

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/368916725>

Proposal of Digital Maturity Model in Healthcare Sector: BWM, CODAS, and MABAC Approaches

Conference Paper · March 2023

DOI: 10.1007/978-3-031-24457-5_23

CITATION

1

READS

101

2 authors:



Emine Elif Nebati

44 PUBLICATIONS 137 CITATIONS

SEE PROFILE



Biset Toprak

Istanbul Sabahattin Zaim University

11 PUBLICATIONS 8 CITATIONS

SEE PROFILE



Proposal of Digital Maturity Model in Healthcare Sector: BWM, CODAS, and MABAC Approaches

Emine Elif Nebati^(✉) and Biset Toprak

Department of Industrial Engineering, Istanbul Sabahattin Zaim University,
34303 Küçükçekmece, Turkey
{emine.nebati,biset.toprak}@izu.edu.tr

Abstract. Traditional methods that have been going on for a long time have begun to change with the spread and widespread use of the internet. A new transformation has been experienced with digital media. This transformation has brought about changes and developments in various sectors. In the healthcare sector, great steps have been taken at the point of transformation, and the Industry 4.0 revolution has also affected hospitals. In the study, research has been conducted on what changes that Industry 4.0 has created on hospitals, how it affects and contributes the sector. Within the scope of the research, a digital roadmap was proposed for three hospitals that tend to digitalize and focus on development and innovation. Thus, a tool will be created for hospitals to see their faults and evaluate themselves. In the model proposed within the scope of the study, a total of 25 criteria, including six main and nineteen sub-criteria, were determined. With the determined criteria, it is aimed to measure the digital maturity level of three hospitals. In the study, the BWM method was preferred in determining the criteria priorities. In the ranking of the identified alternatives, the CODAS and MABAC methods were compared and the ranking results in both methods supported each other. Since the topic of digital transformation has been attracting attention and demand recently, it is thought that the study will contribute to both the literature and the healthcare sector. However, the methodology has new and limited applications. In addition, to the best of our knowledge, there is no study comparing the digital maturity performance of hospitals in the healthcare sector with the proposed methodology.

Keywords: Digital maturity model · Healthcare industry · BWM · CODAS · MABAC

1 Introduction

With the widespread use of the internet, traditional methods have begun to change, and a new transformation has been experienced, leaving its place to the digital environment. Digitalization is the presentation of any information in a form that is not tied to a physical location. In addition, the transfer of digital technologies to daily life is also called digitalization [1]. Ensuring that companies' activities are sustainable in electronic environments such as computers and mobile phones, digital transformation is now paramount

for companies which want to increase the productiveness and effectiveness of employees. For organizations, digitalization is a new concept that needs to mature. Therefore, it has introduced the concept of “digital maturity” to improve measurement and compare it with other competitors. The digital maturity model is a guide used to define and measure the current state of an organization and compare it with the desired maturity level. It helps organizations deciding when and how to act during their transition to digital transformation [2]. Organizations that implement this approach rapidly increase their production capacity and improve their ability to produce more value [3].

Digital transformation can be implemented in various sectors. The healthcare sector, which is an important building block for all humanity, is one of these areas. Healthcare is an indispensable element for individuals and societies. As technology develops, a universal digital healthcare system is formed by including traditional methods. Another aspect of the digitalization of healthcare is the digitalization of hospitals which is one of the areas where healthcare is provided. Digitalization in hospitals is the integration of all kinds of information flow in the hospital environment with digital technologies. It aims to efficiently use the automation of the manual transactions and the digital environment [4]. The digitalization processes of hospitals around the world are evaluated and certified by the Healthcare Information and Management Systems Society [5].

When literature and the reports of industry are examined, it is seen that the production of digitalization and maturity models applications [6–8] have been observed in various sectors such as defense [9], banking [10] and logistics [11]. Detailed literature research is given in the second part of the study. In particular, when the healthcare sector and hospital practices are taken into account, it has been determined that studies in this field are not sufficient. Based on this gap, a roadmap that can be used in digital transformation for the healthcare sector has been introduced in the study. In this context, 6 main criteria namely leadership, strategy, technology, employees, management, organization, culture, budget and 19 sub-criteria, were determined in the proposed model and digital maturity performances were compared for three hospitals in Istanbul. BWM (Best-Worst Method) was preferred in determining the importance weights of the digital maturity model criteria. The BWM method is a binary comparison-based method that allows us to make comparisons in a specific aim. The reason for choosing the method is to determine the best and worst criteria before comparisons, so that the decision maker has a clear idea about the assessment range. This process makes pairwise comparisons approach more reliable [12]. The three hospitals were listed by CODAS (Combinative Distance-based Assessment) and MABAC (Multi-Attributive Border Approximation Area Comparison) methods. The ranking obtained by both methods supported each other. MABAC and CODAS methods are current methods recommended to be used in solving MCDM problems. With the proposed roadmap and analysis, it is thought that a tool has been created through which hospitals can see their faults and evaluate themselves. The readiness of the selected institutions for Industry 4.0 and digitalization in terms of technological, administrative, budgetary and employees has been evaluated comprehensively.

This study contains five sections after the introduction. Section 2 presents a literature review on digital maturity, while Sect. 3 explains the methodology used in the study. Next, in Sect. 4, the proposed model is applied in a real-world case study and provides a sensitivity analysis. Lastly, Sect. 5 concludes the research and discussion.

2 Literature Review

Within the scope of the study, 40 studies from national and international sources have been examined by searching for the keywords digitalization, digitalization in hospitals, digital maturity, digitalization in the healthcare sector, and digital maturity level for the years between 2016–2022. [6] has worked on the development of a maturity model and an associated tool and evaluated the Industry 4.0 maturity of enterprises. Review, conceptual modelling, qualitative and quantitative empirical validation methods were used in the study.

[7] measured the digital maturity of a company manufacturing machinery in Sakarya and identified the strengths of the business and the areas that need to be improvement. [13] compared the Industry 4.0 maturity of a company in the defense sector with 12 organizations in its supply network. [10] presented a case study in the banking industry to identify companies' most important criteria for DMM and to rank companies. HFL, AHP, and ARAS methods were used in the study. [14] investigated the factors affecting digital maturity and how it could be measured in a Scandinavian FMCG company. [9] proposed a two-stage maturity model to evaluate the adaptation level of companies in the logistics sector to the digital transformation process. The BMW method was used in the study. [15] examined the effects of digital transformation on the defense industry. In this study, hesitant fuzzy AHP approach was used to prioritize the Industry 4.0 maturity features that was developed for the military industry. [16] tried to explain digital perception in healthcare communication in terms of healthcare institutions, healthcare units, and patients receiving healthcare services. Within the scope of healthcare communication, the study stated that keeping up with the speed of digital transformation is no longer a matter of preference for doctors and patients, but a necessity. [17] tried to examine the effect of institutional digital maturity on clinical outcomes in secondary care services within the British National Health Service. [18] examined the digital transformation of institutions, detailed the healthcare sector, and presented a digital transformation proposal. [19] developed the Industry 4.0 Maturity Model for hospitals by using the Hesitant Fuzzy AHP method in his study and investigated the change brought about by the concept of Industry 4.0 in hospitals.

