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The Classification of Success Performance of Entrepreneurial and Innovative Universities with Artificial Intelligence Methods

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ABSTRACT

With the increasing competition in higher education in the world and our country, universities are becoming entrepreneurial structures that attach importance to collaborations with industry, Intellectual and Property Rights, techno-parks, incubation centers, and international mobility of students and academics in addition to their traditional education and research functions. In this study, the Entrepreneurial and Innovative University Index (EIUI) score is used to categorize universities. In addition, it also investigates the distribution of the EIU index according to the status of universities (Foundation - State) and the relationship between URAP ranking scores. This study classifies universities using artificial intelligence methods that have been widely used in recent years. This positioning study, while clustering EIU universities in our country, aims to provide guidance for other universities to analyze their current situation and to determine future strategies in line with their competencies and goals.

Keywords: Entrepreneurial and Innovative University Index, Artificial Intelligence, Random Forest, Classification, University Performances, URAP, Research University.

JEL Classification Codes: Yazar tarafından gönderilmeli

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INTRODUCTION

Universities are among the most important institutions that contribute to society, economic stability, social welfare, the ability of nations to engage in international cooperation and internationalization, and the quality of life in a wide range of economic, social, and cultural terms.

At present, it is known that with the development of distance education opportunities and the increase in the applications of technology developments associated with education, the content and volume of education have increased significantly. These paradigm shifts require the redesign of all educational processes, from preschool education to higher education. The speed of circulation of educational outputs in terms of both graduates and knowledge has accelerated at an accelerated pace. As a result, industry, production, and financial structures attach more importance to collaborations with universities to access and benefit from the knowledge produced at universities faster and earlier. As a necessity of these conditions, universities have gone beyond being just areas where knowledge is produced, and have become institutions that work in cooperation with industry, transform knowledge into marketable products, create incentives for graduates and researchers to establish companies, and provide various benefits as a component of social projects. Although the variety of activities of universities has increased, their most important mission is education and scientific research. Additionally, scientific research is crucial for universities to gain a reputation and status abroad (Altbach, 2008).

Universities are adapting to promote regional, social, and economic welfare through contact with industry while maintaining their traditional roles of education and research (Odabaşı, 2006). It is observed that universities go beyond providing graduates who meet the human capital demand of this change and that the organizational structures of universities include new units such as career development centers, technology transfer offices, start-up incubation centers, and similar entities to adapt to this process.

The growing demand for higher education in our nation and around the world, in addition to the shift to mass education in the 1990s and the lack of adequate public resources, have forced institutions to look for

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new funding sources. Higher education institutions have turned to initiatives that provide universities with external resources, partnerships with universities in various regions, the use of intellectual property rights, techno-parks, incubation centers, international mobility of students and academics, and institution procedures where students are viewed as "customers" in this competitive environment. Due to the implementation of neo-liberal policies by some country governments, such as the USA, it has also been stated that colleges should be "entrepreneurial" to develop resources (Küçükcan&Gür, 2009).

The most important step in the economic, social, societal, and technological changes and developments of this paradigm is the spread of entrepreneurship culture. The cornerstone of the entrepreneurship ecosystem is entrepreneurial individuals and entrepreneurial organizational structures. The roles, areas of accountability, structures, and procedures of universities, as well as their capacity to raise money and perceive their surroundings, have all undergone significant changes as a result of this circumstance. Universities have now a new mission to pursue as a result of this transformation. The goal of this mission has been to increase university knowledge of entrepreneurship and to institutionalize the entrepreneurial ecosystem within the university. (Geçgil et al., 2018). An entrepreneurial university is, essentially, one that encourages research, entrepreneurship, education, and training. (Etzkowitz et al., 2000).

As a reflection of this change, the entrepreneurial university vision has started to become one of the positioning options of universities in our country. As a result of these processes, nowadays universities have become financially self-sufficient institutions, develop business ideas, contribute to employment, and adopt entrepreneurial activities along with education and research (Uysal&Çatı, 2016).

At the same time, some studies argue that the entrepreneurial university approach will lead to close cooperation with industry and that being involved in the free market economy has a negative impact on academic and educational achievement (Kirby, 2006). Three main types of potential threats were highlighted by Anderson (1990). The first is that colleges expose themselves to commercial risks. For instance, businesses occasionally risk losing money. The second category of risks is the management risks. Since outputs can be measured in terms of money in commercial companies, evaluation and control are conceptually simple. In universities, however, the objectives are many and difficult since they call for value judgments. There is the possibility of misuse and waste of institutional culture and goal-oriented support. Becoming an entrepreneurial university requires a fundamental, long-term, culture change in the entire organization. Thus, the created entrepreneurial culture may conflict with the academic culture over time (Çetin 2007).

On the other hand, it can also be stated that universities with entrepreneurial university visions exhibit significant developments in terms of academic autonomy and academic productivity. These universities develop high-value-added products with the knowledge they produce, create a strong financial structure, actively cooperate with their internal and external constituents, expand their research facilities and physical capacities, and thus attract qualified academics and successful students.

The evaluation of whether universities are entrepreneurial, innovative, student-oriented, research-oriented, or not has been tried to be measured and ranked with many scales developed in recent years. In order to meet this need, various institutions and organizations have developed indices and scores based on different parameters. The Times Higher Education - QS World University Rankings, Newsweek Magazine's Top 100 Global Universities, Shanghai Jiaotong University Academic Ranking of World Universities, Cybermetric Labs Webometrics, and others are the most well-known of these (Saka &Yaman, 2011). While examining the common criteria used in these scales, criteria such as the number of articles in different journal platforms, projects, patents, number of awards, number of academicians, university infrastructure and social facilities, campus facilities, technological infrastructure, etc. come forward. It can be said that these rankings are developed within the framework of different scales such as universal, regional, field/sector-based, and national levels.

University rankings based on different systems are not objective and there is no complete compatibility between the rankings. These differences in rankings indicate that there are significant contradictions between the ranking criteria. Therefore, when evaluating the rankings of different systems, the ranking criteria on which they are based should be taken into consideration. However, despite the criticisms of these ranking systems, most of the top universities find these rankings significant and are interested in taking the necessary actions to find a place for themselves in the top rankings (Saka &Yaman, 2011).

THEORETICAL FRAMEWORK

There are many studies on the definition, elements, structure, and culture of the entrepreneurial university in the literature. The large number of shareholders and characteristics around the entrepreneurial university concept have led to the production of different diagrams in the theoretical literature. The most popular of these is the Helix structure. Leydesdorff and Etzkowitz first examined the relationship between the government, the university, and the business sector with the Triple Helix model.

