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A MCDA Based Model for Assessing Digital Maturity in Manufacturing SMEs

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Abstract: This paper presents the findings of research focused on the development of a comprehensive model for assessing the digital maturity of small and medium-sized manufacturing enterprises (SMEs) using multi-criteria decision analysis (MCDA). A systematic review of the literature was conducted to analyse the current state of digital maturity assessment models and evaluate their applicability to the SME sector. The proposed model covers critical digital dimensions relevant to SMEs, including the extent of adoption of digital technologies, the existence of supporting policies and strategies, and the integration of digital technologies into business processes. The developed model enables SMEs to benchmark their current digital maturity level with the desired goals, thus facilitating the formulation of actionable and customized digital transformation strategies. The model was validated through case studies in real production environments to ensure its practical relevance and applicability.

Keywords: Digital Maturity Model; digital transformation; MCDM; SME; strategy

1 INTRODUCTION

The activity of manufacturing companies in today's dynamic market is extremely demanding and challenging. Due to the new conditions created by the pandemic and energy crises of the past, business processes must be adapted to ensure that products are produced faster, with higher quality, at lower costs and in a unique way to maintain or achieve competitiveness. Business processes need to adapt quickly and work as much and as fast as possible towards digital transformation [1]. Digital transformation is a key process in modern companies, enabling them to use new technologies to improve business processes, increase efficiency and drive innovation [2]. In the age of digitalization, assessing a company's readiness for digital transformation is crucial to ensure a successful transition to digital operations [3].

2 DIGITAL TRANSFORMATION

The digitalization and digital transformation (DT) of companies are key processes for the further development of the economy and society and must therefore be approached strategically and comprehensively [2, 4].

2.1 Basic Concepts

The digital transformation and the resulting innovations are changing organizations, institutions and society in a general sense [1]. Understanding the conceptual differences between digitization, digitalization, and digital transformation is crucial for reaching the industrial level of Industry 4.0. Digitization refers to the process of converting physical, analogue objects or properties into a digital format. This includes the conversion of physical documents, audio recordings, images and other materials into binary data that computers can process [5]. Digitalization involves the use of digitized data to improve business processes. This includes automating and optimizing existing processes via digital platforms to become more efficient and productive [6].

Digital transformation is a broader concept that encompasses a fundamental change in the way a company operates through the use of digital technologies. It includes not only the optimization of existing processes, but also the creation of new business models and strategies enabled by digital technologies [7]. In this process, technologies such as big data, artificial intelligence (AI), the Internet of Things (IoT) and cloud computing are used to optimize business processes, improve the customer experience and create new business models [8].

Although these terms are very similar, it is important to understand the characteristics of each term and their proper application in the era of digitalization. Wen et al. confirmed that manufacturing companies with greater sustainability are more adaptable to DT and tend to implement differentiated competitive strategies. Therefore, they concluded that the impact of innovation promotion is greater for firms with higher sustainability [9].

2.2 Investigation of Existing Digital Maturity Models

Digital maturity models are tools or frameworks that assess an organization's internal readiness for digital transformation. Their aim is to provide a deeper insight into the ability of organizations to implement digital technologies and adapt to digital changes in business operations. These models analyse several dimensions, such as organizational culture, strategic capabilities, level of digital skills, technological infrastructure and innovation capability. They are constantly evolving and adapted to specific industries and other characteristics, including industry specific requirements, the size of the organization and the level of development of individual companies.

As there were no clearly defined models for assessing digital maturity, Rossmann's study focuses on defining a concept for building a digital maturity model and the corresponding measurement framework. The results of his study show that the digital maturity framework consists of eight dimensions and 32 factors covering the areas of strategy, leadership, business model, operating model, people, culture, governance and technology. Each dimension includes specific elements that can be assessed based on their maturity level [10]. His work provides a clear theoretical contribution to the conceptualization and operationalization

