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Ege Academic Review

Ekonomi, İşletme, Uluslararası İlişkiler
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Volume 22 • Number 2 • Nisan 2022

Cilt 22 • Sayı 2 • Nisan 2022

Contents

EGE AKADEMİK BAKIŞ / *EGE ACADEMIC REVIEW*

Cilt 22 • Sayı 2 • Nisan 2022
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Integrating Quality Function Deployment with Fuzzy Cognitive Maps for Resolving Correlation Issues in the Roof Matrix

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ABSTRACT

The roof matrix represents correlations among engineering characteristics (EC) in the house of quality (HoQ) in Quality Functions Deployment (QFD). Correlations are usually measured qualitatively and omitted in the analysis. However, ignoring them may cause duplication of effort, decreased product performance, and unsatisfied customer requirements (CR). Hence, this paper intends to propose an approach to considering the correlations quantitatively. Fuzzy Cognitive Maps (FCM) were used for this purpose. Additionally, Axiomatic Design (AD), for examining relationships between CRs and ECs, and Fuzzy Analytic Hierarchy Process (FAHP) with the Extent Analysis (EA) were used for checking the consistency of the evaluations. The proposed approach was applied in a sheet metal die-making company for ranking CRs and ECs. Results show that FCM enables analysing the quantitative roof matrix practically. The square roof matrix that supports FCM's adjacency matrix structure successfully represents asymmetric relationships among ECs. Integrating the correlations into the analysis resulted in a change in the final ranking. It also helped determine the most manageable ECs, better satisfiable CRs, and most critical/least manageable ECs.

Key Words: Quality Function Deployment; Fuzzy Cognitive Maps; Asymmetric Square Roof Matrix; Independence Axiom; Fuzzy Analytic Hierarchy Process; Extent Analysis.

JEL Classification Codes: C61, M11, L15

1. INTRODUCTION

Quality Function Deployment (QFD) is one of the well-known customer-oriented methodologies. It provides a conceptual map for cross-functional planning and communication applications. It is used for exploring real-world situations where human preference is involved in the decision-making process. However, decision-makers' logic and subjectivity play a crucial role in that process. Hence, such an environment may require fuzzy logic to make realistic decisions. QFD methodology does address such fuzziness at some level, but it becomes more effective and provides more realistic results with fuzzy logic (Upadhyay, Hans Raj, & Dwivedi, 2012). Some other issues regarding QFD are couplings, correlations and the roof matrix type. Couplings are relationships between customer requirements (CR) and engineering characteristics (EC). According to Manchulenko (2001), only %5-10 of companies use QFD continuously because of the long development time and cost resulting from the couplings. Contrarily, correlations are interrelationships among ECs. According to Özgener (2003), strong positive correlations between ECs may result in duplication of effort. On the other hand, negative correlations may adversely affect the product's performance because the improvement of one EC acts against the others. Hence managing negative and positive correlations is crucial. However, to the best of our knowledge, there are not many studies regarding the management of the correlation effect. Finally, the widely used type of roof matrix is the triangle roof matrix that supports symmetric relationships among ECs. However, an asymmetric square matrix is more suitable because interdependencies among ECs are asymmetric so one-way in real-life. While one EC is the source of the effect, the other one receives the effect. The roles of these two ECs as being a source or receiver may change in their relationship with other ECs. Also, the existence and strength of the relationship differ depending on CRs.

For all above considerations, this paper is set out to structure a correlation management model in QFD. For this purpose, square roof matrix and Fuzzy Cognitive Maps (FCM) was used as they allow determining and

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visualising all kinds of casual asymmetric relationships among ECs. Additionally, the Independence Axiom (IA) of Axiomatic Design (AD) was employed to reduce the CR-EC coupling effect. The proposed methodology was applied to a die making company in the automotive industry. A team of experts and customers from the subject company participated in the application process. Hence, the Fuzzy Analytic Hierarchy Process (FAHP) with the Extent Analysis (EA) was also applied to obtain consistent evaluations.

The study presented in this paper is one of the first investigations to utilize FCM for resolving correlation issues among ECs by quantizing correlation values and examining cyclic and acyclic networks among ECs. This paper also provides an EC classification/management approach by using centrality and casualty values of ECs that are major FCM outputs.

The remaining part of the paper proceeds as follows: The second section reviews the literature, the third section concerns correlation issues, the fourth section provides brief information about the methodologies employed, the fifth section explains the proposed model with a real-life application, and the sixth section presents and discusses the results.

The terms "EC-EC interrelationships" and "correlations" are used interchangeably in this paper.

2. LITERATURE REVIEW

There have been a variety of applications with different focus areas of QFD methodology, such as (i) selecting strategic maintenance techniques (Baidya, Kumar Dey, Kumar Ghosh, & Petridis, 2018) and heating systems (Ozdemir, Alcan, Basligil, & Cakrak, 2018) by employing QFD with AHP, (ii) rating/prioritizing ECs with QFD and technique for order preference by similarity to an ideal solution under fuzzy environment (Wang, Yan, Wang, & Yu, 2020), and also with z-numbers, QFD and evaluation based on distance from average solution methods (Mao, Liu, Mou, & Liu, 2021), (iii) determining weights for team members and CRs by utilizing QFD with z-numbers (Song, Wang, & Li, 2020), (iv) for assessing risk in mining sector by using QFD with AHP and fuzzy inference system (Cinar & Cebi, 2020), analysing supply chain resilience in freight forwarding with QFD and two-step house of quality (HoQ) design (Isti'anah, Praharsi, Maharani, & Wee, 2021), (v) determining supplier evaluation criteria and final set of suppliers accordingly by using QFD with interval data envelopment analysis (Bao & Li, 2021).

The literature about QFD integrated with AD applications is new and limited compared to other study areas of QFD. Cauchick Miguel, Carnevalli and Calarge (2007) proposed an AD-based QFD model. The aim was overcoming difficulties in determining CRs, translating them into FRs and resolving dependencies between them. The authors focused on only IA of AD. Carnevalli, Miguel and Calarge (2010) proposed a theoretical and conceptual model of QFD. They aimed to minimize usage difficulties of QFD, such as interpreting the voice of customer (VoC), defining and prioritizing quality characteristics and working with large matrices. However, they did not tested the proposed model in a real-life problem. Arsenyan and Büyüközkan (2016) combined QFD, AD and a fuzzy rule-based system. The integrated methodology was applied to a technology planning problem of a textile company. Lapinskienė & Motuzienė (2021) combined QFD and AD with Complex Proportional Assessment of Alternatives (COPRAS) in a building design problem. The authors both utilized independence and information axioms of AD to achieve independence and calculate the success probability of the solutions to be used as input in COPRAS. Orbak, Korkmaz, & Aydın (2021) employed QFD with AD in selecting a suitable intercity bus seat design with considering commuters' specifications and corresponding technical requirements. For a brief literature review about QFD and AD, please refer to Fauzi Malik, Napitupulu, & Ginting (2020).

The literature about considering the correlation matrix by quantifying its impacts is also very minimal (Chan & Wu, 2002). Tseng and Torng (2011) presented a methodology based on the partitioning and tearing algorithm of the design structure matrix. The proposed approach dealt with the weakness of correlations among ECs that were mostly ignored but affected the implementation sequence of the project tasks and resulted in delays or queuing in product design/project development. Li et al. (2012) used rough sets for estimating correlations. Their approach introduces a category factor for a correlation to determine the effects of the correlation categories on the related measures. According to the authors, this approach was effective in using the knowledge of the QFD team and accomplishing decision-making in the new product development process (Li et al., 2012). Bencherif, Mouss and Benaicha (2013) proposed using the theory of inventive problem solving for resolving negative correlations among ECs. In this approach, negatively correlated ECs were replaced with positive ones. That may result in information loss in the correlation matrix. In the paper of Cavallini et al. (2013), information axiom was used for investigating negative correlations among ECs by applying the simple probability. However, their application

conflicts with the nature of the IA, which is originally based on conditional probability. In the paper of Iqbal, Grigg, Govindaraju, & Campbell-Allen, (2015), Manhattan Distance Measure (MDM) was used for ranking ECs. In order to apply MDM, the authors used two hypothetic ideal and undesirable roof correlation matrices besides the given correlation matrix. The ideal matrix represented the perfect situation where all the correlations were strong positive (+1). The undesirable matrix represented the worst situation where all the correlations were strong negative (-1). Then Manhattan distance from the ideal matrix and undesirable matrix were calculated. The strength of each EC was calculated by dividing the former MDM value by the latter. This approach may be practical for considering all types of roof correlations in the rankings, but the term "ideal" may not be ideal for all types of EC correlations due to the correlation issues explained in Section 3. In another study, Fuzzy Analytic Network Process (F-ANP) and EA was used for determining the importance weights of ECs (Mistarihi, Okour, & Mumani, 2020). However, interrelationships among ECs were not evaluated regarding CRs. Finally, Fazeli & Peng (2021) adopted a broadly similar position with ours. They did not only attempt to quantify EC-EC correlations, but also investigated cause and effect relations, and interdependence and emphasised the importance of direct and indirect relationships between ECs. They employed decision- making trial and evaluation laboratory for this purpose. Moreover, the authors also highlighted the importance of using an appropriate roof matrix. According to them, with their terms, "a square-shaped non-symmetric matrices" suit better real-life design problems in which "unequal mutual interactions" exist. However, in their study, correlations were not evaluated/determined with respect to each CR and all evaluations were done under the assumptions of CRs were uncorrelated.

3. CORRELATION ISSUES AMONG ECs

Close attention must be paid to negative roof correlations because negatively correlated EC's conflict with each other. An improvement of one may worsen the other one. They require special planning or breakthrough attempts since they represent bottlenecks in product design (Li, Tang, & Luo, 2010) and adversely affect the performance of the product (Bencherif et al., 2013; Iqbal et al., 2015). On the other hand, positive correlations indicate that ECs are mutually supportive. An improvement in one results in an improvement on the other at least to some extent. However, high positive correlations among ECs, which is defined as "ideal correlation" by Iqbal et al. (2015), may cause undesirable results. For example, increased alloy content of steel provides better hardness. However, too much increase in the alloy content and so hardness makes the material fragile. Moreover, strong positive or even any positive roof correlations may cause duplication of effort (Özgener, 2003) by magnifying the relationship. Assume that there are four ECs. EC_2, EC_3 and EC_4 affect EC_1, and EC_3 affects EC_4. If EC_3 is improved, both EC_1 and EC_4 directly and simultaneously get affected. Additionally, EC_1 is being indirectly affected by the path of EC_3 - EC_4 - EC_1. Because of that simultaneous improvements, it is desired to have correlation values zero or close to zero. It is crucial to have a network that does not constitute a cycle (acyclic network) in the roof matrix. In other words, a desirable roof matrix is a diagonal matrix where each EC is independent of each other. Independence is also essential for resource allocation to the subject QFD project/product (Tseng & Torng, 2011). For example, if there is a subset of ECs that are not correlated with the rest, it is advisable, easier, and manageable to implement the tasks related to that particular subset of ECs firstly. Because any change in these ECs will not affect the others. If there are interdependencies between ECs, tasks affect each other, and more information is required to achieve the best design. Consequently, both the positive and negative correlations in the roof matrix are not desired. A method that considers all types of correlations is necessary to use for analysing the roof of HoQ.

In many studies, the EC correlation matrix is assumed as symmetric, and triangular roof matrix is used. However, interdependencies among ECs in real-life cases are not symmetric. What is more, their influence on each other varies depending on the CRs (Reich & Levy, 2004). In this vein, the asymmetric roof matrix was proposed by Moskowitz and Kim (1997), and improved by Reich and Levy (2004). Reich and Paz (2008) explained the necessity of using an asymmetric square roof matrix with a cellular phone design problem. The battery size (EC_1) has a strong positive effect on the usage time between charges (EC_2) regarding the use of a cellular phone for a long time (CR_1). On the contrary, usage time between charges (EC_2) does not affect the battery size (EC_1). Therefore, there is a one-way effect between EC1- EC_2. Additionally, if that correlation is investigated for having a user-friendly interface (CR_2), it is evident that there is none correlation between EC_1- EC_2.

For all the reasons explained above, the FCM method may be a solution to holistically examining the roof matrix of HoQ as it naturally supports the asymmetric relationship between ECs. To the best of our knowledge, FCM has not been applied to QFD.

4. PRELIMINARIES

4.1.Fuzziness and Fuzzy Numbers

As stated in section 1, fuzzy logic was used throughout this study as it captures the subjectivity of decision-makers effectively and provides realistic results. Lotfi A. Zadeh introduced the ordinary fuzzy sets theory in 1965 (Zadeh, 1965). It was based on the rationality of uncertainty due to imprecision or vagueness. It is a practical way to represent vague knowledge and linguistic variables and, therefore, widely applied to solve real-life problems that are usually subjective, vague, and imprecise. A fuzzy set is characterized by a membership function $\mu(x)$ that defines a membership value between [0, 1] for each point in the input space. While 0 and 1 indicate the minimum and maximum degree of memberships respectively, all the intermediate values indicate degrees of partial memberships (Sanayei, Farid Mousavi, & Yazdankhah, 2010). There are various kinds of fuzzy numbers used in membership functions such as triangle, trapezoid, and the bell curve. However, the use of triangular functions is relatively common in the literature (Karsak, 2004) as they can be managed easily from the computational point of view. A triangular fuzzy number can be represented merely as (l, md, h). These parameters denote the smallest possible, the most promising, and the largest possible values that describe a fuzzy event. In linguistic variables of view, various types of relations (fuzzy scales) can be used. For example, five different relations can be denoted as very low (VL), low (L), medium (M), high (H) and very high (VH). There are also fuzzy scales of which linguistic variables are in [-1; 1].

Since the development of ordinal fuzzy sets, several extensions of it have been introduced, such as Type-2, interval-valued, intuitionistic, nonstationary, hesitant, pythagorean, spherical, and interval-valued spherical fuzzy sets (SFS), fuzzy multisets, and neutrosophic sets (Kutlu Gündoğdu & Kahraman, 2020). The lately developed of them are hesitant and SFS. Hesitant fuzzy sets proposed by Torra (2010) consider uncertain/ hesitant judgements of decision-makers. In this method, contrary to using pre-determined membership functions they are determined/calculated by aggregating potential membership functions belongs to decision-makers into one. SFS developed by (Kutlu Gündoğdu & Kahraman, 2019) are a synthesis of pythagorean and neutrosophic fuzzy sets. In SFS, membership functions are determined with the squared sum of membership, non-membership and hesitancy/indeterminacy parameters. Finally, different from single valued SFS, an interval with upper and lower degrees for the parameters are set and considered in interval-valued SFS developed by (Duleba, Kutlu Gündoğdu, & Moslem, 2021).

We preferred using ordinary fuzzy sets of Saaty throughout the study as our focal point is resolving correlation issues in the roof matrix. Also, it would be better employing recently developed fuzzy sets in case of having large groups of decision makers where indeterminacy/hesitancy is high. In our study, we have worked with a small group of decision-makers.

4.2. Axiomatic Design

IA of AD was used for the purpose of achieving a product design of that FRs and DPs, which correspond to CRs and ECs in QFD, are independent of each other. What is more, the base of IA and CR-EC matrix of QFD perfectly matches each other as both aim resolving dependence issues between CRs and ECs. Hence it is particularly useful and proper for examining CR-EC relationship. AD is a structured and rational method for improving design activities in four stages: Customer domain (customer needs), functional domain (FRs that satisfy customer needs), physical domain (PhD- design parameters that satisfy FRs) and process domain (process variables that resolve each FR). Each domain is related to each other and characterized by a set of information. The design process must be developed in a top-down manner. It should start with obtaining information from customers and continue with PhD until the point where the design object is defined with sufficient detail, and no decomposition can be done. This process is called hierarchical decomposition and zigzagging (Park, 2007). Its objective is to decompose both the FRs and the DPs for further detailing before manufacturing the product (El-Haik & Wasiloff, 2004). It shows the designing hierarchy of an object and makes designing a much more controllable process (El-Haik & Wasiloff, 2004; Goncalves-Coelho, Mourao, & Pereira, 2005). Therefore, it is obvious that QFD and AD has a similar base on behalf of design domains. AD uses independence and information axioms for improving the design. All FRs should be independent of any other, and the information content of design should be minimum. Therefore, the AD may be a key to describe (Liu, 2011) and calculate the independence level of the relationship matrix (Çebi & Kahraman, 2011) In this study, only IA was used.

According to IA, there are three design types; uncoupled, decoupled, and coupled. The uncoupled designs are ideal designs since they have a diagonal matrix that provides none relationships between FRs and DPs (between CRs and ECs). Therefore, the design complexity of the product

is low, and costs and other constraints related to the design are manageable. If the matrix is triangular, the design is decoupled and acceptable. All other types of matrix are accepted as coupled and should be avoided. If there are fewer DPs than FRs, the design is assumed to be coupled and should be avoided. In the reverse situation, the design is accepted as either coupled or redundant. In this case, only redundant designs are acceptable if they are uncoupled or decoupled (El-Haik & Wasiloff, 2004; Goncalves-Coelho et al., 2005).

4.3.Analytic Hierarchy Process

It is hard to define the best choice as the human mind is incapable of evaluating all alternatives on a set of criteria. AHP is one of the most common, practical, easily applicable and powerful decision-making methodologies for determining priority rankings of criteria originally developed by Saaty (Saaty, 1986, 1994). Hence, in this study, fuzzy version of the AHP was utilized for obtaining consistent judgements from decision-makers. It is such a method that is based on a stepwise comparison of alternatives regarding two criteria for determining the best option (Abastante & Lami, 2012). It enables decision-makers to determine overall rankings of the alternatives. It provides a consistency rate to measure the consistency of judgment of decision-makers (Kordi, 2008; Srichetta & Thurachon, 2012). It consists of five steps (Srichetta & Thurachon, 2012). In the first step, criteria and sub-criteria are determined, and hierarchically arranged into a tree-like diagram of which top level represents the goal of the decision problem. In the second step, decision-makers assess the relative importance of each criterion by using a (1-9) scale defined by Saaty. In the third step, the average weight for each normalized criterion is calculated. In the fourth step, a pairwise comparison matrix is obtained. Finally, the overall score for each alternative is calculated. To date, there are different scales used in AHP, namely linear, which is the original one proposed by Saaty, power, geometric, logarithmic, root square, asymptotical, inverse linear and balanced (as cited in Ishizaka, 2019). We preferred using the linear scale of Saaty as our focal point is resolving correlation issues in the roof matrix.

4.4. Fuzzy Cognitive Maps

FCM method was used in the roof of the HoQ. The significant advantages of using FCM are that it allows us to quantify EC-EC relationships, process negative, positive and zero correlations, and investigate whether there is a network of interdependencies among ECs (which is the existence of a cyclic network). Also, it is particularly is practical, easily applicable and interpretable. It enables the examiner to describe the complex interactions between the factors of a problem (Christoforou & Andreou, 2017). They are based on the experience and knowledge of the experts; describe the behaviour of the system symbolically, and illustrate the system by a directed graph. Developing an FCM consists of three steps. Firstly, experts determine the essential factors affecting the behaviour of the system. Secondly, they decide each concept representing the factors. Finally, they determine and quantify the interrelationships between the concepts. For the last step, it is advised to have a single map for each expert firstly, and aggregate all into one map secondly. In that way, each expert transforms his/her knowledge on a map (Groumpos, 2010) without being affected by each other.

FCMs are a combination of neural networks, graph theory, fuzzy logic, semantic networks, and expert systems. The fundamental unit of a map is the concept, which is a variable and represented by a node. There are two types of variables, which are casual (driver) and effect variables (receiver). Relationships/interconnections between them are represented with fuzzy weighted arcs. For example, if C_1 affects C_2, they are called casual and effect variable respectively. The origin of the arrow is at C_1, and it terminates at C_2(Groumpos, 2010). Arc values vary in the interval of [-1,1] (Groumpos, 2010; Papageorgiou, 2012).

5. PROPOSED MODEL and APPLICATION

The structure of the model proposed in this study is as follows: IA is used for examining if CR-EC relationship matrix was coupled or decoupled. Then the EA is used for computing the relative weights of the customer requirements, but before that, FAHP is used for checking the consistency of the customers. Afterward, the FCM method is used for quantitatively analysing the asymmetric EC-EC relationships. Finally, the importance rankings of the CRs are obtained by computing the importance rankings of their corresponding ECs. The steps of the proposed model are as in Fig. 1. It was practiced in a company that produces sheet metal dies for the automotive industry.

Step 1. Team formation. Project scope and priorities are defined and communicated to other departments to prevent questions about the team and to encourage team members to dedicate their time accordingly. In product design, teams are generally composed of experts from marketing, design, quality, finance, and production departments. On the contrary, in product improvements, teams are small as the QFD process will only need to be modified (Besterfield et al., 2011).

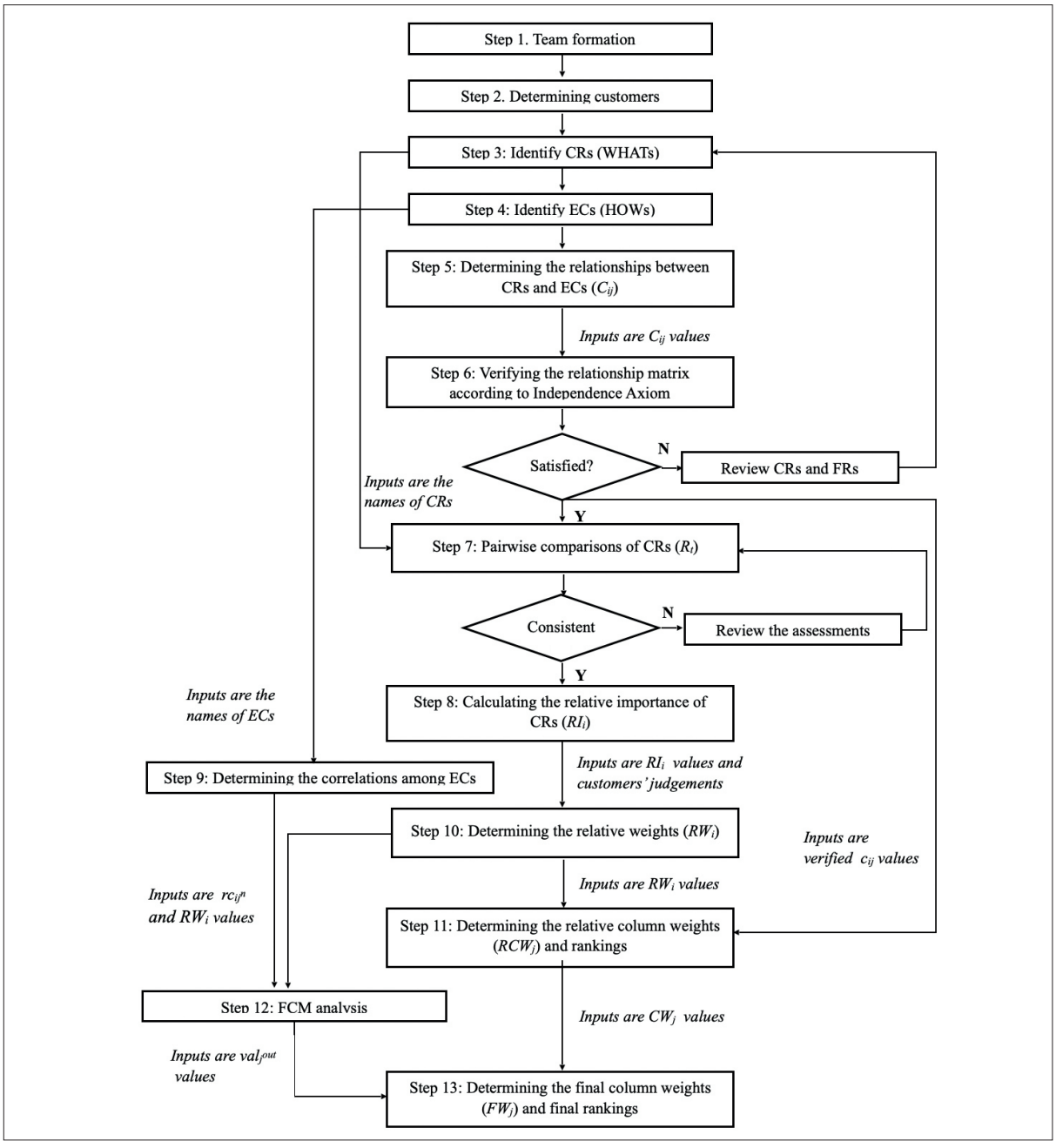

Fig. 1: Steps of the Proposed Model

Application: *The team of experts consisted of a plant manager and technical manager from the subject company, and a deputy technical manager of another sheet metal die company. Each had 10-15 years of experience. Their assessments were weighted equally since their length and area of experience is the same.*

Step 2. Determining customers. According to Mazur (1997), determining which customers to be involved in the QFD process depends on the diversity of the market, product complexity and use, and sophistication of customers as cited in Erkarslan and Yılmaz (2011). If QFD practice is done for an existing product, current customers should be the primary source of information. Otherwise, potential customers should be the main source of information.

Application: *The top ten customers, seven of which were from Europe and the rest were from the local market, were chosen regarding their shares in the capacity.*

Step 3. Identifying CRs (WHATs). Once customers to contact are decided, CRs are collected (van Aartsengel & Kurtoğlu, 2013). Then they are placed on the left side of the HoQ as $CR_1, CR_2, \ldots, CR_k$ where k is the number of the CRs.

Application: *CRs were identified by examining the past orders and customer service feedback data: Repeatability, visual quality of stamped parts (trimming burrs, material thinning, wrinkles), high production speed, easy accessibility of standard components in sheet metal dies, long lifetime*

of tool steels used for trimming and cold forming, ease of replacement and conformity of design data with the sheet metal die. Please refer to appendix for more information about CRs.

Step 4: Identifying ECs (HOWs). In this step, raw CRs are transformed into ECs that will represent technical attributes by the expert team. Then, they are placed above the relationship matrices of HoQ as $EC_1, EC_2, \ldots, EC_m$ where mn is the number of the EC's.

Application: *The corresponding ECs were determined: Repeatability of CNC machines, visual quality parameters of stamped parts (cutting clearance, the surface roughness of the tool steels, blank holder pressure/force), strokes per minute (spm), the ratio of standardized elements, the hardness of tool steels, replacement time and the number of software. Please refer to appendix for more information about ECs.*

Step 5. Determining CR - EC relationships. The experts determine the effect of ECs on CRs based on their experience by using a linguistic scale. Then linguistic matrices of the experts are converted into a fuzzy matrix, and aggregated into one with Eq. (1) where n denotes the number of experts, C_{ijn} denotes the fuzzy relationship between i^{th} CR and j^{th} EC estimated by the n^{th} expert, and $C_{ij} = \left(C_{ij}^{\,l}, C_{ij}^{\,md}, C_{ij}^{\,h}\right)$ represents an aggregated relationship evaluation matrix of the experts.

$$C_{ij} = \frac{1}{\mathrm{n}} \otimes \left(c_{ij1} \oplus c_{ij2} \oplus \ldots \oplus c_{ijn}\right) \quad (1)$$

$i = 1, \ldots, k \;\; j = 1, \ldots, m$ and $n = 1, \ldots, e$

Application: *Three evaluation matrices were obtained from the experts. They used a five-level linguistic scale: Very low (VL) (0, 0.1, 0.2), low (L) (0.2, 0.3, 0.4), medium (M) (0.4, 0.5, 0.6), high (H) (0.6, 0.7, 0.8) and very high (VH) (0.8, 0.9, 1). Then the matrices were fuzzified and aggregated into one with Eq. (1) as in Fig. 2. A brief numerical depiction is given below.*

While C_{11} denotes the aggregated fuzzy relationship between CR_1-EC_1, $C_{11} = \frac{1}{3} \otimes \left(c_{111} \oplus c_{112} \oplus c_{113}\right) = \frac{1}{3} \otimes \left[(0.8, 0.9, 1.0) \oplus (0.6, 0.7, 0.8) \oplus (0.6, 0.7, 0.8)\right] = (0.66, 0.76, 0.86)$

Step 6. Verifying EC-CR relationships according to IA. In the conventional AD, relationships are symbolized by 0 (absence of the relation) or 1 (presence of the relation) therefore, a design with a weak relationship is considered as a coupled design (Çebi & Kahraman, 2011). It cause a loss in VoC during the process of redefining CRs until an uncoupled design is achieved. However, it should be acceptable even it is categorized as coupled. A fuzzy dependency coefficient $\tilde{C}$ can prevent rejecting such designs. Where C_{ij} is the fuzzy relationship between the each CR_i and EC_J, $\tilde{C}$ is calculated with Eq. (2).

$$\tilde{C} = \frac{\sum_{i=1}^{k-1} \sum_{j=i+1}^{k} C_{ij}}{\sum_{i=1}^{k} \sum_{j=i+1}^{k} 1} \quad (2)$$

To decide whether a coupled design is in the limits of acceptable tolerance, $\tilde{C}$ is compared with a tolerance level γ. The tolerance level is firstly defined by Suh (1990). It can have any value based on the nature, time, and budget of the QFD project and experts' opinions. If $0<(\tilde{C}) \leq \gamma$, the design is assumed to be decoupled, the relationship matrix satisfies IA; couplings are negligible, and time and cost effects of couplings are in acceptable limits. If $(\tilde{C}) > \gamma$, the matrix is coupled, IA is not satisfied, the couplings will have harmful effects on QFD results, and they have to be eliminated until the dependency coefficient value is below **γ**. The coupled matrix is manipulated by changing the order of CRs and corresponding ECs. Couplings can be eliminated or minimized to an acceptable level by the reordering algorithm defined by Çebi and Kahraman (2010): The sequence of CRs and ECs are determined by Eq. (3-4) where C_{ij}^{md} is the middle value of a fuzzy triangular number, which represents $CR_i - EC_J$ relationships, SCR_i and SEC_J are the sequence scores of CR_i and EC_J, respectively. Then, CRs are ranked regarding to their SCR_i values from minimum to maximum in the matrix.

$$SCR_i = \sum_{j=1}^{m} C_{ij}^{md} \quad (3)$$

$$SEC_J = \sum_{i=1}^{k} C_{ij}^{md} \quad (4)$$

Application: *Where C_{1j} is the fuzzy relationship between CR_1 and all EC_Js,* $\sum_{j=i+1}^{k} C_{1j} = C_{1(21)} \oplus C_{1(22)} \oplus C_{1(23)} \oplus C_{13} \oplus C_{14} \oplus C_{15} \oplus C_{16} \oplus C_{17} =$

$= (0.67,0.77,0.87) \oplus \ldots \oplus (0.13,0.23,0.33) = (1.80,2.20,2.60).$

Likewise, all calculations were done for each CR. Then, calculated values were summed up to obtain

$\sum_{i=1}^{k-1} \sum_{j=i+1}^{k} C_{ij} = \sum_{j=i+1}^{k} C_{1j} \oplus \sum_{j=i+1}^{k} C_{(21)j} \oplus \sum_{j=i+1}^{k} C_{(22)j} \oplus$

$\oplus \sum_{j=i+1}^{k} C_{(23)j} \oplus \sum_{j=i+1}^{k} C_{3j} \oplus \sum_{j=i+1}^{k} C_{4j} \oplus \sum_{j=i+1}^{k} C_{5j} \oplus$

$\sum_{j=i+1}^{k} C_{6j} \oplus \sum_{j=i+1}^{k} C_{7j} = (1.80,2.20,2.60) \oplus$

$\ldots \oplus (0.00,0.00,0.00) = (5.13,6.33,7.53).$

Hence $\tilde{C} = \frac{\sum_{i=1}^{k-1} \sum_{j=i+1}^{k} C_{ij}}{\sum_{i=1}^{k} \sum_{j=i+1}^{k} 1} = (0.14, 0.18, 0.21)$, *which is greater than γ=which is greater than (0.1,0.1,0.1) which was set by the experts. Hence, CRs and ECs were re-ranked following to the reordering algorithm as explained below.*

