PROGRESS OF INDUSTRIAL REVOLUTIONS – REALITY CHECK FOR BOSNIA AND HERZEGOVINA

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ABSTRACT

This study examines the level of digitalization in Bosnia and Herzegovina through a survey of 140 companies from various sectors and sizes. Bosnia and Herzegovina, like other countries in the Western Balkans, is classified as a developing country. These Western Balkan countries offer significant nearshoring opportunities due to lower labor costs compared to the EU. To capitalize on these opportunities, digitization, automation of industry, and green transition are among the priority tasks. Supported by EU investments, Western Balkan countries are investing in infrastructure and production, improving development, raising living standards, and adapting production processes to Industry 4.0 standards. However, the survey shows that technology adoption is mostly a continuation of Industry 3.0, with limited integration of advanced analytics and data connectivity. While a significant number of companies possess modern machinery, indicating production capabilities, the adoption of robotics and Industry 4.0 technologies remains concerningly low. Despite their awareness of advanced industrial technologies and significant usage of ERP software, companies lack serious intentions to digitize, suggesting a need for further investigation into the factors hindering this transition.

Keywords: Digitalization, Automatization, Industry, Bosnia

JEL Code: L06, L01

1 INTRODUCTION

The COVID-19 pandemic and geopolitical tensions have disrupted global supply chains, leading to expectations that companies may relocate production facilities closer to their home markets. This process is known as “nearshoring”, which refers to the relocation of business processes, production, or services to a nearby location, closer to the company‘s headquarters or primary market. For example, a company might move its operations from a distant location such as China to Bosnia and Herzegovina due to shorter distribution

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and supply chains. Similarly, an Asian company might invest in Montenegro to be closer to its partners in Europe. This strategy is becoming increasingly important as companies seek to reduce risk and dependency by shortening supply and distribution chains. The Western Balkans (WB) is an excellent location due to its proximity to European markets, relatively low wages, and availability of skilled labor. However, to be competitive, WB countries need to improve the regulatory framework, offer financial incentives to businesses, and reduce red tape to attract investment. Investment in infrastructure and technology is crucial for the region's long-term competitiveness, as digitalization is one of the key enablers to comply with EU regulations and needs. In this study, we wanted to examine the level of digitalization and Industry 4.0 principles in the industrial environment of Bosnia and Herzegovina from the perspective of companies.

2 INDUSTRY 4.0

The goal of Industry 4.0 is to enhance the production environment by enabling self-awareness, self-learning, autonomous decision-making, self-execution, and adaptability in manufacturing processes(Lu, 2021).

2.1 Industry 4.0 in developed countries

Industry 4.0 paradigm is progressing significantly in Europe and globally. Europe, particularly Germany and Italy, has led with national strategies that focus on smart factories and digitalization. Globally, developed countries are ahead, while developing nations are catching up. At its core, Industry 4.0 (German: Industrie 4.0) refers to the strategic initiative by Germany aimed at positioning the country as a leading market and provider of advanced manufacturing solutions (Reinheimer, 2015). Almost simultaneously with the German initiative, the USA also launched recommendations contained in a strategic plan geared to stimulate the next generation of manufacture, designated Advanced Manufacturing Partnership (Liao *et al.*, 2017). Other examples of governments that launched such initiatives are: Australia: "Modern Manufacturing Strategy" (Department of Industry, Science, Energy & Resources, 2020), South Korea: "Manufacturing Innovation 3.0 Strategic Action Programme" (Hee-Cheol *et al.*, 2018), India: "SAMARTH Udyog Bharat 4.0" (Ministry of HI & PE, Government of India, 2020), Japan: "Revitalization Strategy Reform 2015" (Government of Japan, 2014), China: "Made-in-China 2025" (Jost *et al.*, 2016), Singapore: "Research, Innovation and Enterprise 2020 Plan" (Dervishi *et al.*, 2022), Brasil: "Plano de CT\&I para Manufatura Avançada no Brasil – ProFuturo" (Ministério da Ciência, 2020), Russia: "Digital Economy 2024" (Vinokurov, 2021), and South Africa: "Manufacturing Indaba", 2018 (Siyenza Management, 2023). Many other similar initiatives that tend to embrace the same principles and technologies are already started all over the world and can be found in works (Teixeira & Tavares-Lehman, 2022; Majstorovic & Mitrovic, 2019).

