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Industry 5.0 Maturity Models: Towards Sustainable Development – Theoretical Review and Case Study in a Selected Company

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Abstract:

Purpose: *This article introduces Industry 5.0, explains the role of maturity models in digital transformation, and demonstrates how they support sustainable development and personalization in manufacturing. It distinguishes Industry 4.0 from 5.0, emphasizing sustainable practices and human-centric approaches. The article provides practical guidance on assessing organizational maturity and showcases successful implementations of Industry 5.0 principles, aiming to inspire companies to adopt innovative, efficient, and environmentally sustainable solutions. By integrating technology and human factors, organizations can enhance both efficiency and sustainability in production processes.*
Design/Methodology/Approach: *The study employs a mixed-methods approach, beginning with a literature review to establish a theoretical foundation and identify key frameworks. A quantitative maturity model tailored to Industry 5.0 is developed, leveraging existing models for validity. The empirical component involves a case study of Beiersdorf, using structured interviews and surveys with managers and technical experts involved in Industry 5.0 initiatives. This design provides qualitative insights and quantitative validation, ensuring a comprehensive analysis of Industry 5.0 maturity.*
Findings: *The research demonstrates that adopting Industry 5.0 principles fosters effective human-machine collaboration, enhances operational efficiency, and promotes sustainability. Maturity models offer a structured framework for organizations to evaluate their progress toward Industry 5.0 implementation. Companies adopting these principles can achieve sustainable development goals while delivering personalized, adaptive production processes aligned with market demands.*
Practical Implications: *The proposed maturity model enables organizations to systematically assess their readiness for Industry 5.0 adoption, supporting strategic decision-making and prioritization of initiatives that enhance collaboration, efficiency, and sustainability. It also offers policymakers and educators a foundation to integrate Industry 5.0 principles into workforce training programs, aligning skills development with technological and sustainability goals. Industries can leverage these insights to implement innovative, customer-centric, and sustainable production processes.*

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Originality/Value: *This research introduces a novel Industry 5.0 maturity model and demonstrates its application in a real-world context. By integrating qualitative and quantitative methods, the study provides a comprehensive perspective on the dimensions of Industry 5.0 maturity. It bridges gaps in existing research, linking human-machine collaboration to operational efficiency, sustainability, and personalized production, contributing to theoretical and practical advancements across diverse sectors.*

Keywords: *Industry 5.0, maturity models, sustainable development, personalization.*

JEL Codes: *D20, D22, 039.*

Paper Type: *Research article.*

1. Introduction

Industry 5.0, focusing on human-centricity, resilience, and sustainable development, emphasizes the integration of advanced technologies such as big data, artificial intelligence, IoT, and cobots in manufacturing (Bajic *et al.*, 2023). To support sustainable development and production personalization, maturity models of digital transformation play a crucial role.

These models help assess readiness for intelligent production deployment based on pillars such as sustainable development, resilience, and human-centricity, enabling a smooth transition to Industry 5.0 practices. Additionally, combining maturity models related to sustainable development with digitization aspects helps define strategic improvement measures for companies transitioning towards green and digitalized technologies, ultimately contributing to economic, environmental, and social sustainability in production operations.

2. Literature Review

The most recent milestone in this evolutionary path was Industry 4.0, which was defined by the integration of cyber-physical systems (Abbas and Ahmad, 2023, p. 20-21). Nowadays, society is on the threshold of another significant upheaval, Industry 5.0, in which the combination of human skill and technical innovation promises to reshape and reinvent the industrial landscape. This evolving paradigm, referred as "The Human -Tech Symbiosis," envisions a future in which human capabilities, capacities, creativity, and decision-making are fully utilized in tandem with modern technologies (Brangier and Adelé, 2014).

Industry 5.0 is concerned not only with increasing efficiency and production, but also with solving the serious global challenges of sustainability and environmental

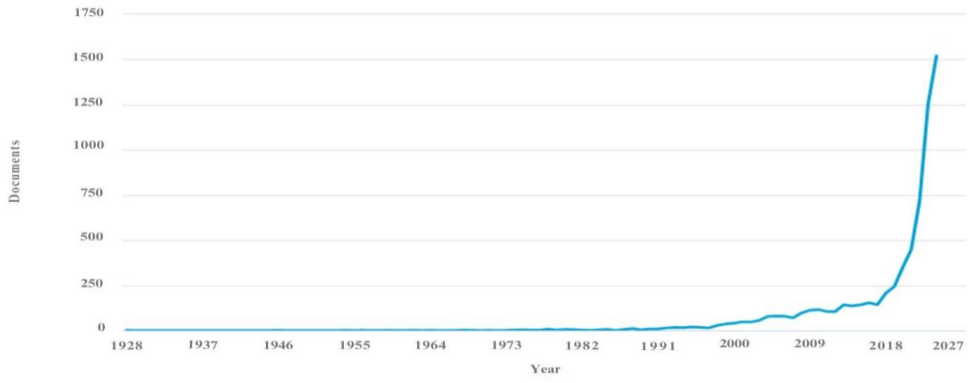
responsibility. Today, as an entry point to the era of Industry 5.0, it is critical to examine this paradigm's present maturity level, particularly in terms of human factor and sustainability (Verma and Pradesh, 2024, p. 91-102). The capacity to find a harmony between technology innovation and human interaction, all while decreasing the ecological imprint of industrial activities, is critical to the effective implementation of Industry 5.0. This paper aims to investigate and assess the current level of Industry 5.0, taking into account the interaction between human factors and sustainability (Ghobakhloo, Amoozad, Iranmanesh, and Jafari-Sadeghi, 2024).

