclusion of machines, cobots, and management aspects is a promising direction of development that brings significant potential for improving the efficiency and management of production, with a focus on the following elements:

The integration of BPMN 2.0 notation makes it possible to model and automate manufacturing processes at different levels of complexity. This allows the precise definition of process steps, their sequences, and trigger conditions. Production processes can be performed more efficiently, eliminating unnecessary delays, human error, and redundant operations.

BPMN 2.0 notation can accurately describe interactions between humans and machines, including cobots. This allows you to define when and how machines (including cobots) should be involved in a process. For example, you can specify whether cobots should perform specific operations or only assist workers in particular tasks. This allows you to optimize production efficiency, using people and machines in a balanced way.

One of the critical aspects of integrating BPMN 2.0 notation into production processes is the ability to generate visualizations on dashboards and control panels. For managers and management personnel, these visualizations are invaluable for real-time monitoring processes, analyzing performance, identifying areas needing optimization, and making ongoing decisions. This makes process management more efficient and data-driven.

Integration of BPMN 2.0 notation gives you the ability to scale and adapt production processes to changing needs and conditions. You can easily modify processes, add new steps, or streamline existing ones. This gives your organization greater flexibility and the ability to respond to market and industry changes.

Integrating BPMN 2.0 notation into actual manufacturing processes is essential for automating, optimizing, and managing production. Organizations can achieve greater efficiency and competitiveness in the market by working with machines, including cobots, and generating visualizations on dashboards. This approach also enables better utilization of human and machine resources and continuous improvement of production processes.

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