2.2 Industry 4.0 in developing countries

While developed countries are investing heavily in Industry 4.0 and paying special attention to digital transformation, developing countries are still struggling due to specific political, social, economic, and infrastructural issues. The distinction between developed and developing countries is primarily determined by their respective levels of economic advancement and the quality of life. One of the most used indicators is Gross Domestic Product (GDP), which is often employed as an indicator of economic health and growth. The growth of GDP is beneficial for industrial development, as it is often associated with increased manufacturing output, economic stability, and improved resource allocation. However, GDP does not

fully encompass all dimensions of development, such as income distribution and environmental sustainability. One of the regions still in the developing phase, according to GDP, is the Western Balkans, including Bosnia and Herzegovina (GDP: 19860), Serbia (GDP: 24511), Montenegro(27776), Albania (GDP: 18060), Kosovo (GDP: 13547), and North Macedonia (GDP: 23424) (Trading Economics, 2023). These countries have similar GDP levels, and accordingly, we can infer a similar stage of industrial development and the application of Industry 4.0 technologies.

The Balkans are an integral part of Europe, a geostrategic priority for the European Union, and a relevant market for products and services. They are therefore all committed to implementing fundamental reforms for economic development and integration. Digitalization is one of the primary objectives for WB countries on their journey to joining the EU, encompassing the integration of advanced technologies in production, healthcare, banking systems, education, and other sectors. Several countries have already established official state digitalization strategies. Additionally, various non-profit and non-governmental organizations aim to develop a robust, globally competitive digital economy within their nations. On the other hand, the European Union, along with individual EU member states, significantly contributes to the advancement of digitalization by providing funding and expertise to facilitate more rapid and effective digital transformation. For example, in June 2023, the Digital Europe Program was opened to all Western Balkan countries (European Commission, 2024), except Bosnia and Herzegovina, which joined in May 2024 (EC B&H, 2024). This initiative also contributes to the implementation of the Economic and Investment Plan (EIP) for the Western Balkans, underpinning the digital transition of the region through the EU4Digital program—an accelerated digital transition for the Western Balkans (EC EU4Dig, 2024). Additionally, the European Bank for Reconstruction and Development (EBRD) and the European Investment Bank (EIB) are providing significant funding to the Western Balkan countries for digitalization (EBRD, 2022) (EBRD, 2023).

2.2.1 Why is progress so slow?

Even though there is significant effort from government and non-government sectors as well as from the EU and its members, the progress is still slow according to the recently published reports (Rupp *et al.*, 2023), (Petar, 2023), (Bajic *et al.*, 2024), (ACIT Centre & EPIK Institute, 2022), (Dervishi *et al.*, 2022). One of the top reasons for such slow progress is technical knowledge. Digital literacy in the Western Balkans, including public administration (Dervishi *et al.*, 2022), lags behind the EU due to lower education levels and structural issues, with additional concerns about data privacy, security, and reliability contributing to a lack of trust in digital services (Bajic *et al.*, 2024), (Rupp *et al.*, 2023). Inadequate technical infrastructure in the Western Balkans, especially in rural areas (Petar, 2023), limits digital transformation efforts, development, and global value chain integration (OECD, 2021), while also increasing susceptibility to cyber threats (Bajic *et al.*, 2024). Also, businesses in the Western Balkans have low adoption of advanced digital technologies and limited integration of emerging technologies, with the lack of e-payment systems being a significant barrier that requires regulatory adoption and trust-building measures. The government sector in the Western Balkans faces challenges in improving online services, enhancing digital solutions, ensuring data security, aligning with legislation principles (Rupp *et al.*, 2023), and addressing legal and regulatory gaps to maximize EU investments in digital transformation (Bajic *et al.*, 2024).

3 METHODOLOGY

According to independent external reports (see Section 3), the adoption of Industry 4.0 technology is progressing slowly due to various factors. This study aims to assess the current state of awareness and implementation of advanced technologies and concepts within industrial environments. Specifically, it investigates the extent of awareness, the perceived benefits, and the barriers to greater engagement with these technologies. To address these questions, we conducted interviews with approximately 140 companies in Bosnia and Herzegovina. The companies interviewed varied in industry sectors and sizes. The study utilized four sets of questions: one focusing on company information (4 questions), then a set of questions for status of machinery (4 questions), another on the digitalization process (11 questions), and a third on the automation process (9 questions). The questionnaires were shared over email, via social networks, or by private visits.

4 RESULTS

In this chapter, we present the results of our research through a series of detailed charts and graphs. These visual representations provide an overview of the data collected, highlighting key trends and anomalies. Each chart is accompanied by an analysis to explain the underlying findings and their implications. The results are organized thematically to provide a clear and logical flow.

4.1 About Companies

- Q1: What type of industry does your company operate in?
- Q2: What is the size of the company in terms of the number of employees?

The interviewed companies span various industries (Figure 1a), with metal and wood being the most dominant (30% and 14%, respectively). Regarding the number of employees, most companies are small-sized, with only 5% having more than 350 employees.

- Q3: What is the size of your company in terms of the year's revenue?
- Q4: Who are the owners of the company?