To accomplish this goal, a deep-dive into the core components of Industry 5.0 is required to find out how human-machine cooperation, skill development, and creativity may be used to improve operational performance (Stoker, 2021, p. 3-8). Furthermore, since environmental concerns and corporate social responsibility have become major topics in the current industrial landscape, our study examines the integration of sustainable practices within Industry 5.0.

The Figures presented below provide insight into research trends and interest in the topic at hand in different regions of the world, and show which countries and authors are playing a key role in the development of these concepts. The evolution of the number of publications in recent years, especially after 2020, is described below, and differences in the dominant countries and research areas for each topic are analyzed.

Figure 1 below shows the number of publications related to the Industry 5.0 topic over the years. An initially low level of interest is noticeable, with few publications before 2000. A significant increase in the number of publications can be observed from 2018 onward, indicating the growing popularity of this topic in recent years. Peak growth can be seen in 2021-2023, when the number of publications doubled, suggesting a growing interest in the topic in the scientific community, and indicative of the intense development of Industry 5.0-related research.

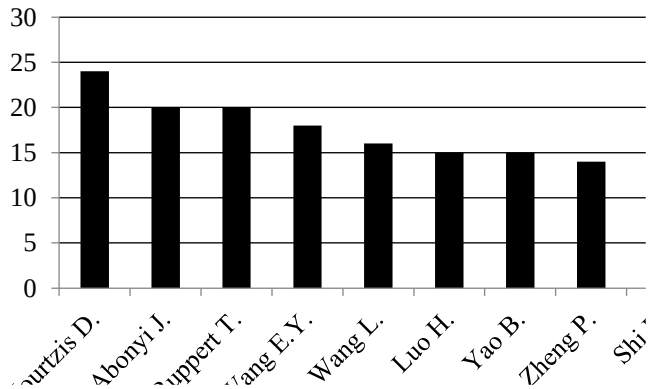
Figure 1. *Number of publications related to Industry 5.0 over the years*



Source: *Elaborated based on Scopus database.*

Figure 2 shows the authors who have published the most articles related to the Industry 5.0 topic, indicating some of the names of key researchers who have contributed most to the development of this field. The listed authors have made significant contributions to popularizing the topic internationally.

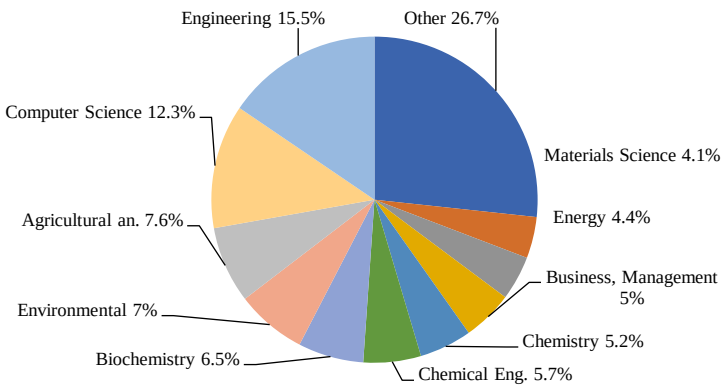
Figure 2. *Authors with the most articles related to Industry 5.0 topic*



Source: *Elaborated based on Scopus database.*

Figure 3 shows which scientific disciplines most often publish articles on Industry 5.0. The dominant sciences are engineering, computer science and management-related sciences. The figure 3 suggests that the topic of Industry 5.0 is interdisciplinary and includes both technical aspects, such as automation and artificial intelligence, among others, as well as organizational issues, related to management in industry.

Figure 3. *Scientific disciplines most often publish articles Industry 5.0*



Source: *Elaborated based on Scopus database.*

In the next step, publications containing a combination of Industry 5.0 and Industry 4.0 keywords were analyzed. In the analyzed publication database, the first mention meeting both criteria appeared only in 2018.

Modern meaning of "maturity" often relates to "state of being complete, perfect, or ready" (Simpson, Weiner and Oxford University Press, 1989, p.1158). Following this definition, maturity term implies a progression in the developing of a complex operational system to achieve set requirements. Overall, it can be considered as a tool that allows multistage analysis of serval specific dimensions to determine the level of complexity.

In the context of maturity model, they compose of sequentially sorted maturity levels for classification of object through descriptive assessment which is divided into few stages. Where the highest levels can be called state-of-the-art in terms of introduction of changes and achieving set goals. While on the other hand lower levels represent the absence or weak implementation of earlier listed dimensions. (Schumacher, Erol and Sihn, 2016, p. 162-163)

The phrase "Industry 5.0" generates as many as 6,772 results, indicating very high interest in this area in scientific literature and research. This indicates the rapid growth of the topic related to the new phase of industrial development, which focuses on integrating people and technology in a more sustainable way.

Combination of Industry 4.0 and Industry 5.0 - The combination of the phrases "Industry 4.0" and "Industry 5.0" yields 988 results, suggesting that researchers are examining these two approaches in a combined manner. It is possible that the research is focusing on the transition from technologies and processes specific to Industry 4.0 to the more humanistic and ecological perspective of Industry 5.0.

Maturity models in the context of Industry 5.0 - The phrase "maturity models Industry 5.0" generates only 10 results, which may mean that research on the application of maturity models in the context of Industry 5.0 is still in its early stages. This suggests the niche nature of this research area, which could be an interesting gap for further exploration.