In the first stage of this model, it is seen that the government assumes an inclusive, guiding, and developing role for the university and the business sector, while in the second stage, it is stated that the structures have independent institutional characteristics but are related to each other. In the third stage, the relationship between the state, university, and the sector is seen to be in the form of structures that are institutional partners and intersectional clusters (Lefebvre, Pallez, &Fixari, 2009).

Carayannis and Campbell added the media to this diagram in 2009, and in 2010 they took into account the impact of the environmental factor and transformed the model into a Quintuple Helix model. The Helix diagram is also important in terms of showing the key actors of the entrepreneurial university ecosystem and its development over time (Barth, 2013).

Rankings that evaluate universities in terms of entrepreneurship and innovation activities have a relatively short background compared to general university rankings. The most comprehensive ranking on this subject is "The World's Most Innovative Universities" ranking by Thomson Reuters (Uslu et al. 2020). The literature on this subject focuses more on qualitative characteristics and the determination of variables.

The most basic components of the entrepreneurial university concept are social sensitivity, entrepreneurial institutional identity, and innovation-oriented characteristics (Yıldız, 2019). While examining the sub-dimensions of the TUBİTAK entrepreneurial and innovative university index, we can state that it considers many indicators within the theoretical framework covering these basic components.

In general, the index ranks the top 50 universities in Turkey in terms of entrepreneurship by score. It does not provide a comparison in terms of sub-dimensions, nor any details on the clustering and distribution of similar universities.

RESEARCH MODEL

The contribution of this study to the theoretical framework is to conduct a multidimensional positional analysis of universities beyond a linear ranking. It does this analysis by factoring in URAP ranking scores, university status, and being a research university in addition to the sub-dimensions of the EIUI. The study expands on the Helix approach, which is its theoretical basis, with a quantitative analysis within the framework of the EIUI. The research model of the study is shown in the figure as follows.

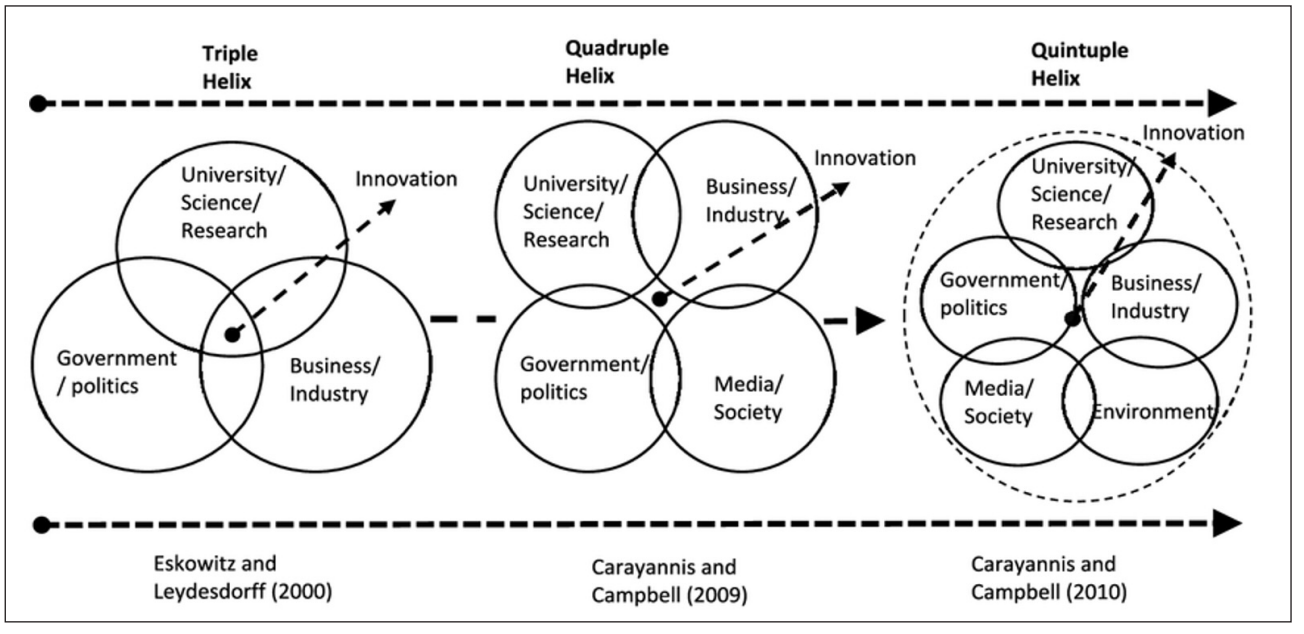

Figure 1: Helix structure of Entrepreneur universities (Barth, 2013)