	EC_1			EC_{21}			EC_{22}			EC_{23}			EC_3			EC_4			EC_5			EC_6			EC_7		
CR_1	0.66	0.76	0.86	0.66	0.76	0.86	0.4	0.5	0.6	0	0	0	0	0	0	0	0	0	0.6	0.7	0.8	0	0	0	0.13	0.23	0.33
CR_{21}	0.4	0.5	0.6	0.73	0.83	0.93	0.4	0.5	0.6	0	0	0	0	0	0	0	0	0	0.53	0.63	0.73	0	0	0	0	0	0
CR_{22}	0.46	0.56	0.66	0.66	0.76	0.86	0.66	0.76	0.86	0.4	0.5	0.6	0.73	0.83	0.93	0	0	0	0.26	0.36	0.46	0	0	0	0	0	0
CR_{23}	0.46	0.56	0.66	0.6	0.7	0.8	0	0	0	0.73	0.83	0.93	0.4	0.5	0.6	0	0	0	0.26	0.36	0.46	0	0	0	0	0	0
CR_3	0	0	0	0	0	0	0	0	0	0	0	0	0.73	0.83	0.93	0	0	0	0	0	0	0	0	0	0	0	0
CR_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.66	0.76	0.86	0	0	0	0.33	0.43	0.53	0	0	0
CR_5	0	0	0	0.06	0.16	0.26	0	0	0	0	0	0	0.46	0.56	0.66	0	0	0	0.8	0.9	1	0	0	0	0	0	0
CR_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.26	0.36	0.46	0	0	0	0.66	0.76	0.86	0	0	0
CR_7	0.53	0.63	0.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.66	0.76	0.86

Fig. 2: Fuzzy Aggregated EC-CR Relationships Matrices of the Team

Table 1: Triangular Fuzzy Conversion Scale

Linguistic variables	Crisp scale	Fuzzy scale	
		Fuzzy values	Reciprocal values
Equally preferred (EQP)	1	(1, 1, 1)	(1, 1, 1)
Equally to moderately preferred (EQ-MP)	2	(1, 2, 3)	(1/3, 1/2, 1)
Moderately preferred (MP)	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderately to strongly preferred (M-SP)	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strongly preferred (SP)	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strongly to very strongly preferred (S-VSP) preferred	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strongly preferred (VSP)	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very strongly to extremely preferred (VS-EXP)	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely preferred (EXP)	9	(8, 9, 9)	(1/9, 1/9, 1/8)

While SCR_1 *denotes the sequence score of* CR_1 $C_{1j}^{md}s$ *denote the middle values of the fuzzy triangular values of* CR_1 – EC_j *relationships,* $SCR_1 = C_{11}^{md} \oplus \ldots \oplus C_{17}^{md} = 0.77 \oplus \ldots \oplus 0.23 = 2.96.$

Likewise, all calculations were done for each CR. Then obtained SCR values were examined to determine the new order, $SCR_i = 2.96, 2.46, 3.80, 2.96, 0.83, 1.20, 1.63, 1.13, 1.40$ *respectively. Hence, the new order, which provided a* $\tilde{C}$=(0.06, 0.07, 0.09) *smaller than γ, became* $CR_3 < CR_6 < CR_4 < CR_7 < CR_5 < CR_{21} < CR_3 < CR_{23} < CR_{22}$. *Finally, CR-EC relationship matrix given in Fig. 2 was updated according to the new ranking and placed in the HoQ in Fig. 8.*

Step 7. Pairwise comparisons of CRs. In this step, customers make pairwise comparisons of CRs, and their consistency is checked. A nine-point linguistic scale is used for the comparison, as in Table 1. Afterward, linguistic comparisons are translated into fuzzy triangular numbers. Where $= (r_{ijt}^l, r_{ijt}^{md}, r_{ijt}^h)$ denotes a pairwise fuzzy comparison value between the element i and j of the customer t, and R_t denotes the pairwise comparison matrix of the customer t can be represented as $R_t = \begin{bmatrix} (1,1,1) & \cdots & r_{1kt} \\ \vdots & \ddots & \vdots \\ r_{k1t} & \cdots & (1,1,1) \end{bmatrix}$ where $i \text{ and } j = 1, \ldots, k \text{ and } t=1,\ldots,s.$

AHP outcomes crucially depend on the consistency of pairwise comparisons made by decision-makers. It is necessary to check the consistency of all R_t matrices because the fuzzy extent value RI_i will be obtained in step 8, will be dubious if R_t's are inconsistent, where consistency ratio bigger than 0.1. In this case, the customer that has inconsistent comparisons should review and revise his/her judgments until the consistency ratio is below 0.1. Kwong and Bai (2003) proposed to defuzzfy R_t matrices with Eq. (5) before calculating the consistency index CI with Eq. (6) and consistency ratio CR with Eq. (7).

$$r_{ijt} = \frac{\left(r_{ijt}^l + 4r_{ijt}^{md} + r_{ijt}^u\right)}{6} \quad (5)$$

$$CI = \frac{\lambda_t - d}{d-1} \quad (6)$$

$$CR = \frac{CI}{RI(d)} \quad (7)$$

Where λ_t is the largest eigenvalue of R_t, d is the dimension of the matrix and $RI(d)$ is a random index depending on d, Table 2.

Table 2: $RI(n)$

d	3	4	5	6	7	8	9
$RI(d)$	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Application: *A multi-level AHP tree was designed for checking the consistency as CR_2 had sub criteria. Customers used the FAHP scale given in Table 1 for the linguistic comparisons. Evaluation matrices of Customer 1 of which $\lambda_{max} = 7.269, CI = 0.045, CR = 0.034$ for the main criteria, $\lambda_{max} = 3.01, CI = 0.005, CR = 0.008$ for the sub-criteria of CR_2 were given as an examples below.*

Linguistic matrix:

$$R_{1(main)} = \begin{bmatrix} EQP & SP & EQP & EXP & MP & EXP & SP \\ 1/SP & EQP & 1/MP & MP & EQP & VSP & EQP \\ EQP & MP & EQP & EXP & MP & EXP & SP \\ 1/EXP & 1/MP & 1/EXP & EQP & 1/SP & EQP & 1/MP \\ 1/MP & EQP & 1/MP & SP & EQP & EXP & MP \\ 1/EXP & 1/VSP & 1/EXP & EQP & 1/EXP & EQP & 1/MP \\ 1/SP & EQP & 1/SP & MP & 1/MP & MP & EQP \end{bmatrix} \quad R_{1(sub)} = \begin{bmatrix} EQP & EQP & \frac{1}{SP} \\ EQP & EQP & \frac{1}{SP} \\ SP & SP & EQP \end{bmatrix}$$

Fuzzy matrix:

$$R_{1(main)} =$$

$$\begin{bmatrix} 1.00,1.00,1.00 & 4.00,5.00,6.00 & 1.00,1.00,1.00 & 8.00,9.00,9.00 & 2.00,3.00,4.00 & 8.00,9.00,9.00 & 4.00,5.00,6.00 \\ 0.16,0.20,0.25 & 1.00,1.00,1.00 & 0.25,0.33,0.50 & 2.00,3.00,4.00 & 1.00,1.00,1.00 & 6.00,7.00,8.00 & 1.00,1.00,1.00 \\ 1.00,1.00,1.00 & 2.00,3.00,4.00 & 1.00,1.00,1.00 & 8.00,9.00,9.00 & 2.00,3.00,4.00 & 8.00,9.00,9.00 & 4.00,5.00,6.00 \\ 0.11,0.11,0.12 & 0.25,0.33,0.50 & 0.11,0.11,0.12 & 1.00,1.00,1.00 & 0.16,0.20,0.25 & 1.00,1.00,1.00 & 0.25,0.33,0.50 \\ 0.25,0.33,0.50 & 1.00,1.00,1.00 & 0.25,0.33,0.50 & 4.00,5.00,6.00 & 1.00,1.00,1.00 & 8.00,9.00,9.00 & 2.00,3.00,4.00 \\ 0.11,0.11,0.12 & 0.12,0.14,0.16 & 0.11,0.11,0.12 & 1.00,1.00,1.00 & 0.11,0.11,0.12 & 1.00,1.00,1.00 & 0.25,0.33,0.50 \\ 0.16,0.20,0.25 & 1.00,1.00,1.00 & 0.16,0.20,0.25 & 2.00,3.00,4.00 & 0.25,0.33,0.50 & 2.00,3.00,4.00 & 1.00,1.00,1.00 \end{bmatrix}$$

$$R_{1(sub)} = \begin{bmatrix} 1.00,1.00,1.00 & 1.00,1.00,1.00 & 0.16,0.20,0.25 \\ 1.00,1.00,1.00 & 1.00,1.00,1.00 & 0.16,0.20,0.25 \\ 4.00,5.00,6.00 & 4.00,5.00,6.00 & 1.00,1.00,1.00 \end{bmatrix}$$

Defuzzified matrix:

$$R_{1(main)} = \begin{bmatrix} 1.00 & 5.00 & 1.00 & 8.83 & 3.00 & 8.83 & 5.00 \\ 0.20 & 1.00 & 0.34 & 3.00 & 1.00 & 7.00 & 1.00 \\ 1.00 & 3.00 & 1.00 & 8.83 & 3.00 & 8.83 & 5.00 \\ 0.11 & 0.34 & 0.11 & 1.00 & 0.20 & 1.00 & 0.34 \\ 0.34 & 1.00 & 0.34 & 5.00 & 1.00 & 8.83 & 3.00 \\ 0.11 & 0.14 & 0.11 & 1.00 & 0.11 & 1.00 & 0.34 \\ 1.00 & 1.00 & 0.20 & 3.00 & 0.34 & 3.00 & 1.00 \end{bmatrix} \quad R_{1(sub)} = \begin{bmatrix} 1.00 & 1.00 & 0.20 \\ 1.00 & 1.00 & 0.20 \\ 5.00 & 5.00 & 1.00 \end{bmatrix}$$

Finally, consistency ratios for all customers were obtained as follows: 0.034,0.040,0.037,0.037,0.035,0.040,0.034,0.048,0.040,0.041 for the main CRs, and 0.008,0.008,0.058,0.008,0.010,0.008,0.008,0.008,0.093,0.008 for the sub CRs. As seen, they were all below 0.10.

Step 8. Calculating the relative importance of CRs. Pairwise comparisons of all customers are aggregated into one matrix, $\bar{R}$, with fuzzy arithmetic mean of r_{ij} with Eq. (8).

$$\bar{r_{ij}} = \frac{1}{t} \otimes (r_{ij1} \oplus \ldots \oplus r_{ijt}) \quad i \text{ and } j = 1, \ldots, k \text{ and } t=1,\ldots,s \tag{8}$$

Then the EA is applied (Chang, 1996) to obtain only the synthetic extent values as the HoQ is fuzzy and there is no need to obtain crisp values of RI_i. Where $TV_i = \left(tv_i^l, tv_i^{md}, tv_i^h\right)$ denotes the total fuzzy importance value of the each i^{th} object (CR), it is computed by using Eq. (9). Then all TV_i are summed to calculate $TV = (TV^l, TV^{md}, TV^h)$ and its inverse, Eq. (11). Finally, RI_i, of each CR is calculated with Eq. (12), where $RI_i = \left(RI_i^l, RI_i^{md}, RI_i^h\right)$.

$$TV_i = \sum_{j=1}^{k}\sum_{i=1}^{k} \widetilde{r_{ij}} \quad (9)$$

$$\sum_{i=1}^{k} TV_i = TV \quad (10)$$

$$[TV]^{-1} = \left(\frac{1}{TV^h}, \frac{1}{TV^{md}}, \frac{1}{TV^l}\right) \quad (11)$$

$$RI_i = TV_i \otimes [TV]^{-1} \quad (12)$$

Application: A sample calculation step by step is as follows:

Where, t denotes the number of customers, and $\widetilde{r_{13}}$ *denotes the final fuzzy value of* CR_1–CR_3 *relationship,* $\widetilde{r_{13}} = \frac{1}{t} \otimes [r_{131} \oplus r_{132} \oplus \ldots \oplus r_{13\,10}] = \frac{1}{10} \otimes [(1.00,1.00,1.00) \oplus (1.00,1.00,1.00) \oplus \ldots \oplus (2.00,3.00,4.00)] = (1.60,2.20,2.80)$

Where TV_1 *denotes the total fuzzy importance value of* CR_1, $TV_1 = \widetilde{r_{11}} \oplus \ldots \oplus \widetilde{r_{17}} = (1.00,1.001.00) \oplus \ldots \oplus (4.40,5.40,6.40) = (26.80,32.40,36.30)$. *Likewise, all* TV_i *values for all CRs and sub-CRs were calculated to determine a single TV and sub_TV value, which were calculated as* $TV = TV_1 \oplus \ldots \oplus TV_7 = (84.28,102.60,119.18)$, *and* $sub_{TV} = TV_{21} \oplus TV_{22} \oplus TV_{23} = (13.40,15.80,18.25)$. *Then, inverse of TVs were calculated as* $[TV]^{-1} = (0.008,0.010,0.012)$, *and* $sub_{[TV]^{-1}} = (0.055,0.063,0.075)$.

At the end of step 8, RI_i *is of each of the main CRs were obtained and placed in the HoQ, such as relative importance of* CR_1 *is* $RI_1 = TV_1 \otimes [TV]^{-1} = (26.80,32.40,36.30) \otimes (0.008,0.010,0.012) = (0.225,0.316,0.431)$. $RI_{21}, RI_{22}, RI_{23}$ *values of sub-CRs were normalized in order for the sum of* $RI_{21}^{md}, RI_{22}^{md}, RI_{23}^{md}$ *to be equal to* RI_2^{md} *before they were placed in the HoQ.*

Step 9. Determining the correlations among ECs. In this step, a square matrix is used as it supports asymmetric interrelationships between *ECs*. Each expert has one *EC-EC* linguistic relationship matrix for each *CR* as some *ECs* may have none effect on all *CR's*. Then, linguistic matrices are converted into fuzzy matrices to be used in Step 12.

Application: *The scale in (Maritan, 2015) was adopted in this step. The original version of this scale has three levels quantified with crisp values that are, 0 for no correlation, 1 for weak, 3 for medium, and 9 for strong correlations. We used its fuzzy version, where medium values of the fuzzy numbers corresponds to the crisp values of the scale levels, as follows: Negative High-NH (-4; -9; -9), Negative Medium-NM (-1; -3; -5), Negative Low-NL (0; -1; -2), no correlation (0; 0; 1,), and Positive Low-PL (0; 1; 2), Positive Medium-PM (1; 3; 5) and Positive High-PH (4; 9; 9). Since there were nine CRs and three experts, there were 27 matrices in total. Matrices of the first expert was given as an example in Fig. 3.*

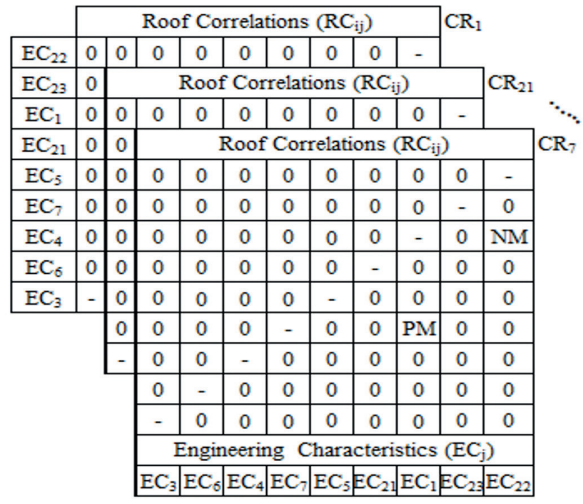

Fig. 3: Asymmetric Linguistic Correlation Matrices Regarding Each CR of Expert 1

Step 10. Determining the relative weights. The expert team identify the competitors and ask customers to make a competitive evaluation by using (1-5) numerical scale. Afterward, all matrices are aggregated into one with Eq. (13-14) where SC_i denotes the performance of the subject company and CC_i denotes the performance of the competitor under the i^{th} CR. Then the experts set goals regarding each CR and evaluate the relationship between the goals and *CRs* by using the same scale. In the end, individual evaluations of each expert are aggregated into one with Eq. (15) where SG_i denotes the strategic goal regarding the i^{th} CR.

$$SC_i = \frac{1}{t} \otimes (sc_{i1} \oplus sc_{i2} \oplus \ldots\ldots\ldots\ldots \oplus sc_{it}) \quad (13)$$

$$CC_i = \frac{1}{t} \otimes (cc_{i1} \oplus cc_{i2} \oplus \ldots . \oplus cc_{it}) \quad i = 1, \ldots, k \text{ and } t = 1, \ldots, s \quad (14)$$

$$SG_i = \frac{1}{n} \otimes (sg_{i1} \oplus sg_{i2} \oplus \ldots \oplus sg_{in}) \quad i = 1, \ldots, k \text{ and } n = 1, \ldots, e \quad (15)$$

After that, the improvement ratio (IR_i), which is a score representing that if the subject company needs improvements in satisfying *CRs* to achieve strategic goals, is calculated with Eq. (16) (1.00 means that no

	SCi	CCi (European)	CCi (Asian)	SGi	IRi	SPi
CR1	4	5	3			
CR21	4	4	4			
CR22	3	4	3			
CR23	4	5	3			
CR3	3	5	4			
CR4	3	4	4			
CR5	4	5	3			
CR6	3	4	3			
CR7	4	5	3			

(a)

	SCi	CCi (European)	CCi (Asian)	SGi	IRi	SPi
CR1				4		1.50
CR21				5		1.25
CR22				4		1.20
CR23				4		1.20
CR3				4		1.50
CR4				4		1.25
CR5				4		1.25
CR6				5		1.25
CR7				4		1.50

(b)

	SCi	CCi (European)	CCi (Asian)	SGi	IRi	SPi
CR1	3.70	4.50	3.10	4.33	1.17	1.42
CR21	4.30	4.60	3.80	4.77	1.09	1.08
CR22	3.50	4.10	3.50	4.07	1.14	1.13
CR23	4.20	5	3.70	4.73	1.11	1.40
CR3	3.40	4.40	3.50	4	1.18	1.42
CR4	3.20	3.80	3.30	3.47	1.04	1.17
CR5	3.90	4.60	3.20	4.33	1.11	1.42
CR6	3.40	4	3.20	4.67	1.37	1.17
CR7	4.20	4.40	2.90	4.47	1.03	1.50

(c)

Fig. 4: (a) Evaluations of customer 1 and **(b)** expert 1 **(c)** aggregated evaluations

improvement is necessary). Next, the experts determine sales points (SP_i) for each CR. Then SP_i ratings are aggregated into one with Eq. (17). According to Chan and Wu (2002), a sales point contains such information that characterizes the product selling ability of the subject company based on how well the subject product/design meets each customer requirement. A "strong" sales point means that the CR is critical and provides a competitive advantage. A "moderate" sales point implies that the importance of the CR and the competitive opportunity it provides is not so great. A "no" sales point means that the CR provides no opportunity and has no importance. Their numeric values are 1.5, 1.25, and 1, respectively. Then a triangular fuzzy absolute weight (AW_i) for each CR is calculated with Eq. (18). Finally, AW_i of CRs are defuzzified and normalized by dividing each normalized AW_i by the sum of all normalized $AW_i s$ to obtain crisp $RW_i s$. In other words, weights of CRs in regards to competitive analysis are expressed as a percentage of the total with Eq. (19).

$$IR_i = \frac{SG_i}{SC_i} \quad i = 1, \ldots, \tag{16}$$

$$SP_i = \frac{1}{n} \otimes (\mathrm{sp}_{i1} \oplus \mathrm{sp}_{i2} \oplus \ldots \oplus \mathrm{sp}_{in}) \quad i = 1, \ldots, k \text{ and } n = 1, \ldots, e \tag{17}$$

$$AW_i = RI_i \otimes IR_i \otimes SP_i \tag{18}$$

$$RW_i = \frac{AW_i}{\sum_{i=1}^{k} AW_i} \qquad i = 1, \ldots, k \tag{19}$$

Application: *In this step, customers' and experts' evaluations were obtained. Customer 1's and Expert 1's evaluation matrices can be seen in Fig. 4(a) and 4(b) respectively. Also, the aggregated evaluation matrix with IR_i was as in Fig 4(c).*

Some, numerical illustrations are as follows: Where SC evaluations were done by the customers and SC_1 denotes the performance of the subject company under the 1st CR, $SC_1 = \frac{1}{10} \otimes (sc_{11} \oplus \ldots \oplus sc_{1\,10}) = \frac{1}{10} \otimes (4 \oplus \ldots \oplus 4) = 3.70.$

Where CC evaluations were also done by the customers, and CC_1 denotes the performance of the competitor under the 1st CR, $CC_1 = \frac{1}{10} \otimes (cc_{11} \oplus \ldots \oplus cc_{1\,10}) = \frac{1}{10} \otimes (5 \oplus \ldots \oplus 5) = 4.50.$

Where SG evaluations were done by the experts, SG_1 denotes the strategic goal regarding the 1st CR, $SG_1 = \frac{1}{3} \otimes (sg_{11} \oplus sg_{12} \oplus sg_{13}) = \frac{1}{3} \otimes (4 \oplus 5 \oplus 4) = 4.33.$

Where IR_1 denotes the improvement ratio of the 1st CR, $IR_1 = SG_1/SC_1 = 4.33/3.70 = 1.17.$

Where SP evaluations were done by the experts, SP_1 denotes the sales point of the 1st CR, $SP_1 = \frac{1}{3} \otimes (sp_{11} \oplus sp_{12} \oplus sp_{13}) = \frac{1}{3} \otimes (1.50 \oplus 1.25 \oplus 1.50) = 1.42.$

With the completion of this step, AW_i and RW_i of each CR were calculated and placed in the HoQ in Fig. 8. A sample calculation is given below.

Where AW_1 denotes fuzzy absolute weight of the 1st CR, fuzzy $AW_1 = RI_1 \otimes IR_1 \otimes SP_1 = (0.22, 0.31, 0.43) \otimes 1.17 \otimes 1.42 = (0.37, 0.52, 0.71),$ *and normalized* $AW_1 = \frac{[0.37+(0.52*4)+0.71]}{6} = 0.53.$

Where RW_1 denotes the crisp relative weight of the 1st CR, $RW_1 = \frac{AW_1}{AW_1+\cdots+AW_7} = \frac{0.53}{0.53+\cdots+0.12} = 0.33.$

Step 11. Determining the relative column weights and rankings. In this step, fuzzy relative column weights (RCW_j) of each EC is computed without interrelationships among ECs. Eq. (20) is used for the computations. All weights are normalized with Eq. (21). With the normalization, each weight is represented as a percentage of the total where i and $j=1,\ldots,m$ and CW_j and RCW_j are triangular fuzzy numbers. In the end, $RCW_j s$ are defuzzified with Eq. (5) and ECs are ranked according to their crisp weights.

$$CW_j = \sum_{i=1}^{k} C_{ij} \otimes RW_i \quad (20)$$

$$RCW_j = \frac{CW_j}{\sum_{j=1}^{m} CW_j} \quad (21)$$

Application: *RCW_j and rankings were calculated and placed in the HoQ, as in Fig. 8. Some sample calculations are provided below.*

Where CW_1 denotes fuzzy column weight of EC_1 $CW_1 = (C_{11} \otimes RW_1) \oplus \ldots \oplus (C_{17} \otimes RW_7) = [(0.66,0.76,0.86) \otimes 0.33] \oplus \ldots \oplus [(0.53,0.63,0.73) \otimes 0.08] = (0.32,0.37,0.43)$. *Then, it was defuzzified to calculate the relative column weight.*

$$RCW_1 = \frac{CW_1}{CW_1 + \cdots + CW_7} = \frac{0.3724}{0.37 + \cdots + 0.13} = 0.18$$

Step 12. FCM analysis. Fuzzy correlation matrices belonging to each expert obtained in Step 9 are integrated into one individual matrix with Eq. (22) where the influence that the i^{th} EC on the i^{th} EC regarding the k^{th} CR of the same expert n is denoted as rc_{ijk}^n. The individual matrices obtained with the integration represents FCM adjacency matrices (maps) of the experts. Therefore, rc_{ij}^n values become arc values that are denoted as w_{ij}^n.

$$rc_{ij}^n = \sum_{k=1}^{K} rc_{ijk}^n RW_i = w_{ij}^n \quad (22)$$

After obtaining individual maps, they are re-integrated into one map to be used as an asymmetric roof matrix in the HoQ. There are arithmetic mean $W_{ij} = \sum_{n=1}^{N} \frac{w_{ij}^n}{n}$, or summation $W_{ij} = \sum_{n=1}^{N} w_{ij}^n$ operators for the map integration. After constructing the integrated map, static or dynamic analysis can be done. We applied static analysis as the system we modelled is irrespective of the behaviour of the system over time. Both for the map integration and dynamic analysis, FCM Expert software (Felix et al., 2017) and for extensive maps and generating different scenarios Mental Modeller software (Gray et al., 2013) can be used.

In the scope of static analysis, the density of the map, centrality, and strength of the nodes are examined (Stach, Kurgan, & Pedrycz, 2010). Density D is an indication of the complexity of the map. It is the ratio of the number of the edges, E, to the maximum number of the edges that the map can have. It is formulated as $D = \frac{E}{V(V-1)}$, where V is the number of concepts (nodes). The degree of a node deg_i is the sum of incoming and outgoing edges of the node. The number of incoming edges of a node j is called in-degree deg_j^{in}, and the number of outgoing edges of a node is called out-degree deg_j^{out}. The degree of a node represents its centrality. Higher the value of the centrality, the higher the number of interactions it has and so significant the node to be. The total strength value of a node j is val_j. It is the sum of the absolute weights of all incoming edges to the subject node $\left(val_j^{in} = \sum_{i \neq j} |w_{ij}|\right)$ and all outgoing edges from the subject node $\left(val_j^{out} = \sum_{i \neq j} |w_{ji}|\right)$. The strength of a node denotes its significance/importance. For further information regarding FCM analysis, please refer to Axelrod (1976), Christoforou & Andreou (2017), Felix et al. (2017), Kosko (1986), Papageorgiou (2012), Papageorgiou & Salmeron (2013) and Tsadiras (2008).

Application: *A set of nine matrices that belongs to each expert obtained in Step 9 were integrated into one individual matrix with Eq. 22. For example, the integrated effect of EC_7 on EC_1 regarding all CRs based on the evaluations of Expert 1 was calculated as below. The integrated matrix of Expert 1 and the final matrix be seen in Fig. (5-6) respectively.*

$$rc_{71}^1 = rc_{711}^1 RW_1 \oplus rc_{71-21}^1 RW_{21} \oplus rc_{71-22}^1 RW_{22} \oplus rc_{71-23}^1 RW_{23} \oplus rc_{713}^1 RW_3 \oplus rc_{714}^1 RW_4 \oplus rc_{715}^1 RW_5 \oplus rc_{716}^1 RW_6 \oplus rc_{717}^1 RW_7 = [(1.00,3.00,5.00) \otimes 0.33] \oplus \ldots \oplus [(1.00,3.00,5.00) \otimes 0.08] = (0.05,0.13,0.22) = w_{71}^1$$

Then, the final map, Fig. 7, was calculated with the arithmetic mean operator as the summation operator requires the use of a threshold function (e.g., Sigmoid

EC_{22}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-
EC_{23}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0
EC_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0	-0.45	-0.42	-0.18
EC_{21}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0	0.06	0.13	0.13	0	0	0
EC_5	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0	0	0	0	0.07	0.20	0.34	-0.34	-0.20	-0.07
EC_7	0	0.03	0.06	0	0	0	0	0	0	-	-	-	0	0	0	0	0	0	0.05	0.13	0.22	0.20	0.45	0.45	0	0	0
EC_4	0	0	0	0.02	0.05	0.05	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EC_6	0	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EC_3	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.15	0	0	0
	EC_3			EC_6			EC_4			EC_7			EC_5			EC_{21}			EC_1			EC_{23}			EC_{22}		

Fig. 5: Individual Roof Matrix of Expert 1

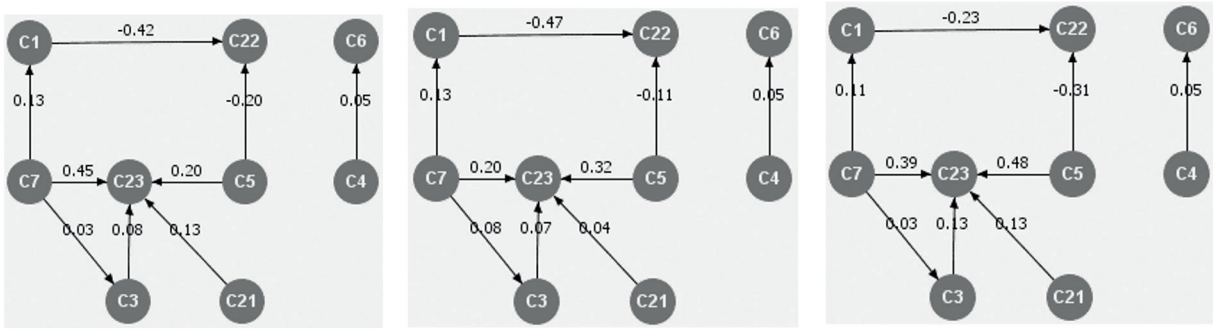

Fig. 6: FCM Representations of Roof Matrices Belongs to the Experts correspondingly (The capital Cs in the nodes denote the "concepts" in FCM analysis. Their corresponding variables are ECs in QFD method.)

function) to transform summated fuzzy values in the interval of [-1, 1]. After that adjacency matrix was placed as a roof matrix in the HoQ in Fig. 8. Finally, the static analysis was done and summarized in Table 3.

Where W_{71} denotes the influence of the 7th EC on the 1st EC, which is the directed arc weight between EC_7-EC_1,

$$W_{71} = \frac{w_{71}^1 \oplus w_{71}^2 \oplus w_{71}^3}{3} = \frac{(0.05,0.13,0.22) \oplus (0.05,0.13,0.22) \oplus (0.03,0.11,0.15)}{3} = (0.04,0.13,0.20).$$

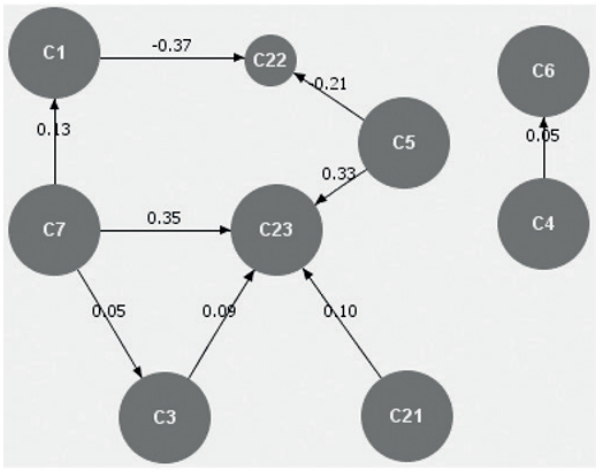

Fig. 7: The Final FCM

Step 13. Determining the final column weights and rankings. The ranking calculated in step 11 is based on only CR satisfying capabilities of ECs. Hence, the better an EC is capable of satisfying CRs, the more critical it is. Asymmetric EC-EC interrelationships are considered additionally here in Step 13. The desired scenario in this step is determining an EC of which CR satisfaction capability is high but total casual effect on other ECs (val_j^{out}) is low. The geometric mean method is used to aggregate those values. However, multiplying CW_j by (val_j^{out}) will lessen the CR-EC relationship effect on the final importance. Because of that, the inverse of (val_j^{out}) is taken into consideration not to lessen the effect. Of the ECs (concepts in FCM) which have none outgoing edges, (val_j^{out}) values are set to 0.01. Therefore, the values of $(val_j^{out})^{-1}$ become in the interval of [0,100]. This requires the change of the range of CW_j from [0, 1] to [0, 100] as well. To do that, CW_j is multiplied with a coefficient, 100. Then the final importance weight of an EC is calculated with Eq. (23). Finally, they are defuzzified with Eq. (5) and re-ranked according to their crisp weights.

$$FW_j = \sqrt[2]{100 * CW_j * (val_j^{out})^{-1}} \quad (23)$$

The general interpretation of FW_j values can be as follows: Higher FW_j means that the j^{th} EC has a higher effect on CRs and lower effects on other ECs. Hence, it becomes an easily manageable and applicable EC. Also, the tasks related to that EC can be implemented firstly due to any change in that EC will have less effect on the other ECs. It may have a high level of strategic importance, and provide competitive advantages and market opportunities to the company. Additionally, since the value of the final weight depends on the column weight, and the value of the column weight indirectly depends on the improvement ratio, a higher final weight may point out more significant differences between SC_i and SG_i. On the other hand, lower values mean that the EC has a weaker effect on CRs and higher effects on other ECs. Therefore, it is not an easily manageable and applicable EC. Implementation priority may not be given to its related tasks because any change in that EC will have a significant effect on the other ECs. Probably, its strategic importance is low, so it provides lower competitive advantages and market opportunities

to the company. Additionally, a lower final weight may point out smaller differences between SC_i and SG_i. In other words, there is not much to do for improving the product/design with respect to that EC.

