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FACING THE CHALLENGES OF INDUSTRY 5.0 – THE CASE OF THE AUTOMOTIVE SECTOR IN POLAND

Summary. The article presents an analysis of the essence of the Industry 5.0 concept, the level of awareness of this phenomenon, and the readiness of automotive sector enterprises operating in Poland to implement its characteristic solutions. To this end, the article addresses the following issues: theoretical assumptions of Industry 5.0, the automotive sector in the European context of Industry 5.0 conditions, and primary research on a sample of 111 automotive companies operating in Poland. The research hypotheses have been verified. (1) The concept of Industry 5.0 is relatively unknown among automotive companies operating in Poland. (2) In automotive companies in Poland, the transition to Industry 5.0 solutions is still in its early stages, and the process of implementing these solutions is rather slow and gradual. (3) In the short term, the number of challenges facing automotive companies in Poland in connection with the transition to Industry 5.0 outweighs the potential benefits to be achieved, and the nature of the issues requires a holistic and long-term approach.

1. INTRODUCTION

Various theoretical concepts are being developed and new categories are being formulated to emphasize the importance, complexity and specificity of the changes taking place in the social system and its subsystems—including the economic subsystem—under the influence of technological progress. Post-industrial society, knowledge industries, information society, knowledge society, knowledge-based economy, information economy, new economy, smart economy, and Industry 4.0 are just some of them.

Currently, the concept of Industry 5.0 is receiving particular attention as a driver of economic development and a determinant of essential changes. Industry 5.0 should be seen as an integral part of a larger civilizational change. As is well known, in the classical division of the economy into three sectors, industry holds the second position in contributing to GDP. An important component of the industrial sector in many countries, including Poland, is the automotive industry. Therefore, it is worth examining the awareness and readiness of the automotive sector in Poland to implement Industry 5.0 solutions.

2. INDUSTRY 5.0 AND AUTOMOTIVE SECTOR – THEORETICAL AND CONTEXTUAL ASPECTS

2.1. Assumptions of Industry 5.0 (I5.0) – Literature review

The idea of Industry 5.0 is a response to the constraints and challenges identified within earlier paradigms of industrial development (in particular, Industry 4.0) [1]. The concept of Industry 5.0 was introduced by the European Commission for the first time in 2021 [2]. The origins of I5.0 can be traced

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back to Industry 4.0, introduced in Germany in 2011. Building upon this foundation, Industry 5.0 extends the original paradigm by integrating three equally important dimensions: human-centricity, sustainability, and resilience [3]. Whereas Industry 4.0 emphasized digitalization and automation at the plant level, Industry 5.0 adds social and system perspectives, highlighting open standards, capabilities and employee well-being [4]. This means designing systems so that technology augments people (ergonomics, HRC, microlearning), reduces environmental impacts (circularity, energy intensity, product carbon footprint (PCF), and enables shock-resistant value chains (data standards, interoperability, cybersecurity) [5]. Industry 4.0 adopted a technology-driven paradigm, whereas Industry 5.0, supported by advanced technology, consolidates and reinforces human-centricity, sustainability and resilience as fundamental pillars of contemporary value-creation systems [6].

The concept of Industry 5.0 emerged as a natural progression of the Industry 4.0 paradigm, incorporating social and environmental considerations into the industrial transformation framework. It highlights the importance of employees' competencies, expertise and their capacity to collaborate effectively with machines and robotic systems, as well as the flexibility of production processes and their environmental impact [7]. It is also noted that Industry 5.0 does not reject the achievements of Industry 4.0, but complements them with human, environmental and social dimensions [8].

The digital transformation rejects the purely digital character, complementing it with a cultural and ethical dimension. The creation of technological solutions must take into account social dialogue and sensitivity to local and global cultural conditions [9]. This concept should not be understood in a purely evolutionary sense. This idea assumes a qualitative change in the approach to the relationship between man, technology and the environment. It excludes relying solely on further automation and digitization of industrial processes, emphasizing their humanization, sustainability, and the assimilation of social and ethical values in the production process [9]. The theoretical foundations of I5.0 are grounded in the notion that technological progress should primarily benefit and support human needs, not completely replace them. Industrial development, on the other hand, should be innovative and cost-effective, but above all ethical, inclusive and focused on the common good. Therefore, the need for synergy between human competences and the opportunities offered by artificial intelligence (AI), robotics, Internet of Things (IoT) or the cloud is emphasized. A key role is assigned to the so-called cobots, i.e. collaborative robots. Their role is not limited to replacing employees, but to support them in performing tasks, especially those that require precision, repeatability or work in dangerous conditions [10].