Figure 2 shows revenue distribution where 27% of companies generate between €10 million and €25 million annually, while 10% exceeds 25 million. Smaller companies with revenues below €500,000 make up 16%. Ownership-wise, 71% of companies are privately owned by domestic entities, and 19% are under private foreign ownership, reflecting significant international investment and diverse market practices.

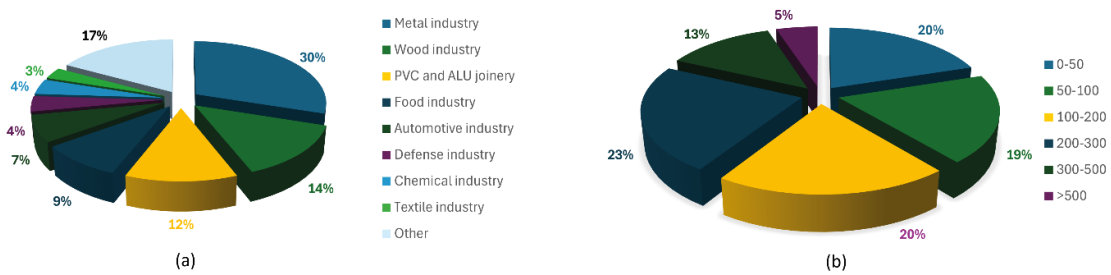

Fig. 1: (a) Distribution of Companies by Industry Sectors
(b) Distribution of companies by number of Em-ployees.

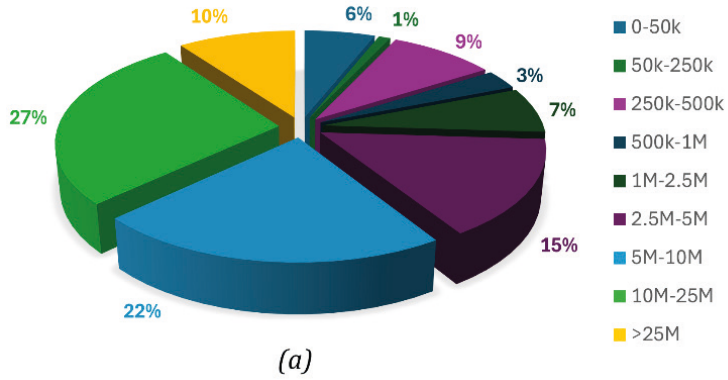

Fig. 2: Distribution of companies by yearly revenues in Euro [€]

4.2 Machines and Robots

The integration of robots and automated machinery has revolutionized production processes, enhancing efficiency and precision. Companies are increasingly implementing robotics and automation to stay competitive and drive innovation.

- Q5: What is the size of your company in terms of the number of machines?
- Q6: What is the average age of machines?

The distribution of companies by the number of machines shows that 48% operate with 20 to 75 machines, indicating moderate mechanization, while 20% have fewer than 10 machines and 9% have over 100, highlighting varying levels of technological adoption shown in Figure 3a. The average age distribution of machinery (Figure 3b) reveals that over half of the fleet is more than a decade old, with 27% over 15 years and 26% within the 10–15 year range, though 17% of the machinery is relatively new, aged between 2–5 years and 7.5–10 years, indicating recent investments in newer equipment.

- Q7: Do you have any robots or cobots implemented?
- Q8: How many robots or cobots do you have?

Survey results show that 28% of companies have implemented robots or cobots, while 72% have not yet adopted such technologies, indicating the early stages of automation for many companies. The distribution of robots among companies is shown in Figure 4 reveals that most companies have only a few.

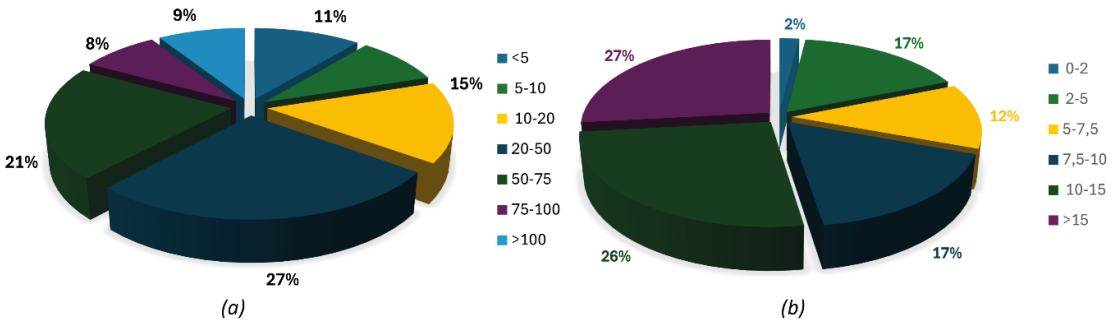

Fig. 3: Distribution of questioned companies by: (a) number of implemented machines (b) average age of machinery.