Application: *With the end of this step, final weights of ECs and their final rankings based on crisp values were obtained and placed in the HoQ as in Fig. 8. Calculation of the final weight of EC1 is given as an example as follows: Where* $val_1^{out} = \sum_{i \neq 1} |w_{1i}| = |-0.37| = 0.37$ *as obtained from Figure 5,* $FW_1 = \sqrt[2]{100 * CW_1 * (val_1^{out})^{-1}} = \sqrt[2]{100 * 0.37 * \frac{1}{0.3724}} = 10.03.$

6. FINAL RESULTS and DISCUSSION

In this study, an integrated QFD methodology was proposed to rank CRs with considering asymmetric interrelationships among ECs quantitatively. It was applied to a company that globally operates and produces sheet metal dies for Tier 1 and Tier 2 suppliers in the automotive industry. The subject product is a sophisticated tool that inherits complex CR-EC relationships and EC interrelationships.

The application of IA for investigating the relationships between CRs and ECs enabled us determining some high-grade relationships, which could cause time and money loss to the company. AD approach of Çebi and Kahraman (2011) was adopted in this study. The aim was obtaining a product design of which couplings in a tolerable limit defined by the experts. As explained in step 6, the final CR-EC relationship matrix was a decoupled matrix $(\widetilde{C} = 0.06, 0.07, 0.09)$ in the limits of the tolerance, $\gamma = (0.1, 0.1, 0.1)$.

According to Table 3, the density of the map is very low. It means that there are not many edges or casual effects between ECs so the complexity of the map is low. However, since the subject problem is an engineering problem regarding a highly sophisticated product, the magnitude of the effects may be important. The center and also the most influential-strongest node of the map is $\boldsymbol{EC_{23}}$. The node that has the most casual effect on other nodes is EC_5 based on its $\boldsymbol{val_5^{out}}$. There are four driver nodes and three receiver nodes on the map. As the map is acyclic as seen in Fig. 7, any change in one concept does not have an indirect effect on itself. If the map was cyclic, CRs and ECs should have been revised, or granulated further. Please refer to Osoba and Kosko (2017) for more information about cyclic maps.

Moreover, it is observable that considering EC-EC interrelationships changes the order, Fig. 7 and Table 4. The rankings of the three strongest ECs (EC_1, EC_5, EC_7) regarding their $\boldsymbol{val_j^{out}}$ dramatically moved to lowest levels. High column weight and casual effect values of EC_1 and EC_5 caused them to move lower levels in the ranking. The highest sales point and very high casual effect values of EC_7 made it to be in the last rank. EC_4 is also in the last four rankings just because of its lowest column weight value. Any change in the values of that four ECs will profoundly affect the other ECs. If other ECs are adversely affected, their corresponding CRs may not be satisfied. Hence the decision-makers have to be careful with them. Thus, they are the least manageable and most critical ECs.

Regarding EC_4, the engineers should consider if it is worth to make any change in it. Even though it is a manageable EC regarding its effect on other ECs, its CR satisfying capability is very low. Therefore, it is better to investigate the final map. If its centrality is high even though its casual effect is at a minimal level, it may not be preferential to make any change because it will both directly and indirectly, affect other ECs. If not, an implementation priority can be given to it. In our example, implementation priority can be given to EC_4 because it only affects EC_6 and EC_6 has none effect on any other ECs.

Regarding the ECs in the first three ranking, namely, $\boldsymbol{EC_{21}}$, $\boldsymbol{EC_{23}}$ and EC_3, their column weights are very high contrary to their casual effects on other ECs. It can be defined as a most desirable situation. Any task implementations regarding them will not affect other ECs but will satisfy most of the CRs. Hence, they are the most manageable ECs, and their corresponding CRs are better satisfiable CRs. Finally, there are two ECs left to discuss about, $\boldsymbol{EC_{22}}$ and $\boldsymbol{EC_6}$. They are in the middle of the ranking with moderate values of $\boldsymbol{val_j^{out}}$ and CW_j. They moved from the lower levels to middle levels in the ranking.

For a general overview, first the proposed model has demonstrated that AD is a very suitable method to be used with QFD as they have a common ground

Table 3: Outputs of the Static Analysis of the Final Map

Density	Concept	Centrality					Strength	Type
	C_1	1	1	2	0.13	0.37	0.50	Ordinary
	C_{21}	0	1	1	0	0.10	0.10	Driver
	C_{22}	2	0	2	0.58	0	0.58	Receiver
	C_{23}	4	0	4	0.87	0	0.87	Receiver
0.125	C_3	1	1	2	0.05	0.09	0.14	Ordinary
	C_4	0	1	1	0	0.05	0.05	Driver
	C_5	0	2	2	0	0.54	0.54	Driver
	C_6	1	0	1	0.05	0	0.05	Receiver
	C_7	0	3	3	0	0.40	0.40	Driver

Table 4: Summary of the HoQ

Name	Ranking	Final Ranking	RI_i	IR_i	SP_i	RW_i	CW_j	val^{out}_j
EC_{23}	5	↑ 1	0.08	1.11	1.42	0.08	0.26	0
EC_3	3	↑ 2	0.24	1.18	1.42	0.25	0.37	0.09
EC_{21}	2	↓ 3	0.01	1.09	1.08	0.01	0.37	0.10
EC_6	7	↑ 4	0.03	1.37	1.17	0.03	0.03	0
EC_{22}	8	↑ 5	0.04	1.14	1.17	0.04	0.03	0
EC_1	4	↓ 6	0.32	1.17	1.42	0.32	0.37	0.37
EC_5	1	↓ 7	0.17	1.11	1.42	0.17	0.43	0.54
EC_4	9	↑ 8	0.03	1.04	1.17	0.02	0.03	0.05
EC_7	6	↓ 9	0.08	1.03	1.5	0.08	0.13	0.40

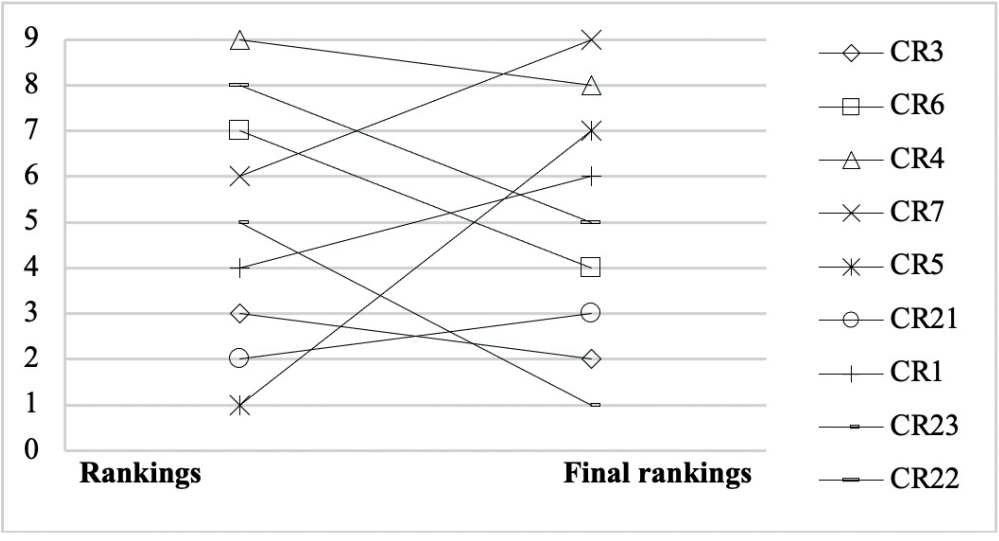

Fig. 7: Comparisons of the Rankings

regarding design domains. It is an efficient method to manage the design process by the decomposition, and to reduce the complexity of the design by managing the couplings in *CR-EC* relationship matrix. Second, fuzzy *AHP* is also a must used method in *QFD* applications, where more than one expert is involved in, to obtain consistent evaluations. The last but not the least, use of asymmetric roof matrix is crucial as it better captures the *EC-EC* relationships similar to what Fazeli & Peng (2021) highlighted and proved in their study. With the same purpose of ours the authors used *DEMATEL* but under the assumption of *CRs*

were not correlated. They also assumed that EC-EC relationships stay same under different CRs. However, value of a particular EC-EC relationship may change depending on the CR considered. In this respect, investigating EC-EC relationship for each CR is better appropriate to real-life problems.

What is more, *FCM* is an appropriate and practical method to be used for analysing the asymmetric roof matrix by quantifying correlations. It provides additional information for managerial practices/ implications, such as determination of the strongest EC, the EC that has the most casual effect on other ECs, and the presence of cyclic or acyclic relationships among ECs. To the best of our knowledge, FCM method has not been used with QFD in the literature.

The present study was subject to some potential practical and methodological weaknesses, such as number of experts, and concepts (ECs) are small, and the fuzzy scale used is not sensitive enough. A much granulised fuzzy scale could has been utilized if the experts were willing to use in their judgements.

For further research, dynamic analysis of $FCMs$ can be considered. It could not be applied in this study as the number of the concepts and experts was small, the density of the map was low, and the fuzzy scale was not sensitive enough. Additionally, hesitant fuzzy sets can be employed. When hesitancy is considered as the uncertainty degree of the fuzzy information decision-makers provided, measuring uncertainty of hesitant information with the help of statistical approaches in machine learning would be interesting. For example, in case of having an extensive group of decision makers (that yields to large enough sample/data), some robust hesitancy functions with sub-sampling techniques could be created for defining low and high level (or null and full) hesitant sets.

					Roof Correlations (RC_{ij})																																		
					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-							
					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0				
					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0	-0.42	-0.37	-0.16				
					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0	0.04	0.10	0.11	0	0	0				
					0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0.13	0.33	0.43	-0.32	-0.21	-0.07	
					0.00	0.05	0.08	0	0	0	0	0	0	-	-	-	0	0	0	0	0	0	0.04	0.13	0.20	0.15	0.35	0.38	0	0	0							
					0	0	0	0.02	0.05	0.05	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
					0	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
					-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.09	0.17	0	0	0				
					Engineering Characteristics (EC_j)																																		
		RI_i			EC_3			EC_6			EC_4			EC_7			EC_5			EC_{21}			EC_1			EC_{23}			EC_{22}			IR_i	SP_i	AW_i			RW_i
Customer Requirements (CR_i)	CR_3	0.17	0.24	0.33	0.73	0.83	0.93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.18	1.42	0.28	0.40	0.55	0.25
	CR_6	0.12	0.03	0.04	0	0	0	0.66	0.76	0.86	0.26	0.36	0.46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.37	1.17	0.04	0.05	0.06	0.03
	CR_4	0.02	0.03	0.04	0	0	0	0.33	0.43	0.53	0.66	0.76	0.86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.04	1.17	0.03	0.04	0.05	0.02
	CR_7	0.05	0.08	0.12	0	0	0	0	0	0	0	0	0	0.66	0.76	0.86	0	0	0	0	0	0	0	0	0	0.53	0.63	0.73	0	0	0	0	0	0	1.03	1.50	0.08	0.12	0.20	0.08
	CR_5	0.12	0.17	0.24	0.46	0.56	0.66	0	0	0	0	0	0	0	0	0	0.8	0.9	1	0.06	0.16	0.26	0	0	0	0	0	0	0	0	0	1.11	1.42	0.19	0.27	0.39	0.17
	CR_{21}	0.01	0.01	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0.53	0.63	0.73	0.73	0.83	0.93	0.4	0.5	0.6	0.4	0.5	0.6	0	0	0	1.09	1.08	0.01	0.02	0.03	0.01
	CR_1	0.22	0.31	0.43	0	0	0	0	0	0	0	0	0	0.13	0.23	0.33	0.6	0.7	0.8	0.66	0.76	0.86	0.66	0.76	0.86	0.4	0.5	0.6	0	0	0	1.17	1.42	0.37	0.52	0.71	0.33
	CR_{23}	0.03	0.08	0.16	0.4	0.5	0.6	0	0	0	0	0	0	0	0	0	0.26	0.36	0.46	0.6	0.7	0.8	0.46	0.56	0.66	0.73	0.83	0.93	0	0	0	1.11	1.40	0.06	0.13	0.26	0.08
	CR_{22}	0.02	0.04	0.09	0.73	0.83	0.93	0	0	0	0	0	0	0	0	0	0.26	0.36	0.46	0.66	0.76	0.86	0.46	0.56	0.66	0.4	0.5	0.6	0.66	0.76	0.86	1.14	1.13	0.03	0.06	0.12	0.04
	CW_j				0.32	0.37	0.43	0.03	0.03	0.04	0.02	0.02	0.03	0.09	0.13	0.17	0.37	0.42	0.49	0.31	0.37	0.44	0.32	0.37	0.43	0.21	0.25	0.30	0.02	0.02	0.03							
	Defuzzified CW_j				0.37			0.03			0.03			0.13			0.43			0.37			0.37			0.26			0.03									
	RCW_j				0.18			0.02			0.01			0.07			0.21			0.18			0.18			0.13			0.01									
	Rankings				3			7			9			6			1			2			4			5			8									
	$100*CW_j$				37.37			3.27			2.82			13.49			42.85			37.38			37.24			25.67			29.98									
	val_j^{out}				0.09			0.01			0.05			0.40			0.54			0.10			0.37			0.01			0.01									
	$1/val_j^{out}$				11.11			100			20			2.50			1.85			10			2.70			100			100									
	FW_j				20.38			18.08			7.51			5.81			8.91			19.33			10.03			50.67			17.32									
	Final Rankings				2			4			8			9			7			3			6			1			5									

Fig. 8: HoQ with the rankings and final rankings

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APPENDIX

CR1 (Repeatability). A car consists of approximately 1000 sheet metal parts that have to fit each other and other elements like molded plastics, injected castings and machined parts in a 0.2-2 mm tolerance. Hence, component fitness is crucially important for OEMs and so providing perfectly fitting sheet metal parts to OEMs for Tier 1 and Tier 2 suppliers. In this respect, repeatedly manufacturing dimensionally precise parts is a critical CR.

CR2 (Visual quality of stamped parts). Trimming burrs, material thinning and wrinkles are the factors affecting the visual quality of stamped parts. Trimming burrs can cause assembly problems, and employee injuries. Thinning and wrinkling affect the strength and durability of stamped parts which are very critical for some security parts like bumpers. Additionally, if the faulty part is a visible body part of a car, it may hurt consumers as well. In this study, they are denoted as CR21, CR22, and CR23 respectively.

CR3 (High production speed. OEMs develop or design mutual/identical automobile components for the purpose of mass production and cost reduction. Resultantly, these components have to be stamped over 2 million per year. Hence, high production speed is an important criteria for customers.

CR4 (Easy accessibility of standard components in sheet metal dies). Dies sometimes are transferred from one stamping facility to another one in a different country. In this case, they can be fixed easily, timely and cheaply only when their standard parts conform to global standards. Resultantly, standardization of die elements is crucial for customers.

CR5 (Long lifetime of tool steels used for trimming and cold forming in dies). Tool steels that are inside of the die wear out and have to be replaced several times during the lifetime of the die. However, they are the most expensive parts of dies as they are custom made. Once they wear out, it takes around five weeks to reproduce them. Such a long time may cause a halt of the production. Therefore, using tool steels with long lifetime is critical.

CR6 (Ease of replacement). Sheet metal presses have to be in production continuously except maintenance, and change times to meet the cost. However, during the production, some critical elements of dies, like piercing punches need replacements several times. If the replacement is easy, the duration of the halt of production decreases. Therefore, the ease of replacement becomes vital for the customers.

CR7 (Conformity of design data with the sheet metal die). Dies are shipped to customers with design data, and customers use the data for maintenance, repair and replacement. If the design data differs from the die, it requires additional labor for fixing the die, and results in increased maintenance/repairing. Therefore, dies should be produced according to the data.

EC1 (The repeatability of CNC machines). Die elements are manufactured in a very tight tolerance for example 0.01-0.10 mm, in CNC machines. Hence their dimensional precision heavily depends on the precision and tolerance interval of the machines. If die elements are manufactured in high technology machines, dies can stamp sheet metals precisely and repeatedly in accordance with the data. Hence, CR1 can be satisfied with EC1 as the repeatability of the sheet metal part production can be realized with the repeatability of the CNC machines used for the die production.

EC21 (Cutting clearance). Trimming burrs are one of the plastic deformation types in forming sheet metals. They can be eliminated by adjusting the cutting clearance, which is the gap between the punch and the die, to an optimum level.

EC22 (Surface roughness of the tool steels). Material thinning is also a type of plastic deformation. It can be eliminated with using proper tool steel regarding its roughness.

EC23 (Blank holder pressure/force). The blank holder holds the sheet metal in between upper and lower parts of the die while the punch forces the sheet metal into the die. Instead of applying a constant pressure to form the sheet metal, applying a variable pressure depending on the type of sheet metal may prevent wrinkling.

EC3 (Strokes per minute-SPM). Production speed can be increased with the increase of spm. Hence CR3 can be satisfied with the EC3.

EC4 (Ratio of standardized elements). The ratio of globally standard components to the total number of components in a die indicates that fixing the die can be done quickly and cheaply. Hence, CR4 can be satisfied with EC4.

EC5 (Hardness of tool steels). Long lifetime or durability of trim and form steels used in a sheet metal die

depends on the hardness of materials used. Chemical properties like carbon ratio, physical properties like shear resistance, length, and temperature of hardening and tempering processes affect the tool steels. The most delineative indicator of these properties is the Rockwell Hardness (HRC).

EC6 (Replacement time). Guiding elements, active surface parts, trim and piercing matrices, trimming and piercing punches are some parts which are replaced frequently. Sometimes, replacements should be done during the production; in other words, when die is mounted on the press. Therefore, these elements should be designed with considering easy replacement criteria of customers. However, there may be some design limits. Time needed to change this kind of elements in minutes can be an indicator of CR6. If the time consumed during a replacement is high, it means that replacing that specific element is not easy.

EC7 (Number of software). Special software in CAD, CAM, CAE, process management and reverse engineering eliminate human errors and guarantee that the manufactured sheet metal die conforms with its design. Therefore, the number of software can be a good indicator of CR.

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Analysis of Variables Affecting Municipal Borrowing with Quantile Regression in Turkey*

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ABSTRACT

The present study aimed to determine the variables that affect municipal borrowing in Turkey and analyze them using the quantile regression. In this analysis, municipal debt was analyzed for five quantiles (10th, 25th, 50th, 75th ve 90th), and it was observed that various variables explained the debt in different quantiles. Some variables are significant in all quantiles and could explain the municipal debt, while certain variables were not significant in various quantiles. The findings show that per capita budget expenditure has a significant and positively correlated per capita municipal debt in all five quantiles; expenditure commitment rate in four, and non-interest fiscal capacity rate in the first two quantiles. Per capita tax revenue variable was also significant and negatively correlated with per capita municipal debt in all five borrowing groups. However, population and per capita capital expenditure variables were found insignificant in almost five quantiles. The present study demonstrated that the proposals and policies developed on the municipal debt could have different determinants for municipalities with varying levels of debt.

Key Words: : Municipality, Borrowing, Fiscal Determinants, Quantile Regression, Turkey.

JEL Classification Codes: C21, H72, H74.

1. INTRODUCTION

Debt stocks of local governments in Turkey have increased significantly, especially in the last thirty years. Municipalities are the primary type of local government in which the debt stock increases. The duties and responsibilities of municipalities have expanded depending on the regulations aimed at strengthening decentralization (Martinez-Vazquez et al., 2016: 1096; Ataay and Güney, 2004: 133; Ministry of Development, 2014: 14-16). Thus, operational expenditures (personnel, purchase of goods and services, interest expenditures) and investment expenditures of municipalities have increased. However, the regulations made to increase revenues were inadequate to finance expenditures in the same period. In addition, it has been determined that the revenue structure of the municipalities triggers an increase in their expenditures (Sağbaş and Saruç, 2004; Acar, 2019; Yaş and Akduğan, 2015). Thus, financing of the budget deficits by borrowing increased the debt stock of municipalities (Çetinkaya, 2020: 194; NALAS, 2011: 29-30). On the other hand, because of providing intergenerational benefits and not financing all of them from the current year's budget, they also financed their investments (Swianiewicz, 2004: 5-6; Miller and Hildreth, 2007: 110). In addition to the two reasons, the inefficient and ineffective management approach has also increased the debt stock of municipalities (Kurtuluş, 2006: 11).

The debt stock of municipalities consists of loans to domestic or foreign financial institutions and organizations and other liabilities in Turkey. Due to the financing problems they had in the past, the debt stocks of the municipalities were either cancelling or assumed by the Treasury (Falay, 1997: 8; Sakal, 2003: 127). Today, the increase in overdue liabilities and budget escrows, which are among the other liabilities of municipalities, is remarkable. In particular, municipalities delay the payment of the goods and services they purchase from the market by recording them in their escrow accounts because there is not enough revenue in the budget provides an idea regarding their fiscal problems (Eroğlu and Tunç, 2018: 45). These financing problems are

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significant for municipalities and the central government as they disrupt the fiscal discipline in the public sector and create macroeconomic instability (Ter-Minassian, 2007: 2-3; Demirbaş, 2015: 6-7). For this reason, it is necessary to determine the factors affecting the borrowing of municipalities in Turkey, taking into account the examples of local governments that went into fiscal crisis due to financial problems (O'Connor, 2009; Honadle et al., 2004; Nacar, 2005). Studies have been conducted to evaluate the reasons for borrowing, types and development of municipalities in Turkey. However, there is no empirical study analyzing the factors that determine the borrowing of municipalities. Thus, this study aims to analyze the factors that determine the borrowing of municipalities in Turkey. With the findings to be obtained, it is thought that helpful information will be presented to the decision-makers, citizens and investors.

In the literature, it has been determined that there are fiscal, economic, demographic, political and institutional factors impacting the borrowing of municipalities or local governments in different countries (USA, Spain, New Zealand, Switzerland, Chile, etc.). The scope of the study is limited to testing the effects of fiscal factors on borrowing. In addition, the population was also included in the analysis as a demographic variable. This analysis was carried out using OLS regression and quantile regression methods. The analysis employed the OLS regression method; it was determined that the debt stock increased as the municipalities' budget expenditures and rigid expenditures increased, and the fiscal capacity ratio decreased. On the contrary, it was determined that the increase in tax expenditures decreased the debt stock. In the quantile regression method, it has been concluded that the effects of these variables change as the debt stock levels differ.

The study includes seven sections. After the introduction, where the study's aim, significance, and methodology were described, the municipal revenues, expenditures, and borrowing in Turkey are introduced in the second section. The third section includes the definition of variables affecting borrowing based on the literature on municipal borrowing. The fourth section describes the methodology. In the fifth section, the dataset and the correlation between the dependent and independent variables are addressed. The sixth section is devoted to the findings and discussion. The final section includes evaluations and recommendations.

2. STRUCTURE OF MUNICIPAL BORROWING IN TURKEY

Due to the principle of the administration's integrity, Turkey is governed by a unitary state structure. Based on this, the public authority is divided between the central government and local governments. Local governments comprise municipalities, provincial administrations, and villages (Constitution, 1982: 123, 127). Municipalities are the most important administrative and fiscal components in this structure.

In the 2020 Local Administrations Annual Report, the total number of municipalities is 1390. Thirty of them are metropolitan municipalities, 51 of which are provincial municipalities, 519 of which are metropolitan district municipalities, 403 of which are district municipalities, and 387 are township municipalities. Although there are a relatively small number of urban municipalities, 77.43% of the population live in areas served by these municipalities (Ministry of Environment and Urbanization, 2021: 27). Some services that municipalities are responsible for can be listed as follows: the development of master plans; implementation, planning, and coordination of transportation and infrastructure services; construction of parks and green spaces; forestation; supporting cultural and sportive activities; providing services for women, the disabled, children and the elderly; preservation of the historical and natural urban texture. The responsibility is distributed among the metropolitan, provincial, and district municipalities within the administrative structure based on the geographical borders (Law No. 5393 Article. 14; Law No. 5216 Articles. 7,8,9).

The municipalities should have adequate revenues to provide services. Notable improvements have been experienced in the transfers from general budget taxes and the own revenues of municipalities since 1980 in Turkey. The changes in regulations have allowed the municipalities to increase their revenues.

Municipal revenues include taxes, fees, expense shares, transfers from general budget taxes, interest and penalty revenues, grants, property and enterprise revenues, and borrowing. Municipalities finance the expenditures required for the services mentioned above with their revenues (Law No. 2464 Article. 59). Although the expenditures are primarily financed with ordinary revenues such as taxes, fees and shares, borrowing has become substantial revenue for municipalities. Due to the diversification of their responsibilities in the process of decentralization, municipal expenditures have increased. However, the same increase has not been observed in

municipal revenues. In developing countries such as Turkey, borrowing requirements have increased due to financing infrastructure investments and balancing revenues and expenditures (Kurtuluş, 2006: 2). However, municipalities are not entirely released on borrowing. The central government enforces fiscal regulations on spending and borrowing, citing fiscal discipline and sustainability factors.

The rule on expenditures aims to reduce the share of municipalities' personnel expenditures in the budget. Within the scope of this rule, it has been determined that the total amount of personnel expenditures will not exceed thirty per cent of the amount to be obtained as a result of multiplying the budget revenues of the last year with the revaluation coefficient, and forty per cent of the municipalities whose population is below 10,000 (Law No. 5393 Article. 49). This rule is essential for providing budget flexibility. Besides, it has implemented rules on the internal and external debt stock of the municipalities. Based on this, it has been determined that the debt stock of the municipalities, affiliates, and corporations where the municipality owns more than fifty per cent of their capital cannot exceed the last amount of budget revenues multiplied by the revaluation rate, and the same limit is also multiplied by 1.5 for the metropolitan municipalities. Thus, the total debt stock has been associated with revenues for fiscal discipline (Yıldırım, 2010: 104; Bali, 2006: 165). However, borrowing for infrastructure investments approved by the Republic of Turkey's Presidency and requiring substantial technological resources has been excluded. Furthermore, the domestic borrowing that does not exceed ten per cent of the calculated amount approves by the municipal council while exceeding ten per cent approves by both the municipal council majority and the Ministry of Environment and Urbanization (Law No. 5393 Article. 68). On the other hand, municipalities can borrow externally only to finance investment projects. Lastly, it has been decided that the Treasury cannot provide any guarantees for public or private sector domestic borrowing. Municipalities are also included in the provision mentioned above (Law No. 4749 Article. 8; Demirbaş, 2015: 23-24).

In Turkey, domestic borrowing is possible from commercial banks, Iller Bankası A.Ş. (ILBANK), and bonds for municipalities. The borrowing from commercial banks should be conducted based on the fiscal rule outlined in Article 68 of Municipal Law No. 5393. Municipalities must offer their payment plan to ILBANK to borrow. If this plan is accepted, they can borrow investment loans or cash loans. Borrowing by issuing bonds is also required in investment project financing, and it should be approved by the Ministry of Treasury and Finance (MTF). The municipalities can also borrow from international organizations or banks (Çetinkaya, 2020: 194-195). The debts from bank loans are a significant part of total borrowing. In addition to bank loans, internal financing occurs when municipalities fail to fulfil their obligations to creditor public institutions and organizations, which is considered borrowing (Kurtuluş, 2006: 9). Financial liabilities to public administrations, operating debts, tax and social security debts are considered internal financing resources. Details of these borrowing are available in the balance sheets published by the MTF and the Local Governments General Activity Reports (LGGAR) (Serbes and Çetinkaya, 2019: 761).

3. DETERMINANTS OF MUNICIPAL BORROWING

The variables affecting municipal borrowing are classified as fiscal (financial), socioeconomic, and political factors in the literature. These variables were analyzed under three categories by Cropf and Wendel (1998), Benito and Bastida (2004) and Balaguer-Coll et al. (2016), and under four categories by Bellot et al. (2017). On the other hand, Ehalaiye et al. (2017) analyzed with only financial variables.

Cropf and Wendel (1998) analyzed the correlation between municipal debt policy and political, socioeconomic, and fiscal attributes. In this context, debt limits, functional responsibility, referenda on general obligations bond issues, reformism, and tax and expenditure limits were used as political attributes. Socioeconomic and fiscal attributes included pre-1939 housing stock, population density, federal grants, sunbelt, and tax reform act. Benito and Bastida (2004) analyzed the impact of financial, socioeconomic, and political variables on municipal borrowing policies. Capital expenditures, capital revenues, independence ratio, and non-financial surplus or deficit were employed as financial variables. Socioeconomic and political variables included coastal or non-coastal municipality, economic level, and population. The political ideology variable was also included among socioeconomic factors. Balaguer-Coll et al. (2016) investigated the correlation between local government debt and financial (fiscal), socioeconomic, and political variables. Capital expenditures, net savings, the ratio of non-financial deficit to non-financial surplus, own fiscal capacity, and expenditure commitment were determined as fiscal variables. The level of tourism, level of economic activity, and population density were determined as

socioeconomic variables. Political variables included the color of the municipality government party, foral regions, and decentralization.

Bellot et al. (2017) investigated the variables explaining local government borrowing in six European nations. These variables were analyzed in four groups: political, demographic and size, budgetary, and economical. On the other hand, tax rules and structural change indicators were also included as dummy variables. The employed political variables included majority in parliament, political affiliation, election year, and regional parties supporting the central government. Demographic and size variables were determined by the annual population growth rate, population density ratio of 64 to the total population, population density, the ratio of regional population to the total population, and city-states. Budgetary variables included the percentage of tax revenue over operative revenue, the ratio of the sum of staff expenditures and purchases to total expenditures, the ratio relating operative expenditures to total expenditures, the ratio relating primary operating balance to operative revenue, capital expenditures, the golden rule, operative revenue in constant Euros per capita, total regional financing, and the real per capita financing to the average of the regions. Lastly, the economic variables included the annual GDP growth rate, GDP per capita of each region in PPP, and the ratio for regional GDP per capita to the national GDP.

Ehalaiye et al. (2017) analyzed financial (fiscal) determinants of local government debt. Capital expenditures and investment in infrastructural assets, rates revenues, net surplus, other assets apart from infrastructural assets, and other income generated apart from rates revenues were employed as fiscal variables. Also, the type of council and global financial crisis is defined as the control variable and dummy variable, respectively.

