ANALYSIS OF SELECTED INDUSTRY 4.0 ELEMENTS IN THE FIELD OF WOOD-BASED STRUCTURES

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Abstract
The concept of Industry 4.0 is currently being promoted in all branches of industry, and its elements affect both the implementation area and the production sphere of the construction industry. Buildings based on wood are no exception in this regard, and certain positive examples in this direction can be observed. Currently, it is possible to observe that elements of automation and robotization are used abroad at a different implementation level than in Slovakia, which is also proven by the responses to selected survey questions presented below. The benefits associated with the use of elements of automation and robotization, especially in the production sphere, are indisputable and therefore it is necessary to implement them ever more to increase the performance of the construction industry as such and achieve better competitiveness and sustainability. The aim of the article is to introduce the issue of automation and robotization through theoretical starting points and, on a practical level, to map the views of companies operating in the timber construction sector as regards what they envision under these terms in their corporate structures and processes.

Keywords
Automation, Industry 4.0, robotization, sustainability, wood structures

1 INTRODUCTION

The intelligent and fully automated factory is at the center of Industry 4.0. The goal is to create a kind of autonomous production system in which machines, people, products and factories will communicate with each other independently. Cyber systems increase the efficiency and flexibility of production [1]. This enables individual implementation at the customer's request for costs that will be the same as those typical of mass production. This will increase the competitiveness of smaller industrial companies in production and market penetration. Current building products or elements of production are developing or changing faster than in the past, and so production systems and companies must become able to keep up with the busy times, as the current market development is more about speed and flexibility than about prices and the quality of products. Industry 4.0 reacts flexibly to the connections between individual companies and can thus react to the fluctuating market and changing market conditions, or to the developing situation with the delivery of services and orders at any given moment [2]. These smart factories embedded in the ecosystem will also ensure highly efficient utilization that reduces costs, supports production, uses resources more efficiently and thus brings higher profits to companies. Companies will share their free capacities with each other, and thus one company can expand its capacities, production facilities and machines. This process will help companies minimize fluctuations in orders and the market itself [3]. Such a method of production, which is controlled by orders, requires the individual standardization of production steps. The additional result is thus that the means to achieve the automatic selection and calculation of orders, their allocation and the final control of the condition and quality of products must be created [4], [5]. The result is additional efficiency. In addition, maintenance can be carried out based on the evaluation of process and machine data. This is what is termed a “predictive maintenance procedure.”

The aim of the article is to introduce the issue of automation and robotization in the sector of wooden buildings through theoretical starting points. Via a practical investigation, the views of companies operating in the timber construction sector on what they imagine under these terms in the context of their corporate structures and processes are mapped.

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2 AUTOMATION AND ROBOTIZATION IN CONNECTION WITH THE SUSTAINABILITY OF CONSTRUCTION

During the construction of buildings, it is necessary to think about the life of the completed building and also about the life of the environment in which it will be located and which it will influence to a large extent [6]. We can define this as the sustainability of construction, which has begun to be emphasized especially during the last decades. Due to the growing number of people in the world, non-renewable resources are running out ever faster, and it is important to think about the use of different renewable resources, but also to minimize the damage to and pollution of the environment [7].

Therefore, the development of techniques and technology is also necessary, starting as soon as in the process of construction planning and continuing up to the process of the complete realization of construction. The development and use of technology to ensure sustainability depends on several factors, including the reduction of the overall complexity of buildings, material recycling and construction time [8], [9]. Although it is clear that ecological considerations should be the most important aspect,, in many cases the time of construction plays a role.

Motivation and reasons for automation

We can divide automation into two types, complex and partial, but both involve the exclusion of humans from production processes by automating such processes [10], [11]. The reasons for this can be divided as follows:

Enforced Automation:

- if human health or life is at risk (automation when working with radioactive material),
- if human activity is a potential source of many errors, the consequences of which may lead to loss of life or threats to health (automation during the ~~automatic~~ navigation of airplanes during landing),
- if a person is not able to perform the necessary activity in terms of speed, range of quality, accuracy or other reasons (automation in the control of nuclear reactors, spraying robots).