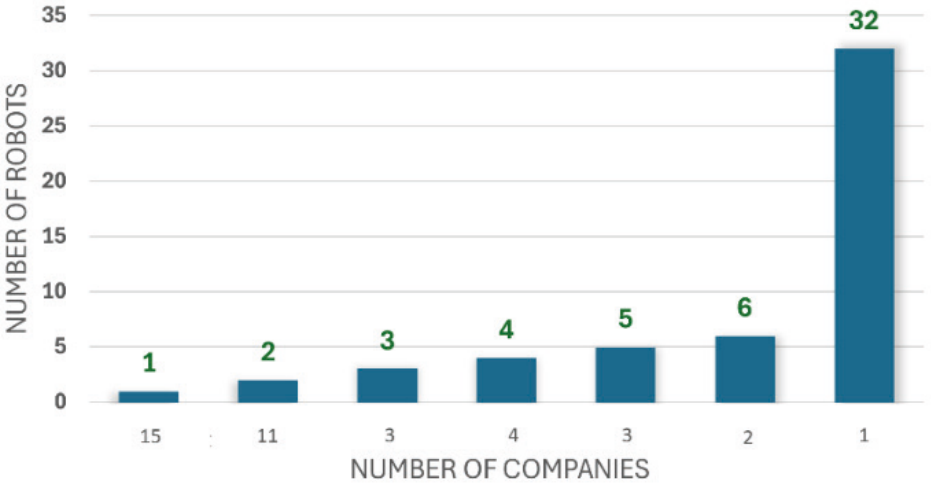

Fig. 4: Distribution of questioned companies by the number of implemented robots

4.3 Digitization

One of the first steps in the process of digitalization and its maintenance is to have people who will take care of your current IT infrastructure and develop it further.

- Q9: Does your company have an internal IT department, or does it use the services of other companies for its IT needs?
- Q10: From which organizational level are digital/IT processes managed in your company?

Many companies use a hybrid approach for IT services, combining internal and third-party expertise (43%), while others rely solely on third-party providers (29%), maintain in-house IT operations (24%), or operate without any IT support (4%). Most companies manage IT processes at the director level (39%) or through the head of IT (28%), but 10% have no designated IT responsibility, posing potential risks. The results are shown in Figure 5.

- Q11: How would you best describe the current level of digitalization in your company?
- Q12: To what extent has your company's management placed digitalization on the list of strategic priorities?

According to the companies questioned, 80% of them claim that they have a medium or high level of digitalization, indicating ongoing or completed digital transformations, while 20% have low digitalization, highlighting growth potential (Figure 6a). A significant portion of companies prioritize digitalization at multiple levels, with 30% prioritizing it and 3% not prioritizing it at all, suggesting varying stages of digital transformation.

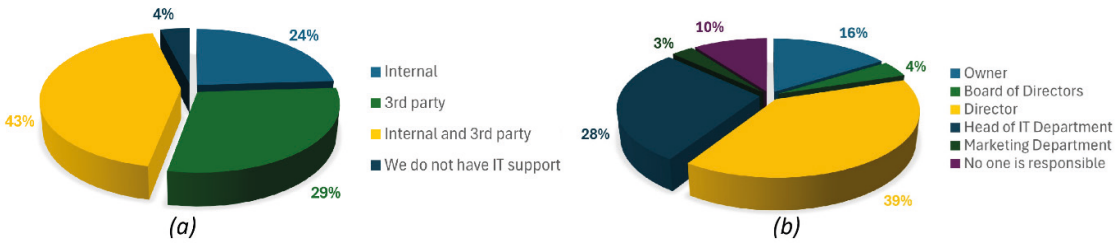

Fig. 5: (a) Distribution of IT Support Strategies Among Companies
(b) Organizational Levels Managing Digital/IT Processes.

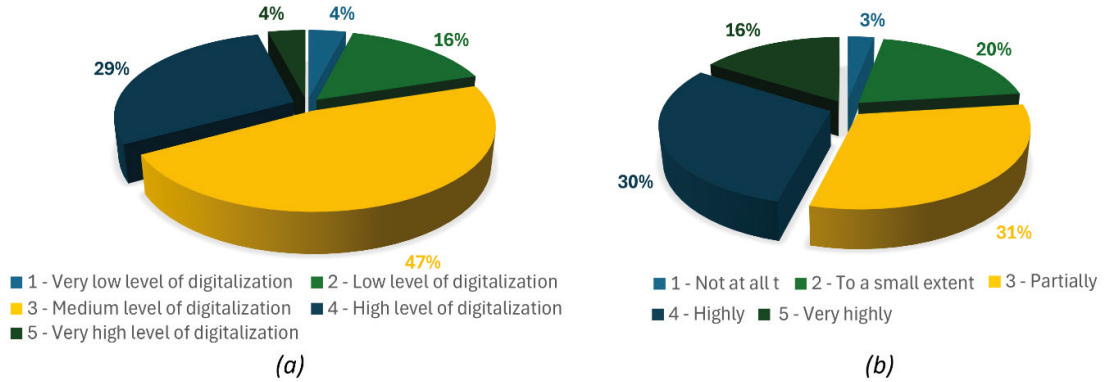

Fig. 6: (a) Current Level of Digitalization in Companies as They See It
(b) Management's Strategic Prioritization of Digitalization.