of the framework and extends previous research. Numerous other studies on different existing models have led to the creation of a variety of new variants of digital maturity models because they have identified shortcomings in the existing models [11, 12]. Kruljac and Knežević, analysing twenty-one digital maturity models (out of more than 150 available in the literature), conclude that the analysed models can only serve as analytical tools for assessing digital maturity based on their own criteria. The reason for this is the lack of empirical research on all key elements of the models as well as their limitation to commercial and non-academic application [13]. An analysis of the popular and commonly used models by IMPULS, PwC and Uni-Warwick revealed that they are only partially applicable to SMEs due to a lack of specific relevant categories and practical guidelines that need to be clearly defined and understandable. This allows users to accurately determine the current digital maturity level and areas for improvement [14]. When examining existing maturity models, it was found that none of the existing maturity models for digital transformation fully meet all defined criteria, such as a detailed description of model components, and their applicability across all industries is highly questionable [15]. In their analysis of the adaptation of Industry 4.0 DMM models for manufacturing and logistics companies in SMEs, the authors concluded that there is still considerable room for further research on topics such as digitized production and that the specific requirements of SMEs in the context of developing countries need to be taken into account to enable a more successful adoption of Industry 4.0 [16]. The comparison of existing models conducted in the study provides valuable insights into the current business environment and model requirements and enables the development of new approaches [6]. Future research could focus on analysing the differences in the application of digital maturity models in different industries or investigating the impact of cultural, regulatory and economic factors on the adoption and adaptation of these models in different countries and regions. Very often SMEs have limited resources for business development and improvement to maintain or increase their competitiveness in the market. Therefore, it is important to make appropriate strategic decisions on how to use the limited resources to achieve the best results in improving business processes. Digital transformation indices and digital maturity assessment models provide companies with important guidelines for navigating through digital transformation. The digital maturity model is a useful tool in the company's digitalization process to effectively assess the current state of digitalization and identify key areas for the development of a digitalization strategy. There are numerous examples in the literature that confirm the applicability and necessity of using these tools. Verhoef et al. state that SMEs using digital maturity tools can more easily develop sustainable strategies, reduce operating costs and increase productivity [17]. Westerman & Bonnet emphasize the importance of applying digital maturity models, especially in organizations with limited resources, i.e. SMEs. They find that SMEs using digital assessment models achieve faster results and increase resilience to market changes [3].

The literature review has provided the necessary information and knowledge required for a complete understanding of the specifics of the digital transformation process and its application in different environments. Since there are many models developed for different industries and different applications, it is important to find and select the most appropriate model that can make the greatest contribution on the path to digitalization in an organization.

3 DEVELOPMENT OF A DIGITAL MATURITY ASSESSMENT MODEL FOR SMEs

Most available digital maturity assessment models are predefined for specific industries, company sizes, geographic locations and similar factors. In general, these models are locked to the end user and do not offer the possibility to change the process of digital maturity assessment, such as prioritization and applicability of certain factors in the successful implementation of digital transformation. According to the latest analyses of the achieved industrial level of Industry 4.0, which is often equated with the level of digital maturity, digital maturity in the region is still in its infancy. Apsolon has determined the Croatian Digital Index (HDI), which analyses the readiness of the Croatian economy to face the challenges of extremely rapid growth and the development of new digital technologies by analysing data from 273 Croatian companies [18]. The state of digitalization of the Croatian economy in 2021 was assessed with an average score of 2.59 on the scale of 1 to 5, which is a slight increase compared to 2020, when the score was 2.52. The average score for the digital readiness of companies for digital transformation in 2021 is 3.26. Although the proportion of large companies in this survey is much lower than that of medium-sized companies, it can be assumed that the result for medium-sized and small companies would be significantly lower, namely below the score of 3.0, considering that the awareness, approach and implementation of digital transformation is much more pronounced in large companies. Mladineo and colleagues have continuously analysed the digital maturity of manufacturing companies in the Republic of Croatia over the last decade [19]. The average overall digital maturity score for 2022 is 2.45, while it was 2.15 for 2015. The analysis shows a very low level and very slow progress over the seven years observed. It is therefore clear that there is still a lot of room for improvement and acceleration of digital transformation in Croatia. For a successful digital transformation, companies need to define a precise strategy and guidelines for effectively managing the process. The digital maturity model is a critical success factor as it enables organizations to assess their current state and create roadmaps aligned with their goals [20]. It is impossible to choose the optimal existing model, which is usually developed for a specific industry, environment or organization. The more detailed it is defined, the greater the possibilities for significant deviations in calculating the realistic assessment of the current state and, consequently, in determining the priority activities for improvement. Another major problem is the organization's motivation for digital transformation. Since the level of Industry 4.0 in the Republic of Croatia is 2.45 and reaching the desired level of 4.0 requires a lot of effort and time, the question arises as to how to reduce frustration along the way and increase

motivation. One of the tried and tested ways is to make improvements in small but sustainable steps with realistically achievable intermediate goals. A user-customizable solution such as a digital maturity assessment model with the ability to influence the importance of specific areas and priorities of each organization can significantly support the successful journey of digital transformation. For this reason, the development of such a model, applicable in SMEs, was undertaken.