Automation for economic reasons:

- the use of automatic control will reduce the direct or overhead costs of production compared to non-automated production,
- substantial increase in labor productivity and production volume (increase in sales of products, expansion of product range),
- shortening of development and production time (faster product creation, more products created at the same time),
- flexible response to changes in production requirements (need to redesign an offered product or production technology),
- higher competitiveness on the market.

Types of automation

We know two types of automation used in production processes and non-production processes. In this work, I mainly deal with automation in production processes, i.e., automation in the process of manufacturing wooden buildings. Automation in production is one of the main areas of use of automation technologies.

Production automation can be divided into programmable automation, flexible automation and fixed automation. We define programmable automation as a form of automation for the production of products in certain batches. The production equipment is programmed and purposefully changed for each new batch of production, so that it is suitable for each given product. They are, for example, industrial robots. Flexible automation is a kind of extension of programmable automation. With programmable automation, we must have enough time to conduct changes and programming for each new product or dose. However, with flexible automation, the amount and variety of manufactured products is sufficiently limited, and thus it is possible to replace devices automatically and in significantly less time than with programmable automation. Fixed automation, also called "hard automation", is suitable for products manufactured in large quantities. We also call it inflexible automation, as it is characterized by its immutability. The program of the technical automatic device cannot be changed, or it is very difficult and expensive.

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Automation in production

Today, automated control and regulation is coming to play a major role in wood production as well as the production of building materials. Automatic regulation of pressure, power, temperature, position, level, speed, the grouping or concentration of substances, etc., is commonly used in industrial production [12], [13]. Automatic regulation saves the machine operator from having to perform many routine processes and activities that are constantly repeated, and it also ensures the manufacturing process is of a high-quality, and productive, and especially that the operation of the machine during the production of building materials or wooden structures is easier and more comfortable [14], [15]. We know that perfect and precise regulation increases the efficiency of management and thus offers competitive sellers the ability on the domestic market as well as abroad.

Automation can be characterized as a process in which human physical and mental activity is gradually replaced by the activity of technical devices. It is a technology concerned with the execution of processes using programmed commands, combined with automatic feedback control to ensure that the instructions are executed correctly, and thus the resulting system is capable of operating without human intervention. It is connected with the use of computing, measuring and automation technology in the management of machines, processes and equipment. Automation represents the most effective means of increasing labor productivity, increasing production, reducing costs, improving quality and overall increasing the efficiency of production management [16], [17]. It removes subjective human influences on the production process and enables the stable and safe operation of processes that would otherwise be impossible to implement at all.

Today, automation is fully intertwined in everyday activities. Processes and tools are implemented in the sphere of private and public life. Many devices are automated using artificial intelligence, and smart technologies are being promoted. The implementation of the Industry 4.0 platform is also a major part of the automation of production technologies in construction and woodworking. The principle of this platform is to connect various machines and devices, thus increasing the degree of automation.

Robotization in industrial production

Automation technologies have been under development for years and have now reached such a high level that they have achieved significant status and recognition in the world and among scientists. Robotics, a special branch of automation, is a prime example of that technology. First, I will introduce the term “robotics” so that we can associate it with automation and understand the difference between that and robotization.

Robotics is an automation technology that began to develop around 1960. This science deals with robots and their introduction to production processes and production technologies, so that eventually the main essence of production is robots. The first mention of the word robot came from Czechoslovakia in 1920, when the word was coined by the author Karel Čapek. A robot is a machine or device that performs, for example, work, demanding operations, programs and activities, just like a human, but even better and more precisely.

The most typical characteristic in terms of human resources in modern industry is the robot. The most characteristic type of industrial robot is a mechanical arm that is driven by power from a source. The arm is programmed to move in every direction, performing activities and completing tasks via a sequence of movements. Today, many robots have replaced human workers in industry, as robots can perform even complicated series of operations [18], [19]. In short, robotization is the use of robots to correctly and quickly perform tasks that we have programmed as needed.