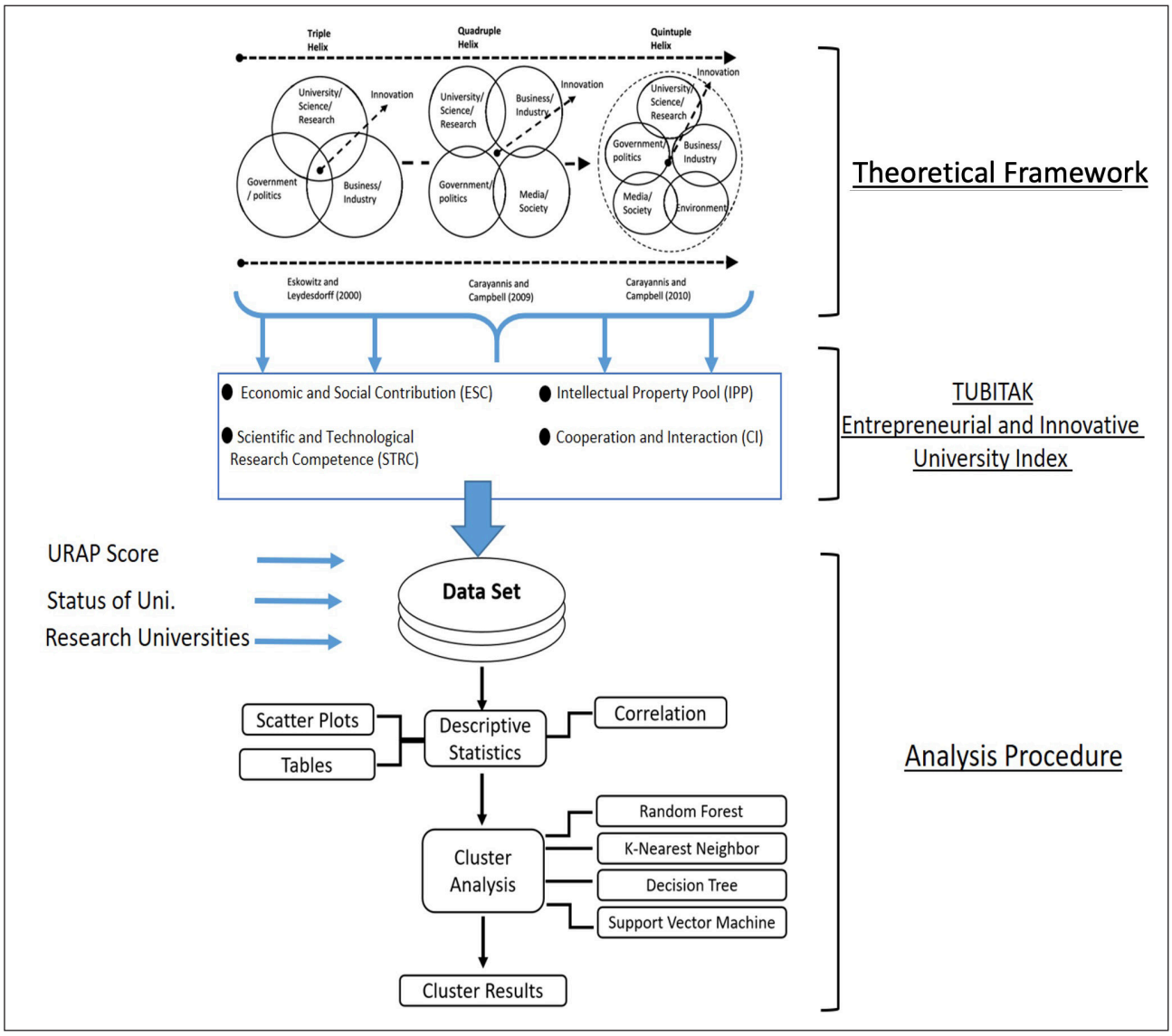

Figure 2: Theoretical Framework, Analysis Procedure of Research Model

The methods used in the study are similar to some of those used in the entrepreneurial university literature shown in the analysis procedure diagram. Erdoğmuş and Esen (2016), Shin, J. C. (2009), and Valadkhani and Worthington (2006) were categorized universities using hierarchical cluster analysis. The two-step clustering algorithm, a different clustering method, was used in the analysis. However, scatter plots, artificial intelligence-based clustering methods, and correlations with other parameters have not been sufficiently studied.

There are very few studies examining the relationship between universities with an Entrepreneurial and Innovative University (EIU) vision and success parameters. In addition, there is a significant gap in the literature regarding the categorization of this relationship according to different variables. The study aims to provide answers to the following questions for this reason:

- How are the universities in our country distributed in terms of the sub-factors that make up the EIUI score?
- What is the position of research universities in the EIUI?
- How is the distribution of the EIUI according to the status of universities (Foundation - State)?
- Is there a relationship between universities entrepreneurship and innovation activities and URAP ranking?

Within the framework of the answers to these questions, we aim to offer strategic planning suggestions to universities. Clustering on the axis of parameters will provide information about the position of universities and guide them on which issues they should focus on to be more successful.

The study limitations include the fact that the data set comprises 50 universities and 4 parameters. The clustering analysis includes these variables, but decision-makers can position other possible universities by the interpolation method. Another limitation is that the intangible outputs that constitute organizational identities are not included in a quantitative-based classification system.

The theoretical motivation of the study is that the approach developed around entrepreneurial and innovative universities will be instructive for other universities. This positioning study aims to determine the universities that other universities in our country can take as a reference according to their competencies and goals.

The literature section of the study gives information about previous studies, while the methodology section explains the variables and data used in the analysis. In the findings section, the results of the analysis are shown and interpreted with tables and graphs. In the discussion section, evaluations are made by comparing the relationship between the studies in the literature and the findings part.

LITERATURE

Tosun H. (2020) analyzed the effectiveness of 52 foundation universities founded between 1984 and 2010 in his study and offered some recommendations for the institutions. Analysis of the study's findings reveals that foundation universities are not uniformly different from public universities. In addition, it was found that the foundation universities were not productive, except for higher education institutions such as Sabancı, İhsan Doğramacı, Özyeğin, and Koç Universities, which showed high performance. Through the exception of the top five universities identified in the context of EIUI, it is evident that the majority of the foundation universities included in the study lack a culture of research and development.

Tekin, E. (2021) examined the effect of the universities' index scores on URAP performances by panel data regression method by using the data of EIUI for the years 2012-2017. The study's findings showed that institutions with a focus on entrepreneurship and innovation had students who performed better academically. Additionally, it was discovered that while the intellectual property pool dimension has a negative and significant impact on university academic performance, the other pillars of entrepreneurship and innovation—cooperation and interaction, economic contribution, and commercialization—have a positive and significant impact. Entrepreneurship and innovation culture do not affect the academic performance of universities.

There are numerous studies in the literature that use various techniques to evaluate how effective universities are. (Günay et al. (2017), Işıldak et al. (2018), Arslan&Güven (2018), Ertuğrul & Sarı (2017), Kutlar&Babacan (2008)). While the data envelopment analysis is mostly preferred for efficiency measurement in the literature, data on the number of researchers, budget and expenditure variables, number of students, and university infrastructure are used as input variables. As efficiency outputs, the number of academic activities, educational activity outputs (number of graduates, master's and doctoral degrees, etc.), and outputs related to university financial infrastructure are taken as reference (Çağlar and Gürler 2020).

Orhan and Yalçın (2021) analyzed the entrepreneurship and innovation efficiency of universities in Turkey and ranked them according to their relative efficiency. They also identified the universities that inefficient universities can take as references. The Data Envelopment Analysis (DEA) method was used in the study and the criteria to be taken into account in the ranking were also determined.

Using multi-criteria decision-making methods, Ömür and Karataş (2018) analyzed the results of 50 entrepreneurial universities in Turkey in 2016. The Entropy weight method was used to compute the criteria weights for the universities assessed using the 2016 data and the EIU index criteria, and the MAUT and SAW methodologies were then used to assess performance. Significant consistencies were found between the success rankings obtained as a result of the study and the classifications of our study. However, no inferences were made about the modeling success of the MAUT and SAW methods used in the study.

Geçgil et al. (2018) developed a new index for measuring university entrepreneurship levels in their study. The content, validity, reliability, and factor analyses of the developed scale were made and the scale was introduced to the literature.

Turkish universities were categorized using hierarchical cluster analysis by Erdoğmuş and Esen (2016). The CoHE and URAP rankings, EIU index rankings, and CoHE yearly reports made up the study's data. Universities are split into two major groups based on their institutional size and performance, according to the analysis's findings.