[20] proposed a new model to help manufacturing businesses determining their digital maturity level before transitioning to Industry 4.0 and it was analyzed with the AHP method. [21] presented information compiled from the literature about the development stages of the digital hospital concept, information systems, and digital hospital studies. [22] proposed an Industry 4.0 maturity model to assess the maturity level of Indian manufacturing organizations. [23] aimed to examine applied studies on Industry 4.0 maturity models by conducting literature research. Researchers proposed new models as a result of the study. [24] proposed a maturity model that evaluates the use of key

Industry 4.0 technologies with the AHP method. In the study, an Industry 4.0 scale was presented and the Industry 4.0 maturity of a food manufacturing company was calculated with the scale (Sarı 2020). [11] used IMPULS maturity model criteria and sub-criteria to evaluate the Industry 4.0 maturity level of logistics companies. Multi-Criteria Maturity Model Approach were used and compared to rate logistics organizations. [25] aimed to determine the level of digital maturity of logistics organizations. [26] aimed to evaluate the digital maturity of the business and used the Best-Worst method as a methodological approach. [27] tried to reveal how a roadmap can be developed for digital transformation in businesses and the validity and reliability of the digital transformation scale.

When the digitalization and digital maturity studies in the literature are examined, there are studies on the implementation of digitalization and digital maturity level measurement in many different sectors such as healthcare [19, 28], production [8, 29], defense industry [14], logistics [25], and banking [10]. In the studies, the prominent criteria in the field of digital transformation were observed as leadership, strategy, culture, technology, employees, budget, and management and organization. It has been observed that various techniques such as literature review are used to determine the criteria. When the healthcare sector applications of digitalization are evaluated, it is understood that the effects of digitalization in healthcare are discussed in the new period. With the new applications, the field of healthcare has developed and more beneficial and effective results have been observed for the society [28]. Especially in recent years, the importance of the concept of digital transformation has emerged. Assuming that its importance will increase in the years ahead, it is inevitable that the studies in this field will spread to all sectors. As a result of the literature research, it has been observed that there are limited studies in this field, especially in the healthcare sector. It is hoped that this study, carried out in this context, will contribute significantly to the literature and the industry in digital transformation research in the field of healthcare.

3 Methodology

3.1 BWM Method

The BWM method was developed by Rezaei in 2015. It is used in criterion weighting and is based on the idea of comparison between two criteria. Compared to MCDM methods, in the BWM method, the results are more reliable with the consistency of the comparisons and require less comparison data. The steps of the BWM method are given in Fig. 1 [30], and the consistency index is given Table 1.

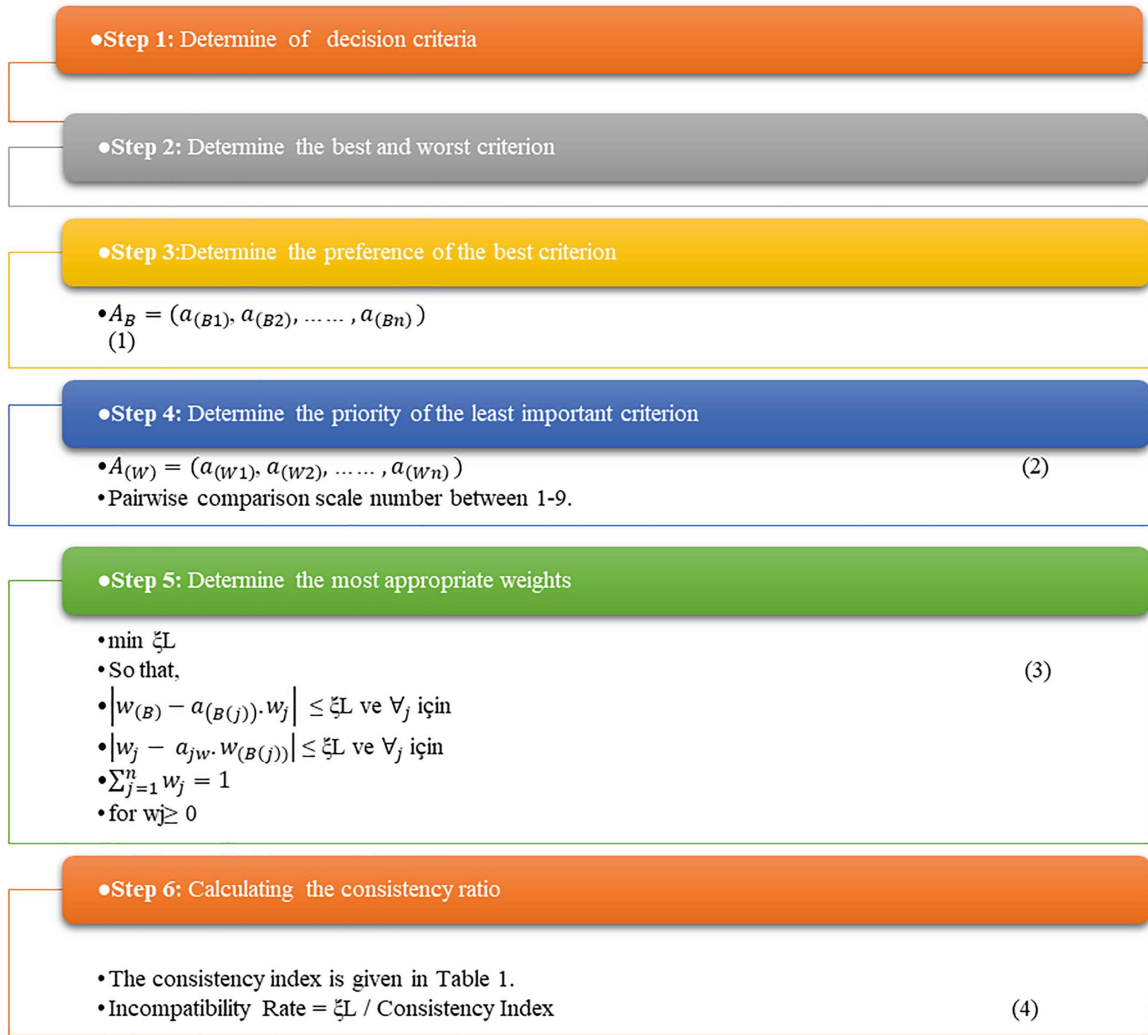


Fig. 1. Steps of BWM method

Table 1. Values of consistency index

ABW	1	2	3	4	5	6	7	8	9
Consistency index	0,00	0,44	1,00	1,63	2,3	3,00	3,73	4,47	5,23

3.2 MABAC Method

This method evaluates by considering the distances to the boundary proximity area. The MABAC method has seven stages as seen in Fig. 2 [31–33].