Readiness models a Industry 5.0 - In contrast, the phrase "readiness models Industry 5.0" did not yield any results, which may indicate a lack of research or publications directly addressing readiness models in the context of Industry 5.0. This may also signal that this topic is just beginning to gain traction and is still awaiting more detailed study.

Provided data suggest that while Industry 5.0 is receiving growing interest in the literature, more specific issues such as maturity and readiness models in this context are relatively under-researched. Thus, there is great potential to further develop research on the adaptation and implementation of these models, which can

contribute to a better understanding of the practical aspects of implementing Industry 5.0 in enterprises.

Among the ten keyword links found between Industry 5.0 and maturity models, it was possible to find publications that address the relevant topics presented in the article. Researchers were able to access three works that found information on maturity levels in the context of industry development. In the article "Diagnostics of Opportunities - A Dialogue Tool for Addressing Digital Factory Maturity", the authors presented ten relevant maturity levels in a visualization shown in Figure 1.

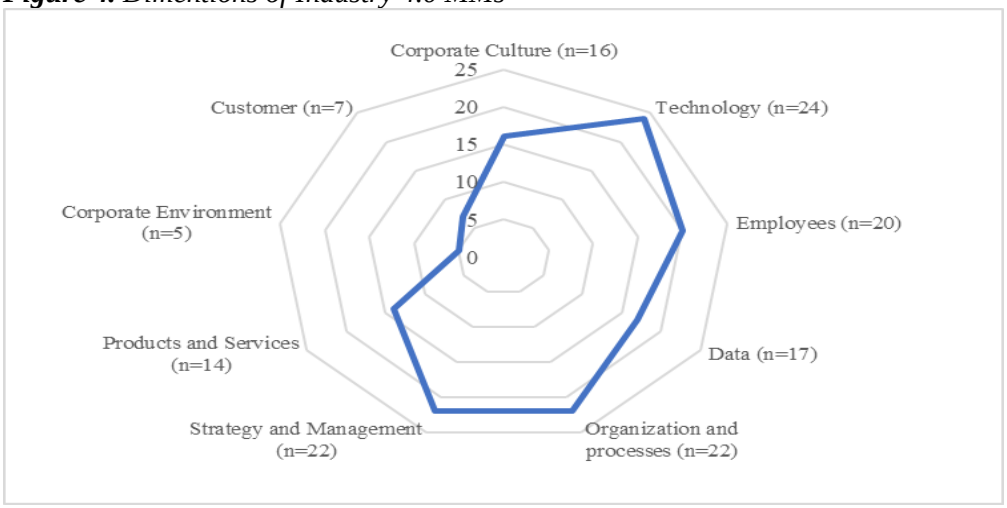
1. No knowledge- the company does not have sufficient experience of the technology in question,
2. Basic knowledge- the organization demonstrates fundamental concept and is not at the stage of implementation,
3. Proof of concept- research has been conducted and the technology has been tested,
4. Pilot initiated- the company has started a pilot project,
5. Pilot develop- the organization is in the development stage of the project,
6. Piloted, adds value- there are benefits to the company associated with implementation,
7. Vertical exp.- implementation of approach in company departments,
8. Horizontal exp.- implementation throughout the production process,
9. Optimized- the project is optimized,
10. Light house- the company becomes a model for new implementers in the field of Industry 5.0.

Figure 4 shows the current level, marked on the model in dark blue, and the expected level, circled in a more light, transparent color. In addition, the arrows on the model define the space between the As-is and To-be levels. This allows organizations to identify the directions of change and the areas that need to apply the most radical changes. A number of criteria related to four main groups of factors that influence were considered: autonomous manufacturing, smart governance and strategy, connected manufacturing, virtual manufacturing.

Publication "Maturity assessment for Industry 5.0: A review of existing maturity models" focuses on the comparison of two approaches: Industry 4.0 and Industry 5.0. Maturity levels are presented by identifying the main characteristics of the two attitudes to industry development.

Other key development factors are presented in Figure 4 and Figure 5 for Industry 4.0 and Industry 5.0, respectively. Based on this, it is possible to compare the relationships and characteristics of the two models, as well as to draw conclusions- how the essence and point of view of a particular type of industrial evolution is changing.

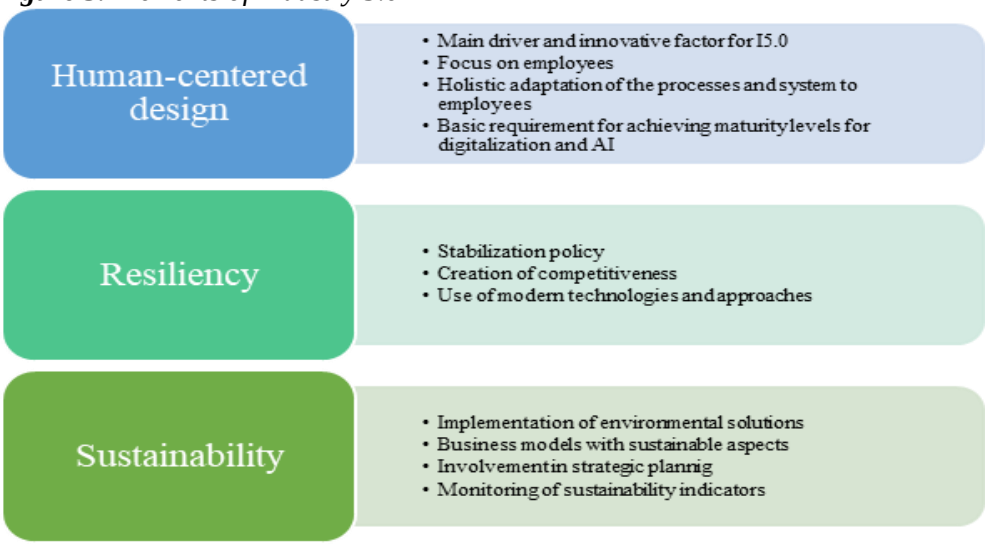
Figure 4. *Dimentions of Industry 4.0 MMs*