Brusca and Labrador (1998), Brusca and Condor (2001), and Balaguer (2001) also investigated the variables affecting municipal borrowing. In these studies, variables such as the number of inhabitants, the annual revenues per inhabitant, the annual expenditures per inhabitant, the net operating balance, the gross operating balance, budgetary surplus per inhabitant, and capital expenditures were employed (as cited in Benito and Bastida 2004: 500).

The studies mentioned above demonstrate different perspectives on the analysis of the variables affecting municipal debt. In the study, only fiscal and population variables were included in the analysis due to inadequate data and lack of standard data for all municipalities. Based on the variables employed in the literature, budget expenditure per capita, expenditure commitment rate, non-interest fiscal capacity rate, per capita tax revenues, and per capita capital expenditures were accepted as fiscal variables. At the same time, the population was determined as the demographic variable.

4. ESTIMATION METHODS

The quantile regression method was employed to estimate the models in the study. This method was chosen because it is thought to provide a different perspective on determining explanatory variables affecting the borrowing of municipalities with different debt levels. Classical regression OLS estimates were also reported to compare the findings. Quantile regression analysis was developed by Koenker and Bassett (1978). The quantile regression method is used to predict conditional quantile functions. It allows the investigation of the effects of the estimates produced for each quantile. OLS method employed in classical regression investigates the mean conditional distribution. In contrast, quantile regression allows the investigation of all conditional distributions for different quantiles. Since different quantiles are examined, it allows a more holistic analysis of the distribution. The estimated regression coefficients in a quantile can be compared to the regression coefficients in another quantile, allowing the determination of similarities and differences (Koenker and Hallock, 2001: 143).

The quantile regression models provide more detailed information than the classical regression models. In quantile regression analysis, unlike OLS, there is no assumption about the homogeneity of error variance and the distribution of errors, and it appears to be a more flexible approach than the linear regression model (Topaloğlu and Ege, 2021: 415).

In the quantile regression analysis, the Q demonstrates the quantile regression function. When x is known, the function of the conditional distribution of y in p. quantile can be expressed with Equation 1.

$$Q^{(p)}(y_i|x_i) = \beta_0^{(p)} + \beta_1^{(p)}x_i$$

The quantile regression analysis has been developed to estimate functional correlations between any quantile and independent variables in the distribution of the dependent variable. Also, the quantile regression

Table 1: Population Sizes (PS) and Debt Stocks of Municipalities

Population Sizes	Number of municipalities	Total Population	%	Debt (TL)	%
5.000-10.000	1	6.048	0.006	23.998.951	0.03
10.001-20.000	2	27.156	0.028	46.280.572	0.06
20.001-50.000	8	307.744	0.321	353.160.596	0.47
50.001-100.000	18	1.412.025	1.473	1.125.905.263	1.49
100.001-500.000	71	18.869.798	19.690	8.191.333.790	10.82
500.001-1.000.000	27	19.169.531	20.003	8.198.279.031	10.83
1.000.001-5.000.000	20	35.568.224	37.114	32.800.120.227	43.32
PS > 5.000.001	2	20.474.257	21.364	24.981.875.558	32.99
Total	**149**	**95.834.783**	**100**	**75.720.953.988**	**100**

functions allow the prediction of the marginal effects of the distribution of the dependent variable in different quantiles (Koenker and Hallock, 2001: 143; Tan and Wang, 2017: 312; Kılıç and Dilber, 2017: 335).

The 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} quantiles have been used to investigate the study's per capita municipal debt variable. The study aims to determine the points where the borrowing level is very low, low, medium, high, and very high; in other words, all distribution regions have five quantiles.

5. DATASET AND DEFINITIONS OF THE VARIABLES

5.1 Assignment of the Sample

The study's sample includes metropolitan, provincial, and district municipalities, for which data are available in the Public Administrations Reports published by the Turkish Court of Accounts (TCA). The data used in the analysis are cross-sectional data for 2017. This sample involves N=149 municipalities. The population of the municipalities included in the sample is 5000 or above. Population sizes and debts of the 149 municipalities included in the analysis are given in the Table 1.

When Table 1 is examined, the first column shows the population sizes, the second column shows how many municipalities with this population size, the total population of these municipalities shows in the third column, the ratio in the whole population shows in the fourth column, and the total debt of the municipalities with that population size shows in the fifth column and the last column shows the ratio of this debt to all municipal debts.

The municipalities with the largest population are in the 1-5 million population range. The total debt of 20 municipalities in this range constitutes 43.32% of all municipalities' debts. The total debt of two municipalities with populations of more than 5 million (Istanbul and Ankara) constitutes 32.99% of the total debt of all municipalities.

When the amount of debt per capita, calculated by dividing the total debts of municipalities by their population, is examined for 149 municipalities, it is calculated that the minimum debt per capita is 29.14 TL, and the maximum debt per person is 3968.08 TL. The average calculated for the debt per person was found to be 644.51 TL (±635.92). Since the Skewness (2.51) and Kurtosis (8.80) values were also examined, it was determined that the debt per capita variable was not normally distributed.

5.2 Definitions of the Variables

Per capita budget expenditure is the first variable to explain municipal debt stock. The total budget expenditure of each municipality is divided by the population to calculate this variable. The increase in the expenditures of the municipalities have been associated with the expansion of their duties and responsibilities (Kurtuluş, 2006: 4-8), the decision of the executives regarding investments or other areas by considering their political concerns (Çetinkaya and Demirbaş, 2004: 19-20), the failure to pay the goods and services purchased from the market on time (Serbes and Çetinkaya, 2019: 793-794). In addition, it has been determined that the current revenue structures of the municipalities are triggering an increase in expenditures. It has been determined that as the grants of the municipalities from the general budget increase, their expenditures increase at a greater rate (Sağbaş and Saruç, 2004: 79; Acar, 2019: 66). This increase disrupted the fiscal structure of municipalities and raised their need for borrowing. Previous studies reported a correlation between municipal borrowing and budget

expenditures. Brusca and Labrador (1998) employed this variable and suggested that the increase in annual budget expenditures per capita expanded municipal borrowing (as cited in Benito and Bastida, 2004: 500). A positive correlation is expected between per capita municipal debt and per capita budget expenditures within this study's scope.

Per capita capital expenditure calculated by dividing the population's municipal capital (investment) expenditures is the second variable to explain municipal debt stock. Investment expenditures, which are one of the two essential components of the budget expenditures of municipalities in Turkey, have increased due to the investment need created by the rapid population growth, especially in metropolitan municipalities (Güler, 1997: 43-44; Şengül, 2009: 201). This need has been widely financed by bank loans from the 1980s (Eroğlu and Tunç, 2018: 43). Thus, it can be argued that there is a correlation between municipal borrowing and capital expenditures in Turkey. Cropf and Wendel (1998), Benito and Bastida (2004), Balaguer-Coll et al. (2016), Ehalaiye et al. (2017) and Bellot et al. (2017) analyzed the correlation between capital spending and municipal debt. In each study, it was assumed that the increase in capital spending increased municipal debt. Accordingly, a positive correlation is expected between municipal debt and capital expenditures.

Expenditure commitment rate calculated with the ratio of total rigid expenditures to budget expenditures is the third variable explaining municipal debt stock. It is stated that expenditures that are obligatory to be paid because they are based on institutional or legal regulations and that are not preferred to be reduced due to political reasons are of a rigid attribute (IFS, 2017: 1; Munoz and Olaberria, 2019: 3). Personnel expenditures, transfers to social security institutions, expenditures for health goods and services, fiscal transfers to local governments, assistance to public economic enterprises, or interest expenditures are considered rigid expenditures (IMF 2014: 11; IMF 2013: 24). Personnel expenditures, state premium expenditures for social security institutions and interest expenditures are among the rigid expenditures of municipalities. Çebi (2015: 4) emphasized that these rigid expenditures could grow public debt stock and the borrowing costs, increasing the total expenditures permanently. This variable was employed by Balaguer-Coll et al. (2016). Similarly, Bellot et al. (2017) used the ratio of staff expenditures and purchases to the total expenditures variable. A positive correlation was estimated between the variable used in both studies and municipal debts.

The non-interest fiscal capacity rate calculated with the ratio of budget expenditures to non-interest budget revenues is the fourth variable affecting municipal debt stock. This variable represents the primary budget balance given by each municipality in a fiscal year. Pınar (2015: 126) and Tokatlıoğlu and Selen (2017: 164) described the primary budget balance as an indicator that reflects whether budget revenues could finance non-interest public spending. Based on this definition, it is known that municipalities will reduce their debt stock by running a budget surplus. However, despite the increase in their expenditures to compensate for the decrease in the liveability of the cities and the welfare of the citizens due to the rapid and unplanned increasing population (Falay, 1995: 13-24; Gül, 2009: 97-98), the budget deficits of the municipalities have gained continuity because of the insufficient tax revenues and the inability to collect all the accrued taxes (Arıkboğa, 2016: 292-293; Yılmaz and Bağlı, 2011; Ökmen and Koç, 2015: 562). Benito and Bastida (2004) and Balaguer-Coll et al. (2016) used this variable in their studies. They concluded that the higher the ratio, the higher the borrowing. Thus, we estimated that municipal borrowing would increase as the rate increases.

Per capita tax revenue calculated by dividing the municipal tax revenues by the population is the fifth variable explaining municipal stock. It has been stated that, especially in countries with high dependence on fiscal transfers, the efforts of the administrators to collect taxes will decrease, and moral hazard will arise (Letelier, 2011: 396; De Mello, 2000: 375). Thus, the high dependency of municipalities on fiscal transfers has revealed that they increase their expenditures more than their revenues (Yaş and Akduğan, 2015: 64). This result can also be associated with the common pool problem (De Mello, 2000: 375). Also, the high fiscal dependency and the lack of taxation powers have led to a low ratio of tax revenues to budget revenues (Ulusoy and Akdemir, 2009: 281-282; Eroğlu and Serbes, 2018: 96-97). Benito and Bastida (2004) and Balaguer-Coll et al. (2016) employed the rate of tax revenues to total revenues. Benito and Bastida (2004) predicted that municipal debt would decrease as tax revenues increase. However, Balaguer-Coll et al. (2016) assumed that the direction of the correlation could be both positive and negative. The municipal debt could decrease as tax revenues increase, while the increase in municipal revenues could reduce the fiscal risk and facilitate access to loans. In the study, it is assumed that municipal borrowing will decrease as the tax revenues increase.

Table 2: Definition of Variables

Variable	Definition	Transform	Expected Sign
Dependent Variable			
Per capita municipal debt stock	Municipal debt stock/ Population	Logarithmic	
Independent Variables			
Per capita budget expenditure	Budget expenditures/ Population	Logarithmic	+
Per capita capital expenditure	Capital expenditures/ Population	Logarithmic	+
Expenditure commitment rate	Rigid expenditures/ Budget expenditures	Rate	+
Non-interest fiscal capacity rate	Non-interest budget expenditure/Non-interest budget revenues	Rate	+
Per capita tax revenue	Tax revenues/ Population	Logarithmic	-
Population	Population living within the municipal boundaries	Logarithmic	+/-

The last variable employed to explain municipal debt stock is population. This variable has been employed with different forms such as the population density (Cropf and Wendel, 1998; Balaguer-Coll et al., 2016); the population in different groups (Benito and Bastida, 2004); annual population growth rate, population over 64 years, and population density (Bellot et al., 2017). Cropf and Wendel (1998) determined a significant and positive relationship in one of the two models they established between borrowing and the population and that the relationship between these variables was insignificant in the other. Balaguer-Coll et al. (2016) concluded that as the population density increased, municipal debt was expected to decrease (negative correlation). Bellot et al. (2017), the direction of the correlations between these variables and municipal debt varied by country. Based on previous studies, it has been assumed that the correlation between municipal borrowing and population is uncertain in Turkey. An essential part of the overall budget, which has the highest share of municipal resources' revenue share, is distributed according to Turkey's population. Thus, population growth can decrease municipal borrowing requirements by increasing the municipal revenues. Therefore, a negative correlation can arise between municipal debt and the population. However, the increasing urban population, new investments, and extended public services to preserve the quality of life can increase the borrowing requirements by triggering expansion in spending. Thus, a positive correlation can be assumed between municipal borrowing and the population.

The dependent variable of this study is per capita municipal debt stock. The variable was calculated by proportioning the municipalities' total debt to their population and used by taking the logarithm. The definitions of all variables, the conversions, and the direction of the expected correlation between the dependent and independent variables are explained in Table 2.

The correlation coefficient was used to examine the relationships between the variables. The correlation coefficients calculated for the variables used in the study are summarized in Table 3.

When the correlation coefficients between the variables were examined, it was seen that there were no highly correlated variables.

6. FINDINGS AND DISCUSSION

Two methods were employed to estimate the correlations between the dependent variable and independent variables. The first method was the classical regression, and the second was quantile regression. The method compatible with the study's aim is the quantile regression, which investigates the significance of the variables at various municipal debt levels. Therefore, a variable not significant in the classical regression estimate

Table 3: Correlation Coefficients

	1	2	3	4	5	6
1. Per capita municipal debt	-					
2. Per capita budget expenditure	.664**	-				
3. Per capita capital expenditure	.220*	.528**	-			
4. Expenditure commitment rate	.145	-.150	-.641**	-		
5. Non-interest fiscal capacity rate	.313**	.363**	.422**	-.318**	-	
6. Per capita tax revenue	.114	.426**	-.110	.200*	-.024	-
7. Population	-.164*	-.208*	.361*	-.625**	.095	-.535**

*p<.05; ** p<.01

Table 4: OLS Regression Estimates for Municipalities' Debt Stock

	Estimate	Std. Error	t value	p
Intercept	-2.13**	0.57	-3.72	0.000
Per capita budget expenditure	1.69**	0.15	10.81	0.000
Per capita capital expenditure	-0.15	0.08	-1.76	0.080
Expenditure commitment rate	1.29**	0.34	3.73	0.000
Non-interest fiscal capacity rate	0.35*	0.14	2.40	0.017
Per capita tax revenue	-0.22**	0.05	-4.21	0.000
Population	0.015	0.06	0.23	0.811

*p<.05; ** p<.01

can be found significant in the quantile regression model using different quantiles. OLS regression estimates are presented in Table 4 in detail.

In OLS estimates, it was concluded that the *per capita budget expenditure* and *expenditure commitment rate* was statistically significant at 1%. The correlation between these variables and per capita municipal debt stock were positive, consistent with the expectations. The positive correlation reflects that an increase in *per capita budget expenditure* and *expenditure commitment rate* will increase per capita municipal debt. The *non-interest fiscal capacity rate* was statistically significant at the 5% significance. Also, the correlation between the variable and per capita municipal debt stock were positive, consistent with the expectations. The positive correlation reflects that an increase in non-interest fiscal capacity rate will increase per capita municipal debt. *Per capita tax revenue* was also statistically significant at 1%. In contrast, the correlation between per capita tax revenue and per capita municipal debt was negative as expected. Accordingly, it can be stated that per capita municipal debt reduces as per capita tax revenue increases. The *per capita capital expenditure* and *population* variables were not found statistically significant based on OLS estimation findings.

Quantile regression estimates are presented in Table 5 in detail.

In the quantile regression model, it was observed that the *per capita budget expenditure* was significant in all five quantiles and positively correlated with per capita municipal debt. These findings revealed that per capita budget expenditure could be a significant variable to explain municipal borrowing. It could also be enounced that the findings reported by Brusca and Labrador (1998) were confirmed for Turkish municipalities. Two factors can explain the fact that per capita budget expenditure is a determinant variable for all Turkish municipalities with various debt levels. Firstly, it can be stated that the fiscal dependence of all metropolitan, provincial, and district municipalities in Turkey on the central government is effective. The main fiscal indicator reflecting the municipalities' dependence is the ratio of transfers from general budget shares to total

Table 5: Quantile Regression Estimates for Municipalities' Debt Stock

	Quantile regression				
	0.10	0.25	0.50	0.75	0.90
Intercept	-3.12*	-2.17**	-1.71**	-1.46*	-0.45
Per capita budget expenditure	1.65**	1.63**	1.60**	1.62**	1.57**
Per capita capital expenditure	-0.28	-0.19*	-0.10	-0.02	-0.04
Expenditure commitment rate	1.78**	1.31**	1.10**	1.50**	1.15
Non-interest fiscal capacity rate	0.84**	0.64**	0.13	-0.03	-0.36
Per capita tax revenue	-0.26*	-0.23**	-0.17**	-0.21**	-0.24**
Population	0.11	-0.01	0.03	-0.02	-0.05

*p<.05; ** p<.01

budget revenues. This rate was 72.1% in metropolitan municipalities, 54.1% in provincial municipalities, and 40.7% in district municipalities in 2017 (Ministry of Environment and Urbanization, 2019: 120). Thus, it can be stated that dependence on the central government raises municipal spending and thereby increasing the borrowing requirement (Sağbaş and Saruç, 2004: 89; Yaş and Akduğan, 2015: 64-65; Acar, 2019: 67). Due to the high fiscal dependency, it can be interpreted that municipalities consider the liberating role of the central government and postpone reducing their spending and borrowing tendencies by paying less attention to their financial situation (Letelier, 2011: 397). The second factor can be stated that the principle of the economical use of public resources is not yet adequately established in the municipalities. Municipal procurements are considered as one of the concrete examples of the wasteful use of resources. In procurement processes, the relations between the municipalities and their companies have led to controversies. Meşe (2011: 210-211) argued that these companies got most of the procurements, especially for services such as cleaning, parks, road construction, and security. It is considered that the companies receive the procurements organized by the municipalities, and the resources remain in the municipality, leading to prudence. However, İlhan (2013: 19-22) argued that awarding the tenders to companies would not be adequate to determine prudence. He employed two instruments indicating whether the costs changed when a service was awarded to a municipal company or a private company. These instruments were the price advantage rate and the fiscal year profit or loss of the companies. The price advantage ratio reflects how much the contract price held is below the cost estimating calculated by the administration. With the calculation made for 2008 and 2009, it was concluded that private companies performed the services at a lower cost than municipal ones. Furthermore, it was reported that the municipal corporations' total losses were higher than their total profits during the years mentioned above. Thus, it can be enounced that awarding the procurements to the municipal companies does not lead to the economical use of municipal resources. On the other hand, the implementation of the employment policy through companies can increase the waste of public resources. The number of permanent employees in public institutions and organizations has been reduced with the public personnel reform in Turkey. This decline was reflected in the municipalities with the implementation of personnel employment as a provision to the extent required by their responsibilities. Furthermore, a fiscal rule adopted an upper limit for personnel expenditures in the budget have been enforced. However, since the restrictions mentioned above do not apply to municipal companies, municipalities utilize these companies for employment needs. Thus, it was stated that it would be difficult to determine the number and cost of municipal and company personnel. Although the number of permanent personnel decreased after the public personnel reform, it was estimated that the de facto personnel expenditures of the municipalities have increased due to the employment of additional personnel in companies. Thus, it can be stated that the municipal spending principle's prudence was not observed in the utilization of municipal resources (Meşe, 2011: 207-209; Karahanoğulları, 1998: 283-284). Avoidance of the municipalities to pay for the services procured from the private sector due to the lack of resources may also be a detriment to the principle of prudence in resource utilization. Thus, companies can determine the services'

contract price above current market prices since they think they will not receive payments on time. Similarly, the prudence principle is breached due to the allocation of more resources than the budgeted amount for a service. The ratio of the escrow liabilities to the liabilities of local governments in Turkey was realized as 17.2% in 2017 (Ministry of Internal Affairs, 2018: 102). The majority of the amounts were in the municipal escrow account. Thus, it can be stated that municipalities face significant fiscal problems (Eroğlu and Tunç, 2018: 45).

The significant and positive correlation was maintained in four quantiles determined in the quantile regression model for *expenditure commitment rate*. However, this variable was not significant in the group of municipalities with very high borrowing. Thus, the expenditure commitment rate can be considered as one of the three significant variables explaining municipal borrowing. The variable is insignificant in the last group because the municipalities in this group cannot reduce their borrowing even when they reduce personnel, state premiums to social security institutions, or interest expenditures. Therefore, it can be stated that the first two variables will be more effective in reducing the borrowing of municipalities with very high debt. It could be stated that the findings reported with the OLS regression model by Balaguer-Coll et. al. (2016) were confirmed for Turkey. However, the findings obtained with quantile regression analysis were different. They concluded that the effect of the variable increased as the municipal debt expanded. It was determined that the direction of the relationship was negative in municipalities with low and medium debt, and positive in municipalities with high and very high debt. Due to the effectiveness of reducing debt, it is crucial to pay attention to the principle of employment proportional to the responsibilities of the municipalities. This rule will allow the reduction of the budget deficit or borrowing requirement for investments, reducing financing costs, and controlling interest expenditures. Furthermore, the reduction of the share of rigid expenditures in the budget is necessary for decision-making during periods of instability (Çebi, 2015: 4). These expenditures could not be easily reduced since they are binding by rules or contracts, or they might lead to political costs due to citizens' reactions.

It was observed that the significant and positive correlation between the *non-interest fiscal capacity rate* and per capita municipal debt stock in 10th and 25th quantiles. However, this variable was not significant in municipalities with moderate, high, or very high debt. Thus, it can be stated that the findings obtained with the OLS regression model by Balaguer-Coll et. al. (2016) are valid for Turkey. However, it was determined that the direction of the correlation between the variable and municipal borrowing was positive in all the quantiles based on their study. Furthermore, it was concluded that the impact was only significant in high debt municipalities. Thus, it could be stated that previous study findings were different compared to the findings on Turkish municipalities. The analysis revealed that the non-interest fiscal capacity rate was statistically significant for Turkish municipalities with low and very low debt. However, the correlation was insignificant for municipalities with moderate, high, and very high debt, indicating that it was not effective in reducing municipal debt. Thus, it is possible for the municipalities in the first two groups to reduce their borrowing by balancing their budgets. The budget could be balanced by increasing revenues or by reducing spending. There are several methods to increase municipal revenues. One of these methods is to improve fiscal autonomy and increase municipal revenues. However, it is not sufficient to target revenue growth alone. It is also significant that whether municipalities collect their accrued revenues. The amounts of tax collecting are especially important for municipalities' tax revenues. In 2017, the metropolitan municipality with the highest collection received tax revenue of 5.5 times more than the municipality with the lowest collection. This rate occurred about 21 times in provincial municipalities, while 44 times in district municipalities. In addition to the regulations that aim to increase municipal revenues, economical use of municipal resources sparingly can help achieve a balanced budget and decrease borrowing.

The *per capita capital expenditure* variable was found insignificant in every quantile except the low per capita municipal debt level (25th), where the variable was found statistically significant. Furthermore, a negative correlation was determined between the per capita capital expenditure and per capita municipal debt.

7. CONCLUSION

The study aims to determine the variables affecting municipal borrowing in Turkey. Thus, the correlation between per capita municipal borrowing, which was determined as the independent variable, and per capita budget expenditure, per capita capital expenditure, expenditure commitment rate, non-interest fiscal capacity rate, per capita tax revenue and population variables were analysed with OLS regression and quantile regression methods.

In OLS regression analysis, the variable with the highest coefficient in municipal borrowing was determined as per capita budget expenditure in Turkey. Therefore, municipalities can decrease borrowing significantly by reducing their budget expenditure. Furthermore, it was concluded that as the share of rigid expenditures such as personnel, state premiums to social security institutions, and interest expenditures in municipal budget expenditures would decrease, municipal debt would reduce. On the other hand, it was determined that as municipalities' capacity to cover spending with primary budget revenues increases, municipal borrowing would decrease. Thus, the correlations between the first three variables and the municipal borrowing were positive, as expected. On the contrary, the direction of the correlation between municipal tax revenues and municipal borrowing was negative. Thus, it can be stated that municipal borrowing will decrease as tax revenues increase. However, contrary to the first four variables, no significant correlation was determined between per capita municipal debt and per capita capital expenditure and population variables.

In contrast with the OLS regression method, five quantiles (10^{th}, 25^{th}, 50^{th}, 75th, and 90^{th}) were constituted using the quantile regression analysis, which allows the determination of explanatory variables for municipalities with different debt levels. Accordingly, it was determined that per capita budget expenditure was an important variable in explaining municipal borrowing and significant and positive in all quantiles. Furthermore, there was a significant and negative correlation between per capita tax revenue and per capita municipal debt. However, different findings were obtained for the expenditure commitment and non-interest fiscal capacity rates compared to the OLS regression model. This difference was evident in the non-interest fiscal capacity rate variable. While this variable was significant and positive in explaining the debt of municipalities with very low (10th) and low (25th) borrowing, it was not significant for municipalities with moderate (50th), high (75th), and very high (90) debt. On the other hand, the expenditure commitment rate was significant and positive in the first four quantiles; however, it was insignificant in municipalities with very high debt. Conversely, the per capita capital expenditure was significant only in the 25th quantile and was insignificant in the remaining quantiles. The population variable was also insignificant in explaining the per capita municipal debt in all quantiles.

The findings obtained with quantile regression analysis demonstrate that priority measures should be taken concerning expenditure to reduce the debt of municipalities in Turkey. However, it is not essential to designing the content of the measures to reduce the expenditures of the municipalities. The real problem in expenditures is that administrators do not utilise municipal resources economically. It is essential to award procurements to the company offering the best proposal to look out for public interest, based on the principles of competition and transparency. On the other hand, making arrangements for the municipalities to achieve a revenue level proper with their responsibilities, economical use of resources can be provided. As the fiscal dependencies of the municipalities increase, the administrators' tendency to consider the central administration as a liberator balancing the municipal budget in times of crisis may decrease. Thus, the administrators can perform more responsibly and economically in using the revenues they obtain as a result of a particular effort. Furthermore, it was considered that increasing the municipalities' own revenues and income-generating capacities will be beneficial in solving the financing problems. Municipal debt can also be reduced by decreasing the share of rigid expenditures in budget expenditures, especially in municipalities except for the very high debt group.

The regression results, estimated by selecting various quantiles, provided a different perspective for the municipalities with various debt levels to determine the explanatory variables that affect their borrowing and intervene with these explanatory variables when they are required to act strategically about their debt. Considering the ongoing debate about municipal borrowing in Turkey, the findings can assist decision-makers in preparing budgets and strategic plans, utilise resources effectively and economically, and even restructure the relationship between the central and local governments. Thus, the perceptions of investors regarding the financial situation of municipalities may change positively. This change allows municipalities to reduce their borrowing costs. On the other hand, with the efficient use of resources, the fiscal capacity of the municipalities can be strengthened, and citizens can be provided with better quality and low-cost services. In addition, with the improvement of their fiscal position, it becomes easier for municipalities to make timely payments to companies for goods and services purchased from the market instead of allocating them as a budgetary escrow. Thus, trust in municipalities will increase, and companies will also receive their progress payments on time.

The limitations of the study that investigated the explanatory variables of municipal borrowing should also be noted. The first limitation is the small number of municipalities for which data were available. Another limitation of the study is that certain fiscal, socioeconomic, and political variables could not be used due to the unavailability of the data and lack of standard data for all municipalities. The inability to use these variables enables the analysis of the effects of only the determined models' fiscal variables and population variables. In contrast, the scope of the models is limited due to the exclusion of the effects of political and socioeconomic variables from the analysis.

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Evaluation of Efficiency Measurement of Selected Technoparks with Data Envelopment Analysis (DEA)

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ABSTRACT

Technology Development Zones (Technoparks) are units that focuses on working effectively and producing productive works due to their structures. It is known that each technopark differs in terms of its production method and the benefits it provides. This research respond to give information about the general conditions of the Technoparks whose data were shared publicly and they were valuated within the scope of expected and realized benefits. Data Envelopment Analysis (DEA), one of the Multi-Criteria Decision Making (MCDM) Methods is applied in the study. DEA is considered as one of the most frequently preferred analysis methods to measure efficiency, especially in structures with economic decision-making mechanisms. This paper includes 9 Technoparks, which share the data of the determined performance indicators up-to-date, according to the analysis of efficiency measurements performed with 3 inputs and 2 outputs. Collaboration and patent numbers among the variables used in the study are the output variables; infrastructure, offered advantages and proximity to the university refer to the input variables. The efficiency of the technoparks was measured with CCR (Charnes, Cooper and Rhodes) Input and Output Oriented Models, the issues deemed to increase the benefits provided by the technoparks are evaluated, and suggestions are made within the scope of the findings.

Key Words: : Multi-Criteria Decision-Making (MCDM) Methods, Technoparks, Mathematical Models, Efficiency Measurement, Data Envelopment Analysis (DEA).

JEL Classification Codes: C44, C61, M13, O14, O32, Q55

1. INTRODUCTION

Technoparks, which are considered to be an important building block in the commercialization of technological knowledge by turning them into products, also playing a key role in increasing the enterprises with high technology both in terms of quantity and quality, contribute to the country's economy and the development levels of the countries. In the global competitive environment, it has become even more important to carry out all activities effectively in terms of increasing the sustainable competitiveness of institutions and providing competitive advantage. It is necessary to systematically examine all processes and activities carried out in order to achieve the expected benefit from technoparks. In this way, it will be easier to report mature activities within the system and focus on critical activities. With this added value, businesses that provide sustainable competitive advantage will also determine the system they should follow.

It is seen that the competitive environment is getting harder in every sector and concepts such as known information technologies, entrepreneurship and innovation are being redefined. In particular, it is important that their structures and working systems are effective so that technoparks can play an active role in meeting the knowledge and technology with the industry and ensuring the commercialization of ideas. Because of its structure, technoparks are regions where rapid and intense developments are present, at the same time contributing to economic growth and where competition is fierce.

In technoparks where university-industry cooperation is transformed into practice, the main goal is to combine the outputs of the R&D centers with industry and advanced technology. In this way, the production of advanced technology products, determination of market share and sustainable competitive advantage will be provided. For this, it will undoubtedly be possible if the added value provided by technoparks to the market is at a higher level than its competitors, and it is possible to create and implement strategies that cannot be easily imitated.

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The rest of the paper is organized as theoretical background, provision of data and method and finally, some concluding remarks.

2. LITERATURE REVIEW

The success of a technopark is determined by the number of R&D projects produced, the number of patents, the personnel, and the economic contributions to the region and the country. It creates the technological infrastructure that enables the employment of qualified labor force and the regions to become attractive for foreign investors who want to make technology-based investments (Kubas and Ozmen, 2020: 105). Technoparks, which contain technological innovation-oriented studies in their ecosystem, include the R&D outputs commercialized by academicians who produce information in the university, and thus contribute to the establishment of university-industry collaboration (Ozdemir, 2020: 75).

Technoparks application areas from research variable to business development variable, they are listed as science park, technology park, technology development center, business incubator. At this point, the basic principle is to prepare a ground that can give weight to industrial cooperation in order to accelerate technology transfer in the light of new inventions and new products at every step and to increase the level of economic prosperity and employment (Guler and Kirbaslar, 2020: 25).

In technoparks that constitute the infrastructure of the knowledge economy in the global arena, productive studies based on a systematic basis are included in order to increase the knowledge of individuals and society, to design the processual systems and applications of this knowledge (Akbulut, 2020: 256).

The main target in establishing technoparks is to increase the development levels of countries, to prevent brain drain, and to rapidly support technological developments in order to ensure economic development (Bayzin and Sengur, 2019: 300). Although the purpose of establishment varies according to countries, the main factors can be listed as competition with the increase of global trade, decrease in employment in traditional manufacturing industry, acceleration of technological developments and technology production (Alkibay et al., 2012: 67). There are a number of objectives that technoparks are expected to contribute to; Attracting new entrepreneurs to the regions, increasing the R&D and innovation capacities of companies, expanding cooperation, providing infrastructure opportunities, etc. (Cansiz, 2017: 155-167; Ozdemir, 2020: 75).