- Q13: How do you confirm completion in production?
- Q14: Which Enterprise Software Solutions have you implemented and what are the future plans?
- Q15: Which of the Industry 4.0 technologies have you implemented in your business?

The results in Figure 7a show that 31% of companies use mobile phones or tablets and 40% still rely on paper to confirm production completion. This indicates that there is still the possibility for improvement. Positively in Figure 7b, Enterprise Resource Planning (ERP) systems are widely adopted by 82% of companies, with manufacturing execution systems (MES) and computerized maintenance management systems (CMMS) also having significant adoption rates at 44% and 48%, respectively. A similar survey in 2022 with companies from a similar market showed significant growth (see Figure 8a) in enterprise system adoption by 2024. The most notable increases were in Enterprise Resource Planning (ERP) systems, which rose from 50% to 82%, and Computerized Maintenance Management Systems (CMMS), which increased from 17% to 48%. These results suggest companies are increasingly investing in enterprise systems to enhance efficiency and competitiveness.

The current adoption of Industry 4.0 technologies shown in Figure 8b among businesses reveals a mixed landscape. A significant 42% of companies prioritize cybersecurity, while 37% embrace the Internet of Things. However, 27% have yet to implement any Industry 4.0 technology. On a positive note, 21% plan to adopt these technologies, indicating growing awareness. Additionally, 18% are exploring 3D printing and big data, while AI adoption remains low at 8%, and digital twins at 2%.

Fig. 7: (a) Distribution of production confirmation
(b) Acceptance and Future Plans for Enterprise Software Solu-tions

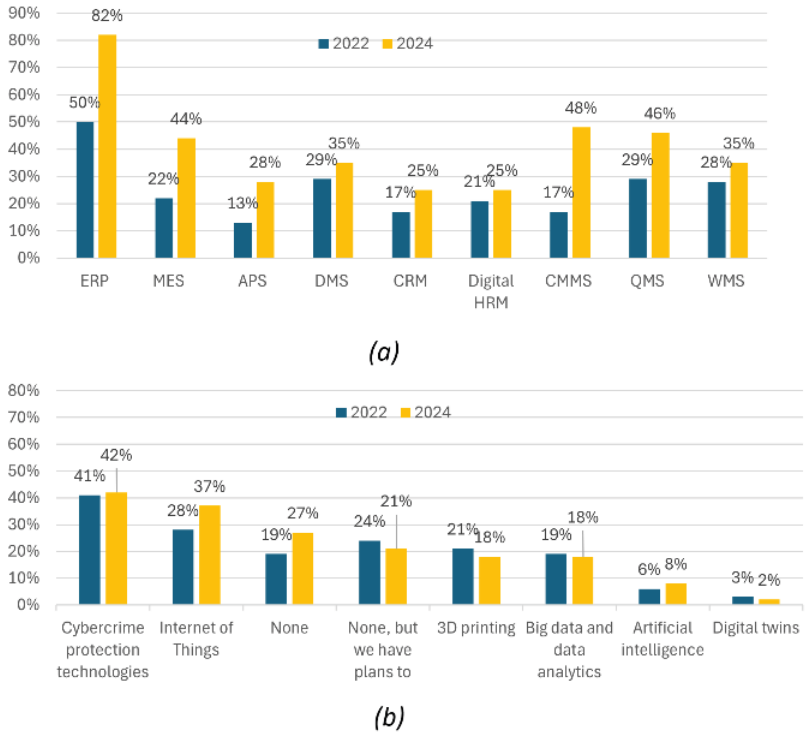

Fig. 8: Comparison between 2022 and 2024:
(a) Enterprise software solutions usage
(b) Technology Implemented

Overall, while some businesses lead the way, many still have untapped potential, suggesting a promising future for advanced technology integration. Between 2022 and 2024, the adoption of various technologies showed mixed trends. Cybercrime protection technologies saw a slight increase from 41% to 42%, and the Internet of Things (IoT) rose from 28% to 37%. However, the percentage of companies not adopting any technologies increased from 19% to 27%. Plans to adopt technologies decreased from 24% to 21%. Adoption of 3D printing and big data analytics remained stable at 18%, while artificial intelligence increased from 6% to 8%, and digital twins decreased from 3% to 2%. These trends highlight evolving priorities and challenges in technology adoption.