Source: *Own elaboration based on Hein-Pensel et al., 2023*

Industry 4.0 is oriented toward maximum support of technology as the most important factor in the graphics in Figure 4 Modernity is to be based on full digitization and automation of processes. A different approach, which is shown in Figure 5 indicates a new attitude, which is to put the human being at the center. Man is important and for him the technology is improved. The guiding thought is to support people, not to purely replace them with process automation. The main goal is to improve the integration between humans and technology, that is, to integrate activities so as to create a sustainable and resilient business model.

Figure 5. *Elements of Industry 5.0*



Source: *Own elaboration based on Hein-Pensel et al., 2023.*

Model visualized above indicates the key features of Industry 5.0, gathering them into groups to detail the maturity levels of Industry 5.0 development in an organization. Based on the publication, several distinct maturity levels of companies can be distinguished (Hein-Pensel *et al.*, 2023):

1. Digitization and autonomy- implementation of advanced digital technologies and process automation,
2. Human- centered design- creating a system of cooperation between humans and artificial intelligence,
3. Resilience- stabilizing solutions and developing system resistance to disruption,
4. Sustainability- adapting work to the requirements of sustainable development.

Industry 5.0, through the integration of disruptive technologies and human-machine collaboration, enables companies to drive sustainable innovation, develop nature-inclusive business models, and contribute to achieving Sustainable Development Goals (Kasinathan *et al.*, 2022).

Blockchain technology plays a pivotal role in linking Industry 5.0 with sustainable development by enhancing transparency, efficiency, and resilience in industrial systems. Its decentralized and secure framework supports sustainable practices such as circular economies, ethical supply chains, and renewable energy integration. By enabling traceability and accountability across industries, blockchain strengthens efforts to meet the Sustainable Development Goals, promoting a balance between economic growth, environmental protection, and social equity (Fraga-Lamas *et al.*, 2024)

Industry 5.0, envisioned as a human-centric and socio-environmentally sustainable evolution beyond Industry 4.0, is studied for its potential to deliver sustainability through functions such as circular intelligent products, intelligent automation, and renewable integration, with researchers developing models and roadmaps to maximize synergies among these functions and exploring enablers like Corporate Governance 5.0 (Ghobakhloo *et al.*, 2022).

Article “From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology” is a paper that collects existing information on maturity levels for Industry 5.0 and key characteristics of Industry 5.0 in the literature. The conclusions formed on the basis of the analysis of the article lead to the possibility of specifying the levels of maturity presented by the authors of the article. Among them we find levels such as:

- Implementation of Industry 4.0 technologies- they are the foundation for further development towards Industry 5.0 (creation of digital twins, introduction of IoT, advanced data analysis),

- Intelligent production systems- creation of solutions that have the ability to automatically adapt to the needs of the company (introduction of artificial intelligence, growing importance of IoT),
- Integrating human with technology- building a system to support the employee (collaborative robots, AR),
- Sustainability- developing a new technology work ethic and supporting the environment,
- Full integration of technology 5.0- stabilization and experience in all key features of Industry 5.0.

Based on the above description of the various maturity models, a table was created that gathers information on the approaches to implementing Industry 5.0 analyzed briefly and in simple form in Table 1.

Table 1. *Summary of the analyzed models*

Article	**Authors**	**Maturity Levels**	**Key Features**	**Year**	**Cited**
"Diagnostics of Opportunities - A Dialogue Tool for Addressing Digital Factory Maturity"	Ericson Öberg, A. Goncalves Machado, C. Stålberg, L.	1. No knowledge 2. Basic knowledge 3. Proof of concept 4. Pilot initiated 5. Pilot develop 6. Piloted, adds value 7. Vertical exp. 8. Horizontal exp. 9. Optimized 10. Light house	Article focuses on the developmental approach, from lack of knowledge toward a highly developed expert approach and becoming a model for other organizations to follow.	2024	0
"Maturity assessment for Industry 5.0: A review of existing maturity models"	Hein-Pensel, F., Winkler, H., Brückner, A., Wölke, M., Jabs, I., Mayan I.J., Kirschenbaum, A., Friedrich, J., Zinke-Wehlmann, Ch..	1. Digitization and autonomy 2. Human-centered design 3. Resilience 4. Sustainability	Publication puts the human being at the center, for whom a system of advanced technology is built to comprehensively support his activities and needs in his daily work.	2023	73
"From Industry 4.0 towards Industry 5.0: A Review and Analysis	Zizic, M.C. Mladineo, M. Gjeldum, N. Celent, L.	1. Implementation of Industry 4.0 technologies 2. Intelligent production systems	Work focuses on detailing the differences between Industry 4.0 and Industry 5.0. The purpose	2022	159

of Paradigm Shift for the People, Organization and Technology"		3. Integrating human with technology 4. Sustainability 5. Full integration of technology 5.0	of this article was to highlight the needed changes that must take effect in 4.0 organizations to meet the ethical and sustainability requirements of the Industry 5.0 model.		