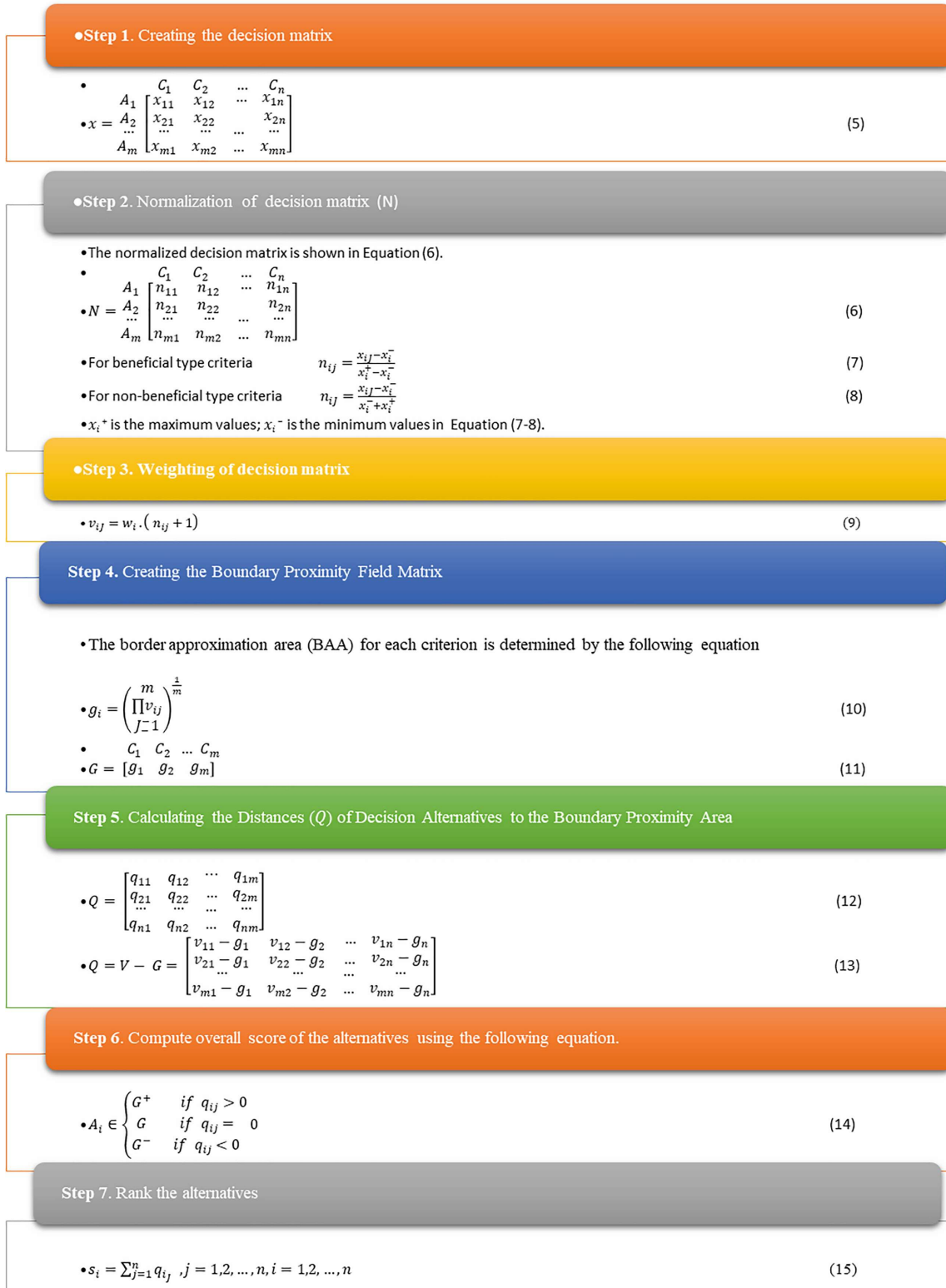


Fig. 2. Steps of MABAC method

3.3 CODAS Method

CODAS (Combinative Distance-Based Assessment) is a current method recommended by Ghorabae et al. (2016). The performances of the alternatives are determined based on their distance from the negative-ideal solution [34]. It is implemented by following the steps below in Fig. 3 [35].