3.1 Definition of Maturity Model

Before the final definition of the model with the corresponding structure was established, the objectives or guidelines for the creation of the model were determined, which must be adapted considering the current state of digital maturity of manufacturing SMEs in our environment. The number of dimensions, the number of digital maturity levels and the number and content of digital transformation elements to be assessed should allow the user to assess the digital maturity level using the model in up to 90 minutes. Due to the differences and specificities between SMEs, it must be ensured that users have the opportunity to influence the determination of the importance of the individual elements of digital transformation.

The first step in defining the basic model is to determine the basic structure of the model itself, i.e., defining the dimensions with the corresponding basic elements and determining the method for validating the importance of the dimensions as well as defining and selecting the number of maturity levels. The conclusions from the presented literature review [8, 10, 11, 15, 16], the current maturity level in SMEs in Croatia [18, 19] and the authors' several years of personal experience in this field led to the selection of the six dimensions and the four levels of digital maturity. The digital dimensions and four levels of digital maturity with brief descriptions are presented in Tab. 1 and Tab. 2.

Table 1 Dimensions of digital transformation in the model

	Dimensions of digital transformation
1	Strategy
2	Technology
3	People and Expertise
4	Operability
5	Products / Processes
6	Organization

The basic elements of digital transformation are the result of a combination of research findings from the available literature and defined models by the following authors: Rossman [10], Schumacher et al. [8], Lichtblau et al. [21], and Ustundag et al. [22].

Certain elements of the mentioned models were revised based on the authors' many years of personal experience in collaboration with competent industry experts with fundamental knowledge of digital transformation.

Initially, 86 elements were defined, which were reduced to 66 elements in 6 dimensions after consultations and adjustments. The number of elements in each dimension varies and ranges from five in the *Products/Processes* dimension to fifteen in the *Technology* dimension, which is also the most important and influential in the entire process of digital transformation.

Table 2 Description of Defined Levels of Digital Maturity

Digital Maturity Stage	Description of the Digital Maturity
1 - Initial Stage	At this level, the company has little or no strategy for digital transformation. Activities are sporadic and not aligned with the company's goals.
2 - Developing Maturity	The beginning of the development of basic digital initiatives, pilot projects and a low level of digital skills among employees.
3 - Defined Maturity	A clear digital strategy is defined, initial integration of digital and business processes begins and processes for digital capability development are established.
4 - Managed Maturity	Digital strategies and technologies are fully integrated into business processes. The company uses data and technology to optimize business efficiency, with a high degree of technology integration, intensive use of analytics and data for decision-making and a digital infrastructure that effectively supports business processes.

Based on the analysis of the presented literature and the exchange of opinions with competent experts from academia and practice in the field of multi-criteria decision making (MCDM) and considering the objectives set for the model, the AHP method — Analytical Hierarchical Process — was chosen to determine the importance of each dimension. The AHP method proposed by Saaty is one of the most popular decision-making methods for solving complex problems, as it includes both subjective and objective evaluation measures. Based on pairwise comparisons, weighting coefficients are calculated by finding the dominant right eigenvector (EV) of the positive reciprocal decision matrix [23]. Pairwise comparisons are also used to determine the relative importance of the alternatives for each criterion [69]. In this way, the user can more realistically and objectively determine the importance weights for each dimension and the corresponding elements of each dimension depending on the strategy and the current state of their organization.

The rating scale for determining the current state of each element of the digital transformation dimension is defined as follows from zero (0) to four (4):
0 – not applicable
1 – completely negative statement
2 – predominantly negative statement
3 – predominantly positive statement
4 – completely positive statement

The basic model was defined using the MS Office package Excel. This complied with the guidelines for the use of readily available software solutions and at the same time allowed a certain degree of autonomy in determining the weighting of the importance of the individual dimensions.

3.2 Digital Maturity Assessment Process Using the DMM Model

It is important to note that the application of the model requires a competent group of experts within the organization who are familiar with the basic concepts, principles,

technologies and rules of digital transformation. The group should have a comprehensive understanding of all processes in all areas of business operations, including strategy setting, operational execution, monitoring and reporting on business activities. The size of the group depends on the size and organization of the business processes in each individual company. The process of using the model is illustrated in Fig. 1. The first step in entering data into the digital maturity assessment model is to determine the weighting of each dimension in the model. The chosen method of multi-criteria decision making, AHP, ensures a quick, understandable and objective determination of the weightings for each dimension. This form of applying the open type method was chosen for the sake of simplicity and for a better understanding of how the method works. This form of applying the AHP method in previous studies in collaboration with expert groups from the business community was very well received for these reasons [24].