Using the Two-Step Clustering algorithm, one of the traditional approaches, Gözükara, İzlem. (2015) did a clustering analysis of 72 foundation universities in Turkey in terms of academic criteria. The study used

data on undergraduate and associate degree students, faculty and program numbers, faculty members, master's and doctoral program numbers, and the number of papers and projects. As a result of the study, foundation universities were generally divided into two clusters in terms of each parameter. The study does not suggest any improvement policy other than the current clustering of foundation universities.

In the study conducted by Yıldırım and Yıldırım (2020), the period 2012-2017 was determined as the study period. Using the EIUI scores published yearly for 50 universities, an alternative ranking method was developed by calculating interval-valued gray numbers to represent this period and analyzing them with the ARAS method. It is seen that the approach proposed in the study is consistent with the results of the studies conducted both with single annual studies where near-term analyzes are made and with the results of the studies conducted by combining all published period data.

In their study conducted in 2018, Er and Yıldız examined the index values published for 2016 and 2017 with the help of the ORESTE method and factor analysis. In this study, unlike TÜBITAK's point of view, the ORESTE method was applied to the EIUI data by considering both dimensions as criteria instead of assigning weights and using university evaluation scores by prioritizing these criteria. The two-factor models provide the chance to compare the conventional university structures and their views on entrepreneurship and innovation culture as a result of the factor analysis. These structures make it simpler for colleges to identify the factors that will help them rise in the rankings.

Alma et al. (2016) investigated global university rankings and attempted to create a field-based ranking system for Turkish universities. Raponi et al. (2016) used the binary-clustering method to compare the commonalities between the economics faculties of 55 Italian institutions. The main criteria used in clustering are education, productivity, research ability, and internationalization opportunities. As a result of the study, while classifications were made according to different criteria, it was seen that the status of the universities (State - Foundation) was the most prominent clustering distinction.

Shin, J. C. (2009) used a hierarchical cluster analysis to categorize universities in South Korea according to the number of publications, the number of doctoral graduates, and projects with outside funding. Among the results of the study, it was emphasized that in the classification of universities, attention should be paid to the research, education, social, or engineering missions of universities.

By using a hierarchical clustering analysis between 1998 and 2002, Valadkhani and Worthington (2006) categorized the research output of 37 Australian universities based on the number of PhDs, the number of academic staff, the number of prizes and scholarships, and the number of publications. Different categorization approaches and models weren't compared because the study is one of the pioneering studies in the literature.

In the study by Karahan and Kızkapan (2022), the entrepreneurial and innovative university index data of 2021 were used to calculate the performances of the universities. Their own institution, Firat University, was compared to the successful universities using the Promethee Gaia method.

Saygın et al. (2020) used the EIU Index data from 2012 to 2017 to measure the efficiency of universities using Data Envelopment Analysis, and they attempted to track changes in efficiency values over time using the Malmquist Total Factor Productivity Index.

In his study, YüzbaşıKünç, G. (2021) examined the performance of 41 state universities established within the scope of the "one university for each province" policy in Turkey by using the data of the 2009- 2019 periods with multidimensional scaling analysis. As a result of the study, it was concluded that the universities have progressed in terms of variables such as the number of publications, number of students, and staff, but remain below expectations. The positioning comparison was made according to the top 14 successful universities in the URAP ranking and it was determined that universities other than Giresun University, Burdur Mehmet AkifErsoy University, and TekirdağNamık Kemal University were not very successful.

DATA AND METHODOLOGY

The study population comprises 50 universities included in the TÜBİTAK-EIUI 2022 ranking. Along with the sub-factors of the relevant universities, the total scores of the EIUI, URAP ranking score, whether they are research universities or not, and their status (State - Foundation) were included in the study as variables.

The Index (EIUI), which is the main parameter of the study, was announced by TÜBİTAK (The Scientific and Technological Research Institution of Turkey) in 2012 and is calculated every year and the information of the

top 50 universities shared with the public. With this index's assistance, universities' scientific activities, patent studies, entrepreneurship, and innovation culture, as well as their industrial relations, can be analyzed and their success in producing high-value-added products can be monitored.

TÜBİTAK has identified a total of four pillars within the EIUI. These are Economic and Social Contribution (ESC), Cooperation and Interaction (CI), Scientific and Technological Research Competence (STRC) and Intellectual Property Pool (IPP), Universities are evaluated according to a total of 23 different indicators in the pillars of the index (TÜBİTAK 2022). The Ministry of Science, Industry, and Technology, TPE (The Turkish Patent and Trademark Office), the Ministry of Development, KOSGEB (Small and Medium Enterprises Development Organization), TTGV (The Technology Development Foundation of Turkey), TÜBA (The Turkish Academy of Sciences), and the universities are the sources of the data announced by TÜBİTAK.

The other performance indicators evaluated with the EIUI are the status of the universities (foundation-state), URAP ranking score, and whether they are research universities or not. Every year, the METU Graduate School of Informatics's URAP (University Ranking by Academic Performance) Research Laboratory conducts university rankings in Turkey and around the globe (URAP, 2022). The Council of Higher Education (CoHE) announced the "Research and Candidate Research Universities" on September 26, 2017, using a total of 33 criteria and 3 main titles. The determination of these universities was carried out within the scope of the "Specialization and Mission Differentiation Project" carried out by CoHE(YÖK 2022).

Since the data set of the study includes many variables (performance criteria) and units (universities), multivariate statistical analyses for example factor analysis, principal component analysis clustering analysis, and discriminant analysis can be used. Cluster analysis was chosen because the location of universities was the main inspiration for the study.

Cluster analysis aims to classify observations according to their similarity or distance. In other words, the main objective is to form groups of each individual (observation) with other individuals who are most similar to him/her or whose distance to him/her is the least in line with the characteristic or characteristics examined. The groups obtained should be homogeneous within themselves and heterogeneous to each other (Orhunbilge, 2011).

Clustering methods may vary according to the structure of the variables and the characteristics of the objects to be classified. The methods used vary according to criteria such as the appropriate distance method, error evaluation criterion, and model suitability.

Various cluster validity methods have been developed and utilized for the evaluation of algorithms in clustering methods. In this way, cluster accuracy, validity and the appropriate number of clusters can be determined in clustering analyses and clustering processes can provide much more appropriate and quality results. However, in recent years, technological developments such as machine learning and artificial intelligence have enabled the development of new methods and/or approaches.

In this study, we combined traditional classification techniques like Decision Tree and K-Nearest Neighbor (k-NN) with approaches based on artificial intelligence, such Random Forest (RF) and Support Vector Machine (SVM). In order to do classification, Support Vector Machine seeks out the hyperplane that optimizes the boundary between two classes. (Özkan et al., 2015). The main axis in the study is the Random Forest method, which shows better classification success.