Source: *Own elaboration.*

Based on a detailed analysis of existing maturity models, a novel framework for assessing Industry 5.0 maturity has been developed, addressing critical dimensions relevant to manufacturing companies in the context of the new industrial revolution. The creation of this model involved a systematic breakdown of existing frameworks to understand their structures and identify the dimensions they considered. Building on this foundation, the proposed model introduces a refined approach to evaluating organizational maturity comprehensively.

The first step in developing the assessment was the selection of critical dimensions that are essential for determining a company's maturity level. Each dimension was further divided into specific criteria, enabling a detailed evaluation of each aspect across all potential maturity levels. This structure allows for a thorough and nuanced assessment of an organization's readiness and adaptability.

The proposed dimensions are as follows:

Human Factor: Industry 5.0 emphasizes human-centric design, focusing on enhancing workers' capabilities through technology rather than replacing them. This dimension assesses whether employees are adequately prepared to collaborate with advanced technologies, ensuring effective and efficient integration.

Sustainability: With growing global emphasis on environmental responsibility, this dimension evaluates the extent to which a company's operations align with eco-friendly practices, reducing carbon footprints and waste.

Resilience: In a rapidly evolving industrial landscape, the ability to adapt, recover, and maintain operations during disruptions is paramount. This dimension examines a company's capacity to respond to challenges and maintain stability.

Smart Business Processes: The integration of advanced technologies such as AI, IoT, and robotics into business processes is essential for improving efficiency, reducing costs, and enhancing product quality. This dimension evaluates the degree of technological incorporation within corporate operations.

By analyzing these dimensions, the proposed model provides organizations with a clear framework to assess their current maturity level, identify strengths, and uncover areas for improvement. This comprehensive evaluation aligns with Industry 5.0 principles, equipping companies to remain competitive, innovative, and responsive to market demands while fostering sustainable and human-centric growth. Model is presented in Table 2..

Table 2. *Proposed maturity model*

Dimension	**Subdimension**	**Criteria (with multiplier)**
Human factor	Knowledge flow	Experts' insight (0.1)
		Knowledge/information transfer process (0.2)
	Human centricity	Human-machine collaboration (0.3)
		Human centric design (0.4)
Sustainability	-	Zero waste (0.3)
		Kaizen strategies (0.4)
		Raw material planning (0.3)
Resilience	-	Cyber security (0.4)
		Technology complexity (0.4)
		Digital twins (0.2)
Smart Business Processes	-	Process optimization (0.4)
		Data-analysis (0.6)

Source: *Own elaboration based on Usundag and Cevikcan, 2018, p 68-78.*

In the presented model a 5-level scale is introduced with each of them being clearly described to present an easy-to-follow methodology of assessing each individual. In the grading system the assessment starts from level 0 which indicates lack of any innovative approach to business as well as stagnation of enterprise on basic level without taking any steps towards development.

The highest level is fourth which represents complete maturity of enterprise in Industry 5.0 environment. The remaining levels are the in-between phase of transformation towards a more sustainable and human centric environment. To give better insight on the assessment model in table 3 is representing grading system. (Bajic, Morača and Rikalovic, 2023).

Table 3. *Proposed maturity evaluation scale*

Level	**Description**
Level 0: Absence (0 – 6.99)	None of Industry 5.0 elements are not present in company. Lack of data-analytics and optimization of technologies. Raw material planning on low level.

Level 1: Initial (7.00 – 10.99)	Enterprise is introducing basic data-analysis tools like spreadsheets, simple databases. Proceeding all operations within manual machinery, often basic one. Lack of waste and raw material planning with very limited research and development department. Additionally, knowledge transfer between workers is limited. There is a lack of formal organizational structure which prevents the introduction of knowledge transfer. Employees are trained to operate a few machines rather than focusing on one specific machine.
Level 2: Survival (11.00 – 14.99)	A mediocre set of requirements in enterprise is sustained to ensure proper functionally of business. Integration between machines and business systems is introduced in the early stages. Physical collection of training material is maintained with manuals. Raw material planning is aimed in the short horizon and first waste policies are implemented. The organizational structure is in basic form, often in line structure.
Level 3: Advanced (15.00- 18.00)	The company reached human-machine collaboration with the use of a special interface, which allows to monitor manufacturing in systems. The company maintains manuals and training material partially in cloud and rest in books or paper form. The organization operates on the basis of matrix structure with clear divisions to whom each employee should report. Material planning is performed in the long term to ensure availability of components despite lead times. Waste policies are being implemented into processes trying to reduce utilities, materials and energy costs.
Level 4: Maturity (18+)	Enterprise achieved full IT integration with machines. Employees are trained to operate one specific machinery. Collaboration between humans and machines is on an advanced level to ensure improvement of efficiency. The company maintains a cloud library with all manuals and training resources. Additionally, with specially trained staff to onboard new employees. Data is collected through a system and stored in a cloud, when it is also processed with a business intelligence system. Organizational structure is maintained on often high complexity including matrix structure and agile structure to optimize work on projects. Zero waste policies are base implemented in every department and with use of digital twins aims towards minimizing cost and potential fines for carbon footprint. Cybersecurity is maintained through the IT department with the goal of minimizing the risk of cyber-attack.

Source: *Own elaboration based on Usundag and Cevikcan, 2018, p 63-70.*

3. Research Methodology

The empirical part of the study involves a case study conducted at Beiersdorf. Data

collection methods include structured interviews and surveys, designed to gather both qualitative and quantitative insights. The research sample consists of key stakeholders within the company, such as managers and technical experts, who are directly involved in Industry 5.0-related initiatives.

