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**Maturity Model for Implementing Industry 4.0
concept in a manufacturing company.**

Summary of doctoral dissertation

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With the dynamic development of information and communication technologies, enterprises from various economic sectors are trying to use the potential of digitization and automation to improve their processes, increase efficiency, reduce costs and achieve a competitive advantage on the market. To achieve success and remain competitive, companies must not only adapt to these changes, but also anticipate them and respond appropriately to new opportunities and challenges. In this context, maturity modelling has become extremely important for organizations operating in various sectors and fields.

The maturity model is an analytical tool that is used to assess and measure the level of advancement of an organization in specific areas, such as management, technologies, innovations or business processes. The maturity model enables organizations to understand their current situation and identify areas that require improvement or investment. Additionally, maturity models allow organizations to compare themselves with other entities operating in the industry, define development goals and strategies, and monitor progress and results. The maturity model is an effective tool that enables organizations to assess and measure the level of advancement in specific areas of their operations. Thanks to this, organizations can identify gaps and weak points, develop development strategies and take actions to increase their effectiveness.

At the same time, many manufacturing companies are currently introducing various tools useful in implementing the Industry 4.0 concept. This concept is currently one of the best known and most widely used in practice, especially in manufacturing enterprises. Industry 4.0, semantically linked to the fourth industrial revolution, introduces a new era of production that is based on the combination of digital technologies, automation and data analysis. The introduction of the Industry 4.0 concept involves numerous challenges for organizations that want to adapt to the new industrial reality and use its potential. In this context, the maturity model can be a valuable tool that enables organizations to assess and improve their readiness to implement the Industry 4.0 concept.

The maturity model for implementing the Industry 4.0 concept is a framework that describes the gradual development of an organization in the context of adopting and implementing advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, data analytics and cloud computing. This model identifies the different maturity levels that organizations can achieve in technology adoption and defines key metrics and evaluation criteria for each level.

In many publications on production management, enterprise management and production engineering, the authors describe the idea of Industry 4.0 as one of the possibilities of achieving economic benefits and advantages. The basic motive encouraging managers to implement the Industry 4.0 concept is the belief in the overall increase in the efficiency of production means thanks to a high level of automation. Another benefit of introducing this concept is process optimization thanks to better transparency of resource management. The third premise is to reduce the costs of producing individual units, comparable to large-scale production, and to increase productivity and flexible production adjustment. The fourth premise is to shorten the production time of products and the waiting time for order fulfillment by increasing the availability of machines and devices.¹.

The term Industry 4.0 is growing in popularity in the literature on the subject (Figure No. 1). There are also different names for the concept of Industry 4.0, e.g.: Smart Manufacturing Leadership Coalition, Industrial Internet in the United States, Made in China 2025 in China and Industrial Value Chain Initiative in Japan². However, the term Industry 4.0 is the most popular and most common.

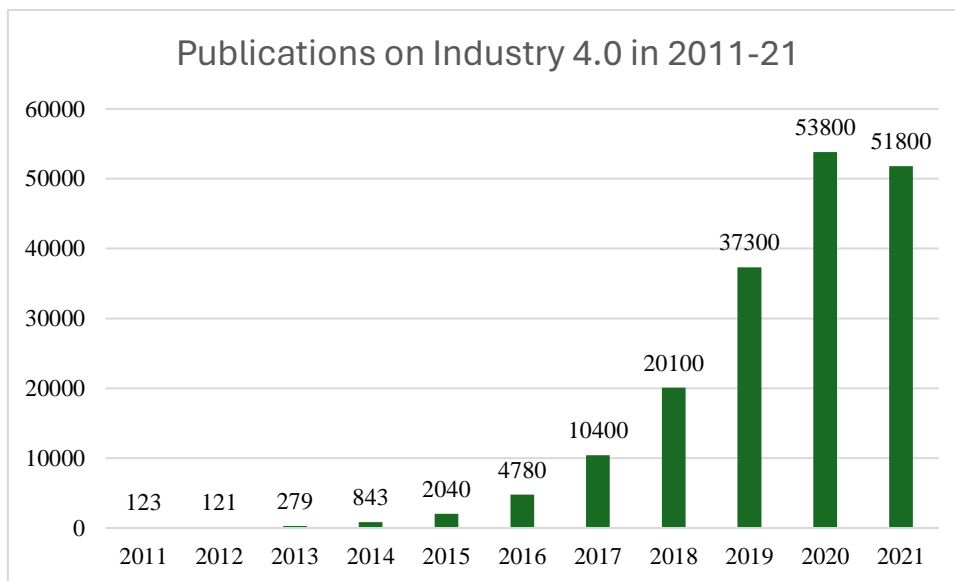


Figure 1. Publications on Industry 4.0 in 2011-21.