Figure 8b shows changes in technological adoption between 2022 and 2024. The results indicate a growing focus on security and IoT, with slight increases in cybercrime protection (41% to 42%) and IoT adoption (28% to 37%). However, more companies are not adopting any technologies (19% to 27%), possibly due to resource constraints. Established technologies like 3D printing and big data analytics remain stable at 18%, while AI adoption is slowly increasing (6% to 8%). These trends highlight evolving priorities and challenges in technology adoption.

- Q16: In your opinion, what are the biggest obstacles to increasing the level of digitalization in your company?
- Q17: What effects has your company experienced from adopting digital technologies/ digitalization?

Figure 9a reveals the main barriers to digitalization in companies. A significant 53% struggle with a lack of expertise and training, while 49% face cultural resistance to change. High implementation costs, affecting 47%, remain a critical hurdle. Overcoming these obstacles is crucial for companies aiming to advance their digital transformation. Digital technologies

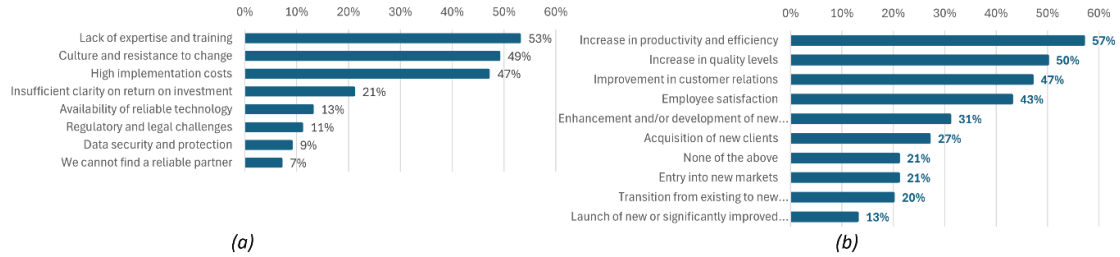

Fig. 9: (a) Key obstacles for digitalization in companies
(b) Effects to the company after adopting digital technologies/digitalization

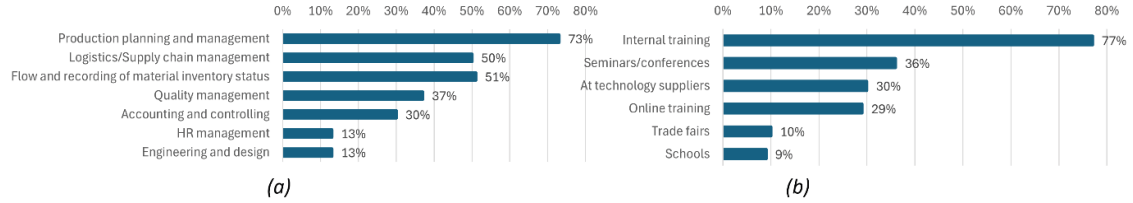

Fig. 10: (a) Business segment that will be enchanted by digitalization
(b) Distribution of Training Locations for Employees.

have revolutionized companies, with 57% reporting increased productivity and efficiency. Nearly half have seen improvements in quality and customer relations, while employee satisfaction has risen due to better workflows and remote work options.

Despite these successes, 21% of companies haven‘t experienced these benefits, likely due to implementation challenges. Overall, as seen in Figure 9b, digitalization is driving positive changes, though some hurdles remain.

- Q18: Which business segment, in your opinion, will become the most efficient because of digitalization?
- Q19: Where do you conduct training for your employees regarding digitalization?

Digitalization has significantly benefited various business segments. Production Planning and Management leads with 73%, thanks to automation, real-time data, and system integration. Logistics/Supply Chain Management (50%) and Inventory Status (51%) also see improvements in tracking and forecasting as shown in Figure **10**a.

As the lack of knowledge presents one of the main obstacles to successful digitalization, we asked companies about their approach to worker training. Figure **10**b shows a strong preference for internal training, with 77% of companies developing their employees‘ digitalization skills in-house.

- Q20: Does your company have a developed digital strategy (with clearly defined activities, goals, and roles)?

In the future, we can expect even more companies to adopt and refine their digital strategies, driving innovation and efficiency in various industries. Nearly half of the companies (46%) have a clearly developed digital strategy, while 45% plan to develop one. Only 9% of companies neither have nor plan to create a digital strategy. This indicates a strong trend towards digital transformation, with most companies recognizing its importance for future growth and competitiveness.