The structured interviews are utilized to collect qualitative data, providing an in-depth understanding of the organization's current maturity level and its alignment with Industry 5.0 principles. The surveys, on the other hand, gather quantitative data to validate the proposed maturity model and measure specific dimensions of Industry 5.0 maturity.

This dual-method approach ensures a comprehensive evaluation, enabling the study to analyze Beiersdorf's maturity status while testing the practical application and accuracy of the proposed model. The findings from this empirical analysis are instrumental in illustrating the model's effectiveness and its potential applicability across different organizational settings.

4. Research Results

Beiersdorf manufacturing Poznań (BMP) is a subsidiary of Beiersdorf. This is a large, innovative factory which is undergoing massive renovation which aims to increase efficiency and volumes produced there)

Research incorporated a series of structured interviews with domain experts to refine and validate our maturity assessment model within the framework of Industry 5.0. The first interview engaged a technology expert and focused on seven strategically curated questions, which addressed critical aspects of technological integration and the effective application of the model.

The second interview, conducted with a sustainability expert, also centered on seven carefully prepared questions and provided valuable insights into the essential role of sustainability within both the maturity model and the broader Industry 5.0 concept.

The discussions uncovered significant findings about how enterprises manage the implementation of new technologies, shedding light on the processes, challenges, and success factors that influence their adoption. Additionally, the interviews emphasized the importance of integrating sustainability principles into organizational strategies, highlighting their alignment with Industry 5.0 objectives and showcasing the intricate balance between innovation and environmental responsibility.

These expert perspectives offered constructive feedback on our maturity model, enabling us to identify potential gaps and implement refinements that enhance its practical application. This research advances the discourse on the interplay between

technology, sustainability, and maturity assessment, contributing valuable insights for academic and industrial applications in the evolving landscape of Industry 5.0.

The final stage of data collection involved distributing a survey among all employees of the company, targeting a group of approximately 220 individuals. The survey aimed to capture diverse perspectives and gather comprehensive insights into employee experiences and attitudes towards key aspects of the organization's practices.

With a statistically significant response rate, the survey provided a robust dataset for analysis, complementing the qualitative findings from the expert interviews. This approach ensured a holistic understanding of organizational dynamics, aligning with methodologies discussed in recent studies on environmental frameworksy. Final results are calculated in Table 4.

Table 4. *Assessment of maturity dimensions*

Dimension	**Subdimension**	**Criteria (with multiplier)**	**Grade (1-5)**	**Points***	**Points accumulated in division**
Human factor	Knowledge flow	Experts' insight (0,1)	4	0.4	4.00
		Knowledge/information transfer process (0,2)	4	0.8	
	Human centricity	Human-machine collaboration (0,3)	4	1.2	
		Human centric design (0,4)	4	1.6	
Sustainability	-	Zero waste (0,3)	4	1.2	4.10
		Kaizen strategies (0,4)	5	2.0	
		Raw material planning (0,3)	3	0.9	
Resilience	-	Cyber security (0,4)	5	2.0	5.00
		Technology complexity (0,4)	5	2.0	
		Digital twins (0,2)	5	0.6	
Smart Business Processes	-	Process optimization (0,4)	4	1.6	4.00
		Data-analysis (0,6)	4	2.4	

Note: **Grade times multiplier.*
Source: *based on Usundag and Cevikcan, 2018, p 68-78. and use of Experts insight and their assessment.*

The maturity assessment model evaluates Industry 5.0 maturity across four key dimensions: Human Factor, Sustainability, Resilience, and Smart Business Processes. Each dimension is further divided into specific criteria, with a corresponding scoring system based on surveys, interviews, and additional qualitative insights. Below, the reasoning behind the scoring of each criterion is

detailed.

Human Factor (4.00/5.00) - This dimension emphasizes human-centric principles in Industry 5.0, such as knowledge transfer and the integration of human-machine collaboration.
Knowledge Flow (0.1). Survey data revealed an average score of 3.92, derived from responses as follows: three participants rated this criterion at 5, six at 4, and four at 3, with one respondent expressing no opinion. The rounded score is 4.
Knowledge/Information Transfer Process (0.2):
Responses showed one participant rating this at 5, seven at 4, five at 3, and one at 2, resulting in an average score of 3.57. This was rounded to 4.
Human-Centricity:
Human-Machine Collaboration (0.3): Nine respondents reported that machines assist them in their tasks (score 5), while two indicated they assist the machines (score 1). Excluding three neutral responses, the average score of 4.27 was rounded to 4.
Human-Centric Design (0.4): Feedback from key interviews highlighted structured approaches to ergonomics, such as workplace analysis and operational training. Survey responses averaged 3.78, rounding the score to 4.