Source: own work based on Google Scholar.

Despite the growing interest in the Industry 4.0 concept, it seems to still pose a significant challenge for many organizations in terms of its effective implementation. Research on the

¹ K. Kiraga, *Przemysł 4.0, 4. rewolucja przemysłowa wg Festo*, „Logistyka” 12/2016, s. 1603–1605.

² D. Heilmann et al., *Industrie 4.0 Im Internationalen Vergleich*, 2016.

effectiveness of implementing the Industry 4.0 concept in manufacturing companies presents the following results:

- More than 1/3 of respondents admit that they are familiar with this concept, but do not know what it is in practice;
- The vast majority of enterprises agree with the statement that implementing the Industry 4.0 concept allows the company to increase its competitiveness in the industry;
- More than half of the surveyed people in the enterprise admit that their companies understand the benefits of implementing the Industry 4.0 concept, but do not know where to start the process of introducing changes and what technologies to choose for implementation;
- The most frequently mentioned areas in which companies have already implemented Industry 4.0 solutions are production, storage and transport;
- The greatest challenges on the way to implementing the Industry 4.0 concept in a company are considered by respondents to be the difficulty in convincing decision-makers to invest in innovations and the problem of specifying the implementation conditions in a way that would provide for a clear period of return on investment;
- More than half of the surveyed people in the enterprise claim that the lack of funds for digital transformation initiatives significantly hampers the functioning of the organization;
- More than half of people surveyed in the enterprise say that their business units do not have a strategic plan that outlines how digital technologies can provide a competitive advantage;
- Half of the people surveyed in the enterprise claim that their organization is not good at implementing digital transformation initiatives³.

In turn, in the report entitled Digital Poland developed by McKinsey showed a significantly lower degree of digitalization in Poland compared to the United States and Western Europe. Poland's "digitalization index" is 34% lower than that of Western Europe. Additionally, in the same study, McKinsey indicates that the "digitalization gap" in relation to Western Europe in

³ Deloitte, *Przemysł 4.0 w Polsce – rewolucja czy ewolucja?* (raport), <https://www2.deloitte.com/pl/pl/pages/technology/articles/raport-przemysl-4-0-rewolucja-czy-ewolucja.html>, dostęp: 27.05.2023.

economic sectors such as "advanced industrial production" and "simple industrial production" are 45 and 78%, respectively⁴.

These studies indicate that the vast majority of companies using the Industry 4.0 concept are unable to fully achieve the business goals set before implementation. This means that although theoretical knowledge of the Industry 4.0 concept is already extensive, there is still a need for research on solutions supporting its effective implementation. Additionally, there is no clear procedure for examining the maturity of an organization that would enable effective checking of the level of implementation of the Industry 4.0 concept. The implementation of new production models results in greater production predictability and also organizational changes, connected with high investment costs, including modern technologies and production processes. Manufacturing companies are not always ready to implement innovations. In this context, organizational maturity means the process of continuous improvement of skills and processes in order to increase their effectiveness over a given period of time⁵.

As a result of the research of literature related to the implementation of the Industry 4.0 concept, it was found that most of the publications concern technological aspects and benefits for the organization. Only a few authors, such as A. Schumacher and German industry organizations, e.g. the German Ministry of Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie - BMWi), the German Association of Mechanical Engineers and Technicians (Verein Deutscher Ingenieure - VDI) or the German Association of the Chemical Industry (Verband der Chemischen Industrie - VCI) focused on the issue of enterprises' maturity to implement these solutions in enterprises. Additionally, it is stated that there is a lack of a model supporting the implementation of the Industry 4.0 concept and that the existing models are largely general and do not constitute a holistic approach to the implementation of the Industry 4.0 concept. There is no detailed methodology for assessing individual model criteria. A review of the available literature on the subject, domestic and foreign, shows that the issue of creating a comprehensive maturity model useful for implementing the Industry 4.0 concept in manufacturing enterprises is an issue that is poorly recognized in practice.

There are general recommendations, but there is no detailed methodology for dealing with this issue in manufacturing enterprises. Therefore, there is a cognitive and methodological gap that will be filled by solving the research problem formulated below. It was described as the

⁴ McKinsey, *Cyfrowa Polska* (raport), McKinsey, Warszawa 2016.

