Assessing the Digital Maturity Level of Higher Education Institutions

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Abstract - **The primary focus of this paper is to propose a methodology for prioritizing the elements in the Digital Maturity Framework for Higher Education Institutions (DMFHEI) and assessing the digital maturity level (ML) of HEIs in Croatia. Developing the DMFHEI requires the application of a sophisticated methodology, which includes a set of methods, techniques, and instruments. Some of the analyses performed are qualitative, such as the comparison of similar frameworks and strategic documents, while others are quantitative, such as the Q-sorting method, focus groups, and multi-criteria decision-making methods. In the framework development phase, the well-known multi-criteria decision-making method the analytic hierarchy process/analytic network process (AHP/ANP) was implemented to prioritize the main areas and elements identified in the framework. The results of prioritization are shown in this paper, as well as the influence of the area and element priorities on the general digital ML of the institution.**

Keywords - digital maturity, framework, prioritization, higher education, AHP, ANP, areas, elements

I. Introduction

Digital technologies in educational institutions have the potential to be one of the leading means of delivering quality education in line with institutions' mission and vision. Using the Digital Maturity Framework for Higher Education Institutions (DMFHEI) makes it possible to estimate the maturity level (ML) of the higher education institutions (HEI), to identify all areas that need to be improved, and to give recommendations about how to achieve the required improvements. This paper aims to propose a methodology for prioritizing elements within the DMFHEI and assessing the digital MLs of HEI in the Republic of Croatia. This paper is divided into the several sections. Section 2 introduces the areas and elements of the DMFHEI. In Section 3, the methodology for prioritizing the elements in the DMFHEI is proposed and the methods used to develop the methodology are described. In Section 4, the application of the methodology for prioritizing the elements in the DMFHEI and for calculating HEI digital maturity is presented.

II. Areas and Elements of the DMFHEI

The DMFHEI has been in development since July 2015. The methodological approach used throughout the development process was mostly qualitative. We have modified methodology used in development of Digitally Mature Framework for primary and secondary schools in Croatia [1]. In the first phase, we completed a qualitative analysis of 15 frameworks for digital maturity [2]–[16], with a particular focus on information and communication technologies (ICT). After conducting qualitative analyses of the e-readiness assessment tools [17] and of the digital maturity assessment frameworks, in the second phase of the framework development process, two focus group studies were conducted to obtain input from experts on defining new framework areas and their elements. The results of the qualitative analyses of 15 digital maturity frameworks and the results of the two focus groups led to the proposal of seven areas and 53 elements for the DMFHEI [18].

In the second phase of the framework development process, the sorting cards (Q-sorting) method was applied [19]. During the Q-sorting process, experts were asked to sort 53 element cards into the seven proposed areas. After this was complete, we calculated a content validity ratio (CVR) [20], which decreased the number of elements by 10, from 53 to 43. In the third development phase, the results obtained by qualitative analysis, the research from the two focus groups, the Q-sorting process, and the calculation of the CVR ratio were analyzed by two external experts to yield a proposal for the DMFHEI. The developed DMFHEI contains areas and elements that are not mutually exclusive or disjointed. The DMFHEI identifies seven areas, within which there are 43 elements. These areas are as follows: 1) Leadership, Planning, and Management; 2) Quality Assurance; 3) Scientific Research Work; 4) Technology Transfer and Service to Society; 5) Learning and Teaching; 6) ICT Culture; and 7) ICT Resources and Infrastructure. After determining the DMFHEI area and elements, the next step was to determine the descriptions of each element. Due to space limitations, we are not able to show the descriptors of all 43 elements; however, we do highlight a few below.

The Leadership, Planning, and Management area [2]–[4], [16] consists of eight elements: financial investment in the use of ICT in learning and teaching, research and development, and the business of the institution; strategic planning of ICT integration in HEI; managing the integration of ICT in learning and teaching at HEI; managing the integration of ICT in scientific research at HEI; the information system for supporting the business processes of HEI; the planning and implementation of training for HEI employees in the field of digital competencies and ICT application; the relationship between HEI and state from the aspect of ICT integration; and HEI policy in ICT integration and monitoring global trends.

The Quality Assurance area [21] consists of six elements: ICT quality assurance policies; the monitoring and periodic review of study programs, from the aspect of ICT application; work evaluation of teaching, research, administrative, and technical staff; the continuous monitoring of the results of scientific-teaching work and progress; procedures for determining the needs, development, or acquisition of ICT resources and their application; approved procedures and follow-up of student enrolment, progress through study, and completion of studies supported by ICT.