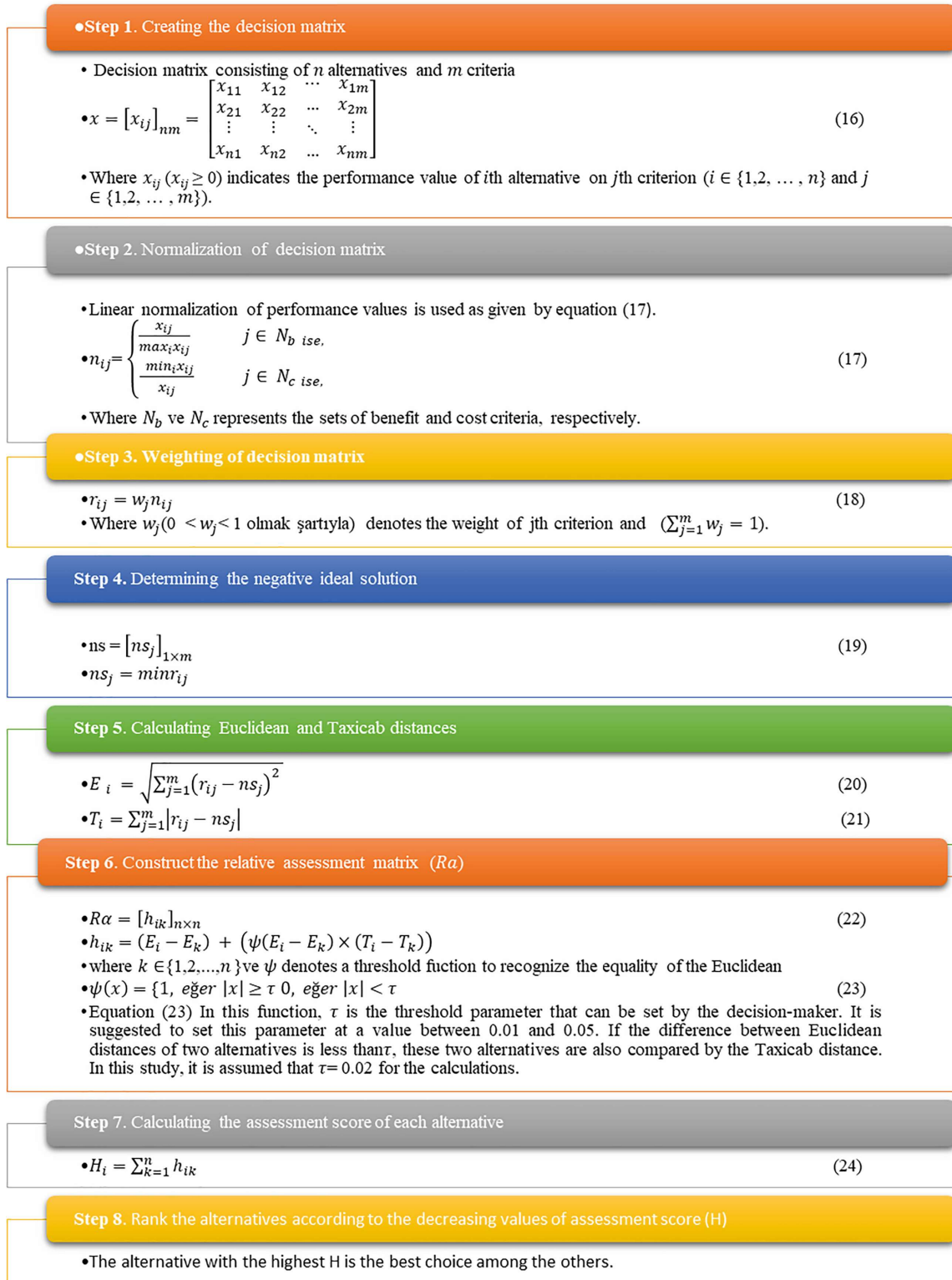


Fig. 3. Steps of CODAS method

4 Digital Maturity Model in Healthcare Sector

In this section of the study, a new model proposal has been presented in order to determine the digital maturity levels of hospitals in the healthcare sector in the adaptation stages to Industry 4.0. The created model aims to measure the digital maturity levels of enterprises operating in the healthcare sector in the transition to Industry 4.0. Based on

results, 6 main criteria and 19 sub-criteria were determined as leadership, strategy, technology, employees, management-organization and culture, budget, sector reports, and expert opinions in the sector. After determining the order of importance of the criteria determined in hospital digitalization with the BWM method, the hospitals were ranked with the MABAC and CODAS method.

4.1 Suggested Criteria for the Digital Maturity Model

In Fig. 4, the proposed model and the criteria are explained in detail. While creating the criteria, the studies in the literature in Table 2 were used.

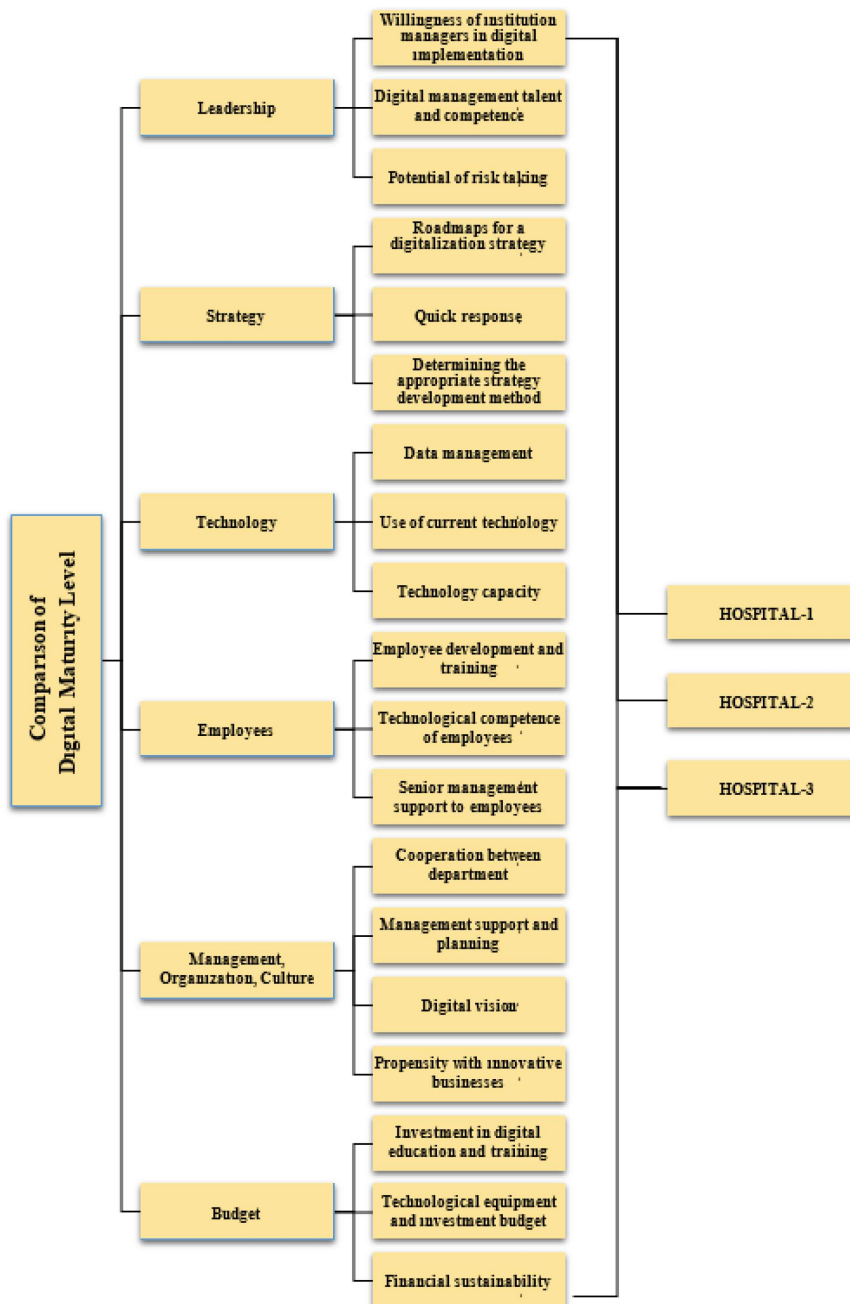


Fig. 4. Recommended model diagram

Table 2. Criteria reference table

Criteria /References	Gill ve VanBoskirk (2016)	Akarun vd. (2020)	Kafa (2021)	Özçelik vd. (2018)	De Bruin vd. (2005)	Demir ve Kocaoğlu (2020)	Ataman (2018)	This study
Leadership	x		x					
Willingness of institution managers in digital implementation			x					
Digital management talent and competence	x					x		
Potential of risk taking	x							
Strategy				x			x	
Quick response	x		x				x	
Roadmaps for a digitalization strategy					x		x	
Determining the appropriate strategy development method								x
Technology				x	x			
Data management						x		
Use of current technology				x				
Technology capacity								x
Employees					x			x
Employee development and training		x						

(continued)

Table 2. (continued)

Criteria /References	Gill ve VanBoskirk (2016)	Akarun vd. (2020)	Kafa (2021)	Özçelik vd. (2018)	De Bruin vd. (2005)	Demir ve Kocaoğlu (2020)	Ataman (2018)	This study
Technological competence of employees			x					
Senior management support to employees								x
Management, Organization, Culture	x	x	x	x	x		x	
Cooperation between department	x	x						
Management support and planning		x					x	x
Digital vision	x							
Propensity with innovative businesses				x				
Budget						x		
Investment in digital education and training	x							
Technological equipment and investment budget	x							
Financial sustainability								x

4.2 BWM Method Application

In determining the importance weights of the criteria, the following BWM method steps were applied.