⁵ M. Hammer, *The Process Audit*, „Harvard Business Review”, no. 85, no. 4. (2007).

lack of a structured and comprehensive model that supports the process of assessing and implementing the Industry 4.0 concept in manufacturing enterprises. The search for a solution to the problem formulated above was supported by the following research questions.

1. What is the basic architecture of the model, what areas of the model should be included, and how to determine the maturity levels of the model?
2. What are the guidelines for using a model determining the degree of preparation of an organization to implement the "Industry 4.0" concept?
3. What recommendations for management staff can be helpful in implementing the Industry 4.0 concept?

The objectives of the work, research methodology and the structure of the doctoral dissertation were subordinated to the analysis and solution of the proposed research problem.

The main goal of the work is to develop a maturity model for the implementation of the Industry 4.0 concept, which will potentially enable orderly and comprehensive implementation of this concept in manufacturing enterprises, as well as to propose a methodology for implementing such a concept, supported by appropriate recommendations.

The cognitive aim of the work is to isolate, compare and analyze organizational maturity models presented in the literature and used in the practice of the studied enterprises in the process of implementation and functioning of the Industry 4.0 concept.

The methodological goal is to develop a research methodology, conduct empirical research using the developed methodology and analyze the limitations and possibilities of using the model.

The pragmatic goal is to present practical recommendations regarding the implementation and functioning of the Industry 4.0 concept in manufacturing enterprises. As a result of such a case study, these companies will be able to implement this concept effectively and efficiently, which will increase their competitiveness and efficiency.

In order to solve the formulated research problem and achieve the planned goals, extensive literature studies and empirical research were carried out. For the purposes of conducting empirical research, it was decided to choose case study as a qualitative research method. This choice resulted primarily from the essence of the research problem (defined in the form of research questions), the specificity of the research subject, i.e. a production company, and the

focus on an important and contemporary phenomenon as a subject of multidimensional research. The empirical research was preceded by a review of the literature on the subject, carried out in order to diagnose the state of knowledge on the development of maturity models useful for implementing the Industry 4.0 concept. The empirical research was conducted in accordance with the research rigor defined by R.K. Yin⁶ and the instructions of A. Dańdy i J. Lubecka⁷ and W. Czakon⁸. During the research design phase, a research tool was developed in the form of a questionnaire for in-depth interviews. The companies were selected deliberately, guided by specific criteria. The actual research (implementation phase of the research process) consisted of conducting eight interviews based on a prepared research questionnaire. Respondents assessed subsequent parts of the model, giving individual elements ratings according to a previously prepared rating scale. The results from the interviews were prepared in the form of case study reports.

In order to increase the reliability of the data obtained, triangulation of data collection methods was used. Triangulation was used in all cases. The data came from an in-depth interview conducted with two respondents representing two levels of the company's organizational structure based on the same research questionnaire. Despite the solutions used, the author is aware of the limitations of the study. The information on the basis of which conclusions are drawn is based largely on the subjective assessment and interpretation of reality made by the interlocutors (respondents). The answers given by the respondents may have been influenced by their subjective feelings as well as the current situation and the actual level of process maturity of the surveyed company.

Through empirical research and analyzes of literature sources, the author tried to fill the cognitive gap caused by the lack of documented empirical knowledge (small number of publications) on comprehensive maturity models useful for implementing the Industry 4.0 concept. In available publications, the description of such models is general. Additionally, the author tried to fill the methodological gap by presenting a comprehensive approach to the maturity model, which defines key elements in the process of implementing and functioning of the Industry 4.0 concept in manufacturing enterprises. In many publications, this issue is described in too general a manner. There is no mention of preparing a procedure in the form of

⁶ R.K. Yin, *Studium przypadku w badaniach naukowych Projektowanie i metody*, Uniwersytet Jagielloński, Kraków 2014.

⁷ A. Dańda i J. Lubecka, *Case Book, Metodologia tworzenia case study*, Wyższa Szkoła Europejska, Kraków, 2010.

⁸ W. Czakon, *Podstawy metodologii badań w naukach o zarządzaniu*, Wydawnictwo Nieoczywiste, Piaseczno 2020.

a design project or taking into account the company's strategy and business results, which may affect the successful implementation of the Industry 4.0 concept.

Work structure was subordinated to the formulated research problem and the purpose.

The dissertation consists of four chapters, which present a review of the literature on the topic of the dissertation (scientific achievements of Polish- and English-speaking researchers), the adopted research method, research results, as well as model approaches and practical recommendations for managers involved in the implementation of the Industry 4.0 concept. In drawing no. 2. there is a diagram of the structure of this dissertation, consisting of three parts.