Taking into account the assumptions of Industry 5.0, technological development should be subordinated to social needs. Hence, it must incorporate values such as empathy, responsibility, and participation [8]. Production processes should be designed to take into account the individualization of products. Personalization of the user experience is also extremely important, as is the sustainable management of natural resources [11]. In this context, significant importance is attached to the concepts of circular economy, climate neutrality and corporate social responsibility [12]. Industry 5.0 has a special role to play for social innovation and open collaborative ecosystems. Organizations are encouraged to interact with a variety of stakeholders—employees, NGOs, local communities, scientific bodies or public administrations, in order to create value beyond the economic dimension [13]. The need to develop new management models that support flexibility, adaptability and continuous learning of the organization can also be emphasized [14]. According to Ivanov (2023) Industry 5.0 operates across three interconnected dimensions: society, network, and plant. It is worth providing a broader outline of the context of the three main Industry 5.0 components. If we are talking about a human-centric approach, the core idea is to design work and technology that aim to augment human capabilities rather than substitute them. This includes safe human-robot collaboration (HRC), collaborative robots (cobots), and the use of human digital twins (HDTs) to model physical and cognitive loads at workstations. Ergonomic solutions, including exoskeletons, and modern learning methods (microlearning, "learning in the flow of work") are key. Updated standards (e.g., ISO 10218:2025) structure the safety and quality of such collaboration.

Sustainability-by-design means that environmental objectives must enter the concept and development phases of products and processes. In practice this means systematic product carbon footprint accounting (per ISO 14067), full life cycle assessment (ISO 14040/44), eco-design (in line ISO 14006) and material and process choices that support repairability, re-use, remanufacturing and

recycling. This includes lowering energy and water intensity, heat recovery, increasing recycled content, designing for a digital product passport (DPP), and embedding environmental requirements in sourcing. Progress is measured by hard metrics: PCF/unit, kWh/unit, recycled-content share, waste ratio, and value recovered in closed-loop systems.

The pillar of resilience and data spaces concerns the ability of organizations and the entire value chain to anticipate disruptions, limit their effects and return to a steady state quickly. Operationally, this means scenario based on sales, inventory and operations planning (SIOP), master production scheduling (MPS), short-horizon demand sensing, transparency of capacity and inventories, and policies for multisourcing and defined buffers. The data layer forms the foundation of this resilience by providing common vocabularies and identifiers (part/lot/serial), clearly specified end-to-end information-exchange models with access controls and full audit trails, as well as consent and retention management aligned with data-sovereignty principles. In practice, this translates into shorter detection and reaction times, more precise corrective actions, and easier part-provenance tracking and collaborative resolution of quality issues.

Industry 5.0 is a paradigm that redefines the purpose of technological development, oriented not only to the need for profit, but, above all, to human well-being, the sustainable advancement of the broader socio-economic ecosystem, and the improvement of life quality [12]. Taking such a perspective requires moving away from a purely technocratic view of innovation towards a systemic and holistic approach in which technology, humans and the environment form interrelated and interdependent components [11].

Below is a holistic approach to defining this phenomenon according to Ivanov's approach. Industry 5.0 can be understood as the convergence of resilient, sustainable, and human-centric technologies with advanced organizational paradigms and management frameworks. It aims to develop and govern value-creation systems that are cost-effective, adaptable, and sustainability-oriented across multiple operational layers, including industrial ecosystems, supply chains, and manufacturing or logistics infrastructures. These systems are inherently data-driven and characterized by dynamic structural adaptability, enabling real-time responses to variations in market demand and supply conditions. Through the rapid reconfiguration and reallocation of their components and capabilities, Industry 5.0 ensures the sustainable and human-centric delivery of products and services to society [6].

2.2. The automotive sector in Industry 5.0 conditions – European context

The automotive sector constitutes a globally integrated network encompassing vehicle manufacturers, component and equipment suppliers, service providers, and specialized retailers engaged in the distribution and sale of motor vehicles [15]. The automotive industry is a key driver of the global economy and stands as the leading private sector contributor to research and development investment in Europe [16].

Amid softening demand, cost pressure and an accelerating regulatory agenda, three overlapping vectors shape the evolution of Europe's automotive sector in 2025 [17, 18, 19]:

- selective electrification and the "hybrid bridge" of transformation,
- supply-chain de-risking and production relocation under geopolitical pressure,
- "compliance-driven advantage" built on data and environmental footprint, from ESG (Environmental, Social and Governance) reporting to cost-operational edge.

Demand in Europe is shifting toward zero-emission powertrains, but at speeds that differ by country and segment. In the first half of 2025, cumulative EU new-car registrations fell by 1.9% y/y, while battery electric vehicles' (BEVs') market share rose to 15.6%, which is evidence of tension between a slower market and a lasting shift in the powertrain mix. Hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) remain important stabilizers of volumes and margins during the transition. In parallel, infrastructure is expanding: the number of public charging points in Europe exceeded 1 million in 2024 (+35% y/y), albeit with uneven geographic distribution, which differentiates adoption paths and local production strategies [4, 5, 17, 18].

Europe's trade landscape is being rewritten. The European Union has implemented and upholds countervailing duties on Chinese-manufactured battery electric vehicles (BEVs) – provisional from 3 July 2024, definitive from 31 October 2024 – at levels of 35-38%. These actions strengthen incentives to localize production and diversify sourcing in Europe while also raising risks of retaliation and component-cost pressure [4, 5]. Competition from China is tangible: according to JATO, Chinese brands doubled their European market share to 5.9% in May 2025, and models manufactured in China already accounted for >7% of registrations in Western Europe in Q2 2025, despite tariffs [20, 21].