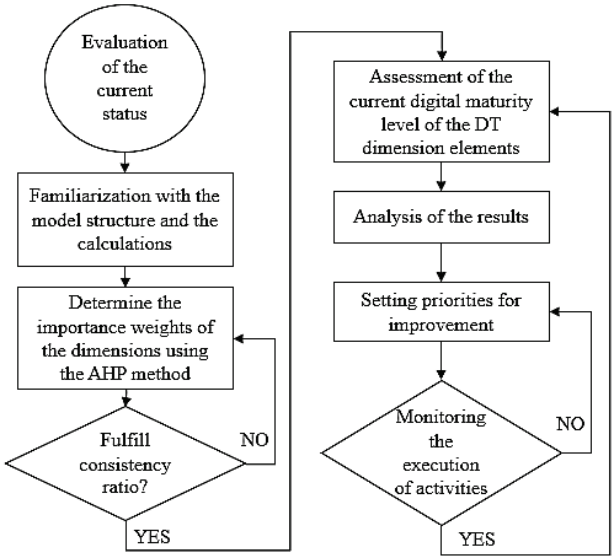

Figure 1 Process of Using the Digital Maturity Assessment Model

After determining the weighting values of the dimensions, the next step is to rate the digital maturity level of each element by selecting a corresponding rating from 0 to 4 from the drop-down menu.

After selecting the available ratings for each element of the digital transformation, the model generates an individual maturity score for each dimension separately according to the mathematical Eq. (1) by Schumacher and authors [8]. In the mathematical expression, *M* stands for the maturity level, *D* for the specific maturity level dimension, *E* for the elements of the digital transformation, *g* for the weighting coefficient and *n* for the number of elements of the digital transformation.

$$M_D = \frac{\sum_{i=1}^{n} M_{DEi} \times g_{DEi}}{\sum_{i=1}^{n} g_{DEi}}. \quad (1)$$

The overall result is displayed in the form of tabular values for each individual dimension, as shown in Tab. 3. For practical use, in addition to the tabular representation, a graphical representation of the results by dimension is provided in the form of a radar chart shown in Fig. 2, and the results by dimension element in the form of a sunburst chart. The overall score for the organization's digital maturity level is defined by the minimum score of all evaluated dimensions. The results achieved for the individual digital dimension elements serve as a basis for strategic decisions and the definition of specific activities for digital transformation projects and programs.

Table 3 Digital Maturity Assessment Results for Digital Transformation

DIMENSIONS	MATURITY	Rank
Strategy	2,07	4
Technology	2,16	3
People and Expertise	1,85	6
Operability	2,22	2
Products / Processes	2,40	1
Organization	1,86	5
Average digital maturity	2,09	
Organizational digital maturity	1,85	

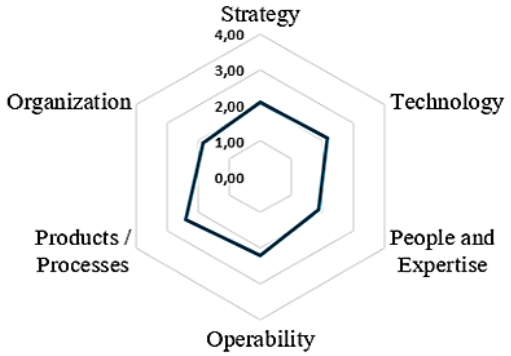

Figure 2 Display of dimensions digital maturity levels by radar chart

4 VALIDATION OF THE MODEL ON A CASE STUDY

The final planned phase in the creation of the new model is its validation using a case study to assess the digital maturity of SMEs in the manufacturing sector. For the validation of the model, three manufacturing companies from the surrounding area were selected, whose experts in specific areas also participated in the development phase of defining individual elements of digital transformation in the digital maturity assessment model. In this way, the competence of users using the model is ensured and qualitative feedback is provided on possible shortcomings or additional user requirements. The selected companies fall into the category of medium-sized enterprises and are active in the manufacturing industry. One company is active in the metal processing industry, another in the glass industry and the third in the production of automotive parts. All companies sell their products on foreign markets, have numerous and high-quality competitors and therefore use the latest manufacturing technologies and are organized according to numerous standards required by the customers or the industries in which they operate.

After receiving the completed digital maturity models from the three manufacturing companies, the individual and collective results of the received models were analysed according to the evaluation procedure shown in Fig. 1. An

example of the evaluation results of the weighting values of specific dimensions using the AHP multi-criteria decision method for Company 1 is shown in Fig. 3.