The Scientific Research Work area [22] consists of six elements: the use of ICT in the preparation and publication of scientific papers; ICT support in the preparation and management of scientific research work and projects; ICT research (collaborative ICT research on HEI); a system of support for researchers at the beginning of their careers in applying ICT in scientific research; continuous training of researchers in ICT application in scientific research; and the networking and collaboration of researchers with ICT support.

The Technology Transfer and Service to Society area [3], [5], [16] consists of three elements: collaboration with stakeholders (i.e., employers, the local community, and pre-tertiary education) supported by ICT; applied research and professional projects supported by ICT and/or for ICT; and the networking of researchers and users of research (stakeholders) supported by ICT.

The Learning and Teaching area [2]–[4], [12], [16] consists of seven elements: preparation, storage, and use of digital content in learning and teaching; innovative learning and teaching methods with ICT; the development of teachers' digital competence; the development of students' digital competence; the use of learning analytics to improve learning and teaching; ubiquitous learning and open curricula; and personalization and support for under-represented groups by using ICT in learning and teaching.

The ICT Culture area [2], [3], [12], [16] consists of six elements: the network presence of HEI; using ICT in HEI promotion; the development of digital literacy and the promotion of innovativeness in ICT application with HEI employees; the self-confidence and motivation of employees in terms of the importance of ICT application; providing access to and support in the application of ICT infrastructure; and the application of ethical standards, copyrights, and intellectual property in the ICT field.

The ICT Resources and Infrastructure area [3]–[5], [12], [16] consists of seven elements: the availability of ICT resources (hardware and software) for learning and teaching; the availability of ICT resources for scientific research; network infrastructures at HEI; access to ICT resources for students (both in and out of the classroom); the digital environment and information systems available to employees and students; the technical support and maintenance of ICT resources at HEI; and the information security system.

III. METHODOLOGY

The main idea of the DMFHEI is to measure the digital maturity of HEI using the criteria (areas and elements) described in Section 2. These criteria are not equally important, so we calculated their weights using the multi-criteria decision making method called the analytic hierarchy process/analytic network process (AHP/ANP). However, to calculate how digitally mature a certain HEI is, it is important to use the appropriate instrument for collecting judgments from examiners. Based on the characteristics of answers (judgments) that must be collected for assessing the digital maturity level of HEI, we decided to use instrument based on rubrics and ratings.

The proposed methodology for prioritizing the areas and elements in the DMFHEI and calculating the digital ML of HEI in Croatia consists of several phases (Fig. 1):

1. Establishing the starting point, which is the hierarchical structure of the DMFHEI's elements
2. Prioritizing the main areas
3. Prioritizing the elements
4. Calculating the total elements' weight
5. Establishing rubrics and evaluating the HEI using the rubrics
6. Transforming the levels to level priorities
7. Calculating the HEI's element priorities
8. Calculating the final ML of the HEI

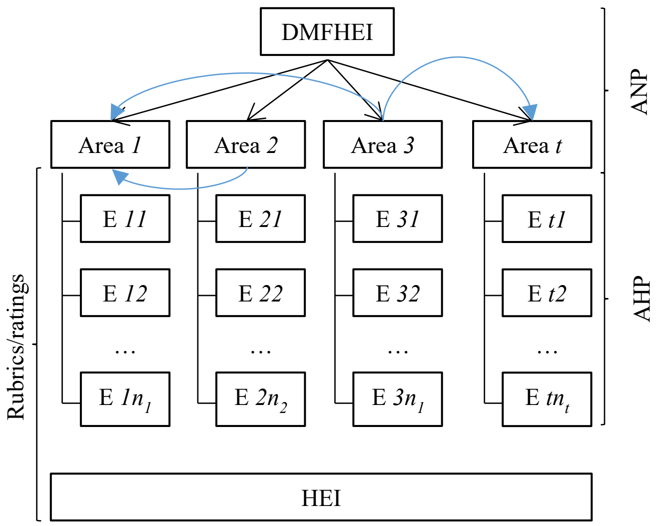

Figure 1. Methodology for prioritizing elements in the DMFHEI and calculating the digital ML of HEI in Croatia.