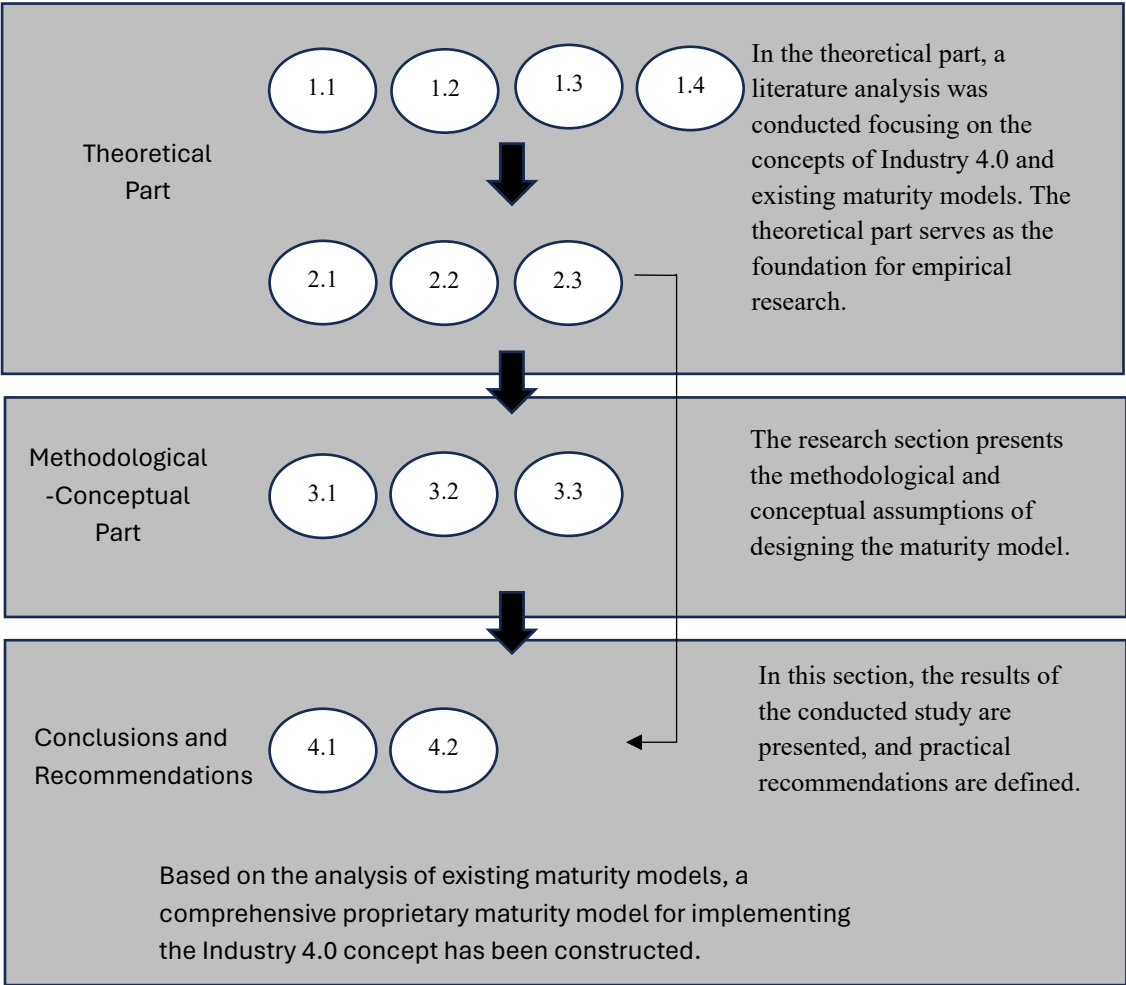


Figure 2. Logical diagram of the dissertation.

Source: own work.

The first is the theoretical part, which aims to review the literature on the subject (contains chapters 1 and 2). The second methodological and conceptual part was developed on the basis of the previous literature review (chapter 3). The third part contains conclusions and recommendations based on the literature review and empirical research (chapter 4).

The first chapter, which consists of four subchapters, presents the essence and goals of the Industry 4.0 concept implemented in enterprises. Its technological, organizational and management aspects were presented, as well as the human factor present in this concept.

The second chapter presents the characteristics of maturity models as well as their basic types. Additionally, the organization's maturity models were analyzed in the context of implementing the Industry 4.0 concept.

The next chapter (third) is methodological and empirical in nature. This chapter presents the methodological positions of management sciences. The case study as the basic method of scientific research used in this dissertation was also characterized, presenting the stages of the procedure. In addition, the justification for the choice of the research method used was presented. The process of designing the structure of a comprehensive maturity model for implementing the Industry 4.0 concept was also presented.