The Random Forest algorithm is a machine learning-based approach that can be easily used for categorical, continuous data sets, or both. Machine learning methods are non-parametric as they do not rely on any assumptions about the distribution of the data. They are data-driven methods and learn the relationships between the predictor and the corresponding responses (Breiman 2001).

The Random Forest method offers the opportunity to obtain a margin of error without a deviation rate, provides the opportunity to obtain the original data set as a whole without dividing it into learning and test data sets, and enables the determination of the relationship and distance between the variables that make up the model thanks to the proximity command. However, the disadvantages are that a confidence interval is not given for the result after the model is created and the result is not in the form of a tree structure. Since the model is created in a complex way, the result's process is presented as a black box (Breiman, 2001, Cutler et al., 2007, Evans et al., 2011).

The classification and regression tree (CART) technique is used to build trees in the Random Forest Method. When the CART method is applied, the variable from which the data set will be divided into branches is chosen using

"information gain," but the proper test criterion (cut-off value) of the variable chosen for branching is determined by the "Gini index." (Akman et al., 2011). The GINI index measures class homogeneity and can be expressed by the following formula (1).

$$\sum\sum_{j\neq i}\left(f\left(C_i,T\right)/|T|\right)\left(f\left(C_i,T\right)/|T|\right) \quad (1)$$

Where T is the training dataset, C_i is the class to which a randomly selected university belongs and $f\left(C_i,T\right)/|T|$ is the probability that the selected university belongs to class C_i.

Applying the bootstrap approach, a sample is chosen from the data set for each tree in the Random Forest method, and a classification is made by utilizing a tree made up of 2/3 of the selected data. This category receives a "vote." The random forest method uses its categorization to choose the tree in the 'forest' that has received the most votes out of all the trees. The more accurate classifier is the tree with a lower error rate.

Random Forest has a similar approach to the Decision Tree. However, by growing trees, Random Forest adds more randomness to the model. When splitting a node, it seeks for the best feature among a randomly selected subset of features rather than the most crucial one. This generates a wide range of trees that are frequently expressed in a better model.

FINDINGS

In the study, for each of the EIUI, the total score of the index for the year 2022, the Scientific and Technological Research Competence score (STRC), the Intellectual Property Pool score (IPP), the Cooperation and Interaction score (CI), the Economic and Social Contribution score (ESC) and the URAP ranking scores of the relevant year were examined. In addition, categorical information on whether universities are research universities or not and their status (Foundation - State) was also included in the modeling.

While analyzing the distribution of Entrepreneurial and Innovative Universities, we observed that 23 of the 50 universities are research universities. While analyzing the status of these universities, we see that 34 of them are state universities and 16 of them are foundation universities. The cross table created according to the parameters is as follows.

Table 1. Distribution of the EIUI's top 50 universities

		University Status		
		State	Foundation	Total
Research Uni.	No	14	13	28
	Yes	20	3	23
	Total	34	16	50

Table 1 shows that three universities are both research universities and foundation universities (Koç University, Sabancı University, İhsanDoğramacıBilkent University), while 20 universities are both research universities and state universities. Among the 129 institutions that are state universities, there are a total of 34 EIUs with a rate of 26.3%. This rate is 21% among foundation universities.

While analyzing the descriptive statistics of the variables, we observed that the university with the highest score in the EIUI was Middle East Technical University with 83.6 points, while the university with the

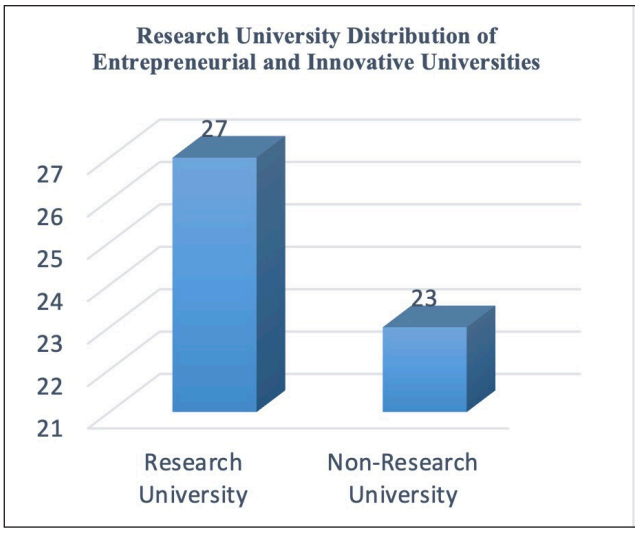

Figure 3. Research Universities with the EIUI

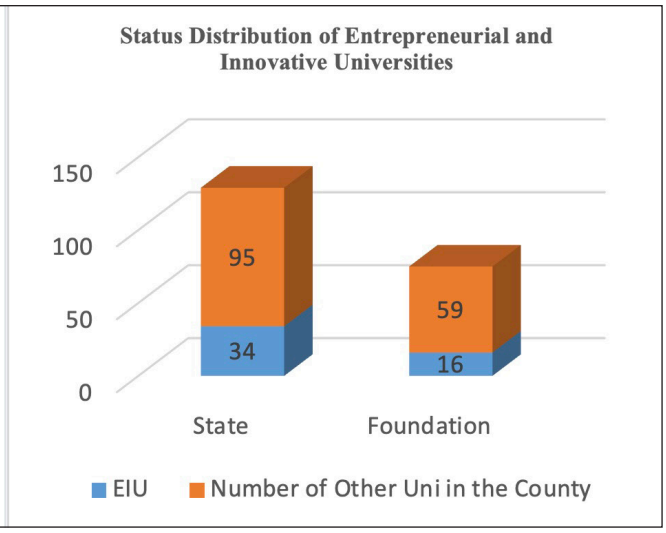

Figure 4. Status of Universities with the EIUI

Table 2. General Statistics of the Variables

Variables	N	Mean	S.d	Min.	Max.	University with Min Score	University with Max Score
Scientific and Technological Research Competence (STRC)	50	7,79	2,05	4,34	12,25	İst. OkanUni.	METU
Intellectual Property Pool (IPP)	50	7,95	3,67	1,82	17,28	Kadir Has Uni.	ÖzyeğinUni
Cooperation and Interaction (CI)	50	14,16	4,03	0,19	23,54	Hasan Kal. Uni.	SabancıUni.
Economic and Social Contribution (ESC)	50	20,85	5	8,79	34,4	Bursa Teknik Uni.	METU
EIUI TotalScore	50	50,74	11,76	36,27	83,6	Hasan Kalyoncu Uni.	METU
URAP Score	50	802,9	152,36	444,27	1097,7	İst. OkanUni.	KoçUni.

lowest score was Hasan Kalyoncu University with 36.27 points. While the mean of the total score of the EIUI was 47.6, the standard deviation was 12.22.