The EU's regulatory wave is redefining compliance as a source of cost-operational advantages. The Corporate Sustainability Reporting Directive (CSRD) covers the first reporting wave for FY2024, forcing the harmonization of non-financial data collection and audit processes. In parallel, Regulation (EU) 2023/1542 introduces a battery passport - mandatory from 1 February 2027 for traction and industrial batteries >2 kWh, together with requirements for carbon footprint and QR-code-accessible information [22]. In practice, this implies end-to-end (E2E) traceability across the value chain, product-level PCF accounting, and interoperable data exchange across the chain (data spaces with PCF rulebooks) [23].

Together, these vectors pose a daily challenge set for suppliers:

- demand swings and mismatched capacity make stable planning hard,
- workforce pressures-skills gaps and rising labor costs,
- tightening ESG reporting and credible PCF accounting,
- the need for deeper data transparency across the chain, from traceability to more efficient recall management.

The sector must raise planning flexibility (SIOP/MPS), digitize inter-company data exchange (data spaces), automate quality control and ergonomics at workstations, and credibly calculate and lower products' carbon footprints. Given the European market picture, I5.0 constitutes a pragmatic framework for developing and applying design principles in industrial systems.

Its three pillars align with the sector's main problems and challenges. In this framing, Industry 5.0 enables simultaneous gains in productivity and worker well-being, reductions in energy/material intensity and faster supply-chain responses under demand volatility and powertrain complexity. The theoretical benefits and concrete Industry 5.0 practices already implemented by recognizable automotive suppliers are presented below.

1. Human-centric operations – productivity without a human cost.

This pillar assumes human-robot collaboration on the line, ergonomic workstation redesign, and learning in the flow of work to raise throughput and quality while reducing physical and cognitive loads. Updated robotics standards (e.g., ISO 10218:2025) clarify safety for such applications. Schaeffler deployed cobots and guided assembly (including ActiNav/universal robots (URs) and adaptive AICA solutions), achieving measurable savings and overall equipment effectiveness (OEE) gains on powertrain lines, a scalable HRC example with rapid payback. In parallel, BMW Regensburg implemented AI-supported quality control (GenAI4Q) that personalizes inspection scope to the vehicle variant, shortening root-cause analysis and reducing rework. That is evidence that human-in-the-loop and AI can coexist in a production line [24].

2. Sustainability-by-design – lower energy, material intensity, auditable ESG.

Industry 5.0 integrates environmental goals with product and process design (PCF per ISO 14067, circularity, readiness for digital product/battery passports) to structurally reduce utility and waste costs. BENTELER combines "smart factory" (self-diagnostics in hot-forming, decision support) with energy decarbonization. The share of green power in the plant portfolio is rising, and cumulative CO_2 reductions are material even before full transition to new process technologies [25]. From a reporting and procurement standpoint, original equipment manufacturers (OEMs) are institutionalizing comparable, component-level carbon-footprint metrics. Mercedes-Benz has set CO_2-reduction targets for suppliers and steers sourcing toward net-carbon-neutral materials, while Stellantis embeds footprint targets into its steel sourcing roadmaps and expands supplier PCF data requirements, enabling like-for-like

evaluation in tenders and supporting compliance with CSRD and eco-design for sustainable products regulation (ESPR) [26; 27].

3. Chain resilience and transparency – traceability and data-space exchange.

Resilience relies on sovereign end-to-end data sharing (quality, batches, capacity), which shortens response times to demand deviations or complaints and enables compliance evidence (e.g., battery/product passports) [28]. The Catena-X ecosystem provides semantic standards (quality, traceability, demand and capacity, PCF), while Cofinity-X acts as the operator offering onboarding and a marketplace of certified applications, significantly lowering the entry threshold for Tier-1/2 suppliers. Case evidence indicates that linking OEM field data with suppliers' production data within Catena-X allows narrowing service actions from mass campaigns to precisely identified VINs, which are safer and cheaper for all sides [23, 24]. Operational adoption is evident at leading OEMs: the BMW Group reports Catena-X–enabled, data-driven quality management and early-warning analytics in series production, while the Volkswagen Group is rolling out Catena-X services via the Cofinity-X marketplace to enhance transparency, sustainability, and supply-chain efficiency (BMW Group, 2025).

The evidence presented above suggests that Industry 5.0 is the most pragmatic roadmap for Europe's automotive transformation: it integrates people, technology and data to build advantage under 2025 conditions. On the shop floor, combining HRC, microlearning, and AI-supported inspection yields more flexible planning, shorter changeovers, and more stable quality, thereby improving efficiency. Across supply chains, shared standards and data spaces enable the rapid identification of root causes and targeted service actions, thereby strengthening resilience and shortening response times. Robust PCF methods and readiness for digital passports streamline reporting and reduce energy and material costs through more informed sourcing. Emphasis on ergonomics and skills development means people reach proficiency faster and work more safely and consistently closing the improvement loop. In short, Industry 5.0 simultaneously raises flexibility and quality, strengthens chain resilience, ensures compliance with a cost benefit and advances skills and ergonomics, which is exactly where the sector needs it today. It presents both the rationale for adopting this philosophy in the automotive industry and a map of benefits, along with practical examples that confirm it is taking root and delivering tangible effects. This is only the beginning: consistent promotion and scaling of the Industry 5.0 path at the plant, supply-chain, and public-policy levels are essential. The faster the sector transitions from isolated pilots to an Industry 5.0 operating standard, the greater the chance of maintaining competitiveness and sustaining the development of Europe's and Poland's automotive industries.