In next part of the paper, the methods used in the proposed methodology are shortly presented.

A. AHP and ANP

In the previous section, an initial hierarchical structure of the DMFHEI was presented. However, in previous researches the authors of the paper have characterized problems in HE field as complex problems with influences, dependencies, and feedback between elements [23]–[26]. So conclusion is that the network structure is more appropriate for modelling strategic problems in HE then hierarchical structure. That means that some areas in the framework can influence other areas. Similarly, some elements can influence other elements, even those that are from different areas. Establishing the network structure by using the ANP on both levels – areas and elements is a very complicated task in terms of implementation because it is very difficult to consistently perform this kind of decision making and it is time-consuming to correctly identify the intensity of the influence of each element upon each of the other 42 elements. So in this paper we are proposing a hybrid approach: the weights of the areas will be determined using the ANP, and the weights of the elements will be determined using the AHP. This will decrease the complexity of implementation (when compared to applying the ANP to determine both the weights areas and elements).

The AHP is the most-used multi-criteria decision-making method in HE [27]. It is based on pairwise comparisons of decision-making elements. In pairwise comparisons, the Saaty scale is used. The scale consists of nine degrees (1–9). Value 1 means that two elements in the pair are equally important. Other values represent the domination of one element over others (weak, strong, very strong, and absolute) [28]. When pairwise comparisons are completed, the inconsistency ratio is calculated. There are four steps in the AHP [29], [30]:

1. Creating the hierarchy structure
2. Completing pairwise comparisons of elements from the same level in the structure with respect to superior elements in the hierarchy
3. Calculating priorities
4. Performing sensitivity analysis

The ANP is a generalization of the AHP. This method supports modeling dependencies and feedback between elements in the problem structure [31]. There are several steps in the ANP (adapted from [26], [32], [33]):

1. Creating the network structure of the problem
2. Completing pairwise comparisons on the node level and calculating the unweighted supermatrix
3. Completing pairwise comparisons on the cluster level and calculating the weighted supermatrix
4. Calculating the limit matrix
5. Performing sensitivity analysis

The ANP has some weaknesses in terms of its implementation, such as the high number of pairwise comparisons, the long duration of the implementation process, and the ease of misunderstanding some of the pairwise comparisons that have to be done (e.g., comparing the cluster of alternatives and the cluster of criteria with respect to the other cluster of criteria). If only ANP were to be applied to the presented case, 826 consistent pairwise comparisons of the criteria and 147 consistent pairwise comparisons of the cluster levels would need to be done. Because of this large number of comparisons that would have to be made by experts in the field, the implementation process becomes almost impossible. In a hybrid approach, 118 pairwise comparisons on the criteria level and 147 pairwise comparisons on the cluster level have to be done. The complexity of the pairwise comparisons on the cluster level will also be decreased when integrating the ANP with the Decision-Making Trial and Evaluation Laboratory (DEMATEL), as suggested in [26].

B. Rubrics and Ratings

The weights of the areas in the DMFHEI will therefore be calculated using the ANP integrated with the DEMATEL. In DEMATEL it is possible to structure the problem and transform it from graphs with influences onto the graph of dependencies, keeping the intensities of dependencies the same. In DEMATEL, the intensities of the influences between criteria are measured on a scale of 5 degrees: 0 means no influence, and 4 means very high influence [34]. Using the AHP, the local priorities of the elements in the DMFHEI will be calculated. By multiplying the local priorities of elements by the associated area weights, the total weights of the elements (TW) are calculated. To calculate the digital ML of certain HEI in some elements (HEI SP), the total weight of each element (TW) must be multiplied by the HEI's element priority (i.e., the HEI's ML per some element), which can achieve values from 0 to 1. The easiest way of determining the ML per some element is through the concept of direct assessment. Considering that local, direct assessment means evaluating the ML of HEI per some element and assigning a concrete value between 0 and 1 based on the HEI's real state, this approach is efficient but potentially dangerous, as it can bring a researcher to the wrong results. A more objective approach is to use rubrics combined with ratings, as "rubrics offer a process for making explicit the judgements in the evaluation and are used to judge the quality, the value, or the importance of the service provided" [35]. There are two basic elements, or dimensions, of rubrics:

- Criteria (in our case, element)
- Levels of how a specific criterion (element) is satisfied (e.g., poor, adequate, good, and excellent [36]). It is possible that all criteria are defined at the same level, but they can also differ within one area.