1. In order to evaluate the Industry 4.0 maturity level, cooperation was made with three decision makers who have a position in hospital managements who are experienced in the sector.
2. Decision makers first determined the most important and least important criteria.
3. Pairwise comparison importance scale was used to evaluate the most important and unimportant criteria according to all other criteria, respectively. According to the scale evaluated from 1 to 9, it is accepted as 1: equally important and 9: absolutely important.
4. After the pairwise comparisons of the most important and least important criteria, the main criterion importance weights and sub-criterion local weights were found using Excel Solver. Consistency rates were also determined. The reliability of the method can be measured by the closeness of the consistency ratios to 0. Being close to zero indicates the reliability of the method.
5. After the Local Weights were found, as the last step, the weights of the main criteria in Table 4 and the local weights of the sub-criteria were multiplied, and as a result, the global weights were determined in Table 5. Consistency rates are shown in Table 3.

Table 3. Consistency rates

Main criteria	Leadership	Strategy	Technology	Employees	Management, organization, culture	Budget
0,084	0,038	0,097	0,059	0,053	0,074	0,049

Table 4. Weights of criteria

Main criteria	Weight
Leadership	0,085
Strategy	0,232
Technology	0,134
Employees	0,128
Management, Organization, Culture	0,328
Budget	0,092

According to the findings, it has been revealed that the most important criteria are management, organization and culture criteria, followed by strategy and technology criteria. The least important criterion is leadership. According to Table 5, the most important criterion for the leadership criterion in digital maturity studies is digital management ability and competence, and the least important criterion is the willingness of corporate managers in digital implementation. The most important criterion for the strategy criterion is rapid response, and the least important criterion is the determination of the

Table 5. Local and global weights of criteria

Main criteria	Weights	Sub-criteria	Local weights	Global weights
Leadership	0,085	Willingness of institution managers in digital implementation	0,219	0,019
		Digital management talent and competence	0,467	0,040
		Potential of risk taking	0,314	0,027
Strategy	0,232	Quick response	0,470	0,109
		Roadmaps for a digitalization strategy	0,311	0,072
		Determining the appropriate strategy development method	0,219	0,051
Technology	0,134	Data management	0,120	0,016
		Use of current technology	0,494	0,066
		Technology capacity	0,385	0,052
Employees	0,128	Employee development and training	0,386	0,049
		Technological competence of employees	0,269	0,034
		Senior management support to employees	0,344	0,044
Management, Organization, Culture	0,328	Cooperation between department	0,287	0,094
		Management support and planning	0,187	0,061
		Digital vision	0,238	0,078
		Propensity with innovative businesses	0,288	0,094
Budget	0,092	Investment in digital education and training	0,534	0,049
		Technological equipment and investment budget	0,332	0,031
		Financial sustainability	0,133	0,012

appropriate strategy development method. The most important criterion for the technology criterion is the use of current technology, while the least important criterion is data management. While the most important criterion for the employees criterion is employee development and training, the least important criterion is the technological competence of the employees. The most important criterion for the management, organization, and culture criteria is the cooperation between the units, and the least important criterion is management support and planning. While the most important criterion for the budget criterion is investment in digital education and training, the least important criterion is financial sustainability.

4.3 Ranking of the Alternatives Using MABAC

In this section, the MABAC method has been applied to obtain the ranking of the digital maturity performance of the hospitals. The steps of the MABAC method followed are presented below.

Step 1: Create the Decision Matrix: In this context, the analysis of hospitals according to digital maturity criteria was evaluated by experts on a scale of 0–100 points. All criteria are considered in terms of maximization. The decision matrix obtained in this direction is given in Table 6.

Step 2 Normalize the Decision Matrix: The normalized decision matrix is given in Table 7.

Step 3 Compute the Weighted Normalized Decision Matrix: After the normalized decision matrix was created, the criterion weights obtained by the BMW method were used. The weighted normalized decision matrix is given in Table 8.

Step 4: The Border Approximation Area (BAA): In the next step of the method, the border proximity area and the distances of the decision alternatives to the border proximity area were determined and the matrices created are shown in Table 9, Table 10, and Table 11, respectively.

Step 5 Calculate the Distance of the Alternative and Compute Overall Score: In the last step, the distance values of the decision alternatives from the boundary proximity field are used and the criterion functions of each decision alternative are calculated. Table 11 shows the ranking of the alternatives according to the MABAC method. According to the table, the best alternative was determined as the first hospital.

Table 6. The decision matrix of MABAC

Alternatives	Criteria																		
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	88,3	88,3	90,0	86,7	86,7	85,0	83,3	83,3	90,0	90,0	81,7	90,0	80,0	83,3	85,0	91,7	90,0	83,3	85,0
Hospital-2	80,0	73,3	81,7	76,7	78,3	76,7	78,3	78,3	76,7	65,0	68,3	68,3	76,7	78,3	78,3	81,7	81,7	81,7	81,7
Hospital-3	81,7	80,0	83,3	83,3	80,0	80,0	80,0	81,7	81,7	81,7	73,3	76,7	73,3	80,0	85,0	88,3	86,7	83,3	83,3

Table 7. The normalized decision matrix of MABAC

Alternatives/Criteria	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hospital-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hospital-3	0,200	0,444	0,200	0,667	0,200	0,400	0,333	0,667	0,375	0,667	0,375	0,385	0	0,333	1	0,667	0,600	1	0,500

Table 8. Weighted matrix

Alternatives/Criteria	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	0,037	0,079	0,079	0,218	0,144	0,102	0,032	0,132	0,103	0,099	0,069	0,088	0,188	0,123	0,156	0,189	0,098	0,061	0,024
Hospital-2	0,019	0,040	0,040	0,109	0,072	0,051	0,016	0,066	0,052	0,049	0,034	0,044	0,141	0,061	0,078	0,094	0,049	0,031	0,012
Hospital-3	0,022	0,057	0,048	0,182	0,087	0,071	0,021	0,110	0,071	0,082	0,047	0,061	0,094	0,082	0,156	0,157	0,079	0,061	0,018