The fourth and last chapter interprets the results of the research, taking into account the use of a comprehensive maturity model. Additionally, practical recommendations were presented for the efficient implementation of the Industry 4.0 concept in manufacturing enterprises.

When preparing materials for the empirical part of this doctoral thesis, care was taken not to provide any important names or own information (both quantitative and qualitative) of the studied enterprises, especially information unrelated to the subject of the work. This was done due to the confidential nature of this information and the need to maintain commercial confidentiality. At the same time, the specific characteristics of the described phenomena and events used in the work, which were necessary to solve the research problem, were used at a relatively high level of generality and only for scientific and research purposes.

The concept of Industry 4.0 is currently an interesting and leading paradigm for managing manufacturing companies in the world. Thanks to the use of innovation, increasing operational flexibility and striving for continuous improvement, it perfectly adapts to the current market conditions, characterized by high variability and customer orientation. However, many manufacturing companies still experience difficulties with its effective implementation. In the light of the above-mentioned business challenges and the observed gaps in the available literature, **this work attempts to solve the research problem consisting in the lack of a structured and comprehensive model that supports the process of assessing and**

implementing the Industry 4.0 concept in manufacturing enterprises. The pursuit of the research goal was guided by the following research questions.

1. What is the basic architecture of the model, what areas of the model should be included, and how to determine the maturity levels of the model?
2. What are the guidelines for using a model determining the degree of preparation of an organization to implement the "Industry 4.0" concept?
3. What recommendations for management staff can be helpful in implementing the Industry 4.0 concept?

In order to answer the above research questions, the author decided to use his own research method, which was based on the analysis of literature and included the following procedure. The first step of the adopted research method included conducting a systematic review of existing models, tools and maturity instruments, both of the organizations themselves and of organizations implementing the concept of Industry 4.0. A thorough analysis of their structure allowed to identify the most important theoretical gaps in the field of maturity models for the implementation of Industry 4.0. The research results indicated that none of the existing instruments has all the desired characteristics:

- providing a comprehensive assessment of maturity for the implementation of the Industry 4.0 concept, taking into account the seven parts of the implementation of the Industry 4.0 concept - strategy, employees, processes, production, resources, product and business results;
- ensuring a measurable value of the maturity level of the implementation of the Industry 4.0 concept;
- enabling the distinction between companies with low and high maturity to implement the Industry 4.0 concept;
- enabling quick and easy self-assessment;
- based on data and facts;
- providing information on existing gaps and possible areas of improvement.

This fact highlighted the practical and research need to develop an original, structured and comprehensive maturity model for implementing the Industry 4.0 concept that meets all the above characteristics..

The second step of the adopted research procedure concerned the design of the structure of a comprehensive maturity model for the implementation of the Industry 4.0 concept. Based on the identified research gaps, the original instrument was designed in such a way that it facilitates practical application in manufacturing enterprises. As a result, the developed structure of the instrument was based on seven categories (strategy, employees, production processes, infrastructure, product and business results) and one hundred and fourteen hints, constituting a set of applied practices and methods of the Industry 4.0 concept. These criteria were assessed using five levels of maturity. The third step of the research procedure was to empirically test a comprehensive maturity model for implementing the Industry 4.0 concept in real business conditions. As part of case studies conducted in four manufacturing companies, the developed instrument went through two cycles verifying and improving its structure, content and method of use. The comprehensive maturity model for the implementation of Industry 4.0 designed as a result of the study has the desired characteristics identified in the literature review.

Proposed comprehensive maturity model for implementation of the Industry 4.0 concept in manufacturing company is shown on figure 3.