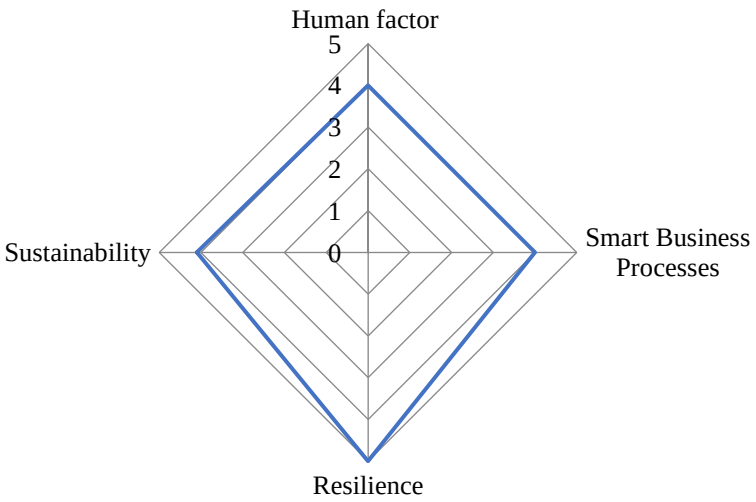
Sustainability (4.10/5.00) - This dimension measures the organization's commitment to eco-friendly operations and waste management.
Zero Waste (0.3): Based on an interview with Ms. Gabriela P., it was confirmed that 60–70% of the company's waste is recyclable and sold to third parties. This aligns with the criteria for a score of 4.
Kaizen Strategies (0.4): Survey results showed unanimous familiarity with Kaizen methodologies, meriting the maximum score of 5.
Raw Material Planning (0.3): Insights from interviews and informal discussions indicated practices aligning with the boundaries of a score of 3.

Resilience (5.00/5.00) - Resilience reflects the organization's ability to adapt to disruptions and leverage advanced technologies.
Cybersecurity (0.4): Beiersdorf's robust Security Operation Center has prevented major data breaches since 2007, justifying a maximum score of 5.
Technology Complexity (0.4): Interviews and survey results collectively demonstrated a high level of technological sophistication, earning a score of 5.
Digital Twins (0.2): The organization uses digital twin technology during the design phase to simulate operational scenarios and employee interactions. This extensive utilization also earned a score of 5.

Smart Business Processes (4.00/5.00) - This dimension evaluates the integration of advanced technologies into corporate processes.
Process Optimization (0.4): While Beiersdorf excels in most optimization practices, the absence of AI technology implementation—confirmed in interviews—limited the score to 4.

Data Analysis (0.6): The organization demonstrated proficiency in two out of three advanced data analysis capabilities. Although survey and interview findings align with a score of 4, gaps in advanced analytics prevented achieving the maximum score.

Figure 7. *Beiersdorf maturity evaluation (split of points between dimensions)*



Source: *Own elaboration based on survey results*

The lowest grade of Beiersdorf which appeared only one time was "3" in the subdivision of "Sustainability" dimension named "Raw material planning". The reason for this might be the volume of goods manufactured on a weekly basis. Greater volumes have trend to fluctuate and even small changes in their number have a massive impact on raw material planning.
The sum of all points collected by Beiersdorf is 17,10, which places them in Level 3 of prepared maturity model. According to a prepared description of this level, it could be assumed that Beiersdorf achieved human-machine collaboration by using a customized interface that allows it to monitor production in systems. They keep manuals and training materials partially in the cloud and the rest in books or paper form.

The organization is structured as a matrix, with defined divisions to which each person reports. Long-term material planning ensures component availability despite lead times. Waste policies are being introduced to decrease utility, material, and energy expenses. This statement is mostly accurate description of current state within this company, yet it is possible to call a success on accuracy of the multipliers of individual subdivisions and collected data from both, anonymous survey among associates and conclusions and information from subject matter experts.

Despite the high maturity level, Beiersdorf is lacking moves in certain dimensions that could positively influence the further operation enterprise take. To visualize the potential steps to develop according to Industry 5.0 principles a roadmap was created. It consists of 2 phases: Short-term improvements which might be achieved within a scope of one or two years, without many difficulties only with the use of resources that are within the company.

Long-term improvements are ones into which Beiersdorf would have to put more time and resources to achieve satisfying results. In addition to that all of the actions to be taken would require over 2 years to implement them functionally in day-to-day business. The proposed roadmap outlines actions to enhance Beiersdorf's Industry 5.0 maturity. In resilience, the focus is on automating production lines and improving machine interfaces to reduce manual operations and downtime.

For smart business processes, the introduction of AI tools for real-time data analysis and blockchain for secure data management is suggested, alongside leveraging Big Data for better resource allocation. Sustainability efforts include increasing the use of recyclable materials, constructing a sewage treatment plant, and installing solar panels to reduce costs and improve environmental impact.

5. Discusion

Presentation of the obtained results is specified below:

1. Maturity Level of Beiersdorf: The total score of 17.10 places Beiersdorf in Level 3 of the maturity model for Industry 5.0.
   Characteristics of Level 3 include:
- Human-Machine Collaboration: Use of customized interfaces to monitor production systems.
- Knowledge Management**:** Manuals and training materials are partially stored in the cloud and partially in physical formats.
- Organizational Structure: Matrix organization with defined reporting divisions.
- Material Planning**:** Long-term planning ensures component availability despite lead times.
- Waste Management: Policies are in place to reduce utility, material, and energy costs.

2. Dimension Grades**:** The majority of dimensions received a grade of 4**,** reflecting Beiersdorf'**s** innovative approach.
   A single grade of 3 was observed in the Sustainability dimension, specifically in the subdivision of Raw Material Planning. Potential reason: Weekly production volume fluctuations significantly impact raw material planning.
3. Key Areas for Development**:**

- Resilience**:** Automating production lines and improving machine interfaces.
- Smart Business Processes**:** Introducing AI tools for real-time data analysis, implementing blockchain for secure data tracking, and optimizing Big Data usage.
- Sustainability: Increasing the use of recyclable materials, building a sewage treatment plant, and installing solar panels.
- Human Factors: Improving onboarding processes and providing employee training in new technologies.