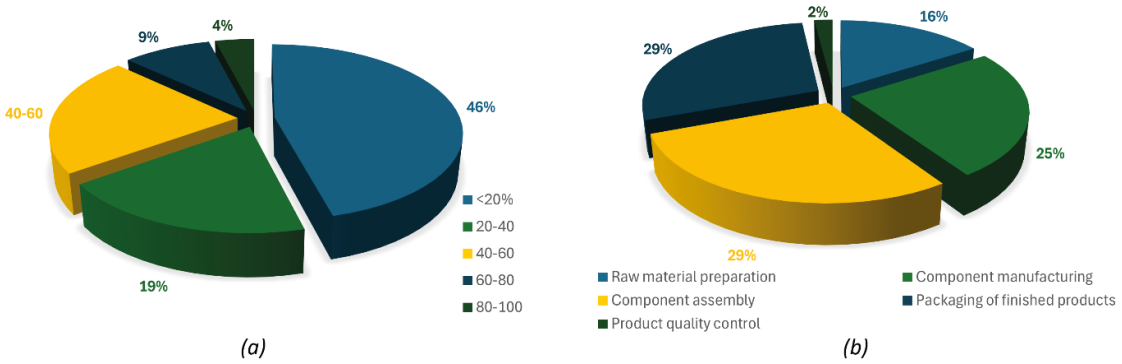

Fig. 11: (a) Levels of Automation in Production Processes
(b) Distribution of manual work in the companies

4.4 Automatization

Automation represents a fundamental aspect of the Third Industrial Revolution, a phase that should now, theoretically, be regarded as part of our historical development. However, our analysis indicates that Bosnia has yet to fully integrate essential elements of this revolution, particularly the automation of processes. Consequently, this study aims to ascertain the extent to which production processes are automated within the companies surveyed through the following questions:

- Q21: How much of your production processes are automated?
- Q22: Which part of the production process relies most on manual labor in your company?

Figure 11a shows that 46% of surveyed companies in Bosnia have less than 20% of their processes automated, while only 4% have high levels of automation (80% – 100%). These findings underscore the significant gap in automation adoption, with many companies still heavily reliant on manual labor in key production areas as shown in Figure 11b. Component assembly and packaging are the most labor-intensive areas, each at 29%, followed by component manufacturing at 25%.

- Q23: How satisfied are you with the current level of automation in your company?
- Q24: Have you considered introducing any form of automation in production?
- Q25: What are the main reasons you are considering introducing automation?

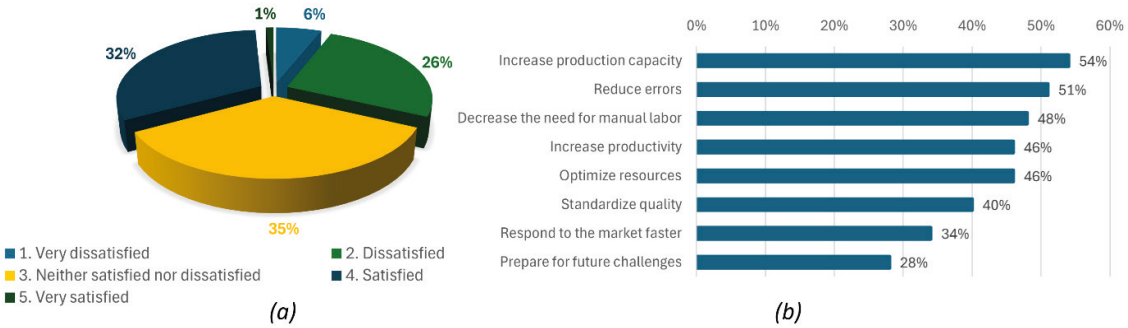

Fig. 12: (a) Satisfaction levels regarding the current state of automation
(b) Main Reasons for Considering Automation

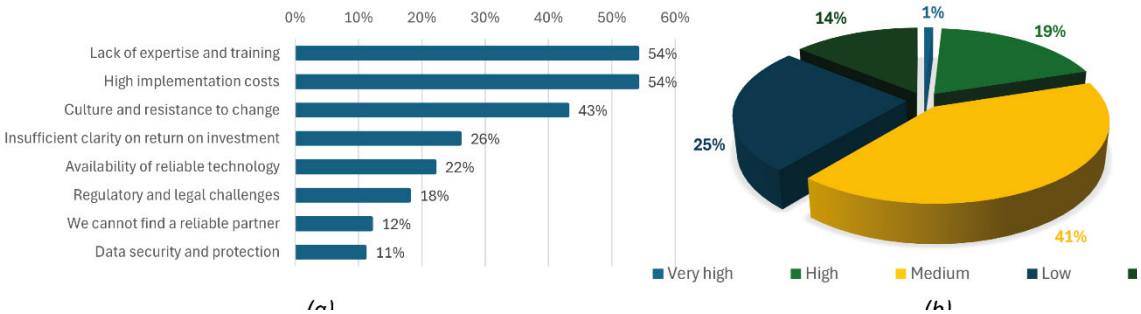

Fig. 13: (a) Main obstacles to not fully automating industrial processes
(b) Employee Knowledge and Skills in Automation Technologies

The survey results in Figure 12a show that 32% of respondents are satisfied with their current level of automation, while 26% are dissatisfied, and 6% are very dissatisfied. These findings highlight a significant trend towards automation, with 74% of respondents considering its introduction. Key motivations include increasing production capacity (54%), reducing errors (51%), and decreasing manual labor (48%), as shown in Figure 12b.