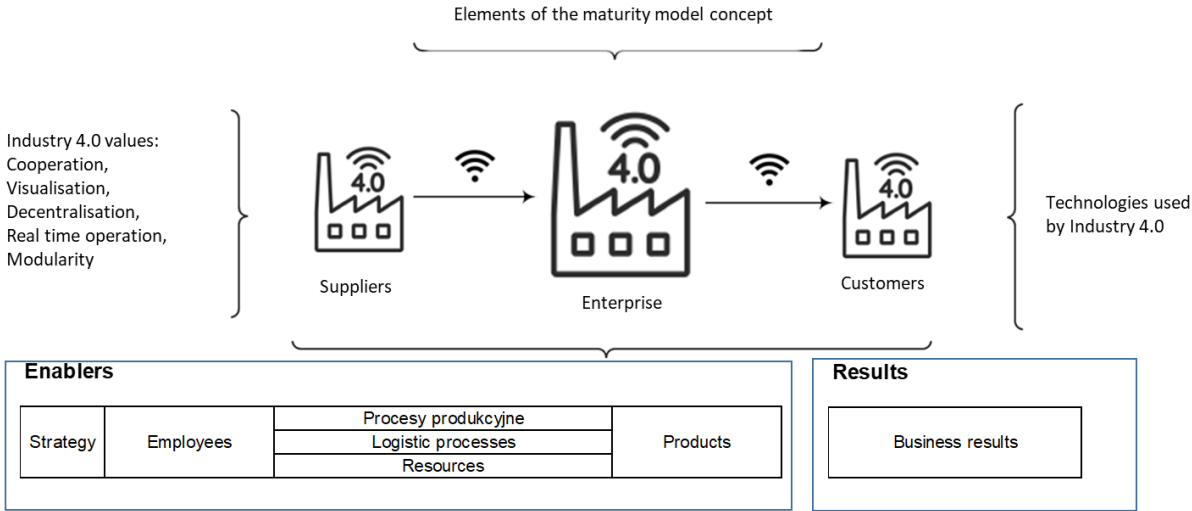


Figure 3 Maturity model for implementation of the Industry 4.0 concept in manufacturing company.

Source own work

The structure of the model is based on seven modules: strategy, employees, production processes, logistics, resources, product and business results, and one hundred and fourteen tips assigned to them. Literature research indicates that the structure of the instrument developed in this way takes into account all key aspects of the implementation and functioning of the Industry 4.0 concept, allowing for a comprehensive measurement of the degree of its implementation. As a result of the case studies, it was found that the use of a comprehensive maturity model

provides a measurable value of the level of implementation of the Industry 4.0 concept. Based on a five-level maturity scale, the developed instrument allows for the measurement of each model criterion. The obtained maturity results of companies A, B, C and D allow to conclude that the developed model distinguish between companies with low and high maturity. The result of the measurements clearly indicates that companies C and D are characterized by higher maturity in the application of the Industry 4.0 concept than companies A and B. The instrument allows distinguishing the level of implementation for each of the twenty-eight assessment criteria, enabling their comparison between each of the surveyed companies. The conclusions obtained support the application of the assessment process developed in the study using the developed maturity model and allow for quick and easy self-assessment of manufacturing enterprises.

The conclusions drawn from the conducted case studies indicate that the maturity assessment made using the model is based on objective data and facts. The maturity level descriptions used in the instrument have been defined in such a way that they are based on quantitative data and clearly formulated questions. Thanks to this, the measurement result should be objective and repeatable. By using descriptive maturity levels for each criterion in the model, the instrument clearly enables the provision of information on existing gaps and suggested improvement actions.

Finding answers to the basic questions posed in the research problem required answering detailed research questions. **In particular, the first detailed research question:** *What is the basic architecture, what areas of the model should be considered, and how to define maturity levels?*

The basic structure of a comprehensive maturity model for implementing the Industry 4.0 concept is based on three main elements: modules, criteria and maturity levels. These components enable a comprehensive assessment of the degree of implementation of the Industry 4.0 concept in the organization. The modules constitute overarching groups reflecting the basic categorical divisions of the Industry 4.0 concept. The comprehensive maturity model is based on seven modules:

1. Strategy
2. Employees
3. Production processes
4. Logistics processes

5. Resources

6. Products (design and development)

7. Business results

The criteria constitute the characteristics of the main modules of the model. They define management practices and methods that should be implemented from the perspective of specific areas, such as strategy, employees, production processes, logistics processes, infrastructure, products and business results. Maturity levels are descriptive assessments that make it possible to determine the current level of maturity of an organization in implementing the Industry 4.0 concept. They use a five-point maturity scale, including:

1. Lack of approach
2. There is a need for application
3. Tool used
4. Solidity in approach
5. Benchmark, The best in the class

Maturity levels allow for a detailed characterization of each criterion and identification of areas for further improvement. Thanks to them, it is possible to clearly determine the level of advancement of the organization in implementing the Industry 4.0 concept and identify areas requiring further development.

When answering the second question regarding the guidelines for using a model determining the degree of preparation of an organization to implement the "Industry 4.0" concept, the answer to this question includes the guidelines in the criteria included in table 17. In order for the organization to be prepared to implement the Industry 4.0 concept, it is important to use appropriate strategies and guidelines at various levels of activity. Below tips are presented and guidelines for preparing your organization to implement the Industry 4.0 concept:

1. Communication Strategy:
 - Ensuring continuous and transparent communication regarding strategies and projects related to Industry 4.0.
 - Creating communication channels that enable employees to track progress and engage in the implementation process.