3 ANALYSIS OF SELECTED KNOWLEDGE IN THE FIELD OF AUTOMATION AND ROBOTIZATION IN SLOVAKIA

The following section presents an analysis of a selected part of a survey focused on the field of automation and robotization in the field of wooden buildings. Respondents working in the wood construction sector, from firms engaged in the production of components up to implementation and trading companies, were involved in the survey. In total, approximately 80 companies were approached with a questionnaire return rate of 43%. Implementation companies, which also mostly produce individual components, were predominant amongst those surveyed. Thus, the sample on which the research was carried out was mostly consistent. The questionnaire was implemented online, mostly with closed types of questions. Some questions were open-ended and were evaluated individually in order to achieve the subsequent unification of answers and a more valid interpretation.

The largest representation of answers was from implementers operating in the Central Slovak region. The construction system that the respondents are most often concerned with is the log construction system, followed by the panel (CLT) and column construction system.

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With regard to the pre-fabrication (pre-production) of structural parts of wooden buildings, the respondents that stated that they use automation elements to a large extent made up 69% of the total. The remaining 31% do not use automation elements. This finding indicates that there is still potential for the situation to change in the mentioned area. On the other hand, it should be noted that different respondents have different conceptions of what the term "automation" means, which is why I shall now present the following aspects that were mentioned by the respondents themselves.

The addressed respondents who provided answers to the previously mentioned question specified the forms of automation elements used (Tab.1). According to their statements, the most common form is automation using CNC (24.30%), which stands for "computer numerical control." CNC is used to automate machine tools. The machines are fully computer controlled and the control functions are controlled by the control system. To a lesser extent (14.2%), automated processes are used in the production of various components of buildings (walls, ceilings, roofs). In a roughly comparable representation, automation was used in the processes of applying glue, sawing and using production lines in production. In addition, some respondents considered it to be automation, or during the automation itself, they also use various software tools related mainly to design.

As part of the prefabrication (pre-production) of structural parts of wooden buildings, 54% of the respondents stated that they use elements of robotization. The remaining 46% do not use robotization elements in prefabrication. The fact that robotization occurs was not such an unexpected finding, but what was more important was that many respondents confuse the term robotization with automation. The following graph shows the elements which the respondents imagine under the term robotization. Here it is possible to clearly see the confusion of the terms "automation" and "robotization" in the area of CNC.

Tab. 1 Use of automation and robotization elements.

Use of automation elements	Use of robotization elements
CNC (24.30%)	
Automated processes in the production of building components (walls, ceilings, roofs) (14.20%)	*Hundegger CNC (36.20%)*
Automated processes for applying glue (8.90%)	*Formatting saw (9.80%)*
Automated processes for sawing or dividing materials (6.50%)	*Press (8.90%)*
Use of the Ledinek line in production (5.70%)	*Bridge crane (8.90%)*
	Technical machines (6.50%)

Tab. 2 Opinions on the benefits and barriers resulting from the use of automation and robotization.

	Advantages of using automation and robotization	Disadvantages of using automation and robotization
Investors / users	*Assembly speed (52.70%)* *Accuracy (24.20%)* *Eco-building (16.30%)* *Usability of waste (6.80%)*	*Higher demands for maintenance (57.00%)* *High expenses (22.00%)* *Lower lifespan (21.00%)*
Companies	*Assembly speed (45.10%)* *Accuracy (24.90%)* *Ease of construction for workers (8.00%)* *Usability of waste (7.40%)* *Higher customer satisfaction (7.30%)* *Lower costs (7.30%)*	*Low market interest (51.80%)* *High expenses (33.50%)* *Lower control of detail executions (14.70%)*

According to the statements of the companies responding to the questionnaire-based survey, the greatest advantage of prefabrication for investors and users is the speed of assembly (Tab. 2). Other benefits for investors and users include the accuracy of individual elements during construction. Thanks to prefabrication, the construction is ecological and also offers the use of waste.

Among the identified disadvantages from the point of view of the companies responding to the questionnaire, the largest disadvantage of prefabrication for investors and users is the higher demand for building maintenance.