3. METHODS AND MATERIALS

3.1. Methods and research tools

The research was conducted to evaluate awareness and preparedness of automotive sector in Poland in the context of Industry 5.0 adoption and to identify the benefits and challenges associated with this transformation. The automotive industry in Poland represents around 8% of the country's GDP and constitutes an important pillar of the national economy.

The study encompassed a sample of 111 firms representing the automotive industry operating in Poland as part of a larger research project dedicated to five sectors. The survey was carried out from August to October 2024 using a non-probability sampling approach. The data were collected through an online survey employing the Computer-Assisted Web Interviewing (CAWI) method and a structured questionnaire. The majority of respondents were in senior or middle management positions.

The choice of this method, compared to other possible options (e.g., CATI or PAPI), was determined by the following factors: cost and time efficiency, convenience of place and time of response for respondents, a higher level of anonymity and freedom in providing responses, as well as the automation of data collection and results presentation. Among the limitations of the CAWI method, the following should be noted: the quality of the collected data, especially in relation to question

comprehension and respondent involvement, limited opportunities to include more complex open-ended questions, and the risk of a low response rate.

Participants were asked to complete a survey consisting of 16 questions addressing several thematic areas, including:

- the degree of familiarity with the Industry 5.0 concept,
- the organization's involvement in the transition toward Industry 5.0,
- the pace of Industry 5.0 adoption within the organization,
- the perceived benefits and improvements resulting from its implementation, and
- the main challenges faced throughout the transformation process.

Drawing upon the theoretical framework and initial empirical findings, a set of research hypotheses was developed.

H1. The phenomenon of Industry 5.0 is comparatively unknown among automotive firms operating in Poland.

H2. In automotive companies in Poland, the transition into I5.0 solutions remains in the initial phase of its development, and the process of implementing these solutions is rather slow and gradual.

H3. In the short term, the number of challenges facing automotive companies in Poland in connection with the evolution to Industry 5.0 outweighs the potential benefits to be achieved, and the essence of the issues requires a holistic and long-term approach.

Based on the collected data, the next subsection presents a graphical presentation of the survey results in two formats: relative (percentage) and absolute (taking into account the number of responses given in situations where respondents could select more than one answer to a given question).

Relevant commentary has been provided for every figure and table.

3.2. Results

Among the 111 respondents from the automotive sector, the majority were representatives of small and medium-sized enterprises (62% and 27%, respectively). Large companies accounted for 11% of respondents, and no micro-enterprises were recorded.

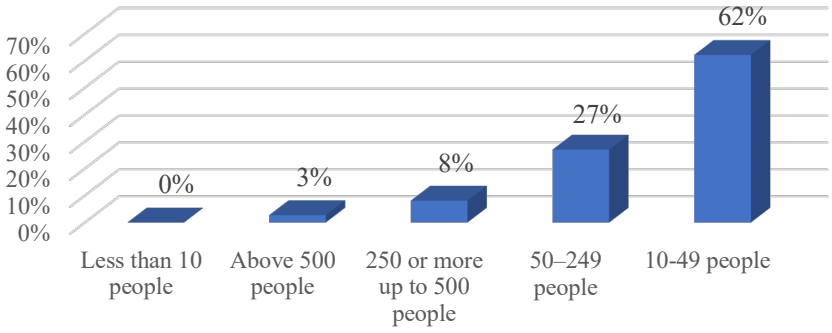

Fig. 1. Research sample structure by number of employees (%), n=111

Most of the surveyed companies (over 75%) had a low understanding of the I5.0 idea. One-fifth declared full knowledge of this phenomenon, while 7% had no awareness of this issue.

The process of active transformation towards I5.0 solutions has been implemented in only one in 10 companies. More than half declared that the transformation is in its initial stages, and almost one-third are considering taking appropriate action in the future. For 6% of respondents, the transition towards Industry 5.0 is not an important issue.

The evaluation of the rate at which Industry 5.0-related solutions are being implemented among the surveyed enterprises indicates a predominantly evolutionary approach, relying on gradual organizational adjustments. Nearly 40% of respondents characterized this pace as slow. Only 6% of respondents observed substantial changes rising from the rapid application of the Industry 5.0 idea.