- Q26: What obstacles do you see as the most important in the process of introducing automation?
- Q27: How do you rate the current level of knowledge and skills of your employees regarding automation technologies?

Figure 13a shows that the main obstacles to introducing automation are a lack of expertise and training (54%), high implementation costs (54%), and cultural resistance to change (43%). Figure 13b indicates that only 1% of employees have very high expertise in automation, while 19% have high-level skills. The largest group, 41%, has medium-level knowledge, but 25% have only basic understanding, and 14% have very limited knowledge. These findings highlight the need for strategic investment in training and technology to overcome obstacles and enhance workforce proficiency in automation.

- Q28: Which of the following 4.0 automation technologies have you implemented in your business?
- Q29: To what extent does your company's management prioritize automation on the strategic agenda?

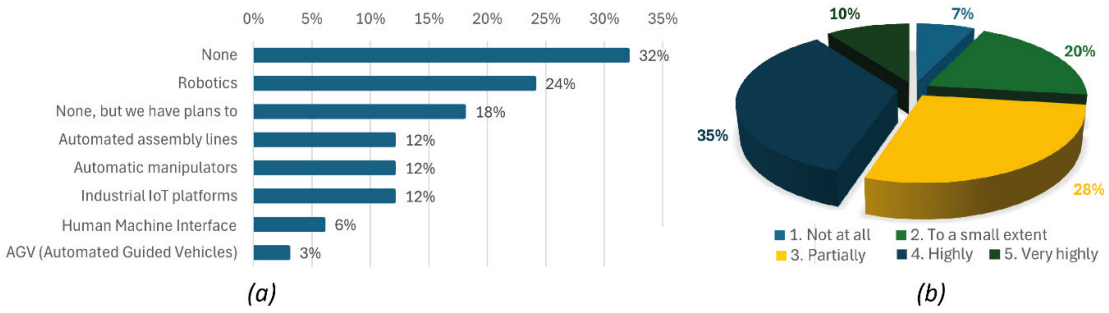

Fig. 14: (a) Adoption of 4.0 Automation Technologies Among Businesses
(b) Management Prioritization of Automa-tion on the Strategic Agenda

The Figure 14a shows varied adoption of 4.0 automation technologies among businesses. A significant portion, 32%, have not implemented any automation technologies, while 24% have integrated robotics, and 18% plan to implement automation technologies. The survey also reveals varying degrees of prioritization of automation by company management. The largest group, 35%, indicates a high level of prioritization, and 10% report very high prioritization.

5 CONCLUSION

Western Balkan countries, including Bosnia and Herzegovina, are strategically positioned to supply Europe with essential products and mitigate future supply chain disruptions, as experienced during the COVID-19 pandemic. However, to be competitive, these countries need to improve their industrial processes and advance digitalization efforts. The survey revealed that while a significant number of companies possess modern machinery, indicating production capabilities, the adoption of robotics and Industry 4.0 technologies remains concerningly low. Only 28% of companies use robots, and the number of robots per company is minimal. The utilization of robots and advanced technologies could significantly enhance production efficiency and quality, and advanced analytics could further boost productivity. Surprisingly, cybersecurity measures are implemented in 40% of surveyed companies, whereas data analytics are used by only 18%. This suggests that the current industry level aligns more with the Industry 3.0 concept rather than Industry 4.0, although a transition towards Industry 4.0 is evident. Conversely, software solutions have been widely adopted, with ERP software usage among 80% of the companies. This indicates that awareness of digitalization and its benefits has permeated industry and management, showing a significant increase compared to previous years. Despite many companies assessing a high level of digitalization within their organizations, the results indicate substantial room for improvement in this area. Struggles with technology adoption persist, with resistance to change being a major challenge, highlighting the need for further education, training, and infrastructure investments. This situation presents an opportunity for investors to leverage the region's proximity to Europe, benefiting from lower labor costs while enhancing manufacturing capabilities and economic stability.

5.1 Future challenges

One of the significant challenges for all countries, particularly developing ones, is the transition to green and sustainable policies. This is due to the substantial investment required in green technologies and infrastructure, which can be financially burdensome. The EU's new Carbon Border Adjustment Mechanism (CBAM) mandates these countries to measure and reduce their carbon footprints to continue exporting to the EU, but many lack the necessary tools and expertise to comply. While the green transition offers opportunities for economic growth and environmental benefits, it demands significant investment and international support. Future surveys we plan to conduct will include questions about green technology adoption to raise awareness and highlight progress in developing countries.

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