Technology parks undertake a coordination role between various actors in order to cooperate and interact with each other, thanks to the triple spiral model (regional development, contribution to innovation and industry), especially considering the geographical proximity to universities in order to facilitate this process (Baycan and Olcay, 2021: 1).

According to Haliloglu's (2021) study of efficiency evaluation of university-industry cooperation, mutual gains of university-industry cooperation are considered important by both institutions and universities. Therefore, significant efforts are made to achieve successful university-industry collaborations. There are many studies that analyze the cognitive effects of university/industry connections through the way entrepreneurs interact with universities, and this research topic is given great importance (Etzkowitz, 1998: 824).

Research universities are leading these collaborations around the world. For example, in Turkey, Middle East Technical University (METU Technopark) and Istanbul Technical University (ITUNOVA Technology Transfer Office) are two of the organizations that aim to produce, commercialize and disseminate the outputs of science and technology projects. It directs academic research and development projects to the industry effectively and on time, and forms an important interface between academics and industry experts to support projects carried out through university-industry collaborations.

The role and activities of the technopark management are found useful by the cooperated institutions to establish a bond with other companies, and their role in increasing innovation is important. With the judgment of science park firms, academics, practitioners and policy makers are provided with valuable information on what benefits firms can seek and what qualifications are required to achieve these perceived benefits. W. K. B. Ng et al. (2021) shows that with the analysis of the data collected from 51 companies in the science parks of the Netherlands, there are economic, innovation and networking benefits of technoparks. In addition, local governments in Sweden support various economies that they expect to contribute to the economy by creating employment through technoparks (Lindelof and Lofsten, 2003: 245).

Collaboration activities in technoparks are of great importance since technoparks are the institution that enables innovation and R&D activities to be delivered to potential customers by proving the product-market compatibility thanks to the cooperation of the public,

industry and universities (Etzkowitz et al., 2000: 315). Connection and interaction can be increased through collaboration activities. Also, the aim of increasing the effectiveness of collaboration with local governments in the entrepreneurship ecosystem is considered among the Public Policies and Practices (Cansiz, 2017: 207). In addition, collaborations have been included in this study due to the necessity of supporting the commercialization of information.

The literature on the performance of technoparks gives conflicting results. Some studies can see that technoparks provide positive results for companies and society in terms of the advantages offered. Firms must follow the correct path in management decisions in order to benefit from the advantages offered by technoparks. Therefore, a strategic management system should be established to help technoparks improve their efficiency performance (Ribeiro et al., 2021: 2).

In the studies conducted by Yang and Lee (2021) in China, it was emphasized that the wrong allocation of technoparks in R&D affects the determinants in the selection of the place of establishment, and that the important variables for the establishment of new technoparks are technoparks that are close to universities and have R&D cooperation.

In the light of the literature reviewed, no study has been found in which the input and output factors of this study are handled together and the performance of technoparks is measured at the level of efficiency. In this study, in order to eliminate this deficiency in the literature, some technoparks were analyzed and evaluated based on the results obtained.

Since businesses have limited resources, they should quickly end their decision-making processes regarding their activities or strategic issues; this situation is not only defined as a rapid decision-making process, but also requires intense struggle in the competitive business environment (Uludag and Dogan, 2021: 3).

When there are interrelated but contradictory goals or options, evaluations made using multiple criteria are called Multi Criteria Decision Making (MCDM) methods (Uludag and Dogan, 2021: 3). Data Envelopment Analysis, which is included in the MCDM approach, enables the determination of effective and inactive decision units by using a large number of inputs and outputs (Cooper et al., 2011: 1).

It has been observed that the studies within the scope of the subject were carried out in line with the opinion of the manager and the expert with the reviewed literature and the information in Table 1. It is aimed to fill the gap in the studies on efficiency measurement of technoparks.

3. METHOD AND DATA

Charnes, Cooper, Rhodes (1978) who first used the concept of Data Envelopment Analysis in the literature (Coelli et al., 2005:162). DEA adopts an input-oriented approach (keeping outputs constant and minimizing input amount) or output-oriented approach (keeping inputs constant and maximizing output) in order to obtain an efficient solution (Sozen et al., 2015: 180). Data Envelopment Analysis (DEA) has a methodology that essentially removes the assumptions and limitations of classical efficiency measurement approaches (Bowlin, 1998).

The basic idea of DEA is to determine the decision-making units with the best function among the comparable decision-making units and to develop the methodology that establishes the efficiency limit (Cook and Seiford, 2009: 11-13). DEA is concerned with the system's overall efficiency.

The efficiency of the system is measured by the presence of inputs and outputs that are proven to affect the performance of the systems (Foroutan and Bamdad, 2021: 14). DEA produces a relative measure and uses input and output variables for this (Sirma, 2008: 20).

Data Envelopment Analysis processes are considered under summary stages (Uludag and Dogan, 2021: 431):

1. Selection of decision-making units:

Many studies have explanations about the number of decision units, input and output variables. For example; In Data Envelopment Analysis the number of decision units should be greater than 3 times the number of criteria (Popovic et al., 2020: 6). However Cook et al. (2014) emphasizes that DEA is an individual performance measurement tool and that specifying the sample size is meaningless. The framework of DEA methodology is divided into stages under the titles of objective and subjective efficiency evaluation; Studies that started with the selection of criteria in objective efficiency evaluations also include the process of reducing the number of criteria (Popovic et al., 2020: 6).

Table 1: Studies Using Data Envelopment Analysis

Application areas	Author name and year	Input variables	Output variables
OECD Countries Environment Performance	Ozkan Aksu and Temel Genger, 2018	Virtually Generated Input	Health Impact, Air Quality, Water Resources, Agriculture, Biodiversity, Habitat, Climate, Energy
Health Efficiency Measurement of OECD Countries	Degirmenci, 2021	Number of doctors, number of hospital beds, health expenditure	Lifetime, surviving infant ratio
Technology Development Zone Executive Firms Management Efficiency Measurement	Baykul, Sungur and Dulupcu, 2016	Number of capacity building activities, total cooperation, key personnel	(Academic) number of spin-offs, domestic-foreign firms, employment
Financial Performance Measurement of Airport Group Companies in Europe	Battal, 2020	Current ratio and financial leverage ratio	Asset Profitability Ratio: Net Profit/ Total Asset
Efficiency Measurement in Borsa Istanbul IT Sector	Ozkan, 2021	Current ratio, cash ratio, receivable turnover, cost of sales growth rate	Market value, asset profitability, equity profitability, net sales growth rate
Performance Measurement of Consumer Arbitration Committees of Provincial Directorates of Commerce	Guner Ertemoglu, Ertemoglu and Peker, 2021	Number of consumer complaint applications, number of expert assignments, number of meetings, number of members, number of reporters	Total number of decisions, number of decisions made in favor, number of decisions taken against, number of decisions taken with lack of duty
Efficiency Measurement in Facilities Providing Oral and Dental Health Services	Esenlik Telatar and Sari, 2020	Dentist, dental unit	Tooth Extraction, root canal treatment, filling treatment, surgical intervention, fixed prosthetic member, removable prosthetic part
Supplier Selection of a Company in On Vehicle Equipment Manufacturing Sector DEA and Global Criteria Method	Umarusman, 2019	Number of personnel, shipping fee, product unit price, lead time	Annual production quantity
Efficiency Measurement of Electricity Distribution Companies	Kara and Uslu, 2020	Line, transformer, subscriber, personnel	Electricity consumption, downtime
Supplier Selection in Plastics Company in Iran	Ozsoy, Orkcu and Orkcu, 2020	Eco design cost, logistics cost, number of raw materials, reliability cost	Hazardous materials, number of sustainable products, fuel cost, occupational health cost
Efficiency Measurement of Social Security Expenditures of OECD Countries	Teles, Konca and Cakmak, 2021	Unemployment payments, retirement expenditures, cash social assistance, disability or occupational injury expenditures, health expenditures	Lifetime, unemployment rate
Efficiency Measurement of Foundation University in Turkey	Ozden, 2008	Total expense, number of faculty members, other academic staff	Undergraduate/postgraduate students, publication
Efficiency Measurement of Health Insurance Companies in Turkey	Naldoken and Kaya, 2020	Operating expenses, number of employees, number of agencies, own resources	Technical revenues, total premium generation, technical profit/loss, investment income
Efficiency Measurement of the Socio-Economic Indicators of Provinces in Turkey	Çakmak and Orkcu, 2016	Number of hospital, bed, intensive care bed, family practice, ambulance, physicians	Inpatient, number of operations, satisfaction in health services
GDP Contribution Analysis for Level2 Regions	Aktas and Kabak, 2020	Employment rate in agriculture, employment rate in industry sector, employment rate in services sector	GDP contribution (%)
Efficiency Measurement of Commercial Banks in Turkey	Demirel and Hazar, 2020	Number of personnel per branch, non-interest income/expense, credit obtained/ total liabilities	Total loans/total assets, net profit/ equity and securities/total assets
Efficiency Measurement of the Turkish Banking Sector	Carikci and Akbulut, 2020	Assets, interest expense, deposits, number of branches	Interest income, term-end profit, loans
Determining the Efficiency Scores of EUROCONTROL Member European Air Navigation Service Provider Organizations	Tasdemir and Aydın, 2020	Institution expenses, number of operational staff, number of support staff	Integrated flight hours, delay values

2. Selecting the inputs and outputs to be used in the model:

In many studies in the literature, it is emphasized that the criteria for input and output variables are obtained as a result of interviews with experts. There are also studies that proceed by comparing the experimental results with the opinions of the experts (Rikalovic et al., 2015: 1). Examples of these studies are Ustundag and Kilinc (2012), who work on Technopark selection for start-up companies, and Chen and Huang (2004), who work on evaluating the criteria for high technology companies to be in technology-based industrial zones.

3. Determination of DEA model and efficiency measurement:

In order to show that a proportional change in input factors causes a change in output factors in the same proportion, a fixed return model should be chosen according to the CCR return-to-scale. Whether a model is input or output oriented is at the initiative of the decision maker, it will be able to make this choice according to the availability of the data or the purpose it wants to achieve (Sozen et al., 2015: 182). In our study, Technoparks that can get output-oriented results and have maximum output by minimizing inputs have been determined.

4. Interpretation of the results:

The Ministry of Industry and Technology does not share the data obtained from the entrepreneurship ecosystem with the relevant actors; since these data are not accessible to the public, the contributions of the funds provided by the state and the ministry to entrepreneurs and the ecosystem are evaluated through Impact Analysis studies (Cansiz, 2017: 16). Studies in this field are blended with data collected from entrepreneurs and/or interviews with experts.

Charnes, Cooper, Rhodes (1978) model is explained below. Decision data of interest are indicated with the index "0".

Notations and Decision Variables;

"S" is the set of weight values of the outputs (s=1, 2,..,s)

"M" is the set of weight values of the inputs (m=1, 2,..,m)

$$u_s = weight\ of\ output\ s$$

$$v_m = weight\ of\ input\ m$$

$$y_{sj} = amount\ of\ unit\ j\ of\ output\ s\ \ (j=1, 2, \ldots\ldots..,n)$$

$$\max z = u_1 * y_{10} + u_2 * y_{20} + \cdots \ldots \ldots \ldots \ldots + \ u_s * y_{s0}$$

Subject to

$$v_1 * x_{10} + v_2 * x_{20} + v_m * \ x_{m0} = 1$$

$$u_1 * y_{1j} + u_2 * y_{2j} + \cdots \ldots \ldots . . + u_s * y_{sj}$$

$$-(v_1 * x_{1j} + v_2 * x_{2j} + \cdots \ldots \ldots . . + v_m * x_{mj}) \leq 0$$

$$v_1, v_2, \ldots \ldots, v_m \geq 0$$

$$u_1, u_2, \ldots \ldots, u_s \geq 0$$

The objective function equation in (1) aims to find the u and v values that will maximize the decision unit. The constraint number (2) is that the sum of the entries is equal to 1. The constraint equation numbered (3) ensures that the weighted output/input ratio does not exceed 1 for each decision unit. With the equation number (4), it is ensured that decision variables are positive.

In order to measure the efficiency of technoparks the information that can be accessed by compiling from both Cansız (2007) and Ozdemir (2020) studies were included in the study. The most important point in the inputs and outputs considered within the scope of the study was the accessibility and reliability of the data.

Dalmarco et al. (2018), it is stated in their studies that universities with Science and Technology Parks are evaluated according to the five performance metrics; Having an entrepreneurial perspective, Development of external links, Providing access to the infrastructures/resources of the university, Providing innovation infrastructures to support entrepreneurship and Application of scientific research. Performance metrics of Science and Technology Parks were prepared within the scope of the study carried out by El Ghazala Technopark serving in Tunisia and supported by the European Investment Bank in 2015.

The similar performance metrics are taken as a basis in the Technology Development Zones Performance Index results by the T.R. Ministry of Industry and Technology. The results of the Technology Development Zones Performance Index for 2020, shared with the public by the Ministry, show only the rankings; however, in the Index results published in 2012, the performance indicators are also expressed. Those indicators are as follows; State Aids and Executive Company Expenditures, R&D Competence, Export and Company Composition, Intellectual Property Rights and Incubation and services.

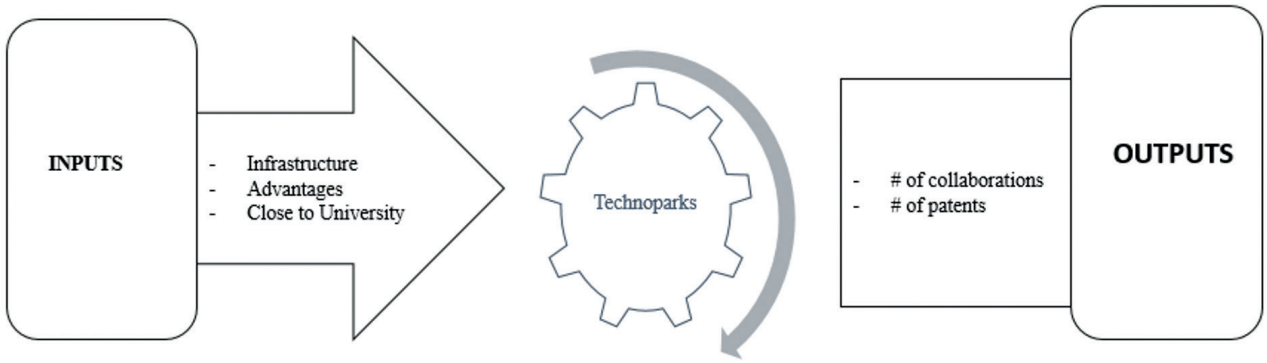

Figure 1: 9 Technopark's Activity Model for DEA

Unlike the documents taken as reference above, the metric "Government Support and Executive Company Expenditures" is not included in our study. Because the same/similar government supports are provided to every entrepreneur/company, submits a project and whose project is approved in order to be included in the Technology Development Zone, so this metric does not differentiate the TDZ Manager Company from each other.

The average distance (km) between the technopark and the university is taken as a basis for access to the resources/infrastructures of the university. If the Technopark or the University is located in more than one campus, the distance between the Rectorate building and the Technopark Executive Building is given, as in Dokuz Eylul University. However, the desired situation here is that two institutions are close to each other. For this reason, distance (km) data cannot be directly included in the analysis. As in Ant Colony Optimization, which is one of the meta-heuristic methods, the inverse of the distance (by measuring 1/Distance) was determined to be close (Dag, 2012: 92).

Under the headings of "Our Policies" on the web pages of TDZ Manager Company (Technology Development Zone Manager companies), they state that "we undertake to create appropriate physical and electronic environments for the security of information assets, to ensure the confidentiality, integrity and accessibility, continuity and control of information assets…". Because, according to the Technology Development Zones Implementation Regulation, was published by the Ministry of Industry and Technology of the Republic of Turkey, they are obliged to keep up-to-date information about some important information for example, the number of personnel, R&D collaborations, industrial property rights, geographical location with institutional/ cooperatives etc. which are mentioned in the Technology Development Zone Feasibility Report Preparation Principles. The data verified by these firms and shared with the public on their websites were compiled. Input and output factors are included in the scope of the study with the values stated below.

1. Number of Patents: The greatest power supporting economic growth is technology, so indicators such as high technology exports and patents are known as factors that show and support the progress of technological developments in the economy (Dereli, 2019: 173). Technology management has a close effect on companies' strategies and competitive success (Lindelof ve Lofsten, 2003; 247). Therefore, a conceptual framework has been developed that demonstrates the use of patent data in key areas of technology management (Ernst, 2003: 233).

2. Collaboration: Economic development strategies require a strong university-industry-government cooperation and partnership (Moeliodihardjo, 2012: 308). Nieto et al. (2021) emphasize the importance of university-industry-government cooperation in the entrepreneurship ecosystem, which they define as the Triple Helix. Academicians can serve as consultants, entrepreneurs or R&D personnel with the university-industry cooperation, in this way it actively contributes to the production and dissemination of information and the commercialization of information, and also the infrastructure of the laboratories and R&D Centers used for information generation are enabled to be more active (Keles and Tunca, 2009: 315). In this study, the reason why 5 is written in the input title of "collaboration" for Technopark Istanbul; the number of institutions that Technopark Istanbul cooperates with is 5. These institutions are the Presidency of the Republic of Turkey, Presidency of Defense Industries, Istanbul Chamber of Commerce, Istanbul Airport Operation and Aerospace Industries Inc., Defense Technologies Engineering and Trade Inc. and Istanbul Ticaret University. It is stated that the

number of institutions that Yıldız Technopark cooperates with is 2; Yıldız Technical University and EBN Innovation Network. It is stated that the number of institutions that ADU Technopark cooperates with is 5; Aydın Chamber of Commerce, South Aegean Development Agency, Small and Medium Enterprises Development Organization of Turkey, Aydın Adnan Menderes University. It is stated that the number of institutions that ITU Ari Technopark cooperates with is 45; Elginkan Foundation, Istanbul Chamber of Commerce, EnerjiSA, ING Bank, Microsoft etc. It is stated that the number of institutions that Kocaeli University Technopark cooperates with is 5; Kocaeli University, Kocaeli Chamber of Commerce, Kocaeli Chamber of Industry, Gebze Chamber of Commerce, Gebze Organized Industrial Zone Technopark. It is stated that the number of institutions that METU Technopark cooperates with is 2; ASO Technopark and Middle East Technical University. Depark and Ankara Technopark carry out one cooperation each, this cooperation is between their own universities.

3. Infrastructure: It is known that technoparks can count various topics from affordable and low-cost office areas, energy and transportation facilities to prototyping centers offered to entrepreneurs within the infrastructures of technoparks can be counted. The data taken as infrastructure output in the analysis in this study are explained as follows; Yıldız Technopark uses the infrastructures provided by the Prototyping Center, The numerical value of all the facilities provided by this center is taken as 1, which means 1 infrastructure is provided. Considering the example of Technopark Istanbul, the reason for specifying this number as 4; Biocube Lab, Clean Room, Post Incubation Area, Prototyping Center is owned and made available to entrepreneurs. Considering the example of Ankara Technopark, the reason for specifying this number as 6; owning a Biochemistry Lab, Mechanics Lab, Electronics Lab, Food, Agriculture and Animal Center, Gen Research Center and Ear Nose and Throat Research Center and making them available to entrepreneurs. Considering the example of Kocaeli University Technopark, the reason for specifying this number as 4; Prototype Development and Test Center, Laser App. Res., Advanced Materials and Alternative Fuel Research Center is owned and made available to entrepreneurs. The number of infrastructure and laboratory facilities offered to entrepreneurs by the remaining 6 institutions is presented as one; this institution is the centers owned by Technopark and offered to entrepreneurs free of charge, namely Prototyping Center / Workshop / Production Centers.

4. Advantage Offered: The most important point in monitoring the performance of technoparks is attributed to the development of international and inter-regional relations (Bigliardi et al., 2006: 489). Contribution to technology development in the national/international market, which is advocated as one of the most important functions of technoparks, is also included in the study (Chan et al., 2010: 138). The opportunities offered by technoparks to entrepreneurs, such as free mentoring, memberships in valuable organizations, opening offices in international incubation centers for a certain period of time or for an unlimited period, are emphasized in this title. In this way, entrepreneurs will be able to come together with startups working in the same field as them, receive consultancy services from valuable mentors and have the opportunity to meet investors related to their sectors. Looking at Technopark Istanbul, it is possible to cluster in 4 different areas; SAHA Istanbul (Istanbul Defense, Aviation and Space Cluster Association), ARGEMIP (R&D Centers Communication and Cooperation platform), İSEK (Istanbul Health Industry Cluster) and Turkish Maritime Cluster. Looking at METU Technopark, there are opportunities to participate in international acceleration programs and clustering in 5 different fields; It includes clustering opportunities in some areas; Growth Circuit Program, Defense Industry, Informatics, Advanced Health and EEN Anatolia project. ADU Technopark, YTU Technopark, Gaziantep Technopark and ITU Ari Technopark gather the opportunities they offer under one title; It is known as Tralles Academy membership, Starcamp International Acceleration Program, TIM TEB Venture House and Innogate International Acceleration Program, respectively.

5. Proximity to the university: Technoparks are known to be an important channel for them to easily spread the information formed in universities, considering their geographical proximity to the university (Baycan and Olcay, 2021: 102). What is meant to be explained with this title is the extent to which physical distance is supported to access the Technopark. In terms of accessing the resources/infrastructures of the university (if the Technopark's Administration Building is located in more than one campus, the closest distance from the Rectorate Building within the university is given, as in Dokuz Eylul University) the average distance between the Technopark and the university.

Four models related to Data Envelopment Analysis method were applied and results were obtained; the results of the analysis performed according to CCR input-oriented and CCR output-oriented models are stated. For

Table 2: Variables used in the study and their values

#	Institutions	Collaboration	Number of patents	Infrastructure	Advantage	Proximity to the university
1	Technopark Istanbul	5	228	4	4	0.09
2	ADU Technopark	5	6	1	1	0.50
3	YTU Technopark	2	263	1	1	0.50
4	Depark	1	27	1	0	0.08
5	Gaziantep Technopark	1	10	1	1	1
6	Ankara Technopark	1	200	6	0	0.05
7	ITU Arı Technopark	45	245	1	1	0.50
8	Kocaeli University Technopark	5	37	4	0	0.04
9	METU Technopark	2	200	1	5	0.50

each model, interpretations are made based on input and output weights according to the reference clusters and residual values.

$$\max z = 5*u_1 + 228*u_2$$

Subject to

$$5*u_1 + 228*u_2 - 4*v_1 - 4*v_2 - 0{,}09*v_3 \leq 0$$

$$5*u_1 + 6*u_2 - v_1 - v_2 - 0{,}50*v_3 \leq 0$$

$$2*u_1 + 263*u_2 - v_1 - v_2 - 0{,}50*v_3 \leq 0$$

$$u_1 + 27*u_2 - v_1 - 0{,}08*v_3 \leq 0$$

$$u_1 + 10*u_2 - v_1 - v_2 - v_3 \leq 0$$

$$u_1 + 200*u_2 - 6*v_1 - 0{,}05*v_3 \leq 0$$

$$45*u_1 + 245*u_2 - v_1 - v_2 - 0{,}50*v_3 \leq 0$$

$$5*u_1 + 37*u_2 - 4*v_1 - 0{,}04*v_3 \leq 0$$

$$2*u_1 + 200*u_2 - v_1 - 5*v_2 - 0{,}50*v_3 \leq 0$$

$$4*v_1 + 4*v_2 + 0{,}09*v_3 = 1$$

$$u_1, u_2, v_1, v_2, v_3 \geq 0$$

Data Envelopment Analysis method with the Solver add-on of the Microsoft Excel package program was applied for each institution and efficiency scores were obtained. The findings provided by the analysis for Technopark Istanbul are listed in Table 3.

Table 3 and Table 4 are included in a single page on the Microsoft Excel spreadsheet. Output and input values explained in Table 3 are respectively c1 cooperation, c2 number of patents, g1 infrastructure, g2 offered advantages, g3 proximity to university. Table 3 contains the output maximization results. In order to obtain these results, the institutions were numbered and the input variables belonging to the institutions were processed on the Microsoft Excel spreadsheet. It is obtained by multiplying the input and output variables included in the weighted calculations and the weight coefficients to these variables. Decision variables are named by c1, c2, g1, g2 and g3, the weighting coefficients and efficiency score of these variables are entered in Table 3.

In the Microsoft Excel table, two equations are entered in the Solver add-on as constraints. The model, which has output maximized objective function and two constraint equations, is solved separately for each institution as a simple linear programming model. The value specified in the output row in Table 4 is the efficiency score.

In Table 3, analysis results are given based on CCR input direction model data. As a result of the analysis, efficiency score of technoparks, reference clusters and how often an effective technopark is taken as reference by inactive technoparks can be seen in the table given by the method. Effective decision-making units according to Table 3 are Teknopark Istanbul, Yildiz Technical University (YTU) Technopark, Dokuz Eylul University Technology Development Inc. (Depark), Ankara Technopark, Istanbul Technical University (ITU) Ari Technopark and Kocaeli University Technopark.

As we have obtained with Excel Solver and the results can be obtained with the CCR Input and Output oriented

Table 3: Efficiency Score for METU Technopark with Solver add-on

		Output		Input			Weighted Calculations	
#	**Institutions**	**c1**	**c2**	**g1**	**g2**	**g3**	**Output**	**Input**
1	Technopark İstanbul	5	228	4	4	0.09	0.87	0.87
2	ADU Technopark	5	6	1	1	0.50	0.03	1
3	YTU Technopark	2	263	1	1	0.50	1	1
4	Depark	1	27	1	0	0.08	0.10	0.31
5	Gaziantep Technopark	1	10	1	1	1	0.03	1.81
6	Ankara Technopark	1	200	6	0	0.05	0.75	1.15
7	ITU Arı Technopark	45	245	1	1	0.50	1	1
8	Kocaeli University Technopark	5	37	4	0	0.04	0.14	0.79
9	METU Technopark	2	200	1	5	0.50	0.76	1

Table 4: Technopark weighting coefficients and efficiency score of the variables of METU Technopark

	c1	c2	g1	g2	g3
Weighting coefficient	0,0015	0,0037	0,1808	0	1,6384
Technopark	9				
Output	0,7612				
Input	1				

efficiency score measurement made in the OSDEA GUI package program. The institutions or DMU Names (Decision Making Units) and Peer Group information, these means that shows the technoparks with which they are compared. In Table 5 DMU Names in which their efficiencies are identified as "Yes" are benchmarking with themselves, so their peer groups are themselves.

4. CONCLUSION AND DISCUSSION

Data Envelopment Analysis enables efficiency measurement. This shows why this method is preferred for analyzing and performance measurement of Technology Development Zone operating in Turkey. 9 Technoparks who shared their data with the public were included in the analysis. The main result is to compare the performances of Technoparks according to input and output variables, which Technopark is more effective and which is taken as a reference. CCR Input and Output oriented efficiency score calculations were made in Microsoft Excel package program. The results are similar to works of literature and interpreted as follows;

Technoparks that are ineffective according to the determined variables: Adnan Menderes University) ADU Technopark (0,11), Gaziantep Technopark (0,04). Since METU Technopark has a high efficiency score (0,76), it is not considered in this category.

Technoparks, whose efficiency were measured within the scope of DEA findings, were evaluated in terms of input and output dimensions. The results of the study

Table 5: CCR Input Oriented Activity Score

#	DMU Names	Objective Value	Efficient
1	**Technopark Istanbul**	1	Yes
2	**ADU Technopark**	0,111	
3	**YTU Technopark**	1	Yes
4	**Depark**	1	Yes
5	**Gaziantep Technopark**	0,038	
6	**Ankara Technopark**	1	Yes
7	**ITU Arı Technopark**	1	Yes
8	**Kocaeli University Technopark**	1	Yes
9	**METU Technopark**	0,761	

are based on the literature (Cansız, 2017; W.K.B. Ng et al., 2021; Lindelof and Lofsten, 2003; Baykul, Sungur and Dulupcu, 2016; Yang and Lee, 2021); and it is thought that the efficiency of inputs and outputs with DEA method provides an important perspective in terms of measuring. In addition, the study can be considered as a first step for similar studies. For the future studies that are planned to be carried out, it will be possible for more Technoparks to share data transparently, so that it will be possible to reach more data at the point of efficiency measurement.

The present study had limitations in data collection and validation. Technology Development Zone Management Enterprises, which share limited data, are stated as the limitations of the study. Geographical differences, demographic features and other technological variables can be added to the scope of future studies, as the east-west synthesis is tried to be achieved within the scope of the study. In this direction, the subject of another study can be formed by considering DEA methods more comprehensively or by using integrated MCDM methods. Future studies are encouraged to take qualitative or other indicators as output/input variables, which can be effective in efficiency measurement according to literature.

In addition to measuring efficiency with the analysis made in the study, it is also emphasized that technoparks should be more transparent in terms of visibility. It is considered important that performance indicators, which are one of the motivation-enhancing tools, should be prompted to think in more detail about data sharing in terms of technology development regions. The proposed methodology, when evaluated against relevant criteria, can be considered representative of the overall paradigm for measuring efficiency.

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Assessment of the Performance of Logistics Villages Operated by the Turkish State Railways Using MCDM and DEA Methods

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ABSTRACT

Increasing competition with globalization brought along the cost problem arising from logistics activities. In this context, logistics villages play an active role in reducing costs. Logistics villages provide significant benefits to users as areas where goods from different modes of transport are transferred, arranged and prepared for transportation, and all logistics-related activities are gathered in one region. Logistics villages have begun to be established by The Turkish State Railways (TSR-Türkiye Cumhuriyeti Devlet Demiryolları) using government resources after 2006 in Turkey. The aim of this study is to assess the logistics performances of the eight logistics villages in operation by analyzing their efficiencies using Multi Criteria Decision Making (MCDM) and Data Envelopment Analysis (DEA) methods. In the study, Entropy-based EDAS, MAUT and MOOSRA methods have been used. The efficiency scores of logistics villages were calculated using output-oriented DEA models. According to CCR and BCC models, İstanbul (Halkalı) and Uşak logistics villages were found to be efficient.

Key Words: Logistics Village, Entropy, MAUT, EDAS, MOOSRA, DEA.

JEL Classification Codes: B23, B27, C67.

1. INTRODUCTION

Tremendously increasing world trade creates an environment where supply chains compete more than companies. Today, the spatial distribution of production and consumption has spread to wider areas (Theo et al., 2017). Although the companies vary according to the content of the product they produce, they supply raw materials from many suppliers located in different geographies. In addition, they have to deliver their products to customers in different locations around the world. They need a network of distributors and retailers to carry out these activities. In this context, a supply chain refers to a network of interconnected businesses from the first point to the end consumer. Logistics is the most important part of the supply chain, and with the effect of globalization, managing the logistics activities demanded by customers has become a very complex and costly process. On the other hand, by the right logistics management, businesses save time and money while providing customer satisfaction (AMCO, 2018).

This change, experienced by globalization has led businesses to seek different solutions in the logistics industry. Because, companies that perform their logistics processes at the lowest cost gain a sustainable competitive advantage. The concept of logistics center or logistics village is a business model that emerged in order to reduce costs and accelerate processes by gathering different logistics activities in one area (Sezen and Gürsev, 2014). These areas which have been very popular in recent years, operate under different names from country to country. Logistics villages are named Freight Village in England, Logistics Centers in the US, Logistics Centers in China, Freight Center in Germany, Logistics Platform or Multimodal Platforms in France, Multimodal Industrial Park in South Korea, and Interport in Italy (Meidute, 2005; Ahi, 2015).