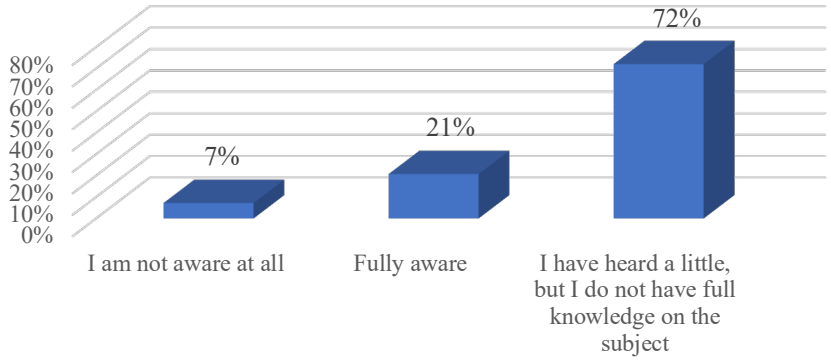

Fig. 2. How familiar are you with the conception of Industry 5.0? (%), n=111

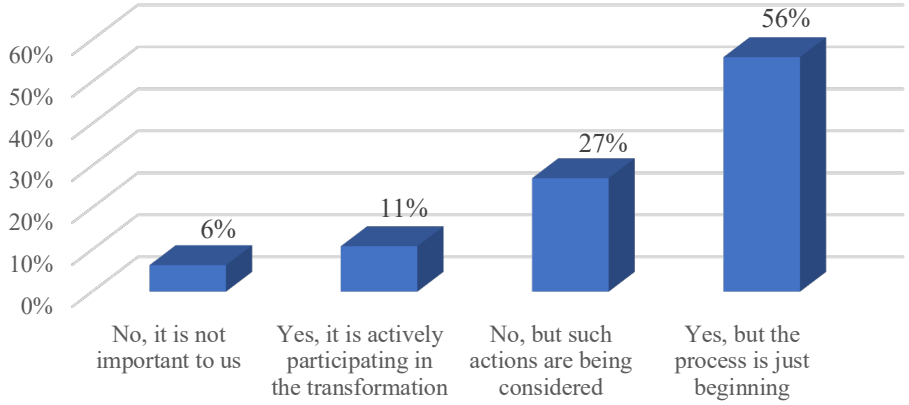

Fig. 3. Is the company you work for involved in the change to I5.0? (%), n=111

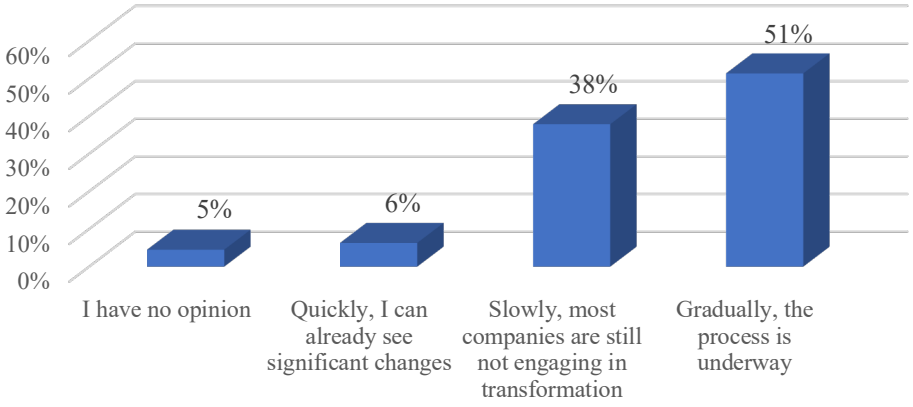

Fig. 4. How would you evaluate the rate at which I5.0-related initiatives are being implemented in your organization? (%), n=111

Among the benefits related to the implementation of Industry 5.0 solutions, companies indicated improving services or products quality, production flexibility tailored to fluctuating markets, increased productivity, and the optimization of operating costs.

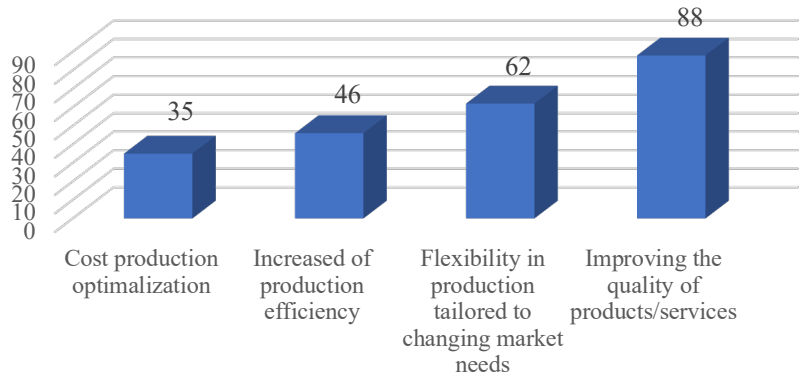

Fig. 5. What benefits or enhancements have resulted from the adoption of Industry 5.0 principles? (number of companies), n=111

Among the challenges associated with transforming business operations towards Industry 5.0, respondents most frequently indicated the need for staff training, acquiring new skills, guaranteeing the security of networks and data, the requirement for systems and infrastructure modernization, as well as the costs of implementing new technologies.