Table 9. Determine the border approximation area matrix

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
g_i	0,025	0,057	0,053	0,163	0,097	0,072	0,022	0,099	0,072	0,074	0,048	0,062	0,136	0,085	0,124	0,141	0,072	0,048	0,018

Table 10. The distance matrix of alternatives from the boundary proximity area

Alternatives/Criteria	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	0,012	0,023	0,026	0,055	0,048	0,030	0,010	0,034	0,031	0,025	0,021	0,026	0,053	0,038	0,032	0,048	0,026	0,013	0,007
Hospital-2	-0,006	-0,017	-0,013	-0,054	-0,024	-0,021	-0,006	-0,033	-0,021	-0,024	-0,014	-0,018	0,005	-0,024	-0,046	-0,047	-0,023	-0,018	-0,005
Hospital-3	-0,003	0,001	-0,006	0,019	-0,010	0,000	-0,001	0,011	-0,001	0,009	-0,001	-0,001	-0,042	-0,003	0,032	0,016	0,006	0,013	0,001

Table 11. Ordering results by the best alternative

	Si	Rank
Hospital-1	0,556	1
Hospital-2	-0,409	3
Hospital-3	0,040	2

4.4 Ranking of the Alternatives Using CODAS

In this section, the CODAS method has been applied to obtain the ranking of the digital maturity performance of the hospitals. The steps of the CODAS method followed are as follows. Decision makers evaluated 3 hospitals on a 1–5 Likert scale, with 1 being the least important and 5 being the most important according to the digital maturity criteria. The numbers defined for the sub-criteria in the study are shown in Table 12.

Table 12. Numbers of sub-criteria

Criterion number	Criteria
K1	Willingness of institution managers in digital implementation
K2	Digital management talent and competence
K3	Potential of risk taking
K4	Quick response
K5	Roadmaps for a digitalization strategy
K6	Determining the appropriate strategy development method
K7	Data management
K8	Use of current technology
K9	Technology capacity
K10	Employee development and training
K11	Technological competence of employees
K12	Senior management support to employees
K13	Cooperation between department
K14	Management support and planning
K15	Digital vision
K16	Propensity with innovative businesses
K17	Investment in digital education and training
K18	Technological equipment and investment budget
K19	Financial sustainability

Step 1: Create the Decision Matrix: The first step of the CODAS method is the creation of the decision matrix given in Table 13. The decision matrix was created by taking the arithmetic average of the scores given by the decision makers.

Table 13. The decision matrix of CODAS

Alternatives	Criteria																		
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	5,0	4,7	5,0	4,3	5,0	5,0	4,7	4,3	5,0	5,0	4,0	5,0	4,3	4,7	4,7	5,0	5,0	4,3	4,3
Hospital-2	4,3	4,0	4,3	4,0	4,0	4,3	3,7	3,7	3,3	3,0	3,3	3,3	3,7	3,7	3,7	4,3	4,0	4,0	4,0
Hospital-3	4,0	4,3	3,7	3,7	4,0	4,3	4,7	4,7	4,7	4,7	3,7	3,7	4,0	4,0	4,7	4,7	4,3	4,3	4,0

Step 2: Compute the Normalized Decision Matrix: The decision matrix created while ranking the alternatives is normalized. All of the sub-criteria are utility criteria, the criteria values of the alternatives are divided by the highest criterion value in the column they are in. The normalized decision matrix is given in Table 14.

Step 3–4: Compute the Weighted Normalized Decision Matrix and Determine the Negative-Ideal Solution: After the normalized decision matrix was created, the criterion weights obtained by the BMW method were used. The weighted normalized decision matrix and the distances to the negative ideal solution are given in Table 15.

Step 5: Calculate the Euclidean and Taxicab Distances: The distances found for the Euclidean and Taxicab distances are given in Table 16.

Step 6: Construct the Relative Assessment Matrix: The relative evaluation matrix and the evaluation score of each hospital are shown in Table 17 $\tau = 0.02$ in the calculations.

Step 7–8: Calculate the Assessment Score of Each Alternative and Rank the Alternatives: According to the performance analysis, the hospital with the best performance in digital maturity studies is 1-3-2, respectively. Evaluation scores and ranking are shown in Table 18.

Table 14. The normalized decision matrix of CODAS

Alternatives/Criteria	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	1	1	1	1	1	1	1	0,929	1	1	1	1	1	1	1	1	1	1	1
Hospital-2	0,867	0,857	0,867	0,923	0,8	0,867	0,786	0,786	0,667	0,6	0,833	0,667	0,846	0,786	0,786	0,867	0,8	0,923	0,923
Hospital-3	0,8	0,929	0,733	0,846	0,8	0,867	1	1	0,933	0,933	0,917	0,733	0,923	0,857	1	0,933	0,867	1	0,923

Table 15. Weighted matrix and negative-ideal solution

Alternatives/Criteria	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19
Hospital-1	0,019	0,040	0,040	0,109	0,072	0,051	0,016	0,061	0,052	0,049	0,034	0,044	0,094	0,061	0,078	0,094	0,049	0,031	0,012
Hospital-2	0,016	0,046	0,034	0,101	0,058	0,044	0,013	0,052	0,034	0,030	0,029	0,029	0,080	0,048	0,061	0,082	0,039	0,028	0,011
Hospital-3	0,015	0,043	0,029	0,092	0,058	0,044	0,016	0,066	0,048	0,046	0,032	0,032	0,087	0,053	0,078	0,088	0,043	0,031	0,011
Negative-ideal solution	0,015	0,040	0,029	0,092	0,058	0,044	0,013	0,052	0,034	0,030	0,029	0,029	0,080	0,048	0,061	0,082	0,039	0,028	0,011

Table 16. Euclidean and Taxicab distances

	Ei	Ti
Hospital-1	0,051	0,193
Hospital-2	0,012	0,022
Hospital-3	0,033	0,097

Table 17. Relative Assessment Matrix (*Ra*)

Alternatives	Hospital-1	Hospital-2	Hospital-3
Hospital-1	0,000	0,039	0,018
Hospital-2	-0,039	0,000	-0,021
Hospital-3	-0,018	0,021	0,000

Table 18. Evaluation scores and ranking

	Hi	Rank
Hospital-1	0,057	1
Hospital-2	-0,060	3
Hospital-3	0,003	2

4.5 Comparison of Results and Sensitivity Analysis

As seen in Table 19, the rankings obtained from CODAS and MABAC methods support each other when digital maturity performances are compared in hospitals.

Table 19. Comparative ranking results

	CODAS		MABAC	
Hospital- 1	0,057	1	0,556	1
Hospital- 2	-0,060	3	-0,409	3
Hospital- 3	0,003	2	0,040	2

As the τ parameter is generally accepted as 0.02 in the literature, the same value was taken as the basis in the study [35, 36]. After the performance measurement, sensitivity analysis was carried out to test the consistency of the application. In this context, in order to investigate the effect of the change in the τ parameter on the ranking, the application was repeated using 14 different τ values between 0.01 and 1.00, and the performance rankings obtained with different τ values are summarized in Fig. 5. As seen in Fig. 5, the hospital digital maturity performance ranking did not change in different τ parameters. Consequently, Hospital 1 had the best performance regardless of τ variation.