For each criterion (element) and level, an evaluation question or statement is defined, and the expert can more easily determine the local ML of HEI for certain element. Rubrics reduce assessment subjectivity. The instrument for the measurement of DMFHEI in this paper is based on the rubrics, and it was validated by several experts. There are several methods available for converting a qualitative rubric (level) to a quantitative priority (local ML):

- Direct assessment (e.g., we define that the level *poor* is the same as priority 0, *adequate* is 0.2, *good* is 0.5, and *excellent* is 1)
- Pairwise comparison (i.e., make pairwise comparisons of the levels and calculate the priorities, which have to be normalized)

Applying either of these two methods will assign a quantitative value to each level. We notice here that some values from the 0–1 scale will not be used.

IV. Results: DMFHEI

We developed an Excel-based application in which the whole DMFHEI calculation is implemented. When the HEI digital ML is to be determined, the user must evaluate the HEI with respect to each criterion. The rest of the calculation is automated. The procedures will be demonstrated in an example HEI. The focus of this paper is to propose a methodology for prioritizing the elements in the DMFHEI and calculating the digital ML of HEIs in Croatia, but not to come up with final priorities (weights and ML priorities). These can be determined after comprehensive data collection.

A. Priorities of the Areas

The areas (and elements) of the DMFHEI were previously identified using different techniques, as explained in [18]. To determine the priorities of areas, the integrated DEMATEL-ANP approach was used. Data were collected in the workshops, seminars, and meetings in the scope of the project Higher Decisions (higherdecision.foi.hr). The respondents were HE employees with experience in managing HEI. First, respondents evaluated the intensities of the influence between areas using the DEMATEL scale (0 = no influence, 1= weak influence, 2 = medium influence, 3 = strong influence, and 4 = very strong influence). The averaged results are given in Table 2. Second, the matrix has been converted to an unweighted and weighted supermatrix using the normalization procedure explained in [26].

Table 2. Matrix of influences

	M	QI	SC	S	T	Cul	Infra
Management	0.00	3.50	2.17	2.83	2.67	2.83	3.33
QI	2.50	0.00	2.17	2.00	3.17	1.83	1.17
Science	1.67	1.67	0.00	3.33	2.67	1.50	1.50
Society	2.17	1.50	2.67	0.00	2.17	2.33	2.00
Teaching	1.17	2.33	2.67	2.17	0.00	2.67	2.33
ICT Culture	1.67	1.83	1.50	2.33	2.67	0.00	3.50
ICT Infra.	2.50	1.33	2.33	2.33	3.00	3.33	0.00

Last, the area weights were obtained from the limit matrix: Leadership, Planning, and Management (0.171), Quality Assurance (0.133), Scientific Research Work (0.127), Technology Transfer and Service to Society (0.136), Learning and Teaching (0.139), ICT Culture (0.141), and ICT Resources and Infrastructure (0.152). The area weights were inserted into the Excel-based application (see Table 3, column ANP).

B. Priorities of the Elements

The priorities of the elements were identified by applying the AHP procedure directly and, after obtaining the priorities from the AHP, by multiplying those priorities with the associated area weights. The local priorities of the elements were inserted into Table 3 (column AHP). The final element priorities were also inserted into Table 3 (column TW).