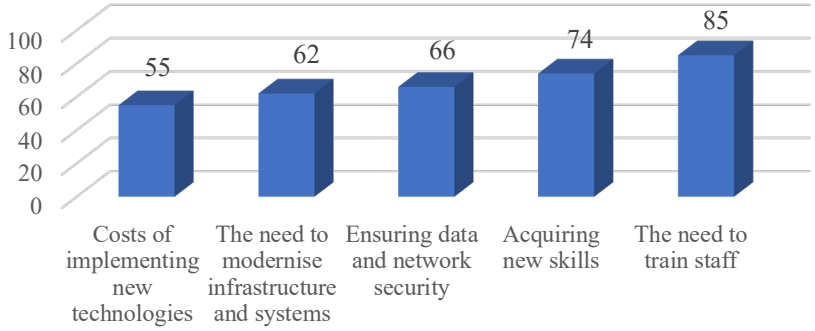

Fig. 6. What challenges arose during the transition to Industry 5.0 in your organization? (number of companies), n=111

Most respondents underlined the need for employees to develop new skills in the framework of I5.0. At the same time, relatively few organizations anticipate that the paradigm will generate new professions, while 9% of respondents saw no tangible implications for the labor market.

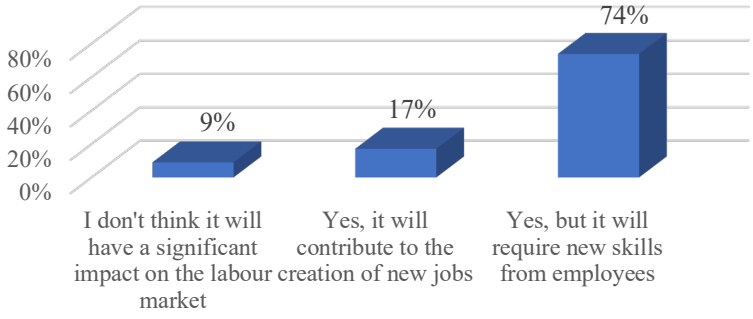

Fig. 7. Does Industry 5.0 generate new jobs or changes in the employees' qualifications? (%), n=111

The main challenges or threats to implementing I5.0 solutions from the viewpoint of sustainable social development, as indicated by the surveyed companies, are increasing social inequalities in access to education and employment and the risk of social exclusion for people without access to new technologies.

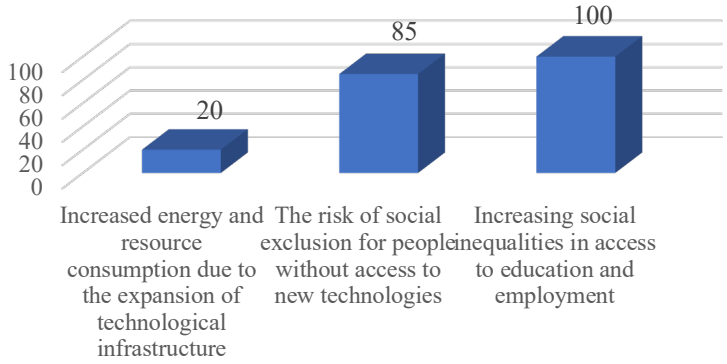

Fig. 8. What challenges or threats may arise in the activities of utilizing/applying I5.0 from the standpoint of sustainable societal development? (number of companies), n=111

Fig. 9 demonstrates that the prevailing view among the surveyed enterprises is that Industry 5.0 can effectively foster sustainable social development. The following activities are undertaken: investing in digital education and skills needed to use new technologies, ensuring equal access to new technologies for all social groups and monitoring the impact of technology on social inequalities, and taking corrective action.

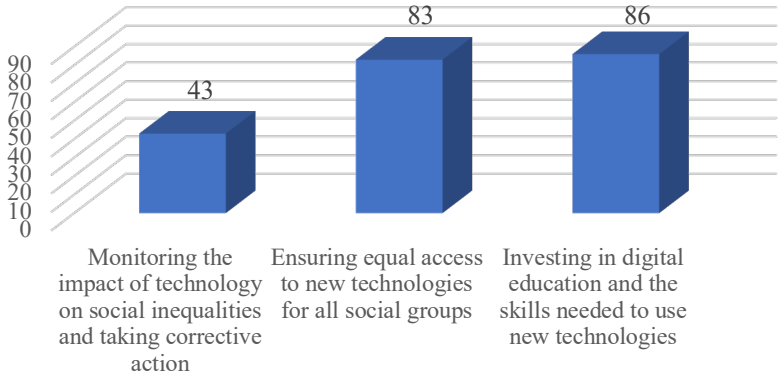

Fig. 9. What actions do you think should be taken to ensure that Industry 5.0 truly contributes to sustainable social development? (number of companies), n=111

For the majority of respondents, the transformations associated with Industry 5.0 are not perceived as critical to addressing societal challenges such as climate change or pandemics. Slightly more than one-third of companies, however, recognize the potential of this transformation to deliver innovative solutions for these issues.

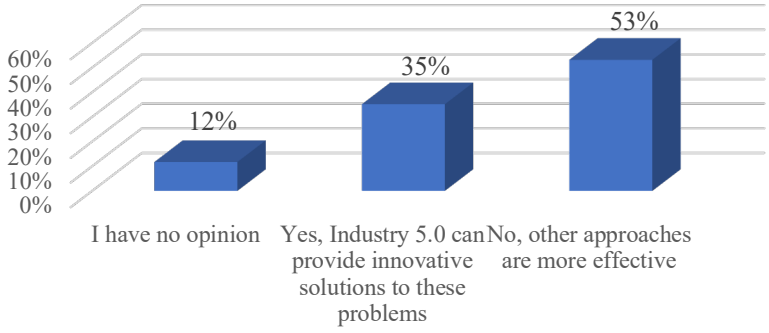

Fig. 10. Do you think that Industry 5.0 could be a key tool in tackling contemporary social challenges such as climate change or the pandemic? (%), n=111

The key technological solutions associated with I5.0 among the examined companies include cyber-physical production systems, AI, IoT, and blockchain.