- Joint discussion of visions, strategies and action plans so that employees can have a real impact on the implementation of the Industry 4.0 concept.
2. Technology Strategy:
 - Developing a clear investment strategy that supports the vision of Industry 4.0.
 - Monitoring technological progress and participating in trade fairs and conferences.
 - Introducing the latest production technologies and replacing obsolete machines.
 3. Elements of Leadership Strategy:
 - Establishing leadership that shapes the future and realizes the aspirations of Industry 4.0.
 - Managing the organization in a flexible, anticipatory and responsive manner.
 - Building a culture of trust, openness and employee involvement in all activities.
 4. Design Approach Strategy:
 - Implementation of a design approach that effectively manages the change process.
 - Establishing an organizational unit to manage project work.
 - Including all interested parties in the implementation process and obtaining their support.
 5. Training and Preparation of Employees:
 - Recognizing employee development needs and providing appropriate training.
 - Organizing training to update the knowledge of production employees and training for new employees.
 - Supporting the individual development of employee talents and enabling them to independently implement process improvements.
 6. Organizational Structure:
 - Adapting the organizational structure to support the strategic goals of Industry 4.0.
 - Introducing digital transformations at all levels of the organizational structure.
 - Open communication and cooperation between different levels of the hierarchy.
 7. Production Processes:
 - Use of advanced production technologies.
 - Ensuring optimization of production processes and using the full potential of automation.
 - Monitor production performance in real time and take corrective actions.
 8. Employee and Data Security:
 - Meeting all work safety requirements.
 - Ensuring data security against cyberattacks.

- Use of threat monitoring and detection systems and regular security training for employees.

Answering the third question regarding recommendations for management. Answer this question is in chapter 4.2. It is recommended that the company's management continue to verify the model and engage in continuous process improvement in accordance with the principles of the Industry 4.0 concept. With the right approach and employee involvement, significant benefits for the organization can be achieved. Implementation of the Industry 4.0 concept in manufacturing enterprises is a challenge which require the involvement of all employees at various levels of the organizational structure. The author proposes an organization maturity model as a tool helpful in the effective implementation of this concept. This model allows to assess the current state of the organization, understand its needs, identify areas for improvement and supports change management. Implementing the Industry 4.0 concept requires understanding the model and its advantages, as well as individual adaptation of the implementation process to the specific needs and goals of the organization. This model is distinguished by its comprehensiveness and takes into account key business indicators. The author recommends using this model as a foundation for the improvement process, due to its comprehensive analysis and adaptation to the individual needs of the organization. To sum up, the following tips can be recommended for management staff regarding the implementation of the Industry 4.0 concept:

1. **Involvement of the entire organization:** The concept of Industry 4.0 requires the involvement of all employees at all levels of the organizational structure. Management should pay special attention to building employee awareness and involvement in implementing this concept.
2. **Maturity model:** The organization's maturity model can be an effective tool supporting the implementation of the Industry 4.0 concept. It is necessary to modify and update it based on research results and respondents' suggestions to better reflect the specific needs and conditions of the organization.
3. **Assessment of the current state of the organization:** Before starting to implement the Industry 4.0 concept, it is necessary to thoroughly understand the current state of the organization. The maturity model allows you to perform this assessment, which allows you to identify areas for improvement and adjust your implementation strategy.
4. **Support for the change process:** Change management is crucial when implementing new technologies and processes in the company. Management should actively support the change

process, minimizing resistance among employees and providing the necessary resources and training.

5. Regular monitoring of progress: It is important to systematically monitor progress in implementing the Industry 4.0 concept and adapt the strategy to the achieved results. The organization's maturity model allows you to track progress and identify areas requiring further optimization.

6. Continuous process improvement: The improvement process should be continuous, and the organization's maturity model should support an organizational culture focused on continuous improvement. Management should promote innovation and flexibility in the organization, encouraging employees to actively participate in the improvement process. Applying the above guidelines can support the effective implementation of the Industry 4.0 concept in a manufacturing company and contribute to achieving the desired results and benefits.

Answering the questions formulated above allowed the research objectives to be achieved. Thus, in order to achieve the cognitive goal, organizational maturity models were isolated, compared and analyzed, presented in the literature on the subject and used in the practice of the studied enterprises, in the process of implementation and functioning of the Industry 4.0 concept. As for the methodological goal, a methodology was developed for the research procedure, for conducting empirical research using the developed methodology, and the limitations and possibilities of using the model were analyzed. In turn, achieving the pragmatic goal came down to formulating and presenting recommendations for the managerial staff, helpful in the process of implementing and functioning of the concept of implementing Industry 4.0 in manufacturing enterprises.