Table 4. Rubric of Area Technology Transfer and Service to Society

Elements	Basic	Initial	e-Enabled	e-Confident	e-Mature
Collaboration with stakeholders (i.e., employers, the local community, and pre-tertiary education) supported by ICT	The HEI does not advocate cooperation with stakeholders (i.e., employers, the local community, or pre-tertiary education) with ICT support.	The HEI partly encourages but does not direct employees and students to cooperation with stakeholders (i.e., employers, local community, or pre-tertiary education) with ICT support.	The HEI is partially committed to cooperating with stakeholders (i.e., employers, local community, or pre-tertiary education) with ICT support.	The HEI encourages and directs employees and students to cooperate with the support of ICT with employers, businessmen, and the local community for the purpose of counselling.	The HEI encourages and directs employees and students to cooperate with the support of ICTs with employers, businessmen, and the local community (face to face, online, or in combination with one another) for the purpose of counselling or future cooperation.
Applied research and professional projects supported by ICT and/or for ICT	The HEI does not encourage or direct employees and students to conduct applied research and professional projects supported by ICT and/or for ICT.	The HEI partly encourages but does not direct employees and students to conduct applied research and professional projects supported by ICT and/or for ICT.	The HEI partly encourages and directs employees and students to conduct applied research and professional projects supported by ICT and/or for ICT.	The HEI encourages and directs staff and students to conduct applied research and professional projects supported by ICT and/or for ICT in order to promote development, innovation, and collaboration between the economy and the scientific research sector.	Applied research is a theoretical or experimental work undertaken to achieve new knowledge and primarily aimed at achieving a practical goal such as developing a new technology or product. The HEI encourages and directs employees and students to conduct applied research and professional projects supported by ICT and/or for ICT in order to improve development, innovation, and cooperation between the economy and the scientific research sector and to promote the development and transfer of technology activities.
The networking of researchers and users of research (stakeholders) supported by ICT	The HEI is not committed to the cooperation and exchange of the knowledge of researchers and users of research and employers.	The HEI is partially committed to cooperating but not to the exchange of the knowledge of researchers and users of research and employers with the support of ICT.	The HEI is partially committed to the cooperation and exchange of the knowledge of researchers and users of research with the support of ICT.	The HEI is committed to cooperating and exchanging researchers' knowledge through the networking of researchers and users of research (stakeholders) and employers with the support of ICT through partnerships with other educational institutions.	The HEI is committed to the cooperation and exchange of knowledge with the support of ICT through partnerships with other educational institutions, the private and public sectors, and the whole community as users of research.

TABLE 3. CALCULATING DIGITAL ML FOR HEI EXAMPLE

Areas	Elements	ANP	AHP	TW	LEVEL	LP	HEI SP
Leadership, Planning and Management	1. Financial investment in the use of ICT in learning and teaching; research and development; and the business of the institution	0,17	0,18	0,031	1	0,00	0,0000
	2. Strategic planning of ICT integration in HEI	0,17	0,20	0,034	2	0,20	0,0069
	3. Managing the integration of ICT in learning and teaching at HEI	0,17	0,11	0,019	3	0,40	0,0075
	4. Managing the integration of ICT in scientific research at HEI	0,17	0,11	0,019	4	0,60	0,0113
	5. The information system for supporting the business processes of HEI	0,17	0,10	0,017	5	1,00	0,0171
	6. The planning and implementation of training for HEI employees in the field of digital competencies and ICT application	0,17	0,10	0,017	3	0,40	0,0069
	7. The relationship between HEI and state from the aspect of ICT integration	0,17	0,11	0,019	2	0,20	0,0038
	8. HEI policy in ICT integration and monitoring global trends	0,17	0,09	0,015	1	0,00	0,0000
Quality Assurance	1. ICT quality assurance policies	0,13	0,21	0,028	1	0,00	0,0000
	2. The monitoring and periodic review of study programs from the aspect of ICT application	0,13	0,16	0,021	1	0,00	0,0000
	3. Work evaluation of teaching, research, administrative, and technical staff	0,13	0,15	0,020	2	0,20	0,0040
	4. The continuous monitoring of the results of scientific-teaching work and progress	0,13	0,14	0,019	3	0,40	0,0074
	5. Procedures for determining the needs, development, or acquisition of ICT resources and their application	0,13	0,16	0,021	5	1,00	0,0213
	6. Approved procedures and follow-up of student enrolment, progress through study, and completion of studies supported by ICT	0,13	0,18	0,024	3	0,40	0,0096
Scientific Research Work	1. The use of ICT in the preparation and publication of scientific papers	0,13	0,11	0,014	1	0,00	0,0000
	2. ICT support in the preparation and management of scientific research work and projects	0,13	0,08	0,010	2	0,20	0,0020
	3. ICT research (collaborative ICT research on HEI)	0,13	0,25	0,032	3	0,40	0,0127
	4. A system of support for researchers at the beginning of their careers in applying ICT in scientific research	0,13	0,11	0,014	5	1,00	0,0140
	5. Continuous training of researchers in applying ICT in scientific research	0,13	0,16	0,020	3	0,40	0,0081
	6. The networking and collaboration of researchers with ICT support	0,13	0,29	0,037	2	0,20	0,0074
Technology Transfer and Service to Society	1. Collaboration with stakeholders (i.e., employers, the local community, and pre-tertiary education) supported by ICT	0,14	0,40	0,055	5	1,00	0,0546
	2. Applied research and professional projects supported by ICT and/or for ICT	0,14	0,30	0,041	5	1,00	0,0409
	3. The networking of researchers and users of research (stakeholders) supported by ICT	0,14	0,40	0,055	5	1,00	0,0546
Learning and Teaching	1. Preparation, storage, and use of digital content in learning and teaching	0,14	0,12	0,017	1	0,00	0,0000
	2. Innovative learning and teaching methods with ICT	0,14	0,19	0,026	2	0,20	0,0053
	3. The development of teachers' digital competence	0,14	0,16	0,022	3	0,40	0,0089
	4. The development of students' digital competences	0,14	0,17	0,024	2	0,20	0,0047
	5. The use learning analytics to improve learning and teaching	0,14	0,18	0,025	1	0,00	0,0000
	6. Ubiquitous learning and open curricula	0,14	0,08	0,011	2	0,20	0,0022
	7. Personalization and support for under-represented groups by using ICT in learning and teaching	0,14	0,10	0,014	1	0,00	0,0000
ICT Culture	1. The network presence of HEI	0,14	0,20	0,028	1	0,00	0,0000
	2. Using ICT in HEI promotion	0,14	0,11	0,016	2	0,20	0,0031
	3. The development of digital literacy and the promotion of innovativeness in ICT application with HEI employees	0,14	0,26	0,037	4	0,60	0,0220
	4. The self-confidence and motivation of employees in terms of the importance of ICT application	0,14	0,15	0,021	5	1,00	0,0212
	5. Providing access to and support in the application of ICT infrastructure	0,14	0,10	0,014	4	0,60	0,0085
	6. The application of ethical standards, copyright, and intellectual property in the ICT field	0,14	0,18	0,025	3	0,40	0,0102
ICT Resources and Infrastructure	1. The availability of ICT resources (hardware and software) for learning and teaching	0,15	0,15	0,023	5	1,00	0,0229
	2. The availability of ICT resources for scientific research	0,15	0,15	0,023	4	0,60	0,0137
	3. Network infrastructures at HEI	0,15	0,13	0,020	3	0,40	0,0079
	4. Access to ICT resources for students (both in and out of the classroom)	0,15	0,18	0,027	2	0,20	0,0055
	5. The digital environment and information systems available to employees and students	0,15	0,12	0,018	1	0,00	0,0000
	6. The technical support and maintenance of ICT resources at HEI	0,15	0,12	0,018	2	0,20	0,0037
	7. The information security system	0,15	0,14	0,022	1	0,00	0,0000
						ML	**0,4296**