Logistics villages are the areas where logistics and transportation companies and related public institutions are located and have efficient connections to all kinds of transport modes. These areas have the opportunity to perform many logistics activities such as handling, weighing, consolidation, packaging, and maintenance & repair. Materials and equipment required to carry out all these activities are available in these areas (TCDD, 2012). Logistics villages are regions that bring together businesses that offer both

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national and international logistics-related solutions, helping to create coordination, cooperation and synergy between them. At the same time, logistics villages provide the most favorable conditions for the establishment of intermodal transport chains as a hub between transport modes. As a result of this situation, companies provide cost advantages (Baydar et al., 2017).

With the effect of globalization, the historical background of logistics villages, whose importance gradually increased in the 21st century, dates back to the 1960s (Mircetic et al., 2014). The first logistics villages emerged with the development of the industry in the US. On the other hand, it has been suggested to establish logistics villages in order to improve urban logistics in Japan. The traffic problem caused by the increasing population in crowded cities has been tried to be overcome with logistics villages. The first examples of logistics villages in Europe started to be established in Garanor and Sogoris in the France-Paris region. In the 1970s, logistics villages, which attracted the attention of other EU countries, started to be established in Germany and Italy. In those years, logistics villages served as transfer centers, mostly used for road-rail integration. In the 1980s and 1990s, logistics villages started to be adopted much more in Europe and their number gradually increased (Postiguillo et al., 2015).

Logistics village project in Turkey dates back to the early 2000s which is much later than in Europe. In this context, TSR has started to make logistics village investments as of 2006 (Karadeniz and Akpınar, 2013). Logistics villages established by TSR are shown in Figure 1.

Samsun (Gelemen) logistics village, which was activated in 2007, is the first project that is completed in Turkey. After that, İzmit (Köseköy) logistics village started operations in 2010, Uşak logistics village in 2012, Istanbul (Halkalı) logistics village in 2013, Eskişehir (Hasanbey) logistics village in 2014, Balıkesir (Gökköy) logistics village in 2014, Denizli (Kaklık) logistics village in 2014, Kahramanmaraş (Türkoğlu) logistics village in 2017, and Erzurum (Palandöken) logistics village in 2018. When the construction of 21 logistics villages shown in Fig.1 is completed, 35.6 million tons of transportation will be possible annually from the total area of 12.8 million m^2 (Uygun, 2019).

The importance of logistics villages in both global trade and logistics sector is increasing day by day. Turkey is a country with a high potential in terms of logistics sector due to its geographical location. When the literature is reviewed, it is seen that most of the studies focus on the determination of the location of the logistics villages. In this study, the performances of the logistics villages operated by TSR were evaluated using the MCDM and DEA approaches. While ranking the performances of the logistics villages have been conducted using MCDM methods, the DEA method was utilized to find out the relative efficiencies of the logistics villages. In this respect, it is aimed that the study will contribute to the literature. On the other hand, the findings of the study would contribute to the efficiency of the operations of the logistics villages, planned to be established in the future.

The rest of this study is organized as follows: In the subsequent section a brief literature review is given.

Fig. 1: TSR Logistics Villages

Table 1: Literature Review

Recent Studies Conducted by Entropy Method	
Risk assessment for dangerous substance transportation in China	Huang et al. (2021)
Evaluation of development potential of ports in China	Mou et al. (2020)
Assessing the risks of ports' container terminals	Khorram (2020)
Analyzing the impact of regional logistics activities in China	Li (2020)
Planning express freight train service sites in China	Huang et al. (2019)
Recent Studies Conducted by MAUT Method	
Sustainable highway alignment selection for China Pakistan economic corridor	Zafar et al. (2020)
Planning warehouse locations for sustainable disaster logistics in Turkey	Ergün et al. (2020)
Developing a transit system selection model for Thailand	Sirikijpanichkul et al. (2017)
Comparison of transport corridors	Zietsman et al. (2006)
Recent Studies Conducted by EDAS Method	
Choosing a logistics center in Turkey	Özmen and Aydoğan (2020)
Determining the best practice for business balance of passenger rail operator	Veskovic et al. (2020)
Evaluation of the third-party logistics companies in Turkey	Yürüyen and Ulutaş (2020)
Analyzing the logistics performances of OECD member countries	Gök Kısa & Ayçin (2019)
Evaluating the suitability of different transportation methods for mine transfer	Maksimović et al. (2017)
Recent Studies Conducted by MOOSRA Method	
Logistics village location selection	Ulutaş et al. (2018)
Recent Studies Conducted by DEA Method	
Evaluation of the efficiencies of container terminals in India	Iyer and Nanyam (2021)
Evaluation of the efficiencies of the EU ports	Quintano et al. (2020)
Measuring the efficiency of freight transport railway undertakings	Blagojevic et al. (2020)
Examining the efficiencies of airports in Greece	Fragoudaki and Giokas (2020)
Evaluation of the efficiency of Vietnam ports	Kuo et al. (2020)

In section 3, detailed explanations are given about the MCDM and DEA approaches. In section 4, the data are described and the ranking and efficiency analyses are made. Finally, the analysis results were evaluated and suggestions for further studies were presented.

2. LITERATURE REVIEW

When the literature is searched, it is seen that many studies on the logistics sector have been carried out using MCDM and DEA methods. Some studies on Entropy, MAUT (Multi-Attribute Utility Theory), EDAS (Evaluation Based on Distance from Average Solution), MOOSRA (Multi-Objective Optimization on the basis of Simple Ratio Analysis) and DEA methods used in the study are summarized in Table 1.

3. RESEARCH METHODOLOGY

The aim of the study is to evaluate the performance of the logistics villages operated by TSR. In Turkey in 2019, eight logistics villages (İzmit (Köseköy), Uşak, İstanbul (Halkalı), Eskişehir (Hasanbey), Balıkesir (Gökköy), Denizli (Kaklık), Kahramanmaraş (Türkoğlu) ve Erzurum (Palandöken) operated. In order to evaluate the performances of logistics villages, seven criteria have been determined: investment cost, total area, distance to the nearest port, distance to the nearest airport, amount of loaded / unloaded goods, number of incoming / outgoing wagons and total annual income.

MCDM methods consist of the methods in which objective and non-objective factors are evaluated together, as a different way from statistical analysis techniques. Analyzes are made within the framework of expert opinions and the study can be developed by taking the opinion of a single expert or a group of experts (Korucuk, 2021).

Since the 1970s, MCDM research has developed rapidly and many MCDM methods have been developed to measure tangible/intangible conflicting criteria and to make a decision among alternatives according to these criteria (Saaty and Ergu, 2015). In the study, the weights were calculated by using the Entropy and Critic methods, which are among the objective weight determination methods in determining the criterion weights. However,

it has been concluded that the weight values calculated using the Entropy method are more appropriate by taking the expert opinion.

In MCDM problems, fuzzy logic arises when more than one option is available to choose the best alternative. Fuzzy MCDM methods are more preferred to be used in solving MCDM problems that include both quantitative and qualitative factors (Aruldoss et al., 2013). Since all of the criteria determined in the study were quantitative, classical MCDM methods were used. Considering the determined criteria, the performances of the logistics villages were ranked using EDAS, MOOSRA and MAUT methods. Then, the relative efficiency scores of the logistics villages were calculated using the DEA method and the results were evaluated.

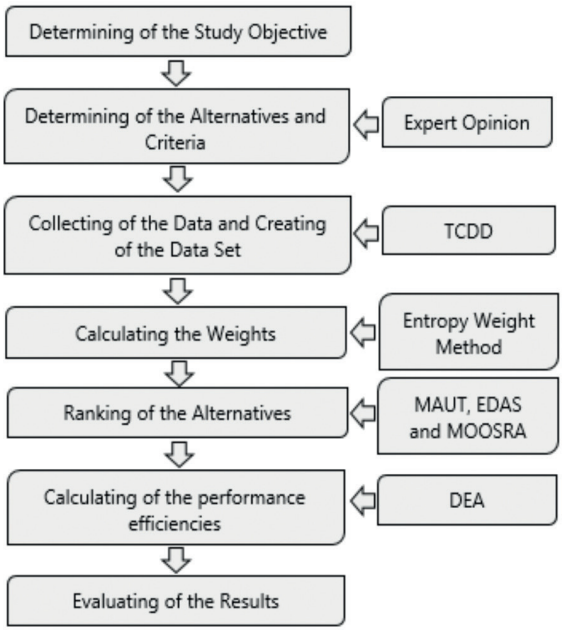

Fig. 2. Methodological Framework

3.1. Entropy Method

Weighting criteria has a significant effect on problem solving and the ranking of alternatives. The Entropy method is one of the most frequently used objective weighting methods. It was first developed by Rudolph in the field of thermodynamics in 1865. This method has been used in many studies in social sciences. Since subjective evaluations of decision makers are not required in the Entropy method, more objective results are obtained. Hence, the criterion weights in the study were made by the Entropy method and the steps of the method are shown below (Shemshadi et al., 2011).

Step 1: First, a decision matrix is constructed.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Step 2: In the second step, the decision matrix which was created in the first step is normalized. This calculation is done using Eq. (2) below.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{j} x_{ij}} \quad (2)$$

Descriptions of the terms used in Eq. (2) are as follows:

i: Alternatives,

j: Criteria,

r_{ij}: Normalized values,

x_{ij}: Utility values for the j. criterion of the i. alternative.

Step 3: In this step, the Entropy values of the criteria are found using Eq. (3) below.

$$e_j = -k \sum_{j=1}^{n} r_{ij} . ln\left(r_{ij}\right) \quad (i = 1, 2, \ldots, m \ \ and \ j = 1, 2, \ldots, n) \quad (3)$$

Descriptions of the terms used in Eq. (3) are as follows:

k: Entropy coefficient {(ln(n))-1},

r_{ij}: Normalized values,

e_j: Entropy values.

Step 4: In this step, the degree of divergence (dj) of the information is calculated. The high (dj) values obtained by using Equation (4) indicate that the deviation between the alternative scores for the criteria is high.

$$dj = 1 - ej \qquad (i = 1, 2, \ldots, m \ \ and \ j = 1, 2, \ldots, n) \quad (4)$$

Step 5: In the last step, the weight values of the criteria (wj) are found with Eq. (5). As a result, the sum of the obtained Entropy values must be 1.

$$w_j = \frac{1 - e_j}{\sum_{i=1}^{n} \left(1 - e_j\right)} \quad (5)$$

3.2. MAUT Method

The MAUT method, which was first found by Fishburn (1967) and Keeney (1974), is one of the most used MCDM methods (Velasquez and Hester, 2013:57). The MAUT method, developed by Loken in 2007, tries to assemble risk preferences and uncertainty using multi-criteria decision support methods (Loken, 2007:1587). The application steps of the MAUT method are as follows (Zietsman et al., 2006:259).

Step 1: Criteria, sub-criteria, and alternatives for solving the problem are defined and determined.

Step 2: The weights (*wj*) of the criteria and sub-criteria are determined for the evaluation of alternatives. The sum of the (*wj*) values must be 1.

$$\sum_{1}^{m} w_i = 1 \tag{6}$$

Step 3: In this step, the criterion weights are multiplied by the criterion values and then the decision matrix (X) is created.

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \dots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{7}$$
$$(i = 1,2\dots, m\ and\ j = 1,2\dots, n)$$

Step 4: In order to normalize the decision matrix, the utility function is determined for each criterion. Values of 1 are assigned to the best value for the utility criterion and 0 to the worst value for the cost criterion. Equations (8) and (9) are used to normalize the other criterion values.

$$u_j\left(x_{ij}\right) = \frac{x_{ij} - \min\left(x_{ij}\right)}{\max\left(x_{ij}\right) - \min\left(x_{ij}\right)} \quad (i = 1, 2\dots,\ m\ and\ j = 1, 2\dots,\ n) \tag{8}$$

$$u_j\left(x_{ij}\right) = \frac{\max\left(x_{ij}\right) - x_{ij}}{\max\left(x_{ij}\right) - \min\left(x_{ij}\right)} \quad (i = 1, 2\dots,\ m\ and\ j = 1, 2\dots,\ n) \tag{9}$$

Step 5: In this step, the utility values of the criteria are calculated using equation (10).

$$U(A_i) = \sum_{j=1}^{n} u_j(x_{ij}) * w_i \tag{10}$$

Step 6: In the last step, the best alternative is determined by ranking the utility values of the alternatives in descending order.

3.3. EDAS Method

The EDAS, developed by Ghorabaee et al. (2015), is a simple and efficient MCDM method. The basic idea of the EDAS method is based on two types of distance calculations PDA (positive distance to average) and NDA (negative distance to average) for determining the best alternative (Stanujkic et al., 2017). The steps of the EDAS method are as follows (Ghorabaee et al., 2015).

Step 1: In the first step, the decision matrix consisting of (n) criteria and (m) alternatives is created.

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \dots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{11}$$

Step 2: In this step, the average solution matrix (AV) is created as follows by calculating the average of all criterion values.

$$AV = [AV_j]_{1xm} \tag{12}$$

AVj values shows the average of the j^{th} criterion and are computed using Eq. (13).

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{\mathrm{n}} \tag{13}$$

Step 3: Then, distances from mean matrices are obtained for each criterion. Distances from mean are divided into positive distance from the mean (PDA) and negative distance from the mean (NDA).

$$PDA = [PDA_{ij}]_{nxm} \tag{14}$$

$$NDA = [NDA_{ij}]_{nxm} \tag{15}$$

For utility-criteria, positive and negative distance values from the mean are calculated by using Equation (16) and (17).

$$PDA_{ij} = \frac{max\left(0,\ \left(X_{ij} - AV_j\right)\right)}{AV_j} \tag{16}$$

$$NDA_{ij} = \frac{max\left(0,\ \left(AV_j - X_{ij}\right)\right)}{AV_j} \tag{17}$$

For cost-oriented criteria, positive and negative distance values from the mean are calculated by using Equations (18) and (19).

$$PDA_{ij} = \frac{max\left(0,\ \left(AV_j - X_{ij}\right)\right)}{AV_j} \tag{18}$$

$$NDA_{ij} = \frac{max\left(0,\ \left(X_{ij} - AV_j\right)\right)}{AV_j} \tag{19}$$

Step 4: In this step, weighted total positive values (SPi) and weighted total negative values (SNi) for all decision alternatives are calculated using Equations (20) and (21).

$$SP_i = \sum_{j=1}^{m} w_j . \ PDA_{ij} \tag{20}$$

$$SN_i = \sum_{j=1}^{m} w_j . \ NDA_{ij} \tag{21}$$

The W_j value in Eq. (20) and (21) shows the weights of the criteria. The sum of all W_j values must be 1.

Step 5: In this step, the SP_i and SN_i values which were calculated in the previous step are normalized by using Eq. (22) and (23).

$$NSP_i = \frac{SP_i}{\max_i(SP_i)} \tag{22}$$

$$NSN_i = 1 - \frac{SN_i}{\max_i(SN_i)} \tag{23}$$

Step 6: After normalization, the appraisal scores (ASi) are calculated using Eq. (24). Then the appraisal scores (ASi) are ranked in descending rank. The highest (ASi) refers to the best alternative.

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \tag{24}$$

3.4. MOOSRA Method

The MOOSRA method was first proposed by Das et al. (2012) as an MCDM method. Having a simple structure in terms of the steps, the method is a frequently preferred MCDM method. (Demircioğlu and Coşkun, 2018). There are similar features between the MOOSRA and the MOORA methods. However, the MOOSRA method has two superior advantages over the MOORA. First, the negative performance score in the MOORA method does not occur in this method. The other is that this method is less sensitive at criterion values with large variations. The application steps of the MOOSRA method are shown below (Jagadish and Ray, 2014):

Step 1: In the first step, the decision matrix (X) is created.

$$X = [X_{ij}]_{mxn} = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ \vdots & \vdots & \dots & \vdots \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{bmatrix} \tag{25}$$

Step 2: In the second step, the decision matrix (X) is normalized. The normalization process in the MOOSRA method is performed using Eq. (26).

$$X_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X^2_{ij}}} \tag{26}$$

Where, the value X_{ij} represents the normalized performance of i^{th} alternative on the j^{th} objective for $i=1,2,3, \dots n$ and $j= 1, 2, 3, \dots m$.

Step 3: In this step, performance scores (Y_i) are calculated using the ratio of the weighted sum of the benefit criteria to the weighted sum of the cost criteria. Performance scores (Y_i) of all alternatives are obtained by using equation (27).

$$Y_i = \frac{\sum_{j=1}^{g} w_j . X_{ij}}{\sum_{j=g+1}^{n} w_j . X_{ij}} \tag{27}$$

In Eq. (27), g is the number of attributes to be maximized, (n - g) is the number of attributes to be minimized, w_j is an associated weight of the j^{th} attributes.

Step 4: In the final step, the alternatives are ranked according to their scores (Y_i) in descending rank.

3.5. DEA

The foundations of the DEA method are based on Farrell's study in 1957. Farrell (1957), measured efficiency by linear programming using multiple inputs and single outputs. This model was later extended by Charnes et al. (1978). Today, it is a non-parametric method that is frequently used in performance and efficiency measurement (Bilişik and Elibol, 2017).

It is possible to collect DEA models into two main groups as input and output-oriented approaches. If control is low (or not) on the outputs, then input-oriented models should be used. In input-oriented models, it is aimed to use the least input to produce the current output value. In output-oriented models, the maximum output value is tried to be obtained with the current input value (Dinç and Haynes, 1999). Regardless of which models for input or output are used, the DEA model can be expressed in linear programming form and solved with linear programming solution methods (Seiford and Thrall, 1990).

Overall efficiency can be calculated by the CCR model based on the assumption of constant return to scale (CRS). In Eq. (28), the output oriented dual (envelopment) CCR model based on the CRS assumption is defined (Luptacik, 2010).

$$\max h_0 = \phi + \varepsilon(\sum_{i=1}^{m} s_i^- + \varepsilon \sum_{r=1}^{s} s_r^+) \tag{28}$$

Subjected to:

$$\sum_{j=1}^{n} x_{ij}\beta_j - x_{i0} + s_i^- = 0 \tag{29}$$

$$-\sum_{j=1}^{n} y_{rj}\beta_j + \phi y_{r0} + s_i^+ = 0 \tag{30}$$

$$\beta_j, s_i^-, s_r^+ \geq 0, \quad j= 1, 2, \dots, n, \quad r= 1, 2, \dots, s, \quad i= 1, 2, \dots, m \quad \phi: \text{free}$$

Technical and scale efficiencies can be calculated by the BCC model, which is based on the assumption of variable returns to scale (VRS). In Eq. (31), the dual BCC model for output based on VRS assumption is defined (Cooper et al., 2000).

$$\max h_0 = \varphi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \quad (31)$$

Subjected to:

$$\sum_{j=1}^{n} x_{ij}\beta_j - x_{i0} + s_i^- = 0 \qquad i = 1, 2, \ldots, m \quad (32)$$

$$\sum_{j=1}^{n} y_{rj}\beta_j - \varphi y_{r0} - s_r^+ = 0 \qquad r = 1, 2, \ldots, s \quad (32)$$

$$\sum_{j=1}^{n} \beta_j = 1 \quad (33)$$

$$\beta_j, s_i^-, s_r^+, \qquad j \geq 0 = 1, 2, \ldots, n, \qquad r = 1, 2, \ldots, s, \qquad i = 1, 2, \ldots, m$$

If an enterprise is technical and scale efficient according to the BCC model based on the VRS assumption, it is also overall efficient according to the CCR model based on the CRS assumption. However, the reverse is not necessarily true.

4. APPLICATION

In this section, the evaluations are made about the purpose of the study, alternatives, criteria, weight values of criteria, rankings obtained by MCDM methods and the DEA scores.

4.1. Purpose of Research and Data

Efforts to establish logistics villages in Turkey began in 2006 which is much later than the developed countries. Later, important logistics village projects and plans were set up in various regions of the country. However, the continuing loss of TSR in recent years has brought up the issue of efficient use of logistics villages. In this study, it was aimed to rank the TSR logistics villages based on their performance levels using MCDM methods, to measure their efficiency by the DEA method and offer solutions within the scope of the findings.

In the study, first of all, the alternatives and criteria were determined by the MCDM method. For this purpose, eight logistics villages established by TSR and operating in 2019 constitute the data set of the study. Logistics villages included in the data set are shown in Table 2.

Criteria used in the study were determined by taking a literature review and expert opinions. In this context, seven criteria were determined to be suitable for the purpose of the study. Criteria and descriptions of criteria were shown in Table 3.

In the study, the data of 2019 TSR Logistics Department were used. The decision matrix created using the data obtained was shown in Table 4.

Table 2: Alternatives

Abbreviations	*Logistics Village Name*
A1	İzmit (Köseköy)
A2	Uşak
A3	İstanbul (Halkalı)
A4	Eskişehir (Hasanbey)
A5	Balıkesir (Gökköy)
A6	Denizli (Kaklık)
A7	Kahramanmaraş (Türkoğlu)
A8	Erzurum (Palandöken)

4.2. Ranking of Performance of Logistics Villages using MAUT, EDAS, MOOSRA Methods

Criteria weights of the alternatives were calculated with the Entropy method before ranking by MCDM methods. Entropy weights of the criteria are shown in Table 5 and the most important criterion is C7 (annual income) with a weight value of 0.36. Other criteria are listed as the amount of loaded / unloaded goods (0.17), the number of incoming / outgoing wagons (0.16), the investment value (0.12), the distance to the nearest port (0.08), the total area (0.07), and the distance to the nearest airport (0.04) according to weight values.

After the criterion weights were determined, the performance rankings of the alternatives were made by MAUT, EDAS, and MOOSRA methods. Then the ranking results were combined by applying the absolute dominance method, and these results were shown in Table 6. The Absolute Dominance means that an alternative or project dominates in ranking all other alternatives or solutions which are all being dominated (Brauer and Zavadskas, 2011). According to these results, the logistics villages with the best three performance values were determined as İstanbul (Halkalı), İzmit (Köseköy) and Balıkesir (Gökköy). Other logistics villages were ranked as Eskisehir (Hasanbey), Denizli (Kaklık), Kahramanmaraş (Türkoğlu), Uşak and Erzurum (Palandöken).

4.3. Measuring Efficiency of Logistics Villages by DEA Method

The selection of input and output variables is very important in DEA application. The selected input and output values affect the validity of the results. The input and output variables and the data related to these variables, which were determined by making a literature review and taking expert opinions, are shown in Table 7.

Table 3: Descriptions of Criteria

Abbreviations	*Criterion Name*	*Unit*	*Description*
C1	Investment Value	Turkish Lira (TL)	It shows the total amount of money spent for the establishment of the logistics village in national currency. In the establishment of a logistics village, it should be aimed to provide maximum benefit with minimum cost in terms of efficiency. For this reason, the investment cost was determined as a cost criterion and it was requested to be the minimum amount.
C2	Total Area	x1000m^2	It refers to the total area where the logistics village is established. Despite being established in a small area, the efficiency of logistics villages that provide high freight transport volumes is more than others. Therefore, it was deemed appropriate to use the total area criterion as a cost criterion.
C3	Distance to the Nearest Port	Km	It shows the distance of the area where the logistics village is located to the nearest seaport. Most of the world trade is carried out by seaway. For this reason, logistics villages established near the ports will be more efficient. Therefore, this criterion was used as a cost criterion in the study.
C4	Distance to the Nearest Airport	Km	It shows the distance of the area where the logistics village is located, from the nearest airport. In recent years, air transport has shown a significant development in the world and also in Turkey. It is thought that airline transportation, which is the best solution to the speed problem in transportation, will be preferred more by reducing the costs. For this reason, logistics villages established closer to airports have the potential to be more efficient than the others. Therefore, this criterion was used as a cost criterion in the study.
C5	Amount of Loaded / Unloaded Goods	Tonne	It refers to the total amount of goods loaded and unloaded in the logistics village within a year. The amount of goods loaded and unloaded in the logistics villages is an indicator of how much the logistics village is efficient. Therefore, the amount of goods loaded and unloaded in logistics villages is expected to be at high levels. For this reason, this criterion was used as a benefit criterion in the study.
C6	Number of Incoming / Outgoing Wagons	Piece	It shows the number of wagons Incoming/Outgoing to the logistics village in a year. The high number of wagons coming / going to the logistics village shows that the logistics village is operating efficiently. For this reason, this criterion was used as a benefit criterion in the study.
C7	Total Annual Income	Turkish Lira (TL)	It refers to the total monetary amount that the logistics village has obtained in a year. This amount includes the income earned from transportation and other services provided by the logistics village. The high amount of money earned is important for the profitability and efficiency of the logistics village. For this reason, this criterion was used as a benefit criterion in the study.

Table 4: Decision Matrix

Criteria / Alternatives	C1 (min)	C2 (min)	C3 (min)	C4 (min)	C5 (max)	C6 (max)	C7 (max)
A1	199,662,062	694	15	12	285,699	8,719	3,117,156
A2	860,328	140	215	8	28,025	681	789,562
A3	26,115,685	220	10	19	596,814	17,668	38,369,451
A4	258,434,785	541	237	10	65,787	1,896	15,011,470
A5	129,084,885	211	187	17	198,950	5,999	1,469,004
A6	36,187,071	125	250	30	79,086	2,500	692,291
A7	160,452,151	805	156	30	102,640	5,396	685,331
A8	144,796,933	350	232	16	22,499	760	1,369,103

Table 5: Entropy Weights of Criteria (w_j)

	C1	C2	C3	C4	C5	C6	C7
w_j	0.12	0.07	0.08	0.04	0.17	0.16	0.36

Table 6: Ranking Alternatives by MAUT, EDAS and MOOSRA Methods

	Alternatives	MAUT	EDAS	MOOSRA	Absolute Dominance
A1	İzmit (Köseköy)	2	2	4	2
A2	Uşak	4	7	7	7
A3	İstanbul (Halkalı)	1	1	1	1
A4	Eskişehir (Hasanbey)	5	4	3	4
A5	Balıkesir (Gökköy)	3	3	2	3
A6	Denizli (Kaklık)	6	5	5	5
A7	Kahramanmaraş (Türkoğlu)	7	6	6	6
A8	Erzurum (Palandöken)	8	8	8	8

Table 7: Input and Output Values

DMU	Inputs				Outputs		
	C1	C2	C3	C4	C5	C6	C7
A1	199,662,062	694	15	12	285,699	8,719	3,117,156
A2	860,328	140	215	8	28,025	681	789,562
A3	26,115,685	220	10	19	596,814	17,668	38,369,451
A4	258,434,785	541	237	10	65,787	1,896	15,011,470
A5	129,084,885	211	187	17	198,950	5,999	1,469,004
A6	36,187,071	125	250	30	79,086	2,500	692,291
A7	160,452,151	805	156	30	102,640	5,396	685,331
A8	144,796,933	350	232	16	22,499	760	1,369,103

Table 8: Efficiency Scores of Output-Oriented CCR and BCC Models

DMU	Overall Efficiency Scores (CCR)	CCR Benchmarks	Technical Efficiency Scores (BCC)	BCC Benchmarks	Scale Efficiency (CCR / BCC)
A1	1.28	3 (0,63)	1	-	1.28
A2	1	-	1	-	1
A3	1	-	1	-	1
A4	1.35	3 (0,53)	1	-	1.35
A5	2.64	3 (0,89)	2.43	1 (0,01) 2 (0,18) 3 (0,81)	1.08
A6	4.02	3 (0,57)	1	-	4.02
A7	5.17	3 (1,58)	3.27	3 (1,00)	1.58
A8	9.58	3 (0,84)	7.86	1 (0,29) 2 (0,09) 3 (0,62)	1.22

It was appropriate to use output oriented CCR and BCC models on the grounds that it is not possible to control the inputs in measuring the efficiency of the logistics villages in DEA application. In output-oriented models, the aim is to obtain the most output with a certain amount of input. EMS (Efficiency Measurement System) program was used to get DEA results. Efficiency scores were shown in Table 8.

When Table 8 is examined, it is determined that according to the output oriented CCR model, İstanbul (Halkalı-A3) and Uşak (A2) logistics villages are efficient due to their scores (1). İzmit (Köseköy-A1), Eskişehir (Hasanbey-A3), Balıkesir (Gökköy-A4), Denizli (Kaklık-A5), Kahramanmaraş (Türkoğlu-A6) and Erzurum (Palandöken-A7) logistics villages are inefficient decision-making units. According to the technical efficiency scores, only Denizli (Kaklık-A5) logistics village is not efficient. According to the scale efficiency scores, it was determined that the logistics villages of Istanbul (Halkalı-A3) and Uşak (A2) are efficient.

5. DISCUSSION

Istanbul (Halkalı-A3) logistics village takes the first place in the rankings obtained by MAUT, EDAS and MOOSRA methods. Erzurum (Palandöken-A8) logistics village ranks in last place. The fact that Istanbul has the largest trade volume in the country plays a significant role in the logistics village of Istanbul (Halkalı-A3)'s taking the first place. Izmit (Köseköy-A1) logistics village is in the second place in Kocaeli city where some of the very important industrial organizations of the country take place. Another feature for both of these cities is that the railways are connected to many ports. Therefore, it can be concluded that logistics villages perform better if they are located close to industrial and commercial centers. In addition, it is seen that especially the logistics villages providing seaway connection are at higher ranks. So, it is an undeniable fact that the variety of transport modes significantly affects the performance of the logistics villages.

According to the CCR model scores for the output oriented by DEA, it is concluded that the logistics villages of Istanbul (Halkalı-A3) and Uşak (A2) are efficient. When the values of the output variables of the Istanbul (Halkalı-A3) logistics village are examined, it is seen that more goods are handled (C5), more wagons are transported (C6) and more income is obtained (C7) compared to the other logistics villages. Therefore, this situation enabled the logistics village of Istanbul (Halkalı-A3) to be efficient and be referred to other logistics villages. On the other hand, the efficiency score of Istanbul (Halkalı-A3) logistics village supported the ranking results obtained by MCDM methods.

When the values of the input variables of Uşak (A2) logistics village are examined, it is observed that the investment cost (C1) of this logistics village is much lower than the other logistics villages. Although it is in the lower ranks according to MCDM rankings, the logistics village of Uşak (A2) is efficient according to DEA results. The reason for this is that the investment cost (C1) of the Uşak (A2) logistics village is the lowest among the decision-making units.

6. CONCLUSION

In this paper, the performance of eight villages logistics operations in Turkey in 2019 was evaluated by MCDA and DEA methods. First, rankings were obtained by Entropy-based MAUT, EDAS and MOOSRA methods. Then, the efficiency of the logistics villages was evaluated by DEA method. Istanbul (Halkalı-A3) logistics village ranked first in three MCDM methods and it was concluded that its performance was also efficient according to DEA method.

In Turkey in 2019, there were eight operating logistics villages operated by TSR except for Samsun (Gelemen). Additionally, two logistics villages are ready to operate, two more are under construction, and eight others are also in the project phase. Evaluating the efficiency of the existing logistics villages and taking efficient logistics villages as models for new projects will yield more successful results. Therefore, according to DEA results Uşak and Istanbul (Halkalı) logistics villages are recommended to be taken as models for future projects. The Uşak logistics village can be taken as a model for low-cost projects in regions with development potential. Istanbul (Halkalı) logistics village can also be taken as a model for big cities where the industry is developed.

Demirkıran and Öztürkoğlu (2020) reached the conclusion that TR10 (Istanbul) is the region with the greatest potential in Turkey for new logistics village projects. In parallel with this result in the study, the logistics village of Istanbul (Halkalı) is in the first place according to the three methods (MAUT, EDAS and MOOSRA). In addition, there is a logistics village project in Istanbul (Avrupa Yakası) to meet this potential.

Turkey should consider the advantages of its strategic position better and increase the amount of investment and the number of logistics villages in this area. In addition to public investments, private sector investments should also be encouraged. It is thought that encouraging private sector investments will accelerate the development process in this area. In this respect, efficiency comparisons of logistics villages operated by the private sector and TSR can be made in future studies.