According to the statements of companies responding to the survey, prefabrication offers advantages both for investors and users, as well as for the companies in question, in terms of speed of assembly during construction. Other advantages for companies are the accuracy of individual elements, the usability of waste, low costs, higher customer satisfaction and the simplicity of the exhibition for workers.

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From the point of view of the responding companies, the biggest disadvantage of prefabrication is the low market interest. Also, the disadvantages according to the questionnaire responses are high costs and lower control of details.

4 DISCUSSION

According to the responses from the questionnaire, the differences between prefabrication in Slovakia and the surrounding countries are 69%. Some selected specific responses are summarized as follows:

- The countries surrounding Slovakia are more advanced in the field of wooden buildings, mainly because of different thinking and the adoption of innovative solutions.
- There is less investor confidence in the field of wooden buildings in Slovakia.
- In Slovakia, prefabrication in the field of redevelopment is not as developed as in other countries. Not all details have been completed, which is reflected in prices.
- Differences resulting from legislative restrictions and other specifics.
- Mostly there is a requirement for the individual construction of wooden buildings according to the requirements of individual investors. It would be desirable if architects and urban planners were also involved in the preparation, in order to create typological units according to the concept of historical architecture in individual regions.

According to the individual answers, it is possible to say that according to the opinion of the responding companies, there is a significant difference in Slovakia compared to foreign countries in the area of prefabrication. On the other hand, we can state that the Slovak construction industry is developing and innovating every year in the field of prefabrication with regard to wooden buildings. The difference between Slovakia and the previously mentioned neighboring countries is decreasing over time, mainly due to the influence of the open market and the awareness of companies operating in this industry segment.

Building structures based on wood are without a doubt, from the point of view of production as well as implementation prerequisites, destined for a more significant implementation of both automation and robotization as such. In particular, the production process of individual components for wooden buildings offers ideal opportunities for increases in automation and robotization.

According to Lachance et al. [20], the prefabrication of components in the wood building industry is a trending topic in the search for sustainable buildings and affordable housing. In the cited work, based on the analysis of these topics, data were given regarding the degree of automation in relation to factors such as the level of machinery and technological tools used, the size of the enterprise and the workforce, the level of leanness and standardization, and the stage of prefabrication. The conclusions show a direct relationship between the size of the company, the volume of production and the use of the Industry 4.0 element. The dominant market players, for example Homag Group [21] and Randek [22], are now dealing with the implementation of the Industry 4.0 element in the production process of components for wooden buildings.

Considerable potential for the implementation of elements of automation and robotization seems to be offered by the initial phase of wood raw material processing according to Landscheidt and Kans [23]. In addition, they state that countries with extensive timber resources can significantly set up effective process innovations in this area and increase both economic efficiency and sustainability as such.

Under certain conditions, the implementation process could use elements of automation and robotization to a greater extent. A dominant factor is also the fact that wet processes are removed for wooden buildings as such, which could affect the implementation of the already mentioned elements of automation and robotization in the implementation process.

5 CONCLUSION

On the basis of the theoretical starting points, it can be concluded that automation and robotization have considerable potential for the streamlining of both production and implementation processes in the construction industry, and not only in the field of wooden buildings. A practical view of this issue is documented by a presentation of part of the findings from a questionnaire-based survey. It follows from the conclusions of selected parts of the survey that the largest proportion of responses came from implementers operating in the Central Slovak region. The construction system that the respondents are most often concerned with is the log construction system, followed by the panel (CLT) and column construction system. Automation elements are used in 69% of the companies that responded in the form of CNC machines. Elements of robotization are used by 54% of the respondents in the form of Hundegger CNC machines. For investors and users, and also from the point of view of

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the responding companies, the biggest benefit obtained is the speed of assembly, but there are disadvantages in terms of a higher demand for maintenance and the low interest of the market in the implementers. According to the survey respondents, it is possible to implement elements of robotization or automation in the prefabrication of timber building components and the actual production of wooden buildings. However, significant deficiencies in this sense appear mainly in the implementation process, where it would be possible to implement mainly the elements of robotization to a much greater extent, because currently a number of demanding processes are implemented in a traditional way without appropriate innovation with the potential to increase the efficiency of the implementation process.

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