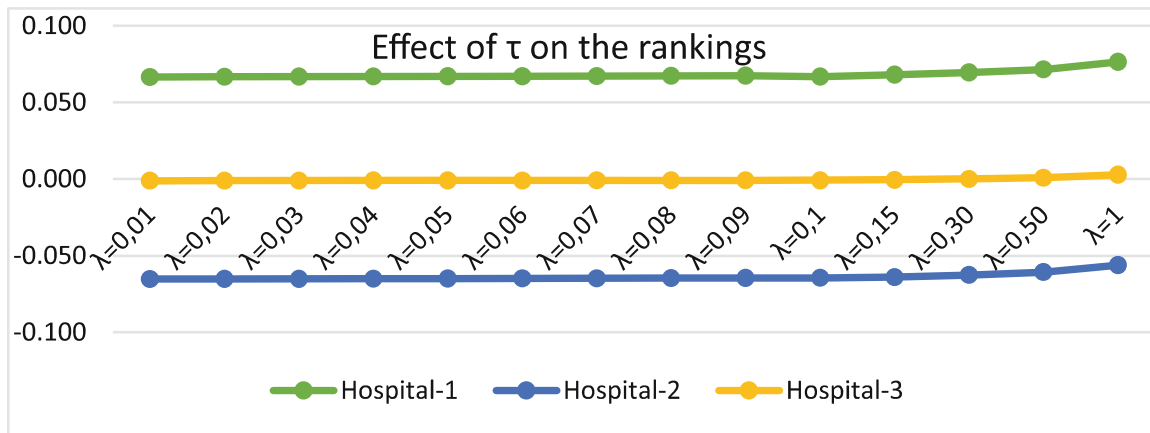


Fig. 5. Effect of τ change on ranking

5 Conclusions

Just as the development of technology has changed the life of humanity and the services provided, it has also greatly affected the healthcare sector and has led to the transition to new orders and methods. With the efforts and innovations to adapt to the new world order, the steps taken in digitalization have gained momentum. The concept of digitalization for institutions is a new concept that requires maturity. On the other hand, the concept of digital maturity, which is a tool and roadmap used to measure, improve and compare it with other competitors, is becoming a necessity brought about by digitalization process. As a result of the detailed literature review, digitalization and digital maturity models, which have gained popularity in recent years, are tried to be applied in many sectors. It is emphasized that digitalization, which is seen as the foresight of the future, provides an important opportunity for development and competition against competitors for many sectors. With the integration of digitalization into companies, the effects of it on their productivity and quality improvements are clear.

Another branch of digitalization in healthcare is the digitization of hospitals. In the study, a digitalization roadmap and evaluation for three hospitals in Istanbul are presented. The aim of the roadmap is to enable hospitals to see their faults, to create a tool where they can evaluate themselves, and to contribute to their progress and development by participating in the digitalization process, which is indispensable for Industry 4.0. In the developed model, whether the hospitals are ready for Industry 4.0 and digitalization was evaluated in terms of technology, management, budget, and personnel. The importance weights of the criteria were determined by the BWM method, which is the criterion weighting method. According to the BWM method, the order of the main criteria, starting from the most important, was measured as “management”, “organization”, “culture”, “strategy”, “technology”, “employees”, “leadership”, and “budget”.

When the sub-criteria are examined, the most important criterion in the leadership sub-criterion is “digital management ability” and “competence”, the least important criterion is the willingness of the corporate managers in digital implementation. In the strategy sub-criteria, the most important criterion is quick response and the least important criterion is the determination of the appropriate strategy development method. In

the sub-criteria of technology, the most important criterion is the use of up to date technology, the least important criterion is data management. The most important criterion in the employees' sub-criteria is employee development and training, the least important criterion is the technological competence of the employees. The most important criterion in the management, organization, and culture sub-criteria is inter unit work, the least important criterion is management support and planning. The most important criterion in the budget sub-criteria is investment in digital education and training, the least important criterion is financial sustainability. The criteria weights found were used in the CODAS and MABAC methods. The ranking was made among the hospitals and it was 1-3-2. Looking at the MABAC and CODAS rankings, it is seen that the hospital rankings are the same and support each other. When the results of the sensitivity analysis were examined in the last part of the application, it was seen that there was no change in the ranking. The study is to present up to date analyzes in terms of the proposed model and methodology. In addition, in today's world where digitalization gains importance day by day, it is of great importance to closely follow developments in the field of health-care. It is thought that the study will contribute to both the sector and the literature by eliminating the gap in the literature.

For future studies, at the stage of determining the weights of the criteria, it can be examined how the weighting method changes the solution by comparing the hospital rankings by finding the weights with different MCDM method. The methods used for the study can be used to solve the other MCDM problem. The performance evaluation problem can also be handled with the fuzzy approach and the study area can be expanded by increasing the number of institutions for future studies.

References

1. Bhatnagar, H.: Demonetization to digitalization: a step toward progress. *Manage. Econ. Res. J.* **3**, 11–15 (2017)
2. Üstündağ, A., Çevikcan, E.: *Industry 4.0: managing the digital transformation*, springer series in advanced manufacturing. İstanbul Teknik Üniversitesi, İstanbul (2017)
3. Ganzarain, J., Errasti, N.: Three stage maturity model in SME's toward industry 4.0. *J. Indust. Eng. Manage.* **9**(5), 1119–1128 (2016)
4. Uysal, Ö.Ü.B., Semiz, Ö.Ü.T.: *Sağlık hizmetlerinde dijitalleşme ve geleceği* (2022)
5. Peker, S.V., Van Giersbergen, M.Y., Biçer, G.: Sağlık bilişimi ve Türkiye'de hastanelerin dijitalleşmesi. *Sağlık Akademisi, Kastamonu* **3**(3), 228–267 (2018)
6. Schumacher, A., Erol, S., Sihn, W.: A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises (2016)
7. Özçelik, T.Ö., Erkollar, A., Cebeci, H.I.: Bir İmalat İşletmesi için Endüstri 4.0 (Dijital) Olgunluk Seviyesi Belirleme Uygulaması. In: 5th International Management Information Systems Conference, Ankara. *Procedia CIRP*, vol. 52, pp. 161–166 (2018)
8. Gülseren, A., Sağbaşı, A.: Endüstri 4.0 perspektifinde sanayide dijital dönüşüm ve dijital olgunluk seviyesinin değerlendirilmesi. *Eur. J. Eng. Appl. Sci.* **2**(2), 1–5 (2019)
9. Eke, E.: Lojistik Sektöründe Faaliyet Gösteren Firmaların Endüstri 4.0 Olgunluk Seviyesinin Ölçülmesi. Bahçeşehir Üniversitesi, İstanbul (2018)
10. Büyüközkan, G., Güler, M.: Analysis of companies digital maturity by hesitant fuzzy linguistic MCDM methods. *J. Intell. Fuzzy Syst.* **38**(1), 1119–1132 (2018)