On the other hand, the findings obtained in the study are valid within the input-output variables and criteria used. These input-output variables and criteria can be developed in future studies. In addition, the performances of logistics villages can be examined using different MCDM methods and the results obtained can be evaluated using sensitivity analysis.

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The Impact of External Financial Factors on the Eco-Innovation Practices of Small and Medium-Sized Businesses

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ABSTRACT

This paper explains how different external financing factors influence SMEs' eco-innovation adoption using the Flash Eurobarometer 441 dataset. This survey was carried out in 28 Member States of the European Union in 2016. The effect of various external financial variables on adopting green operations of 5873 SMEs were examined using binary logistic regression. The findings indicate that traditional external financing approaches, including standard bank loans and green loans, positively affect renewable energy but have no significant impact on other circular eco-innovation applications. Established forms of external public financing, including EU funds and government grants, positively impact the application of water re-design, renewable energy, and energy re-planning activities, but no influence on waste minimization and product re-design practices. The effects of newer forms of external funding are markedly different; the results reveal that crowdfunding has a significant favorable effect on implementing all green actions. Green banks can significantly impact the adoption of water re-planning and waste minimization practices. Peer-to-peer lending is positively correlated to the adoption of actions to minimize waste. Furthermore, business angels and the capital market positively influence product re-design related to green innovations. Risk or venture capital does not affect any form of circular eco-innovations. As a result, some important managerial implications for decision-makers are given.

Key Words: : SME, eco-innovation, entrepreneurial finance, sustainability, logistic regression.

JEL Classification Codes: M10, O30.

1. INTRODUCTION

It is necessary to have a thorough knowledge of what motivates small and medium-sized businesses (SMEs) to adopt innovative green methods to decrease their environmental effects (Hoogendoorn, Guerra, & van der Zwan, 2015). Eco-innovation is defined as radical or gradual changes in processes, goods, or organizations with reduced ecological impact (Demirel, & Kesidou, 2019). Eco-Innovation practices can drive businesses to enhance their competitiveness (Horbach, 2018).

However, SMEs face unique difficulties in adapting their systems to respond to a low-carbon environment while remaining competitive. For many firms, obstacles impede the implementation of emerging technologies and practices in resource management (Bodas-Freitas, & Corrocher, 2019). Several studies have identified obstacles to SMEs' adoption of such practices, including information asymmetry, uncertainty, and financial support. EU governments have developed various policy tools to promote the implementation of energy efficacy procedures (Fleiter, Schleich, & Ravivanpong, 2012).

Sustainable development plans need an in-depth awareness of the barriers to their implementation across companies and industries, as well as a knowledge of organizations' financial resources (Allcott, & Greenstone, 2012). External financing is classified as overt or indirect reliant on whether it delivers direct monetary assistance for the attainment and employment of certain technologies and methods or admittance to guidance and advice to assist in adopting resource efficacy measures (Bodas Freitas, & Tunzelmann, 2008). Restricted access to external financing discourages investment in eco-innovations and has a detrimental effect on the development of sustainable SMEs (Kunapatarawong, & Martínez-Ros, 2016). Numerous studies have highlighted the lack of financing as a significant impediment to adopting new technology, techniques, and innovative efforts (Czarnitzki & Delanote, 2013; Palm, 2018), particularly among SMEs. External financing enables businesses to invest in new technology, processes, and products without jeopardizing existing operating objectives (Bodas-Freitas, & Corrocher, 2019). Yet not much is known about the effect of the different financing mechanisms (e.g., loans, investments, and subsidies) used by SMEs to adopt innovative circular processes.

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Few studies have examined SMEs' resource efficiency techniques and the impact these practices have on business performance. Nor has research clearly defined the financial motivations that motivate SMEs to undertake such activities and how they differ from contemporary and established entrepreneurial financing methods. We want to address this gap in the study. Additionally, a more in-depth assessment of how various types of financing affect the improvements that businesses get from creative activities and products are necessary (Rennings, 2000).

We do so by analyzing the European financial ecosystem around the implementation of sustainable actions and by contributing to the increasing volume of research that illustrates the systemic improvements needed to render the financial ecosystem more sustainable (Migendt, Polzin, Schock, Täube, & Flotow, 2017). This research explores how various forms of external assistance are associated to the scope of implementation of resource efficiency procedures. We apply data from the Flash Eurobarometer 441 "European SMEs and the Circular Economy" study of 5873 European SMEs carried out by the European Union, which surveyed firms on their use of various green initiatives and the forms of external financial sources used to support them.

We concentrate on two main differences in the literature. We respond to the business and government decision-makers' demands to reduce the environmental effects of SMEs (Calogirou, et al., 2010). We analyze the influence of financial support on implementing efficient activities on the adoption of environmentally friendly methods. This research strengthens the scientific literature on implementing innovative green practices by revealing the relationship between external financial support and green practices. To that end, we address the financial obstacles to the adoption of environmentally friendly practices. From a research viewpoint, we go beyond the prevalent emphasis on big firms and targeting SMEs and focus on the lack of distinction between different external finance approaches to various forms of innovative green activities (Halme, & Laurila, 2009; Uhlaner, Berent-Braun, Jeurissen, & Wit, 2012).

The remainder of the paper is the following: Section 2 provides an outline of the research's background and relevant literature, followed by Section 3, which explains the dataset and methodology used in this work. Section 4 delves into the results of the empirical model and its implications. Finally, section 5 exhibits the study's results and discusses the managerial and policy ramifications of the findings.

2. External financial support for adoption of eco-innovations

At the European level, SMEs' contribution to innovation, job development, prosperity, and social stability is identified and seen as necessary to improve productivity. However, it is stated that the environmental effects of SMEs are less explored than those of larger businesses (Ghenta & Matei, 2018). However, SMEs have been recognized as critical to achieving a European circular economy, mainly in terms of SMEs' commitment to endeavors such as innovation, repair, and recycling (Ghenta, & Matei, 2018).

Many SMEs are unaware of the magnitude and consequences of the low-carbon shift and often lack the expertise, capabilities, and financial sources necessary to execute initiatives to increase their sustainability (Bodas-Freitas, & Corrocher, 2019). Other obstacles are linked to the absence of knowledge on the advantages of green activities and the lack of expertise to recognize the potential to incorporate and introduce them (Trianni, Cagno, & Worrell, 2013). Several impediments, such as a scarcity of cash, limited access to external funding resources, and expensive expenses, are entirely financial (Bodas-Freitas & Corrocher, 2019; Fleiter et al., 2012; Ghisetti, Mancinelli, Mazzanti, & Zoli, 2017). It is noted in the literature that the obstacles faced by SMEs in the adoption of circular innovation actions are normally connected to the significant financial expenditures required to implement sustainable solutions and a lack of access to financial resources to support green activities and innovation (Rizos, Behrens, Kafyeke, Hirschnitz-Garbers, & Ioannou, 2015).

Research on this topic often examines financial barriers to adoption. Businesses may need direct financial assistance in the type of angel investors, venture capital, crowdsourcing, and bank loans to conquer financial and expertise obstacles to acceptance (Bodas-Freitas & Corrocher, 2019; Klewitz, Zeyen, & Hansen, 2012; OECD, 2012). The use of such funding, such as direct financial funding for the procurement and application of special technology and activities, typically abides by the financing organizations' regular procedures and rules (Bodas-Freitas & Corrocher, 2019; Bodas Freitas & Tunzelmann, 2008; Klewitz et al., 2012). Access to external financing has been indicated to be difficult considering technological and industrial uncertainties, as well as regulatory changes (Rennings, 2000).

Though, both the finance sector (potential investors and banks) and policymakers have attracted substantial funds to be committed to long-term ecological programs

(EEA, 2014). External finance to advance toward a greener economy enables businesses to acquire expensive equipment and reduce internal spending and capital expenses connected with such acquisitions. This is important for SMEs, which are often constrained by cost limitations and a lack of internal funding (Doh, & Kim, 2014). Numerous SMEs seem to view significant energy and resource efficiency expenditures as a severe problem and allocate insufficient money to energy management (Bodas-Freitas, & Corrocher, 2019; Fleiter, Hirzel, & Worrell, 2012). However, the nature of financing schemes does not often consider companies' technical and business features that may limit the efficacy toward their green engagement (OECD, 2012; Olmos, Ruester, & Liong, 2012). External capital may assist businesses in overcoming financial barriers associated with the purchase and implementation of resource-efficient technologies and operations.

Research suggests that the shortage of financial capital is a substantial barrier to SMEs' involvement in the eco-innovation (Caldera, Desha, & Dawes, 2019; Ghisetti et al., 2017; Álvarez Jaramillo, Zartha Sossa, & Orozco Mendoza, 2018). When facing a scarcity of internal financial capital, SMEs are compelled to accept foreign funding, which is sometimes constrained in supply, limiting the extent of SMEs' entrepreneurship (Revest, & Sapio, 2012). Ecological, innovative SMEs are expected to face significantly more financial constraints than non-green SMEs for a variety of reasons, containing a lesser availability of external financial resources for ecological friendly developments due to risk, information disproportionateness, the lengthy time-critical to launch green inventions, and evolving regulatory settings (Criscuolo & Menon, 2015; Demirel & Danisman, 2019; Mrkajic, Murtinu, & Scalera, 2019).

In implementing green practices, external financing can enhance the need to minimize total production costs and adopt certain procedures to roles, goods, and activities where benefits are more apparent. Furthermore, external financing may increase the emphasis green firms place on return on investment and thus may improve their efforts to leverage the potential of changes in operations, parts, by-products, and waste that could otherwise have been ignored. Therefore, we believe the prospects for access to external finance are especially relevant for SMEs to improve their capacity to establish plans to adopt renewable technology and practices that can conserve money and reduce manufacturing costs. We presume that additional support for adoption would be related to initiatives and innovations projected to offer benefits for SMEs. However, the scientific community rarely evaluates a comprehensive study of the financial ecosystem underlying sustainable SMEs.

This article examines how European SMEs may access different forms of external financing for circular eco-innovation investments and how this access ultimately affects their adoption of sustainable practices.

Table 1: Descriptive statistics for the SMEs analyzed

R&D intensity (%)	Freq.	%
< 5	4532	77.2
5 to 9.9	587	10.0
10 to 14.9	343	5.8
15 to 19.9	116	2.0
≥ 20	295	5.0
Total	5873	100.0

Number of employees	**Freq.**	**%**
1 to 9	3498	59.6
10 to 49	1469	25.0
50 to 250	906	15.4
Total	5873	100.0

Firm's age	**Freq.**	**%**
Before 01.01.2010	4943	84.2
After 01.01.2010	930	15.8
Total	5873	100.0

Turnover (euros)	**Freq.**	**%**
< 25 000	500	8.5
> 25 000 to 50 000	418	7.1
> 50 000 to 100 000	513	8.7
> 100 000 to 250 000	778	13.2
> 250 000 to 500 000	754	12.8
> 500 000 to 2 000 000	1266	21.6
> 2 000 000 to 10 000 000	952	16.2
> 10 000 000	692	11.8
Total	5873	100.0

Sector	**Freq.**	**%**
Manufacturing	917	15.6
Retail	2021	34.4
Services	2087	35.5
Industry	848	14.4
Total	5873	100.0

3. Methodology

We analyzed the role of various aspects for the operational implementation of resource management procedures based on the Flash Eurobarometer 441 "European SMEs and the Circular Economy." The present study includes data from 28 European Union member states. The logistic regression model evaluates drivers that determine the positive resource efficiency behaviors of SMEs. Table 1 provides a review of the main attributes of the SMEs analyzed.

Dependent variable

1) Eco-innovation activities: We analyze the external financial drivers behind the eco-innovation adoptions in the first model. A firms' eco-innovation practices are assessed using a variable that identifies SMEs' environmental operations, including the following methods: Re-design of the method water is used to lessen usage and expand re-usage (Water Re-Plan), usage of renewable energy (Renewable Energy), Re-design energy usage to minimalize consumption (Energy Re-Plan), lessen waste by reprocessing or recycling waste or selling it to another business (Waste Management) and Re-design goods and services to minimalize the usage of resources or usage reprocessed materials (Product Re-Design). These approaches are dissimilar; some are intended to save resources (energy and material savings) to alter the production process actively; others should not modify how the firms work but instead recycle/reuse waste (Bodas-Freitas, & Corrocher, 2019). The dependent variable was coded as 0 for non-adoption or 1 for the adoption of "Water Re-Plan," "Renewable Energy," "Energy Re-Plan," "Waste Management," and "Product Re-Design" as a form of eco-innovation.

Independent variable

1) External financial support: Financial resources are essential for every firm. One of the main distinctions between large and medium-sized enterprises is access to financial resources (Berger, & Udell, 1998). SMEs frequently do not have adequate financial sources to fund their operations and assets, depending primarily on internal resources such as private funds and reserved income. In contrast, for large companies a greater variety of resources, such as equity financing, are available (Hoogendoorn et al., 2015). The literature emphasizes that many SMEs find it impossible to participate in sustainable procedures because of financial expenses (Pacheco, Dean, & Payne, 2010; Roberts, Lawson, & Nicholls, 2006). Indeed, SMEs are prone to say that financial factors are barriers to environmental implementation than to point to an absence of understanding (Pimenova, & van der Vorst, 2004).

Obtaining external financial funding is positively correlated to green activities. The following section summarizes the external financial factors that can affect SMEs' resource efficiency activities. The model reflects the type of external financing accessible for SMEs to use to adopt circular economy innovations. Traditional and modern forms of external financing sources are applied in the model. Traditional external finance encompasses standard bank loans or green loans related to sustainable activities of the firm, EU funds, and government grants. Modern forms of external finance include crowdfunding, specific green banks stimulating the circular economy and eco-friendly investment, peer-to-peer lending, venture capital/risk capital, angel investors, and capital markets.

Control variable

Several control variables were coded as independent variables of the logistic regression model.

1) Firm size: Some reports suggest that company size influences the ecological policies of a business (Bianchi, & Noci, 1998). Variations in size are also an essential factor for the group of SMEs (Uhlaner et al., 2012). Small businesses' spending on sustainability practices can be challenging to explain to investors given the lack of economies of scale and marginal market shares (Hoogendoorn et al., 2015). Small businesses are less accessible to the media and the public due to their scale. Since small companies have a specific level of confidentiality among these secondary clients, such as eco-friendly campaigners, they are less inclined to indulge in ecological activities than big firms (Aragón-Correa, Hurtado-Torres, Sharma, & García-Morales, 2008; Hoogendoorn et al., 2015). Multiple empirical studies have suggested a favorable association between business size and ecological activities (Perrini, Russo, & Tencati, 2007; Uhlaner et al., 2012).

Though, little differentiation has been made among forms of ecological practice. Differentiation between forms by SME size may reveal distinctions in the implementation of different categories of eco-innovation practices. The number of employees and revenue measures firms' size. The number of employees is coded from 1–3 (1 = 1 to 9 employees, 2 = 10 to 49 employees, and 3 = 50 to 250 employees). The turnover factor was coded from 1–8 for various turnover levels (1 = Up to 25 000 euros, 2 = 25 000 to 50 000 euros, 3 = More than 50

000 to 100 000 euros, 4 = More than 100 000 to 250 000 euros, 5 = More than 250 000 to 500 000 euros, 6 = More than 500 000 to 2 million euros, 7 = More than 2 to 10 million euros, and 8 = More than 10 million euros).

2) Type of market served: The type of market served is connected to the form of circular economy innovation. Firms' decision-makers center their environmental policies on the specific key stakeholder communities that are most important to their firm. Firms targeting consumers are more likely to seek product advancement to generate a competitive edge (Orsato, 2006). With an increasing interest for the environment, consumers appreciate the environment-friendly produced products or services. This is especially important when a product or service is offered to end consumers (Gershoff & Irwin, 2012; Hoogendoorn et al., 2015). The type of market served is coded based on the type of offering and customer (from "Product to Consumer," "Product to Company," "Service to Consumer," "Service to Company").

3) Firm age: Company age impacts the degree to which SMEs participate in environmentally friendly activities. Small firms are accountable for novelty, resource shortages, and ongoing questions regarding young companies' survival could have a detrimental effect on their ethical actions (Hoogendoorn et al., 2015; Neubaum, Mitchell, & Schminke, 2004). However, young firms are more likely to be interested in ecological activities (Hockerts, & Wüstenhagen, 2010). Firm age is coded from 1 to 3 for categories regarding the date it was founded (1= Before 01.01.2010, 2 = Between 01.01.2010 and 01.01.2015, 3 = After 01.01.2015).

4) Firm's industry sector: Sector-specific conditions face various ecological risks and benefits and affect businesses' green policies, including SMEs (Hoogendoorn et al., 2015; Orsato, 2006; Perrini et al., 2007). For instance, in resource-demanding industries such as industrial sectors, high levels of environmental effects give rise to cost savings possibilities and provide the ability to gain a comparative edge by distinguishing from others (Gershoff & Irwin, 2012; Uhlaner et al., 2012). Businesses in resource-intensive sectors may experience higher production costs and levels of environmental harm. Companies in such sectors are also more likely to be actively regulated, which renders them more likely to implement sustainability policies (Hoogendoorn et al., 2015) than businesses in less resource-demanding sectors. While these claims make intuitive perception, scientific proof is sparse. Therefore, a model is applied to distinguish the external financial effect on adopting various innovative circular actions based on the firms' sector.

5) Investment in research and development (R&D): Although eco-innovation is intended to influence the environment positively, its impact on companies' resource efficiency is not straightforward. The traditional economic approach has been focusing on engaging in environmentally friendly actions to minimize, for example, emissions, which implies increased costs for a business with few associated gains, reducing the overall productivity of a company (Palmer, Oates, & Portney, 1995). Twenty years ago, a modern green outlook arose that focusing on green practices would cover operating costs and improve company efficiency over the long term (Jové-Llopis, & Segarra-Blasco, 2018). The various levels of R&D investment are classified on a scale of 1–5 (1 = less than 5%, 2 = 5% to 9.9%, 3 = 10% to 14.9%, 4 = 15% to 19.9%, 5 = 20% or more).

Table 3 displays the effects of binary logistic regression for variables estimating the effect of external financial approaches on eco-innovation adoption patterns. The binary logistic regression model is created by applying a dichotomous-dependent variable. The resulting estimates illustrate the effect of potential external financial funding on the adoption of circular eco-innovation activities (Table 1). Our results show different implications of traditional and modern external sources of financing on various approaches to eco-innovation.

4. Results

The overall model fit was measured using the Nagelkerke R^2 test statistic and the omnibus test for model coefficients. The estimates apply a chi-square (χ^2) distribution; the findings suggested that all non-significant p statistics are a good fit for our model. The Wald test was used for a significance test of every external financing variable. Finally, we assessed the ratio of correct case categories and confirmed all values above the threshold of 60% as satisfactory and values over 70% as useful, following the suggestion of (Hair, Black, Babin, & Anderson, 2019).

Assessments of the binary logistic regression model show the effect of external financing on applying circular eco-innovations (Table 2). The overall model is statistically significant (χ^2 (56) = 378.352, $p < 0.001$ for water re-plan, $\chi 2$ (56) = 520.464, $p < 0.001$ for renewable energy, χ^2 (56) = 471.604, $p < 0.001$ for energy re-plan, χ^2 (56) = 1075.160, $p < 0.001$ for minimize waste, and χ^2 (56) = 434.620, $p < 0.001$ for product re-design). Thus, the model effectively differentiates between respondents applying or not applying the different forms of eco-innovation activities. The Nagelkerke R2 varies between 0.104 and 0.223

Table 2: The effect of external finance funds on circular eco-innovation practices

	RE-PLAN WATER		USE RENEW-ABLE ENERGY		RE-PLAN ENERGY		MINIMIZE WASTE		RE-DESIGN PRODUCT	
VARIABLES	β (SE)	Odds Ratio	β (SE)	Odds Ratio	β (SE)	Odds Ratio	β (SE)	Odds Ratio	β (SE)	Odds Ratio
External finance: Traditional sources										
Standard bank loan	-0.048 (0.12)	0.953	0.29** (0.12)	1.337	0.058 (0.09)	1.060	-0.135 (0.09)	0.873	-0.109 (0.1)	0.897
Green loan	0.127 (0.48)	1.135	1.552**** (0.41)	4.723	-0.054 (0.41)	0.947	-0.28 (0.41)	0.756	-0.617 (0.51)	0.539
EU funds	0.576** (0.27)	1.778	1.205**** (0.25)	3.335	0.735**** (0.21)	2.085	0.323 (0.21)	1.381	0.194 (0.24)	1.214
Government grant	0.518* (0.28)	1.679	0.919**** (0.28)	2.508	0.505** (0.24)	1.657	0.109 (0.25)	1.115	0.118 (0.26)	1.125
External finance Modern sources										
Crowdfunding	-0.151 (0.14)	0.860	0.211 (0.13)	1.235	0.11 (0.11)	1.117	0.038 (0.11)	1.038	0.001 (0.11)	1.001
Green bank or other private institution	0.205* (0.1)	1.227	0.035 (0.11)	1.036	0.025 (0.08)	1.025	0.183** (0.09)	1.201	-0.028 (0.09)	0.972
Peer-to-peer lending	-0.033 (0.14)	0.968	0.11 (0.14)	1.116	0.078 (0.11)	1.082	0.184* (0.11)	1.202	-0.096 (0.11)	0.908
Business angels	0.198 (0.16)	1.219	-0.244 (0.17)	0.784	-0.099 (0.13)	0.906	0.064 (0.13)	1.066	0.249* (0.13)	1.283
Risk capital/venture capital	0.03 (0.13)	1.031	0.152 (0.13)	1.164	0.142 (0.1)	1.153	-0.096 (0.1)	0.909	0.061 (0.11)	1.063
Capital market	0.155 (0.11)	1.167	-0.091 (0.11)	0.913	0.078 (0.09)	1.081	0.123 (0.09)	1.131	0.157* (0.09)	1.170
CONTROL VARIABLES										
Firm size										
Number of employees (ref. 1 to 9)										
10 to 49	0.165 (0.1)	1.179	0.015 (0.11)	1.015	-0.03 (0.08)	0.970	0.194** (0.08)	1.214	-0.027 (0.08)	0.973
50 to 250	0.246* (0.14)	1.279	0.331** (0.14)	1.392	-0.039 (0.11)	0.962	0.195* (0.11)	1.216	0.161 (0.11)	1.174
Turnover (€) (ref. Less than 25 000)										
> 25 000 to 50 000	-0.015 (0.19)	0.985	-0.435* (0.24)	0.647	-0.126 (0.15)	0.882	0.347** (0.15)	1.415	-0.056 (0.16)	0.945
> 50 000 to 100 000	-0.065 (0.18)	0.937	-0.225 (0.21)	0.799	-0.272* (0.15)	0.762	0.123 (0.14)	1.131	-0.096 (0.16)	0.909
> 100 000 to 250 000	-0.344* (0.18)	0.709	-0.131 (0.19)	0.877	-0.174 (0.13)	0.841	0.199 (0.13)	1.220	-0.094 (0.14)	0.910
> 250 000 to 500 000	-0.112 (0.18)	0.894	-0.144 (0.19)	0.866	-0.076 (0.14)	0.927	0.391*** (0.14)	1.478	0.081 (0.15)	1.084
> 500 000 to 2 000 000	-0.148 (0.17)	0.862	-0.113 (0.18)	0.893	-0.043 (0.13)	0.958	0.243* (0.13)	1.275	0.06 (0.14)	1.062
> 2 000 000 to 10 000 000	-0.33* (0.19)	0.719	-0.1 (0.2)	0.905	0.081 (0.14)	1.084	0.349** (0.14)	1.417	-0.079 (0.16)	0.924
> 10 000 000	0.082 (0.2)	1.085	0.058 (0.22)	1.060	0.349** (0.16)	1.418	0.333** (0.16)	1.395	0.014 (0.17)	1.014
Firm age (ref. Before 01.01.2010)										
Between 01.01.2010 and 01.01.2015	-0.067 (0.11)	0.936	-0.227* (0.12)	0.797	-0.145* (0.09)	0.865	-0.022 (0.09)	0.979	0.081 (0.09)	1.084
After 01.01.2015	-0.478 (0.37)	0.620	-1.368*** (0.53)	0.255	-0.524* (0.28)	0.592	-0.309 (0.26)	0.735	-0.062 (0.28)	0.940
R&D investment (%) (ref. Less than 5)										
5 to 9.9	0.164 (0.12)	1.178	0.228* (0.12)	1.256	0.14 (0.1)	1.150	-0.133 (0.1)	0.876	0.471**** (0.1)	1.601

10 to 14.9	0.259* (0.15)	1.296	0.459*** (0.15)	1.583	0.155 (0.12)	1.167	0.015 (0.12)	1.015	0.453**** (0.12)	1.574
15 to 19.9	0.413* (0.25)	1.512	-0.025 (0.28)	0.975	0.18 (0.21)	1.197	0.03 (0.21)	1.031	0.532** (0.21)	1.703
20% or more	0.352** (0.17)	1.422	0.413** (0.17)	1.512	0.232* (0.13)	1.261	-0.138 (0.13)	0.871	0.35** (0.14)	1.420
Type of market served										
Products_Consumer	0.065 (0.08)	1.067	-0.033 (0.09)	0.967	0.164** (0.07)	1.179	0.026 (0.07)	1.027	-0.01 (0.07)	0.990
Products_Company	0.063 (0.08)	1.065	0.031 (0.09)	1.031	-0.098 (0.06)	0.906	0.177*** (0.06)	1.194	0.128* (0.07)	1.137
Service_Consumer	0.407**** (0.08)	1.503	0.325**** (0.09)	1.384	0.189*** (0.07)	1.209	0.008 (0.07)	1.008	0.152** (0.07)	1.164
Service_Company	-0.228*** (0.08)	0.796	-0.057 (0.09)	0.944	-0.204*** (0.07)	0.816	-0.044 (0.07)	0.957	-0.048 (0.07)	0.954
Constant	-2.743**** (0.31)	0.064	-2.56**** (0.3)	0.077	-1.226**** (0.21)	0.294	-0.79**** (0.19)	0.454	-1.871**** (0.23)	0.154

*p < 0.1; **p < 0.05; *** p < 0.01; **** p < 0.001

Country dummies are integrated but not presented

across all circular eco-innovations; therefore, our models describe between approximately 10.4% and 22.3% of the variances.

Table 2 reveals the results of the first evaluation of the effect of external funding on the adoption of five various circular eco-innovations. The results show how access to external financing for circular eco-innovation influences the development of circular economy innovations by SMEs and suggest that established and modern external funds have different effects on their adoption.

As for traditional external financing approaches, standard bank loans and green loans positively affect renewable energy but have no significant impact on other innovations. Our findings suggest that EU funds and government grants—established forms of external public financing—positively influence the progress of water re-design, renewable energy, and energy re-planning activities but do not influence waste minimization and product re-design practices.

The results regarding newer modern forms of external funding disclose that crowdfunding has a substantial favorable impact on adopting all green endeavors. Green banks can significantly impact the adoption of water re-planning and waste minimization practices. Peer-to-peer loaning is significantly positively linked to the implementation of waste minimization action. Furthermore, findings indicate that capital markets and business angels positively influence the adoption of product re-design. Risk capital or venture capital does not affect any form of eco-innovations.

The implications of firm size vary across circular economy innovations. Generally, the findings suggest that medium-sized enterprises with a high turnover rate are keen to adopt circular green innovation practices. Waste minimization actions are conducted regardless of firm size; there is no significant relationship between firm size and product re-design activities.

In contrast to established companies, the age of new firms has a more negative impact on establishing renewable energy systems or energy re-plan. R&D investment is significantly related to product re-design activities. Furthermore, R&D-related investments of more than 10% support the adoption of water re-planning actions, and R&D investment of more than 20% also significantly supports the implementation of renewable energy and energy-replanning actions. The findings indicate that firms offering products to consumers are particularly eager to implement energy re-plan actions, while firms offering products to other firms tend to adopt waste reduction and product re-design activities. Furthermore, firms offering services to consumers tend to implement water re-planning, renewable energy, energy re-planning, and product re-design activities, whereas offering services to other companies is negatively associated with water and energy re-planning activities.

5. Conclusion

The results of these models indicate that not all sources of financing increase the adoption of eco-innovations. We find that SMEs employ five different forms of eco-innovation practices under varying circumstances. This is attributed to a variety of factors: funding source, firm size, firm age, R&D investment, and type of market. In general, SMEs' willingness to apply eco-innovations does not appear to rely on their size. However, our findings indicate that micro-sized enterprises are especially likely to make changes to minimize waste.

Our findings show different results between traditional and modern external financing sources to implement various forms of eco-innovations. In general, our results indicate that all traditional external financial approaches are efficient in supporting moves toward the use of renewable energy. The EU and other government funds are adequate when implementing water re-planning, renewable energy, and energy re-planning actions. However, interestingly, traditional forms of external financing do not support waste minimization and product re-design activities.

As a modern form of external financing, we note that green banks play a role in water re-planning and waste minimization. Peer-to-peer lending is particularly likely to result in SMEs' engagement in waste minimization. Furthermore, we noted that financing from business angels and capital markets is associated with product re-design. Risk/venture capital does not seem to play a significant role in SMEs' implementation of eco-innovations. This may be because risk or venture capital institutions lack the patience to invest in resource-intensive and costly green technologies (Demirel, & Danisman, 2019). Projects creating new green technology, including hardware, advanced technologies, and chemicals, are impossible to grow in a limited time, and therefore struggle to gain investment funds (Gaddy, Sivaram, Jones, & Wayman, 2017).

As environmental concerns grow more acute, innovative green activities have begun to draw the interest of decision-makers and the research literature. The results of our study have a variety of consequences for decision leaders in business and for researchers. The current literature indicates that external support might minimize the effects of a lack of internal expertise at SMEs, and external funding may pay off for their absence of financial capital. There has not yet been a discussion in the literature of the cumulative effects of private financing on the adoption rate of green practices.

Provided that financing is aimed at particular types of hurdles to adoption, it is fair to assume that decision-makers can maximize their influence when it is known which form of financial support is most effective, and as a consequence, improve businesses' gains from adoption. As a result, the availability of external funding will maximize firms' willingness to participate in a more holistic approach to implementing resource efficiency practices, concentrating on resource savings, reducing manufacturing costs, and enjoying higher returns. However, companies that already use external funding for these purposes have competencies to understand the importance of green practices, recognize the unique challenges encountered in their implementation, and to identify and approach possible traces of external funding. Therefore, businesses that are willing to access external financial aid to implement resource efficacy efforts are less likely than companies that have not used external funding to face high barriers to implementation, and consequently, will be more likely to benefit.

From a research perspective, this article adds to the literature by presenting details on the external financial factors behind the implementation of innovative green activities. In terms of financial effects, the inefficiency of external public support for greener product re-design indicates a need for reform in the present legal framework. This paper contributes to the scientific literature in a variety of areas. The analysis strengthens our understanding of what external financial sources cause SMEs to be involved in green-efficient activities and why the determinants differ with the type of activity. In doing so, we respond to previous calls to rely on multiple environmental approaches while analyzing organizational conduct (Halme & Laurila, 2009; Uhlaner et al., 2012). Second, we involve several countries in our study. We also concentrate on the type of market, as different markets may require different financial approaches to solve global environmental issues.

We must note that our analyses are subject to a range of significant limitations. First, there are fundamental drawbacks inherent to cross-section analyses. The extent of unobserved variability cannot be completely regulated. This is relevant since certain factors at the organization level (including greening strategies) might involve decision-making. Uncertainty, such as financial restrictions and awareness of environmental management, may affect a company's decision to apply innovative sustainable practices. To resolve this problem, we suggest that future studies acquire time-series and cross-section details from the same company. Second, applying different forms of eco-innovation activities as binary variables contributes to the lack of useful evidence on the intensity of innovative green practices that prospective studies aim to maintain. Future studies can also use long-term data on innovative circular activities of SMEs to explore the importance of the relationships described in this report.