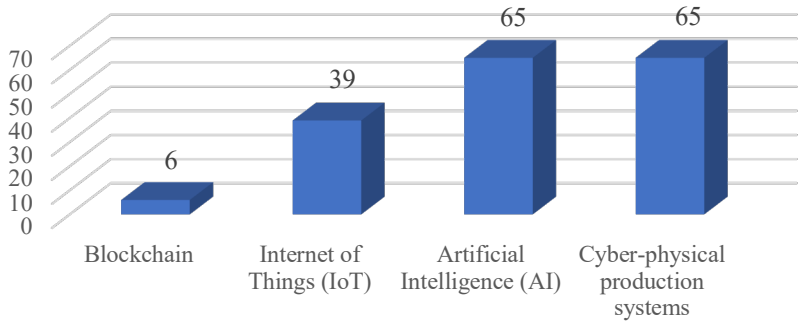

Fig. 11. Which of the following technologies are key in relation to the I5.0 paradigm? (number of companies), n=111

Only a small proportion of surveyed representatives of automotive sector companies recognized the issue of increased privacy and security of personal data risks in Industry 5.0. According to 16% of respondents, this challenge will materialize in a negative sense, whereas nearly three-quarters believe it will not become a significant problem, and one in 10 did not express concern about it.

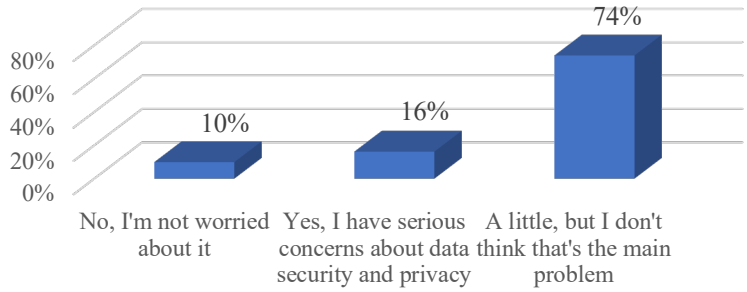

Fig. 12. Are you concerned that the development of Industry 5.0 could lead to greater risks to personal data security and privacy? (%), n=111

The security of networks and IT system, as well as threats related to cybercrime and hacking were identified by 83 companies as the most significant risks in the area of safety and privacy in the 5.0 era. 64 respondents indicated, in this context, the need to protect personal data and user privacy.

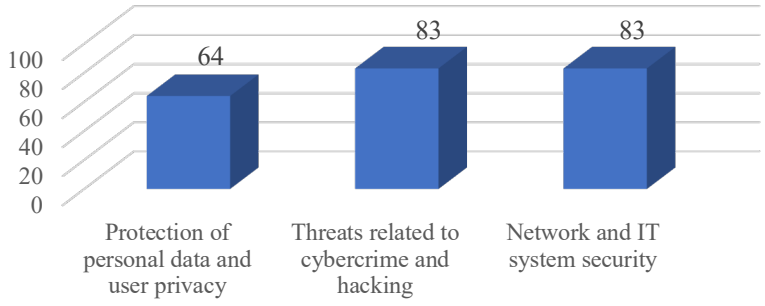

Fig. 13. In which areas do you see the greatest threats to safety and privacy in the I5.0 era? (number of companies), n=111

The key actions that should be taken to mitigate the risks associated with privacy and security in the phase of industrial transformation, defined as Industry 5.0, are, in the opinion of the respondents:

- education about security and privacy risks in an online environment,
- strengthening control and supervision of companies operating in the new technology sectors,

– establishing a more rigorous regulatory framework and enforcing stricter sanctions for breaches of data security and privacy compliance.

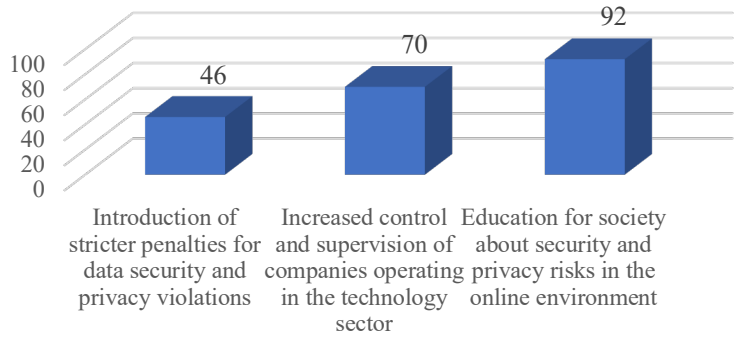

Fig. 14. What actions should be taken to protect security and privacy in the age of Industry 5.0? (number of companies), n=111

A very weak correlation was identified between company size and the level of readiness for Industry 5.0 ($r<0.2$). However, the correlation between the level of understanding of I5.0 solutions and the pace of their application proved to be moderate ($r>0.5$). A strong correlation was observed between the level of implementation of I5.0 and the degree of companies' transformation towards this phenomenon ($r=0.6$).