While analyzing URAP scores of the universities, we observed that Koç University has the highest score with 1097.73 points, while Istanbul Okan University has the lowest score with 444.27 points. The average score of the entire sample was 800.96 with a standard deviation of 154.49.

The significant relationship between the indexes scores used in the study will inferentially help to give an idea about the positioning similarities of the universities. The relationship between the total index scores of entrepreneurial and innovative universities and other variables was analyzed with Pearson and Spearman's rho coefficient. A moderate (Pearson: 68%, p value<0.05) positive correlation was found between the total score of the universities' EIUI and URAP score, and similarly, a positive and significant correlation

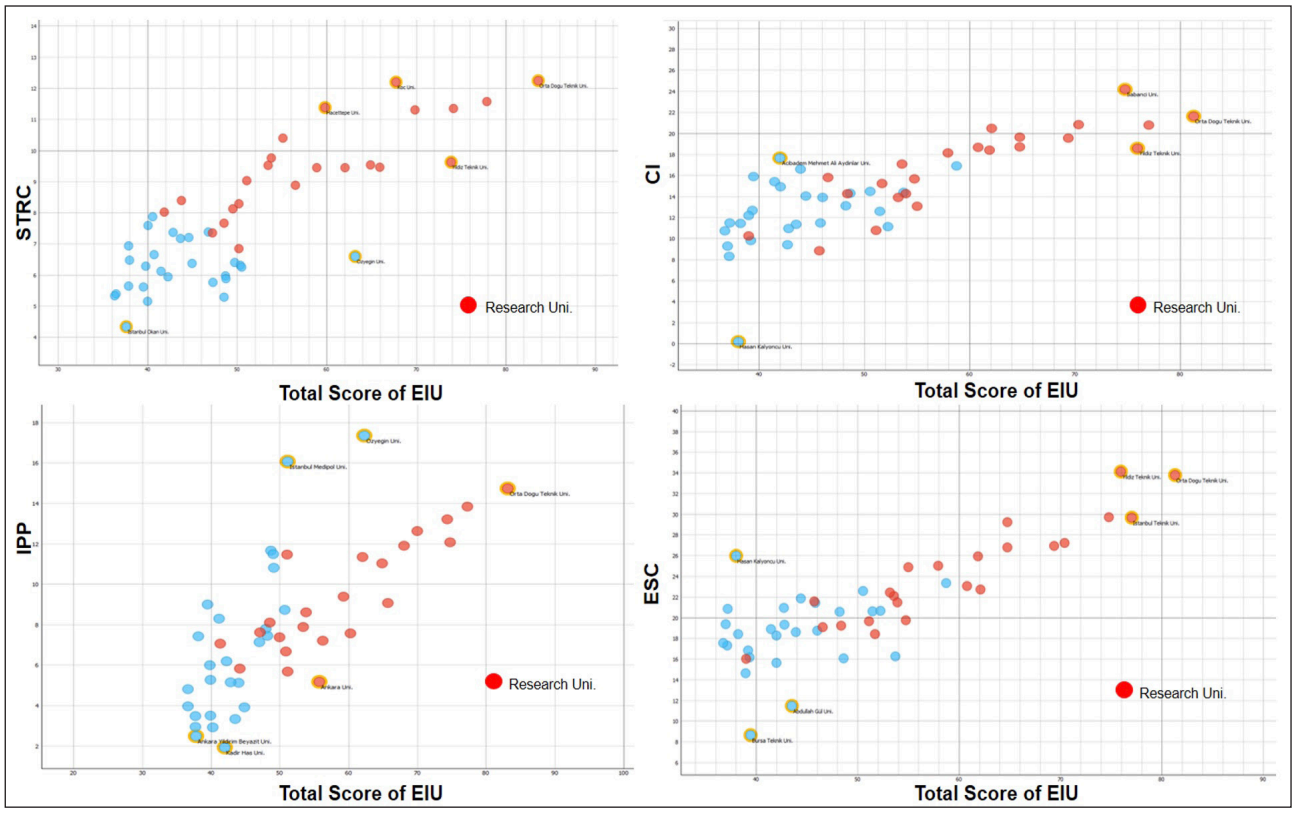

Figure 5. The Distribution of the Total EIUI Score and the Pillars

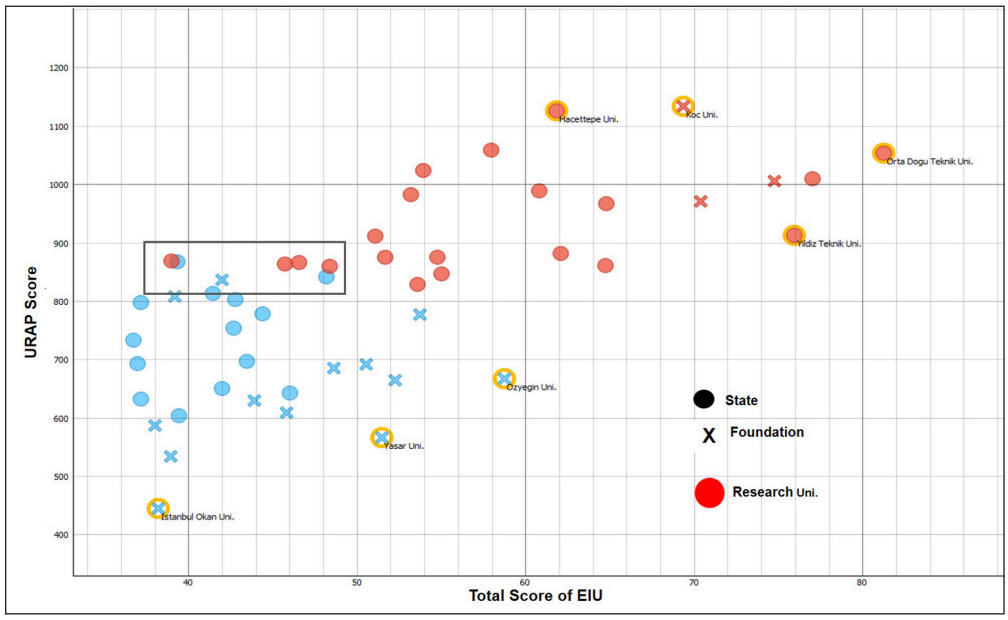

Figure 6. The Distribution of URAP Ranking Score with the Total EIUI Score

was found with the status of being a research university (Spearman's rho: 70%, p value<0.05). A linear relationship was found between URAP ranking score and being a research university at a high level (Spearman's rho: 85%, p value<0.05). In other words, this significant relationship between these variables should be considered together in policy development. If being a research university is among the institutional goals of the universities, some of the criteria to be followed are to strive for a high URAP ranking score and entrepreneurial university score to realize this goal.