6. Limitation of the Study

This study faced several constraints that may have influenced the results, interpretation, and generalizability of its conclusions. First, the relative recency of the Industry 5.0 concept posed a significant challenge for research. As an emerging paradigm, Industry 5.0 is still in its developmental stage, with gaps and potential threats that are not yet fully understood or documented. This lack of established knowledge required navigating uncharted territory, which may have affected the depth and breadth of the analysis.

Additionally, the absence of existing maturity models specifically tailored to Industry 5.0 presented both a limitation and an opportunity. While the lack of reference frameworks made the process of designing a maturity model more complex, it also allowed this study to make a pioneering contribution to the scientific discourse by addressing this gap. The novelty of the approach, however, introduces inherent uncertainties regarding its broader applicability until further validation is undertaken in different organizational contexts.
Finally, the collaboration with Beiersdorf, although valuable, was occasionally hindered by corporate bureaucracy. Procedural and organizational constraints within the company may have restricted the data collection process or delayed access to critical information. These factors could have impacted the comprehensiveness of the findings and may require consideration when interpreting the results.

These limitations underscore the need for continued research to validate and expand upon the findings presented in this study, particularly as the Industry 5.0 concept evolves and matures. Future investigations should aim to refine the proposed frameworks and explore their application across diverse industries and organizational settings.

7. Conclusions

Maturity models play a pivotal role in guiding organizations through digital transformations, enabling them to assess their current standing and identify areas for enhancement. By implementing Industry 5.0 principles, companies can not only achieve sustainable development goals but also delve deeper into personalized production processes. This shift towards more eco-friendly and customized

manufacturing practices can yield benefits such as improved energy efficiency, reduced environmental footprint, and the delivery of tailored products to clientele.

Strategies pivoting around sustainable development and personalization are poised to become integral components of forward-thinking business models in the dynamic corporate landscape. In essence, the article highlights how the adoption of Industry 5.0 and maturity models can empower companies towards heightened operational efficiency, sustainable growth, and personalized manufacturing practices, positioning them favorably amidst evolving market demands and technological advancements.

The purpose of this research was to develop a maturity model as a tool for assessing the maturity of manufacturing company. This prepared model should help in the implementation of Industry 5.0 concept within companies, who are not fully convinced of their current state and readiness for implementation by showing areas which urgently need improvement and marking so called “process gaps”. The model was developed through a multi-methodological approach, which included an evaluation of the literature, conceptual modeling, and a combination of quantitative and qualitative techniques for empirical validation.

The most edifying part was the construction of maturity assessment model, so core of whole thesis, with not many existing models for Industry 5.0, possibility of contribution in development of scientific part of this issue has been inspiring.

The model proposed in this paper is an outcome of the most important aspects of models for Industry 4.0 and 5.0 to be as accessible and understandable, yet accurate as it could be. The second goal was to prepare a specific model, more likely to fit manufacturing companies, well known for their rapid and changeable environment, in which you must react as quickly as possible to stay relevant and valid on the market. The practical part was based on collaboration with Beiersdorf, which was eventful. The corporate bureaucracy has been delaying conduction of interviews and surveys, yet after all barriers had been overcome.

The model itself can be divided into two parts: The first consisting of dimensions crucial for Industry 5.0. In this particular one those are: Human Factor, Sustainability, resilience and Samrt Business Processing. Every dimension has been subdivided into criteria which are graded according to prepared rules and regulations, with multipliers denoting the importance of particular criteria in matter of its dimension and model in whole. Every dimension can get a maximum of 5 points. The total maximum of points to be collected is 20 – the perfect score in this model.

Every level has its own specification, which can and should precisely depict the current state of enterprise. This model can be particularly useful for small and medium businesses, which have ambitions for development and technological

expansion. Even with limited resources and time, this model can be utilized and precisely assess the current state of the company and underline the areas with room for improvement. Moreover, its capabilities are not limited to showing opportunities or weaknesses, but also raise awareness of strengths and best practices in processing.

The possibilities for utilization of settled maturity model are wide and most of the manufacturing companies might benefit from additional information and insight into factors which has become more important nowadays such as sustainability or noticing of significance of human factor in manufacturing processing.

This study highlights several important areas for further exploration within the context of Industry 5.0, particularly concerning organizational maturity and readiness. While the proposed maturity model provides a solid framework for assessing alignment with Industry 5.0 principles, its application remains a relatively uncharted domain, offering substantial opportunities for academic inquiry and practical innovation.

One promising direction for future research lies in the broader application and validation of Industry 5.0 maturity models across various sectors and regions. Investigating how different industries and organizational contexts influence maturity levels can provide valuable insights into the unique challenges and opportunities associated with adopting Industry 5.0 principles.

Additionally, comparative studies could shed light on sector-specific trends and foster the development of tailored strategies for technological and organizational transformation. Another critical avenue for future research involves the development of readiness models for Industry 5.0. While maturity models assess an organization's current state, readiness models could focus on identifying and prioritizing the actions necessary to achieve Industry 5.0 goals.

Further research could also explore the integration of advanced metrics and technologies into maturity and readiness assessments. The incorporation of AI-driven analytics, for instance, could enhance the precision of evaluations and enable real-time monitoring of progress. Such advancements would not only improve the robustness of assessment tools but also provide dynamic insights into the evolving landscape of Industry 5.0.

Additionally, the human-centric nature of Industry 5.0 warrants deeper investigation into the interaction between technology and workforce dynamics. Future studies could examine how organizational cultures, employee training programs, and ergonomic design influence the successful integration of Industry 5.0 technologies.

Understanding these relationships could help organizations foster environments that balance technological innovation with human well-being and adaptability.

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