AHP (Analytical Hierarchical Process)

Goal: Determining the Importance of Digital Transformation Dimensions

Note: Fill in only the orange-filled fields

	Digital Transformation Dimensions	AHP	+/-
1	Strategy	32,61%	7,3%
2	Technology	13,76%	7,0%
3	People and Expertise	33,11%	18,3%
4	Operability	8,15%	2,2%
5	Products / Processes	3,81%	2,2%
6	Organization	8,55%	3,6%
	Consistency Result:		8,6%
	Acceptance Criteria: ≤		10,0%

Figure 3 Display of Weight Factor Results for Dimensions in Company 1

The summary of the final scores for individual dimension can be found in Tab. 4. Company 1 has the highest score for the *Products/Processes* dimension (2.4), Company 2 achieves the highest score in the *Strategy* dimension (2.67), while Company 3 excels in the *Organization* dimension (3.3). All companies have low scores in the *Technology* dimension, which could indicate weaker application or outdated technology in terms of digital maturity. The weighting factors for the dimensions indicate that for two companies the *Employees* and *Expertise* dimension is most important, while for the third company the *Strategy* dimension is most important, indicating a focus on planning and long-term strategy. Company 3 has the highest average maturity score (2.55), indicating a better digital maturity level in most dimensions, while Company 1 has the lowest average score (2.09), which could indicate a significant need for investment.

Table 4 Final Results of Digital Maturity Assessment of Dimensions in Companies

Dimension	Company 1	Company 2	Company 3
Strategy	2,07	2,67	2,4
Technology	2,16	1,89	2,0
People and Expertise	1,85	2,54	2,7
Operability	2,22	2,3	2,0
Products / Processes	2,4	1,83	2,8
Organization	1,86	2,29	3,3
Mean	2,09	2,25	2,55
Digital maturity level	1,85	1,83	2,0

The differences between the results of the individual dimensions in the different companies can be interpreted as follows. Low variability between companies was observed in the dimensions of *Technology* and *Operability*, moderate variability in the dimension of *Strategy*, while significant differences in variability were found in the dimensions of *People and expertise* as well as *Products/Processes*. Variability is most pronounced in the *Organization* dimension. This means that although these companies fall into the category of medium-sized manufacturing companies, they have significantly different organizational structures and levels, which can be attributed to their different industries. In terms of consistency between the companies, Company 1 has the highest consistency. Company 2 has the potential to balance the dimensions to reduce variability and ensure development. Company 3 has the most pronounced differences, which can be both an advantage (focusing on key dimensions) and a risk (neglecting weaker dimensions).

Additional feedback, comments and suggestions noted by users of the model during the maturity assessment process were evaluated. There were no significant suggestions or comments that would affect changes to the content concept or mathematical calculations of the dimension and element scores. The comparison of the analysed digital maturity assessment data with the actual state in each company revealed that the model concept correctly measures the differences between the tested manufacturing companies. The model clearly shows differences in certain dimensions and individual elements of digital transformation, regardless of the roughly equal size of the companies and their basic production function. The model developed last year can be gradually extended to new levels by integrating the criteria of Industry 5.0, which focus on human-centred systems. Given the increasing brain drain from the region to developed countries, future research could explore the potential of advanced AI tools such as Chat GPT and Deep Seek to improve the research process and further refine the model to meet Industry 5.0 standards.

5 CONCLUSION

Digital maturity assessment models are an excellent starting point for measuring the current level of digital maturity and assessing the gap to the target level. Considering the numerous peculiarities between the same and different industries, different organizational structures and different specific business processes, there is a need to continuously adapt digital maturity assessment models to different situations. The subject of this paper is the development of a new model for assessing the maturity level of manufacturing SMEs, tailored to the current state of industrial development in Croatia and the specifics of industrial organization and technology in this environment. The defined model was tested in three manufacturing SMEs in the region. The results were thoroughly analysed and the new model for assessing digital maturity in industrial SMEs in Croatia was validated. The analysis results clearly show that the model provides enough consistency and at the same time enough variability to clearly classify the details of the elements of digital transformation. A possible further development of the model is planned in the classification of the necessary activities to improve the elements of digital transformation that are at a low level of digital maturity in order to link them to the business strategy. The additional number of SMEs to be included in further research will provide new insights for the further development of this model and confirm the applicability of the model in SMEs. When the SME's maturity level has progressed towards Industry 4.0, the model is expanded to include an additional set of criteria that are suitable for Industry 5.0.

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