While examining the scatterplot distribution showing the relationship between Entrepreneurial and Innovative Universities and the sub-components of the total score, we observed that there is a positive relationship in general, while universities that are research universities are more successful than other universities in both pillars and total score. These graphs also provide information about university-based positioning. For example, while METU was successful in all sub-dimensions, Hasan Kalyoncu University scored low in cooperation and interaction. Likewise, although their total index score is relatively low, Istanbul Medipol University and Özyeğin University exhibit significant success in the Intellectual Property score.

While analyzing the distribution of universities' total index scores and URAP achievement scores, we observe that there is a positive correlation. We can conclude that the entrepreneurial and innovative nature of universities is closely related to their academic success and that they affect each other positively. While analyzing the graph in detail, we observed that the index scores of institutions that are research universities and state universities are also high. There is an unstable region with a URAP score of 800 and above and an EIUI score between 35 and 50. Acıbadem Mehmet Ali Aydınlar Uni., Çankaya Uni., Ondokuz Mayıs Uni, Selçuk Uni, Akdeniz Uni, EskişehirOsmangazi Uni, Kocaeli Uni, and Sakarya Uni, which are located in this threshold region, can show the same success performance as research universities if they exhibit small improvements in terms of both parameters. Özyeğin University, on the other hand, has the potential to significantly increase its success if it reflects its high entrepreneurship and innovation score to its URAP ranking.

CLUSTER ANALYSIS

In order the classification of entrepreneurial and innovative universities based on their overall index score, URAP ranking score, status as a research university, and status as either a state or foundation university, we used traditional methods like Decision Tree and K-Nearest Neighbor (k-NN) and artificial intelligence-based methods like SVM and Random Forest.. As a result of the analysis, the first 50 Entrepreneurial and Innovative Universities were divided into 4 clusters. The universities in the clusters are shown in the table below.

Table 3. The Clustering of Universities and Their Distribution

1. Cluster	2. Cluster	**3. Cluster**	**4. Cluster**
Middle East Technical Uni.	Boğaziçi Uni.	Akdeniz Uni.	ÖzyeğinUni.
Sabancı Uni.	Gebze Technical Uni.	Kocaeli Uni.	Istanbul Medipol Uni.
Istanbul Technical Uni.	Izmir Yüksek Teknoloji Ens.	Eskişehir Osmangazi Uni.	TOBB Ekonomi ve Teknoloji Uni.
Yıldız Technical Uni.	Hacettepe Uni.	Sakarya Uni.	EskişehirTechnicalUni.
Ihsan Doğramacı Bilkent Uni.	Ege Uni.	Ondokuz Mayıs Uni.	Bahceşehir Uni.
Koç Uni.	Erciyes Uni.	Süleyman Demirel Uni.	YeditepeUni.
	Ankara Uni.	Selçuk Uni.	Yasar Uni.
	Istanbul Uni.	Konya Technical Uni.	AtılımUni.
	Gazi Uni.	Ankara Yıldırım Beyazıt Uni.	Acıbadem Mehmet Ali Aydınlar Uni.
	Istanbul Uni. - Cerrahpaşa	Pamukkale Uni.	Kadir Has Uni.
	Bursa Uludag Uni.	Çanakkale Onsekiz Mart Uni.	Abdullah GülUni.
	Marmara Uni.	Hasan Kalyoncu Uni.	Izmir EkonomiUni.
	Dokuz Eylül Uni.		Bursa TechnicalUni.
	Karadeniz Technical Uni.		ÇankayaUni.
	Çukurova Uni.		Istanbul OkanUni.
	Fırat Uni.		
	Atatürk Uni.		

Table 4. The Statistics of Clusters

	1. Cluster		**2. Cluster**		**3. Cluster**		**4. Cluster**	
	EIUI Score	URAP Ranking Score	EIUI Score	URAP Ranking Score	EIUI Score	URAP Ranking Score	EIUI Score	URAP Ranking Score
Mean	74,52	1000,91	53,68	910,29	40,98	740,38	45,74	652,02
S.D.	5,7	76,64	6,96	76,45	3,53	83,61	6,8	91,82

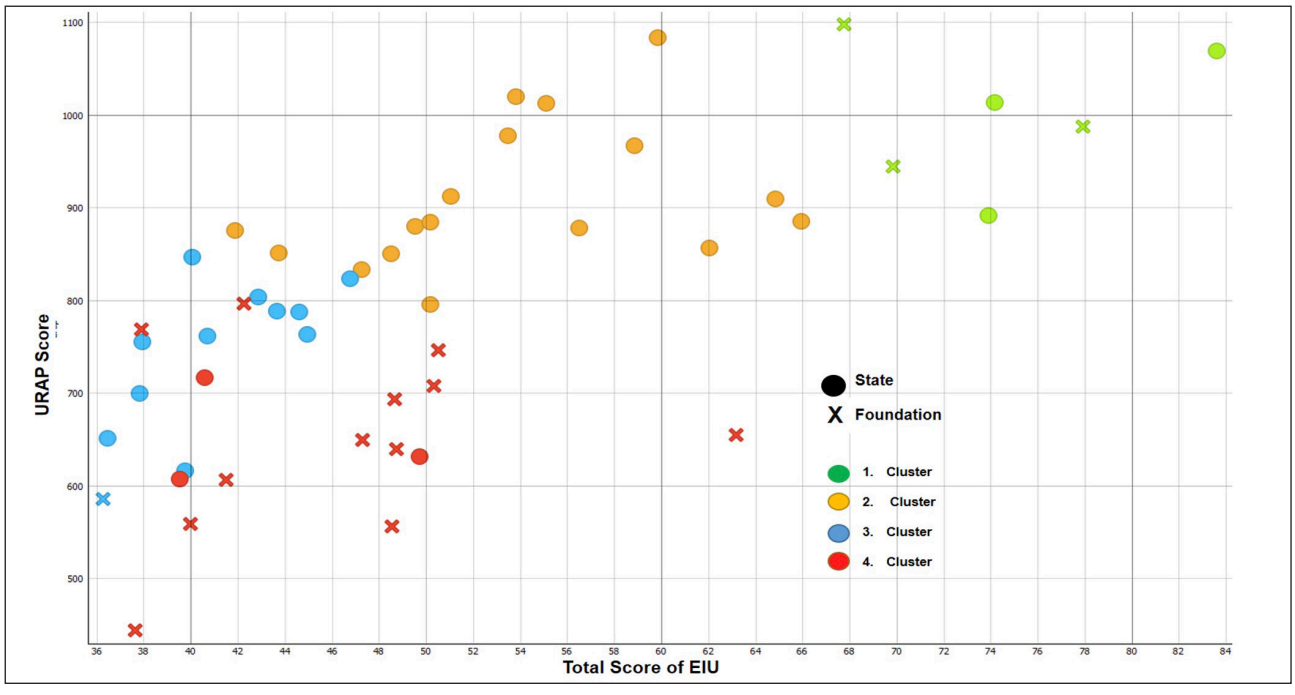

Figure 7. The Distribution of the Clusters of EIUI Total Score and URAP Ranking Score