*ANP = area weight, AHP = element local weight, TW = total element weight, LEVEL = maturity achievement of HEI per each element (expert evaluation using rubrics), LP = priority of certain level, HEI SP = achieved priority of HEI per each element, ML = HEI ML

C. Digital MLs of HEI

A rubric was designed for each area. Each rubric consists of five levels, and each element is described through an appropriate statement. To each level, a local maturity priority (level priority, LP) is assigned. The application supports both direct assessment and pairwise comparisons for determining the LP. After the ML for each HEI is determined using the rubrics (Table 3, column LEVEL), the HEI's element priority is automatically calculated (Table 3, column HEI SP); then, the level is transformed to LP and multiplied by the total weight of the element (TW). Finally, the HEI ML is calculated by summing all the HEI SPs. The instrument used for the measurement of the DMFHEI created to assess digital maturity is very big, so it does not fit the paper limit. Therefore, we bring only a part of the rubric in Table 4, which presents the evaluation elements related to the Technology Transfer and Service to Society area. The whole rubric is available at the webpage of the Higher Decision project (http://higherdecision.foi.hr/).

V. Conclusion

In this paper, we proposed and demonstrated the methodology for evaluating and quantifying the digital ML of HEI based on the created DMFHEI. Still, there are some limitations to the proposed approach, which must be resolved before applying the methodology more broadly. The first limitation is related to data collection in terms of calculating the areas and elements priorities, as more field experts must be included in the process. The second limitation is related to the evaluation of the rubric instrument, which must also be evaluated by more field experts. Those are two main prerequisites for DMFHEI acceptance and its application to HEI in the Republic of Croatia. As a proposal for future work, calculating the elements' weights using the ANP (not AHP) must be examined, as there are also influences between the elements.

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