In order to solve the research problem presented in this work and achieve the research goals, a maturity model was constructed and a maturity assessment was carried out using the case study method on a sample of four cases. These studies were performed in accordance with the specific research rigor of the adopted method. An in-depth interview questionnaire was also developed, which was constructed based on literature studies on the subject and on the basis of the author's experience and knowledge of Industry 4.0 issues. Research limitations and recommendations for future research directions regarding the maturity model of the Industry 4.0 concept in manufacturing enterprises are an important aspect worth taking into account. While conducting research, certain limitations are encountered that may affect a full and comprehensive assessment and analysis of the impact of Industry 4.0 on organizations. One of such limitations may be the lack of sufficient data in the organization and employee perception,

these factors may hinder reliable research. Furthermore, the complexity and dynamism of the surrounding environment are factors that must be taken into account as Industry 4.0 is characterized by a rapid pace of change and continuous technological development. Another challenge is the lack of uniform measures and indicators for assessing progress, which leads to difficulties in comparing results and effectively assessing implementations.

Therefore, there are several recommendations that are worth considering in future research. First of all, should focus on analysing the impact of Industry 4.0 on the efficiency of production organizations. Research should cover aspects such as quality improvement, efficiency increase, cost reduction and downtime minimization. Additionally, it is recommended to study the impact of Industry 4.0 on organizational culture, including leadership, employee engagement and adaptability. Analysis of success factors and barriers will allow the identification of factors influencing the implementation of Industry 4.0 and the development of strategies to overcome these obstacles. It is also important to focus on changing employee competences in order to adequately respond to the new requirements of Industry 4.0. Finally, research should take into account the impact of the implementation of Industry 4.0 on the sustainable development of production organizations, taking into account economic, social and environmental aspects.

The conclusions from this research will provide valuable guidance for future activities related to the implementation of Industry 4.0 in manufacturing enterprises. By understanding the limitations and recommendations, it will be possible to effectively develop strategies that will enable organizations to maximize the benefits of Industry 4.0 and effectively adapt to the changing environment. The author's comprehensive maturity model for implementing the Industry 4.0 concept expands the current knowledge in the field of using maturity models in the field of management, filling existing research gaps. The developed model also takes into account the problem of lack of coherence in understanding the concept of Industry 4.0 identified in this work. The structure of the developed model indicates in an orderly manner the most important methods and techniques of Industry 4.0, at the same time specifying the recommended order of their implementation. In this way, the author's model serves as a kind of compendium of knowledge in the field of implementation and functioning of the concept, which can be used by both practitioners and scientists. From the perspective of applying the instrument in business, the maturity model enables quick, simple and objective self-assessment, indicating the current level of maturity of the company and specifying recommended improvement actions. It thus fills the identified gap in the form of a deficit of practical assessment tools that support the process of implementing the Industry 4.0 concept. The scientific contribution of this

dissertation is also the design of the Industry 4.0 maturity assessment process using the author's maturity model. The measurement procedure developed as a result of the study can be used in any production company, providing a comprehensive examination of the level of implementation of the Industry 4.0 concept. It is recommended that the designed procedure be used on a regular basis by the implementation team using the project approach and the management staff in order to control the current maturity of the enterprise and support the further transformation process.

When using the original maturity model to implement the Industry 4.0 concept, one should remember one key characteristic accompanying all changes. It is the fact that the implementation of this or any other concept is a continuous process and achieving the highest level of maturity never means achieving true perfection. Taking this into account, the categories, criteria and descriptions of maturity levels defined in the instrument should be updated regularly, ensuring a continuous improvement cycle is maintained. The result of the maturity assessment should therefore only be interpreted as progress towards achieving operational excellence of the company.

The maturity model for implementing Industry 4.0 presented in this work allows to fill the existing cognitive gap and at the same time complement the methodology of implementation and maturity assessment, making it practical. Maturity assessment can undoubtedly influence the success of implementing organizational innovations. However, in practice it is often omitted or insufficiently identified. Therefore, it seems reasonable and useful to undertake further, in-depth research on a comprehensive approach to the most important issues and to develop a methodology for implementing Industry 4.0, depending on the level of maturity of the organization, also taking into account the maturity of enterprises to implement changes. It also seems advisable to carry out an exemplification of the proposed implementation procedure in order to check its practical usefulness and examine the possibility of its universal application in enterprises of other industries.