Table 1

Correlation coefficient value for selected question categories (n=111)

	Company size in terms of employment	How would you evaluate the rate at which I5.0-related initiatives are being implemented in your organization?
How familiar are you with the concept of Industry 5.0?	0.04	0.52
Is the company you work for involved in the transition to Industry 5.0?	0.10	0.67
How would you evaluate the rate at which I5.0-related initiatives are being implemented in your organization	0.14	1.00

3.3. Discussion and limitations

A comparison of the essence and solutions characterizing Industry 5.0 with the research findings from 111 Polish automotive enterprises indicates several areas for discussion.

First, it seems necessary to build awareness among companies in this sector of the ongoing transformations characterizing Industry 5.0, which serve as a mature "implementation compass" for the automotive sector and should be scaled to an operating standard to sustain automotive competitiveness. An essential role in the route of knowledge creation and dissemination in this area should be played by industry organizations and clusters (e.g., Silesia Automotive & Advanced Manufacturing Cluster; SA&AM). The human-centricity pillar is therefore confirmed in the presented research results, which are reflected in the following statements: the need for staff training, the acquisition of new skills, and the necessity for employees to develop new competencies.

Second, it can be assumed that as awareness and knowledge regarding the potentials of Industry 5.0 solutions increase, the pace of change in organizations operating in the automotive sector will accelerate. This is confirmed by the presented research findings, which highlight both the greatest benefits and the challenges associated with the application of I5.0 solutions.

Considering another dimension of Industry 5.0 − namely, sustainability − the surveyed automotive companies directed their focus towards digital education, the availability of adopting advanced

technologies, infrastructure, and energy, as well as other resources, together with the risks arising from their potentially unsustainable distribution. Only a relatively small proportion pointed to the positive role of this concept in the framework of mitigating the adverse change of climate.

Within the resilience pillar, the surveyed automotive companies recognized the importance of improving the quality of services or products, enabling production flexibility to adapt to changing markets, increasing efficiency, and optimizing operating costs. Achieving these objectives requires the use of modern technologies characteristic of Industry 5.0 (e.g., systems of cyber-physical production, artificial intelligence, IoT, and blockchain). In the context of organizational resilience related to risks concerning personal data protection and privacy, relatively few respondents identified such threats. Nevertheless, the vast majority of surveyed companies correctly identified the areas where significant risks may arise and indicated the necessary actions to appropriately mitigate them.

The authors identified a lack of comparable research in European countries. Primary research conducted among companies in the automotive sector, even at the scale of a single country, undoubtedly contributes to filling this research gap and represents a novel contribution. Considering studies conducted in related thematic areas, the following conclusions can be drawn:

- the significance of cognitive automation, integrating human-machine collaboration and circular production approaches to facilitate the broader adoption of I5.0 within the automotive sector − Romanian context using a three-round Delphi method [30],
- in the Lean Industry 5.0 context, the social dimensions draw attention to the critical interfaces between humans and technology and emphasize the importance of societal involvement during digital transformation initiatives − illustrated by a case study of one of the largest global suppliers to the automotive sector, with approximately 300 production units and a workforce of 150,000 [31].

The authors are fully aware of the limitations resulting from the sample size and the method of its selection. Nevertheless, there is a research gap in the literature related to primary research, beyond case studies, that addresses Industry 5.0 solutions for companies in the automotive sector. Moreover, the concept of Industry 5.0 remains relatively underexplored when examined in the context of particular economic sectors. Taking the above into account, the research presented in this article constitutes at least a partial attempt to fill this gap. As a next step, the authors intend to expand both the size and scope of the research sample towards achieving representativeness.

4. CONCLUSIONS

This research confirms the hypotheses. The concept of I5.0 is comparatively unknown among automotive firms operating in Poland. In automotive companies functioning in Poland, the transition to Industry 5.0 solutions is still in its early stages, and the process of implementing these solutions is rather slow and gradual. In the short term, the number of challenges facing automotive companies in Poland in connection with the transition to Industry 5.0 outweighs the potential benefits to be achieved, and the nature of the issues requires a holistic and long-term approach.

The article shows that the three dimensions of Industry 5.0 − human-centric operations, sustainability-by-design, resilience and data spaces—map directly to core value-chain issues in the automotive sector (demand volatility, skills shortages, the need for auditable data and end-to-end transparency).

In light of the above, it is recommended that the automotive sector operating in Poland be included in a dedicated support program addressing the requirements associated with the transition toward Industry 5.0. Its financing should be provided through the renegotiation of European Union programs − namely, the European Social Fund (ESF) and the European Regional Development Fund (ERDF) − and by reallocating structural funds toward training and protective actions, as well as investments supporting the restructuring of the automotive sector. The key components of this program should include re-skilling and up-skilling of employees, implementing flexible forms of employment, supporting companies in adapting to current environmental and regulatory requirements (including ESG, Carbon

Border Adjustment Mechanism (CBAM), and carbon footprint measurement), and establishing of a testing and innovation centre for autonomous and connected vehicles.

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