While analyzing the distribution of entrepreneurial universities to clusters and the locations of the clusters, we observe that in Cluster 1 there are universities with high scores in both parameters (Middle East Technical Uni. Sabancı Uni., Istanbul Technical Uni., İhsanDoğramacıBilkent Uni., Koç Uni., Yıldız Technical Uni.), and while 3 of these universities are foundation universities and 3 are state universities.

While the universities in Cluster 2 are spread over a wide area, their proximity to Cluster 1 is noteworthy. In other words, strategic improvements to be made on an institutional basis can lead to cluster upgrading. The fact that all universities in this cluster are state universities is also an important output.

Cluster 3 universities are characterized by relatively low total index scores. Although their URAP achievement scores are as high as those in Cluster 2, their low index scores position them closer to Cluster 4. The fact that the universities in this cluster (Atatürk Uni., Bursa Uludağ Uni., Fırat Uni., Ondokuz Mayıs Uni.,) are relatively distant from entrepreneurship ecosystems or have limited interaction with them lowers their total index score. Setting targets to improve the current situation in the strategic plans of universities will pave the way for institutions to better utilize their potential.

Cluster 4 consists of universities with lower URAP ranking scores and index total scores compared to other clusters. However, it was observed that the EIUI index score was higher than Cluster 3. It is noteworthy that there are many foundation universities in the cluster with sparse unit densities. Both the in-house training plans of foundation universities and the high connection of graduates with entrepreneurial and innovative ecosystems have brought them to the top in terms of this index.

Orange, an open-source software, was used in the analysis. The table below displays a comparison of the classification methods' levels of accuracy.

Tablo 5. The Evaluation Criteria for Clustering Methods

Model	RMSE	MAE	R2
Random Forest	4,16	2,92	0,87
Decision Tree	5,67	4,05	0,76
K-NN	7,6	6,08	0,57
SVM	7,92	5,49	0,54

The three main performance metrics that are utilized to evaluate the efficacy of the methods are the Root Mean Square Error (RMSE), Coefficient of Determination (R2) and Mean Absolute Error (MAE). The Coefficient of Determination (R2) is one of these performance indicators, and it is well known that values of 0.70 and above suggest superior performance outcomes (Alpar, 2011). R2 quantifies how well the model fits the data. Lower values suggest higher performance because RMSE and MAE are error measures.

The investigation showed that, in comparison to other methods, the performance results achieved utilizing the Random Forest method produced better outcomes. The other artificial intelligence-based method, Support Vector Machine, has a determination percentage of 54%, while the classical method, K-NN, has a determination percentage of 57%. The closest result to the results of the Random Forest method belongs to the Decision Tree method with a determination percentage of 76%. The smallest RMSE value was found in the Random Forest method at 4.16. The results show that RF has a higher classification accuracy than the other methods.

DISCUSSION

In terms of the variables used in the study, the method of analysis and recent analysis techniques, it focuses on a different point than many other studies in the literature. However, similar results have been obtained with some studies as follows.

While the study is similar in content to clustering studies in the literature, it also provides information about the positioning of universities in terms of different variables. However, when compared with the results of our study, it can be concluded that foundation universities do not have the targeted performance in terms of the index, while some foundation universities are successful in terms of EIUI pillars, contrary to Tosun H. (2020).

When compared with Tekin, E. (2021) our study, it can be said that similar results were obtained despite the use of different methods. On the other hand, it does not include an output on which areas universities are competent in based on their positioning and which universities are similar to them. Another similar result is the paper of Erdoğmuş and Esen (2016). The universities grouped in Cluster 1 in our study's clustering results were found to be comparable to the cluster in their work.

CONCLUSION

This study studied data from the TÜBITAK EIU Index and the concept of entrepreneurial universities, which is gaining importance today. The universities are clustered by evaluating criteria such as URAP ranking score, university status (Foundation - State), and whether they are research universities or not. The data set emerges as multivariate data due to its structure. For this reason, analyses were made with multivariate classification methods and different artificial intelligence-based statistical techniques.

As a result, the study includes recommendations for clustering universities in terms of relevant criteria and identifying areas with development potential. In the analysis, it is explained with examples that some universities in the index rankings can move to higher clusters as a result of little improvements. For example, Ist. Medipol University and Özyeğin University exhibited significant success in the Intellectual Property score, while they achieved relatively lower scores in other pillars. On the other hand, there is an unstable region in terms of URAP score and index score. Acıbadem Mehmet Ali Aydınlar Uni., Çankaya Uni., Ondokuz Mayıs Uni, Selçuk Uni, Akdeniz Uni, EskişehirOsmangazi Uni, Kocaeli Uni, and Sakarya Uni located in this region will gain significant advantages in research university application processes if they show small improvements in both parameters.

Another outcome of the study is the high correlation between the URAP ranking score and the status of being a research university and the index scores. In addition, the different clustering of foundation universities and public universities on a positioning basis is another noteworthy result. It can be stated that the basis of this phenomenon is the difference in the vision of universities' career development centers and graduate profiles.

The fact that the results of the study have similar results with the limited number of studies in the literature contributes to the development of consistent policies for decision-makers. On the other hand, the first 50 universities of the EIU index are announced. This study provides guidance in terms of location and clustering for other universities outside the index that calculate their scores in terms of other indicators and pillars related to the index.

RECOMMENDATIONS

The first parameter that stands out in the success performance of universities is ranking systems. However, the problems experienced by institutions with different specialization areas, scales, and sizes in these rankings bring different evaluation criteria to the agenda. One of the important results of the study is that the use of clustering, scaling, etc. in addition to ranking systems in the evaluation of the success performance of universities will give more accurate results.

On the other hand, although there are differences in the rankings of universities, it is thought that the common aspects of homogeneous clusters that emerge as a result of cluster analysis will be more helpful for universities in terms of positioning. Considering university ranking systems holistically with clustering approaches provides important support to policymakers in decision-making.

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