11. Baki, B., Serdar, D.: Sanayi 4.0 olgunluk düzeyinin değerlendirilmesine yönelik çok kriterli bir yaklaşım: lojistik sektörü uygulaması. Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi **38**(4), 655–693 (2020)
12. Telli, G., Ayçin, E.: Öğretmen seçim sürecinde en iyi-en kötü ve Mabac yöntemlerinin bütünlük olarak kullanılması. Troy Acad. **6**(2), 733–750 (2021)
13. Bibby, L., Dehe, B.: Defining and assessing industry 4.0 maturity levels–case of the defence sector. Product. Plan. Control **29**(12), 1030–1043 (2018)
14. Johansson, G., Wilhelmsson, S.: Digital Maturity & Operational Performance: a case study in the supply-chain of the Scandinavian FMCG industry (2018)
15. Ataman, A.: Savunma sanayinde endüstri 4.0 olgunluk parametrelerinin tereddütlü bulanık ahp yöntemi ile önceliklendirilmesi. Bahçeşehir Üniversitesi. Yüksek Lisans Tezi, İstanbul (2018)
16. Işık, T.: Sağlık iletişimi bağlamında kullanım şekilleri açısından dijital algı ve önemi”. Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Cilt: 23 Özel Sayı, pp. 1979–1994 (2019)
17. Martin, G., et al.: Evaluating the impact of organisational digital maturity on clinical outcomes in secondary care in England. NPJ Dig. Med. **2**(1), 1–7 (2019)
18. Kosif, F.K.: Kurumların Dijital Dönüşüm Süreçlerinin İncelenmesi: Bir Sağlık Kurumu İçin Öneri. İstanbul Üniversitesi, Fen Bilimleri Enstitüsü, Enformatik Anabilim Dalı, Enformatik programı, Yüksek lisans Tezi, İstanbul (2019)
19. Cem, E., Tekin Temur, G., Sahin, C.: Hastane yönetimi için yeni bir endüstri 4.0 olgunluk modeli geliştirilmesi ve örnek bir uygulama. İstanbul. International Engineering and Technology Management Summit (2019)
20. Kayar, A.: İmalat sektöründeki işletmelerde endüstri 4.0’ a geçiş için dijital olgunluk seviyesinin belirlenmesi: yeni bir model önerisi. Yüksek Lisans Tezi. İstanbul: İstanbul Ticaret Üniversitesi Fen Bilimleri Enstitüsü (2019)
21. Kaya İlhan, Ç., Büyükçelikkok, T.Ö.: “Covid-19 ve medyada dijitalleşme etkisi: ana haber bültenlerinde sağlık haberleri, whatsapp ihbar hattı ve online röportaj kullanımı üzerine bir inceleme. IBAD Sosyal Bilimler Dergisi **12**, 33–49 (2022)
22. Wagire, A.A., Joshi, R., Rathore, A.P.S., Jain, R.: Development of maturity model for assessing the implementation of Industry 4.0: learning from theory and practice. Product. Plan. Control **32**, 603–622 (2020)
23. Baki, B., Serdar, D.: Sanayi 4.0 olgunluk modeli uygulamaları üzerine literatür incelemesi. Kafkas Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi **11**(22), 766–787 (2020)
24. Sarı, T.: Endüstri 4.0 teknolojik olgunluk düzeyinin analitik hiyerarşi prosesi ile modellenmesi: gıda ve içecek imalat sektörü örneği”.BMIJ **8**(3), 3526–3549 (2020)
25. Baltacı, İ.: Lojistik sektöründe dijital olgunluk seviyesinin ölçülmesi ve bir uygulama. Yüksek lisans tezi, Bahçeşehir Üniversitesi, Mühendislik Yönetimi Ana Bilim Dalı, İstanbul (2020)
26. Demir, E., Kocaoglu, B.: Best-worst analysis method of business maturity through digital transformation processes: an example for it sector. Press Acad. Procedia **11**(1), 43–46 (2020)
27. Sağlam, M.: İşletmelerde geleceğin vizyonu olarak dijital dönüşümün gerçekleştirilmesi ve dijital dönüşüm ölçeğinin türkçe uyarlaması. İstanbul Ticaret Üniversitesi Sosyal Bilimler Dergisi **20**(40), 395–420 (2021)
28. Kaya, H.: Dijitalleşme sürecindeki bir hastane çalışanlarının e-sağlık sistemlerinin hizmet sunumuna etkileri konusunda bilgi, tutum ve beklentilerinin incelenmesi. Yüksek lisans tezi, İstanbul Medipol Üniversitesi Sağlık Bilimleri Enstitüsü (2020)
29. Gürsoy, Ö.: Yalın üretim sisteminde dijitalleşme ve endüstri 4.0 uygulamaları ile süreç iyileştirme analizi: bir imalat işletmesinde uygulama. Doktora tezi, Aydın Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü (2021)
30. Rezaei, J.: Best-worst multi-criteria decision-making method. Omega **53**, 49–57 (2015)

31. Pamučar, D., Čirović, G.: The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison MABAC. *Expert Syst. Appl.* **42**(6), 3016–3028 (2015)
32. Pamučar, D., Petrović, I., Čirović, G. “Modification of the Best–Worst and MABAC methods: a novel approach based on interval-valued fuzzy-rough numbers. *Expert Syst. Appl.* **91**, 89–106 (2018)
33. Gigović, L., Pamučar, D., Božanić, D., Ljubojević, S.: Application of the GIS-DANP-MABAC multi-criteria model for selecting the location of wind farms: a case study of Vojvodina, Serbia. *Renew. Energy* **103**, 501–521 (2017)
34. Dahooei, J.H., Zavadskas, E.K., Vanaki, A.S., Firoozfar, H.R., Keshavarz-Ghorabae, M.: An evaluation model of business intelligence for enterprise systems with new extension of CODAS (CODAS-IVIF). *Technická univerzita v Liberci* **21**(3), 171–187 (2017)
35. Keshavarz Ghorabae, M., Zavadskas, E.K., Turskis, Z., Antucheviciene, J.: A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making. *Econom. Comput. Econom. Cybernet. Stud. Res.* **50**(3), 25–44 (2016)
36. Badi, I.A., Abdulshahed, A.M., Shetwan, A.G.: A case study of supplier selection for a steelmaking company in libya by using the combinative distance-based assessment (CODAS) model. *Dec. Making Appl. Manage. Eng.* **1**(1), 1–12 (2018)