This paper's most distinctive aspect is our study of disparities of the efficacy of external financing for different eco-innovations. By utilizing binary logistic models, we have identified disparities in external financing's effectiveness on five different forms of eco-innovations by distinguishing between traditional and modern financing approaches.

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Bibliometric Analysis of Organizational Ecology Theory (OET): To Review Past for Directing the Future of the Field

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ABSTRACT

In this study, 399 articles of the extant literature published in the Web of Science database between 1975 and 2020 were examined using bibliometric analysis to determine the extent of Organizational Ecology Theory (OET) literature and current research priorities. Bibliometric techniques such as performance analysis, citation analysis, co-word and co-citation analysis are used for this purpose. We extracted several thematically clusters from bibliometric networks using co-citation and co-word analysis, describing related but distinct subfields of inquiry within the OET literature. "Organizational change", "organizational forms and identity", and "organizational founding and mortality" are overlapping clusters. Topics such as new organizational type, organizational failure, first-mover advantage, organizational founding, and coevolution may be examined in future research. Therefore, the expected contribution of this study is to provide a helpful inventory of past research to advance OET literature.

Key Words: : Organizational Ecology Theory, Systematic Literature Review, Bibliometric Analysis, Organizational Theory, Science Mapping, VOSviewer.

JEL Classification Codes: D23, L2, M1.

1. INTRODUCTION

In the field of organizational theories, environmental change and organizations' responses to this change are some of the main problems in understanding the behavior of organizations (Aldrich 1979; Aldrich and Pfeffer 1976). There are two different perspectives in organizational theories that deal with the responses of organizations to environmental change. On the one hand, there is the perspective of surviving by adapting to environmental changes, and on the other, extinction by selection in the face of environmental changes (Thompson 1967; Hrebiniak and Joyce 1985; Hannan and Freeman 1977, 1984). Organizational ecology theory seeks to answer the question of "*why organizations are so diverse*" based on selection mechanism as an alternative perspective instead of adaptation to environmental changes (Hannan and Freeman 1977; Carroll 1984). The diversity of organizations refers that the mortality of existing organizations and the birth of new organizations (Hannan and Freeman 1987, 1988; Hannan and Carroll 1992).The OET discusses the issue through concepts based on different levels of analysis: demographic characteristics such as age and size for organization-level studies (Freeman et al. 1983; Barron et al. 1994), concepts such as structural inertia (Hannan and Freeman 1984), density dependence (Carroll and Hannan 1989), resource partitioning (Carroll and Swaminathan 2000), niche width (Freeman and Hannan 1983; Carroll 1985) for population-level research, and finally, community-level research which seeks dramatic changes in social, political and economic conditions (Astley 1985).

There are studies in the field of organization theory and organizational studies using bibliometric analysis (Ferreira et al. 2014; Zupic and Čater 2015; Kücher and Feldbauer-Durstmüller 2019; Zhai and Su 2019; Öztürk 2021a, Diez-Martin et al. 2021). However, we have not encountered bibliometric research regarding the overall organizational ecology theory literature. For this reason, this study will reveal the holistic picture of the literature of organizational ecology theory using bibliometric analysis. In this way, the link between past and future research will be established by stating the clear analytical focus of the research themes and indicating clear directions for future research.

This study aims to present a general overview of the OET literature. In this study, bibliometric analysis is used for describing the performance and science maps of the

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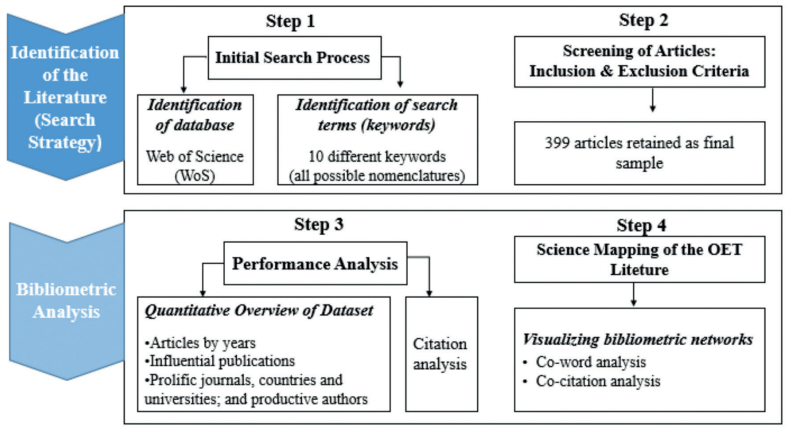

Figure 1 Steps of the research

OET literature. Here the performance refers to the general classification and measurement of the publications in our data set of the research field, while science maps refer to intellectual and conceptual structures. Based on such a goal that motivates this study, the research question (RQ) is: *What is the general overview of the OET literature?*

Being able to answer this question requires a holistic view of the field. Bibliometric analysis is one of the tools widely used by researchers in recent years to reveal any field's development and historical evolution. Bibliometric analysis is a particular type of systematic literature review (Block & Fisch, 2020). When considering the entire field, this tool, which ensure the analysis of large data sets in this way, provide significant benefits for researchers (Cobo et al. 2011).

2. Method

The method of bibliometric analysis is to map the intellectual structure of any research area, topic, or journal using specific indicators (Cobo et al. 2011; Gutiérrez-Salcedo et al. 2018). The bibliometric analysis can be instrumental when someone wants to learn about the evolution of a research area (Zupic and Cater 2015). The bibliometric analysis aims to visualize the structure of a research field by grouping items (articles, writers, journals, citations, keywords, or sub-topics) together (Ariaa and Cuccurullo 2017).

There are two stages in the method parts of bibliometric research: i) identifying the data set, ii) bibliometric analysis of the data set. Firstly in bibliometric studies, data is gathered from a specific database through search terms that directly reflect the relevant field called the *initial search process*. After, the initial search results are filtered depending on the research question, and the data set is made ready for analysis which is called *screening of articles* (Öztürk, 2021b). We used a systematic search method (Block & Fish 2020: 310) to find relevant literature about the OET. In bibliometric studies, it should be adopted a replicable and transparent process (Trandfield et al. 2003) to evaluate existing evidence to minimize bias that results from the random inclusion or exclusion of studies in the literature review process (Linnenluecke et al. 2020: 178).

Secondly, there are two main procedures used to analyze a research field: *performance analysis* and *science mapping* (Cobo et al. 2011; Gutierrez-Salcedo et al. 2018). In this analysis, we follow the steps shown in Figure 1 (Cobo et al. 2011; van Eck and Waltman 2014; Zupic & Cater 2015; Gutierrez-Salcedo et al. 2018; Block & Fisch 2020; Linnenluecke et al. 2020; Öztürk, 2021b).

2.1. Initial Search Process

Data for the bibliometric analysis were gathered from a variety of sources. Many databases, such as WoS, Scopus, Google Scholar, and PubMed, provide datasets for bibliometric studies (Cobo et al. 2011). WoS is the most widely used database, especially among management and organization researchers (Zupic and Cater 2015; Mas-Tur et al. 2020).

In this study, we used the WoS database for the literature search. The reasons of using this database are; (I) WoS contains numerous social science journals. In this regard, it has sufficient data for bibliometric research. (II) datasets can be accessed in a suitable file type. (III) It is easy to access due to university membership. These benefits include significant convenience in accessing the

Table 1 Keywords used to identify relevant articles

Keywords
"population ecology of organization*" OR "organization* ecolog*" OR "population* ecolog*" OR "ecolog* theor*" OR "population-ecolog*" OR "organization* population*" OR "ecolog* perspective" OR "ecolog* approach" OR "ecolog* model" OR "ecolog* of organization*"

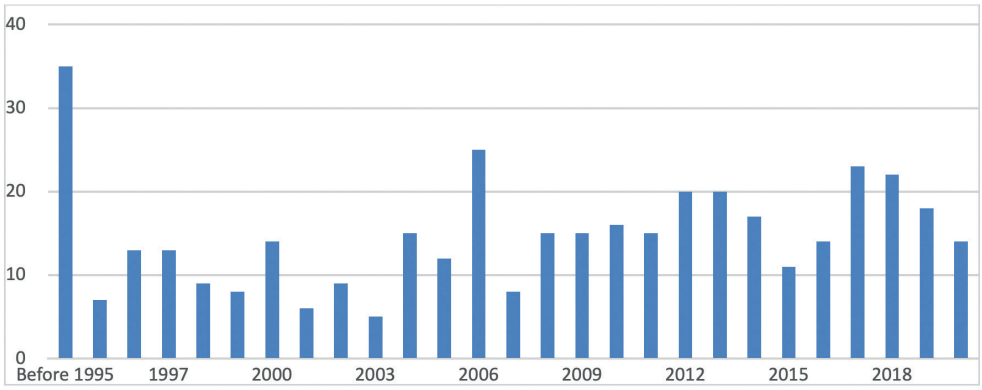

Figure 2 Articles per year. Notes: Evolution of the number of articles over the years since 1975. Notably, the dataset includes only articles published by December 2020. The figure is based on a sample of N = 399 articles.

Table 2 Inclusion and exclusion criteria

Inclusion criteria
Article in business and management fields
Article published in a peer-reviewed journal
Research or review article
Article in the English language
Keywords (in Table 1) included in the article's title, abstract, or keywords
Exclusion criteria
Book, book chapter, book review, proceedings paper, and the editorial material
Article not covering the OET

dataset, moving it to the software, and conducting the bibliometric analysis techniques. Many of the journals in WoS, on the other hand, have a high impact factor which are leading publications in their fields.

Following the selection of the suitable database, we identified keywords representing the OET to be used in the initial search. To ensure that all publications correctly and thoroughly reflect the OET, we performed a "topical query" that included all possible naming forms (nomenclatures) relevant to the theory. Table 1 shows the search terms we use in the initial search.

Between 1975 and 2020, 17204 studies were found by searching for related keywords in the title, abstract, or keywords.

2.2. Screening of Articles

In this phase, we conducted screening processes for the 17204 studies because databases often find publications that are not relevant to our research purpose. Table 2 shows the inclusion and exclusion criteria we applied.

We include only the publications (research or review articles) published in journals in the fields of "business" and "management" as well as English as the research language. Since "population ecology" is a common term in scientific fields such as genetics, biology, ecology, zoology, and entomology, the initial quest yields many academic publications. When the filtration is narrowed down to the fields of business and management, however, the search results decrease in number. Furthermore, we exclude proceedings papers because of their structural limits. We also omitted books, book chapters, and book reviews because they are often a replication of descriptive and prior experience in books written on general organizational theories and are not focused on empirical results. We also didn't include papers that didn't have the keywords (in table 1) in the title, abstract, or keywords (Block et al. 2020).

Following the application of all these filtering criteria, we found 527 articles. Finally, we manually read and checked the names, abstracts, and keywords of each of the 527 publications to ensure that they were indeed within reach of OET, and we removed those that were not. As a result, we selected 399 papers as a final sample.

Table 3 Sub-research questions of the study

The quantitative overview of the dataset	**Performance analysis**
What is the number of articles per year?	
What are the most influential publications?	
Which journals have the highest number of publications?	
Who are the most productive authors?	
Which countries have the highest publication?	
Which universities have the highest publication?	
Citation analysis	
What are the most-cited studies in OET literature?	
What are the most-cited journals in OET literature?	
Does the distribution of citations comply with the Bradford Law?	
Co-word analysis	**Science mapping**
Which terms are mentioned frequently in the OET literature? (density visualization)	
Which do co-word clusters occur? How do these clusters relate to each other? (network visualization)	
How do the mentioned terms in the OET literature change over time? (overlay visualization)	
Co-citation analysis	
Among most-cited studies, which do co-citation clusters occur? How do these clusters relate to each other? (network visualization)	

2. 3. Bibliometric Analysis

In this stage of the analysis, we applied performance analysis and science mapping as two different procedures. Analyses were matched with sub-research questions to operationalize the research question (see Table 3).

Performance analysis will be performed in two ways. Firstly, a summary of quantitative results (such as the number of publications per year, most influential publications, most influential journals, most productive authors, and so on) of the dataset will be presented. Then, we applied a citation analysis to show the most influential studies in the OET field. In the science mapping procedure, we extracted bibliometric networks by applying co-word and co-citation analysis.

3. Results of the Performance Analysis

The performance analysis aims to categorize scientific/bibliometric items (journals, authors, countries, and universities), as well as to assess and quantify their scientific output (Cobo et al. 2011). Also, this procedure focus on assess scientific production using specific quality and quantity indicators (Gutierrez-Salcedo et al. 2018). Information about the development and effect of a particular research area is collected via this method. Several metrics, such as the number of publications, citations, frequently cited publications, number of non-cited publications, research field classification, and normalized citations, may be derived from the publication core (Moral-Munoz et al. 2020). We applied performance analysis into two levels as a quantitative overview of the dataset and citation analysis.

3.1. Quantitative overview of the dataset

This section, centered on basic bibliometric metrics, offers a detailed overview of the 399 articles downloaded dataset about OET.

What is the number of articles per year?

Based on the annual number of publications, Figure 2 depicts the evolution of the OET literature in the WoS database. There are 374 articles out of the 399 publications, while reviews account for 18 and editorial materials for the remaining seven. It is clear from these figures that empirical articles have been conducted more within the framework of the OET than reviews.

Figure 2 shows how the number of publications published in the OET literature has fluctuated over time. In addition, over the last four years, the number of articles has steadily declined.

However, the number of publications in the literature of other theories, such as Institutional and Resource Dependence Theories, has consistently increased over time. Moreover, the percentage of papers

Table 4 Most-cited publications in dataset

Publication	Publication Name	Journal	No. of Cit.	Links
Baum & Oliver (1991)	Institutional Linkages and Organizational Mortality	*Administrative Science Quarterly*	760	32
O'reilly & Tushman (2008)	Ambidexterity as a dynamic capability: Resolving the innovator's dilemma	*Research in Organizational Behavior*	756	3
Haveman (1993)	Follow the Leader: Mimetic Isomorphism and Entry into New Markets	*Administrative Science Quarterly*	672	31
Shane & Stuart (2002)	Organizational Endowments and the Performance of University Start-Ups	*Management Science*	650	1
Geroski (2000)	Models of technology diffusion	*Research Policy*	633	1
Burgelman (1991)	Intraorganizational Ecology of Strategy Making and Organizational Adaptation: Theory and Field Research	*Organization Science*	614	15
Zaheer & Mosakowski (1997)	The Dynamics of the Liability of Foreignness: A Global Study of Survival in Financial Services	*Strategic Management Journal*	537	5
Baum & Mezias (1992)	Localized Competition and Organizational Failure in the Manhattan Hotel Industry, 1898-1990	*Administrative Science Quarterly*	433	58
Pennings, Lee & van Witteloostuijn (1998)	Human Capital, Social Capital, and Firm Dissolution	*Academy of Management Journal*	391	9
Baum & Ingram (1998)	Survival-Enhancing Learning in the Manhattan Hotel Industry, 1898-1980	*Management Science*	379	13

We obtained citation counts of the publications from VOSviewer software. As of December 2020, citations are derived from the Web of Science database.

Table 5 Most prolific journals

Journal	No. of articles	Impact factor (IF)	Total citations
Administrative Science Quarterly	30	8.30	5455
Organization Science	29	2.79	2559
Organization Studies	28	3.92	948
Strategic Management Journal	20	5.46	2439
Industrial and Corporate Change	19	1.98	436
Academy of Management Journal	17	7.57	1835
Advances in Strategic Management-A Research Annual	16	0.75	-
Journal of Business Venturing	9	7.59	359
Journal of Organizational Change Management	9	0.96	53
Academy of Management Review	8	8.41	421
Management Science	8	3.93	1295
Technological Forecasting and Social Change	8	5.84	136
Journal of Management Studies	7	4.88	306
Research Policy	6	5.35	1183
Journal of Management	5	8.85	146
Small Business Economics	5	4.80	210

We obtained citation counts of the publications from VOSviewer software. As of December 2020, citations are derived from the Web of Science database. We acquired Journals' impact factor from their website and Clarivate Analytics in December 2020.

Table 6 Most productive authors in the OET field

Author	No. of articles	Total citations
Carroll, GR	14	1256
Van Witteloostuijn, A	13	586
Barnett, WP	12	1064
Boone, C	10	286
Dobrev, SD	10	506
Lomi, A	10	282
Wezel, FC	9	118
Baum, JAC	7	1992
Hannan, MT	6	741
Larsen, ER	6	126
Greve HR	5	547

We only include authors contributing to the field with five or more articles. As of December 2020, citations are derived from the Web of Science database. Also, we obtained citation counts of the publications from VOSviewer software.

published before 2000 within the total number of articles (% 21,3) is quite remarkable. This ratio shows the theory's historical legacy. Also, with 25 articles, 2006 was the year with the most articles written.

What are the most influential publications?

Table 4 shows the most-cited publications in the data set. This numerical data is essential in terms of delivering the most influential studies in the data set. In addition to the ten most-cited articles, we present in the table the direct citation relationship information of these articles with each other.

Which journals have the highest number of publications?

Table 5 shows the journals in which five or more articles about the OET are published in our dataset. There are 399 papers in the final survey, which were written in 153 separate journals. The 17 journals mentioned in Table 5 published about 57 percent of the 399 papers. The 2019 impact factors and total citations of the listed journals are also shown in Table 5.

The most productive journal is *Administrative Science Quarterly*, which has 30 articles published, respectively followed by *Organization Science* with 29 articles, *Organization Studies* with 28 articles, and *Strategic Management Journal* with 20 articles. Table 5 shows the journals with reasonably high impact factor value. Furthermore, we can assume that journals that publish OET-related articles are of relatively high quality. With very high impact factor values, Journal of Management (IF: 8.85), Academy of Management Review (IF: 8.41), and Administrative Science Quarterly (IF: 8.30) are the highest-ranked journals in the "Management" and "Business" fields according to WoS Journal Categorization.

Who are the most productive authors?

The 399 papers in our sample included a total of 721 authors. The authors who contributed to five or more publications are mentioned in Table 6. Carroll is the most prolific author in terms of article output, having authored 14 articles with 1256 citations. Table 6 reveals an unexpected result: Hannan, as one of the theory's founders, joined the list with minimal articles, while Freeman did not even list. Another interesting finding is that Witteloostuijn and Boone have a relatively large number of articles. They were also the forerunners of theory creation in Europe.

According to the Table 6, 629 of the 721 authors (or more than 80%) contributed to the field with one paper. In addition, when we look at whether a single author or multi-authorship wrote the papers, we find that 109 articles were single-authored. This finding demonstrates that there is no sign to mention a well-structured epistemic community who publish together regularly. In this context, almost three-quarters of the articles were written by more than one author. This ratio can be interpreted as the presence of community and the authors' tendency to collaborate. However, compared to other organizational theories' literature, the number of publications with a single author in the OET literature is considerably higher.

Which countries have the highest publication?

Researchers from 41 different countries wrote a total of 399 articles. Table 7 shows the prominent countries in the OET literature, based on the number of publications and overall citation counts. Table 7 shows the top countries that contributed five or more publications.

We only include countries contributing to the field with five or more articles. As of December 2020, citations are derived from the Web of Science database. Also, we obtained citation counts of the publications from VOSviewer software.

Table 7 Prominent countries

Country	No. of articles	Ratio (%)	Total citations
USA	221	55.38	12852
CANADA	38	9.52	2251
ENGLAND	37	9.27	1514
NETHERLANDS	36	9.02	949
ITALY	21	5.26	253
CHINA	19	4.76	294
AUSTRALIA	18	4.51	166
GERMANY	17	4.26	291
FRANCE	16	4.01	379
BELGIUM	14	3.50	337
SWITZERLAND	9	2.25	148
SOUTH KOREA	8	2.00	582
SPAIN	8	2.00	200
ISRAEL	6	1.50	168
SWEDEN	6	1.50	192
FINLAND	5	1.25	189
TAIWAN	5	1.25	15

We only include universities contributing to the field with six or more articles. As of December 2020, citations are derived from the Web of Science database. Also, we obtained citation counts of the publications from VOSviewer software.

Table 8 Most Productive universities

University	No. of articles	Total citations
STANFORD UNIV	30	3205
UNIV CHICAGO	16	1557
UNIV CALIF BERKELEY	14	1103
UNIV TORONTO	13	981
TILBURG UNIV	10	151
UNIV ANTWERP	10	198
UNIV BOLOGNA	10	114
EMORY UNIV	9	306
CORNELL UNIV	8	596
UNIV ILLINOIS	8	297
UNIV GRONINGEN	7	72
UNIV PENN	7	672
DUKE UNIV	6	387
UNIV MICHIGAN	6	550
UNIV MINNESOTA	6	146
UNIV UTRECHT	6	71
YORK UNIV	6	956

The USA is the most productive country with 221 articles, followed by Canada with 38, England with 37, and the Netherlands with 36. As a result, the United States dominates the OET literature, contributing approximately 55% of all fields' publications.

Which universities have the highest publication?

Researchers from 403 different universities wrote a total of 399 articles. Researchers in 290 of the 403 universities contributed to one paper. Table 8 displays the most

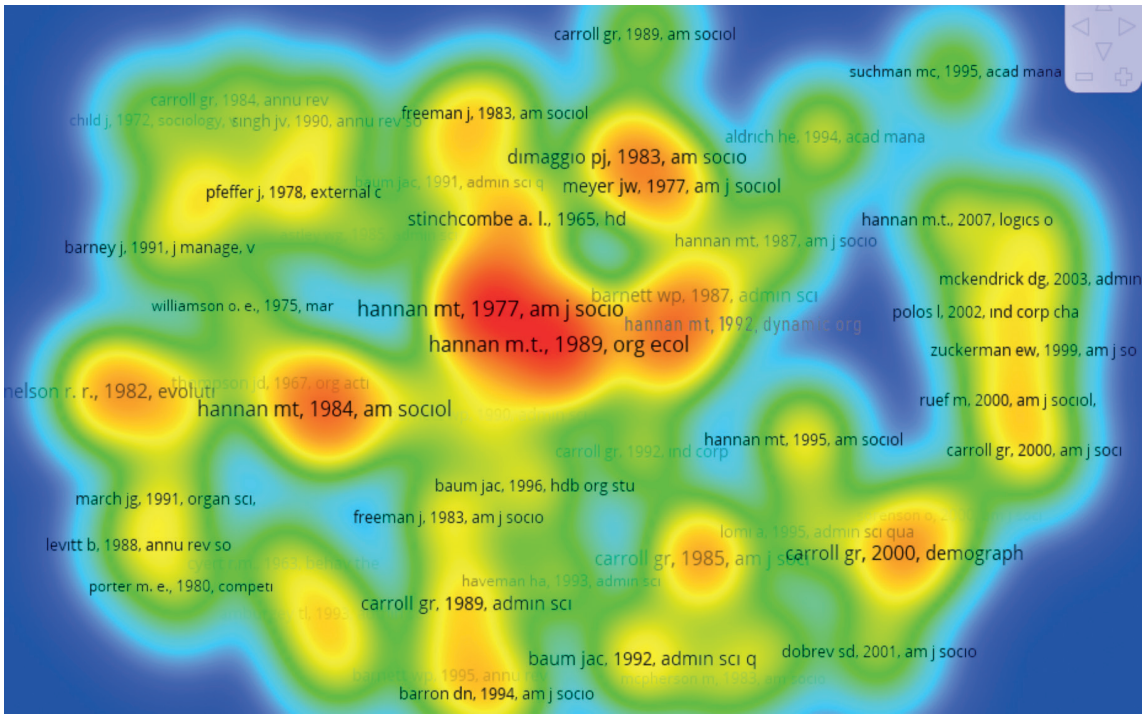

Figure 3 Most influential studies in the OET field. *Notes:* Created with VOSviewer based on a sample of N=399 articles (included in Web of Science). As of December 2020, citations are derived from the Web of Science database (online color figure).

prolific universities in the OET literature, as measured by the number of published articles. Table 8 lists the top universities that contributed six or more publications to the OET literature.

With 30 papers receiving 3205 citations, Stanford University is the most active contributor to the topic. The University of Chicago, the University of California Berkeley, and the University of Toronto follow the rankings.

3.2. Citation Analysis

Performance analysis aims to assess different scientific actors' scientific output on citation impact. Hence, a citation analysis was also carried out as part of the performance analysis. It is possible to classify the most cited (or influential) studies, authors, or journals in a research field using citation analysis (Zupic and Cater 2015). Therefore, citation analysis offers details on the relative importance of studies in a particular research area (Usdiken and Pasadeos 1995). As a result, highly cited studies are likely to be essential or contain more significant contributions than studies that earn little to no citations. The results of the citation analysis are summarized below.

What are the most-cited studies in OET literature?

Here, we conducted a publication-level citation analysis to identify the most influential studies in the OET literature. In total, 17235 studies were cited by the 399 articles in our sample. However, we set the minimum threshold at 30 citations (requiring research to be cited at least 30 times) by the 399 publications to be included in our analysis results. In total, 57 studies met the criteria. Figure 3 depicts the most prominent (cited) studies in terms of Web of Science citations.

The figure's red areas represent the most frequently cited studies, while yellow areas represent the less frequent ones. Also, green and blue areas represent the least cited studies. The font size indicates the citation numbers of the cited studies. Since it is the field's masterpiece, Hannan and Freeman (1977) is the most cited study with 192 citations (11737 in Google Scholar). Hannan and Freeman's book (1989) got the second-highest citations (186 citations, but 7432 citations in Google Scholar). This book covers the theory in general and the fundamental approaches and principles that underpin it. The third most cited study is Hannan and Freeman's (1984) article published in American Sociological Review earned 129 citations (9803 in Google Scholar). It is a descriptive conceptual study that addresses structural inertia, which is one of the fundamental issues of the theory. On the other hand, Hannan and Carroll (1992) received 112 citations (1946 citations in Google Scholar). This work is about organizational population dynamics (density, validity, and competition), which are the theory's key concerns.

The most cited studies mentioned above are that they are conceptual studies written on the theory's general assumption sets or fundamental concepts. Researchers who want to learn more about a subject, literature, or research field should start with those conceptual studies. In this respect, these are generally frequently cited.

Table 9 Most-cited journals

Top 20 Journal	No. of citations
Administrative Science Quarterly	2074
American Journal of Sociology	1380
Strategic Management Journal	1189
American Sociological Review	943
Academy of Management Journal	942
Organization Science	742
Academy of Management Review	733
Industrial and Corporate Change	415
Organization Studies	349
Annual Review of Sociology	309
Management Science	303
Journal of Business Venturing	272
Journal of Management	237
Journal of International Business Studies	235
Research Policy	221
Research in Organizational Behavior	209
Organizational Ecology and Institutional Change in Global Governance	193
Journal of Management Studies	187
Entrepreneurship Theory and Practice	173
American Economic Review	146

What are the most-cited journals in OET literature?

Here, we conducted the journal-level citation analysis. A total of 7129 journals were cited in the 399 papers in the sample. We set the minimum threshold at 30 citations. To be included in our analysis results, a journal had to be cited at least 30 times. 92 journals met this criterion in total. The results are shown in Table 9.

Created with VOSviewer based on a sample of N=399 articles (included in Web of Science).

With a total of 2074 citations, *Administrative Science Quarterly* is the most cited publication. *American Journal of Sociology* (1380 citations), *Strategic Management Journal* (1189 citations), *American Sociological Review* (943 citations), and *Academy of Management Journal* (942 citations) are among the most frequently cited journals.

Does the distribution of citations comply with the Bradford Law?

The distribution of the most-cited articles was tested to see whether they adhered to Bradford's Law. According to the law, "*there is always a small group of core journals that cover a significant percentage (1/3) of articles in a subject, field, literature, research area, or discipline. A second larger number of journals cover the other third of these articles, and a much larger number of journals cover the last third*" (Garfield 1980). A total of 17235 references (and 7129 journals) were cited in the 399 articles. The top 5 journals in Table 9 received more than a third of (6528 citations in total) overall citations cited by the 399 papers. In this respect, the distribution of citations appears to follow Bradford's Law. Therefore, it's possible to suggest that a core group of journals directing the field.

4. Results of Science Mapping

Science mapping represents how disciplines, areas, specialties, and individual papers or authors are connected by their physical proximity and relative locations (Small 1999; Gutierrez-Salcedo et al. 2018: 1276). Since the performance analysis procedure results can be obtained about the performance of scientific actors, no details can be acquired about the relationship and interaction between these actors. In other words, by conducting performance analysis, adequate knowledge cannot be attained about the intellectual, conceptual, and social structures (Aria and Cuccurullo 2017) and dynamics of a research field (Cobo et al. 2011).

Visualizing bibliometric networks often referred to as science mapping. Visualization has proven to be a powerful tool for analysing a wide range of bibliometric networks; including networks of citation relationships between publications or journals (co-citation and bibliographic coupling), networks of co-author-

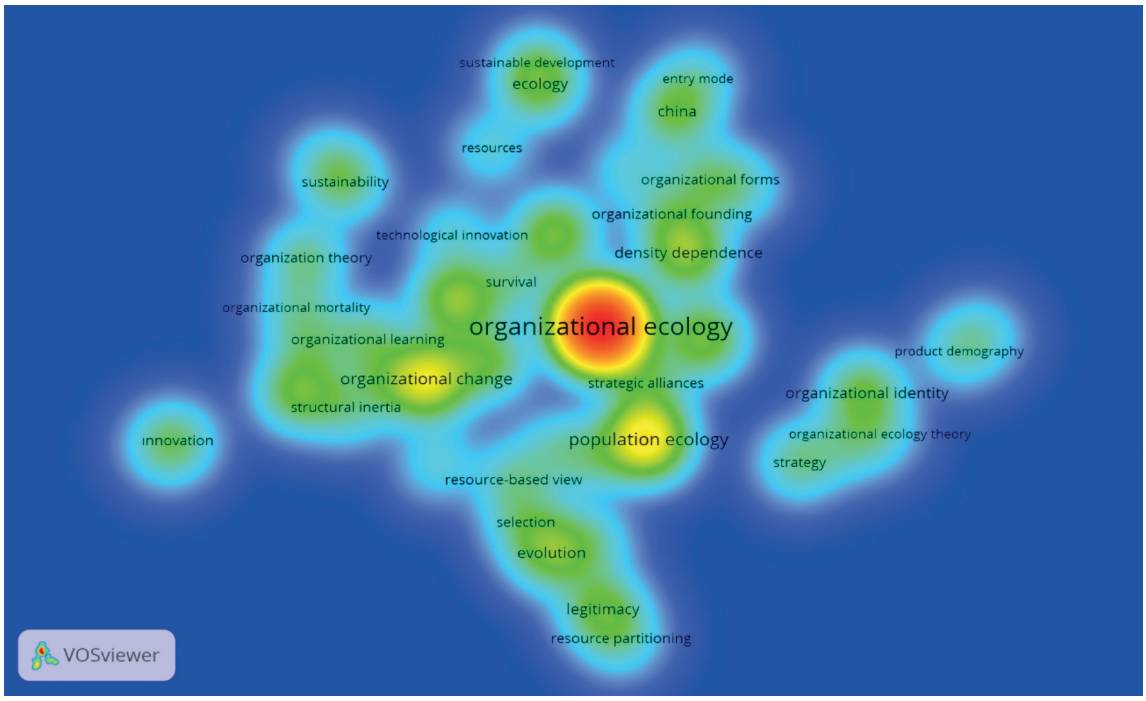

Figure 4 Frequently mentioned keywords in the OET field. Notes: Created with VOSviewer based on a sample of N=399 articles (included in Web of Science, color figure online).

ship relationships between scholars, and networks of keyword co-occurrence relationships (van Eck and Waltman 2014).

We applied co-word and co-citation analysis within the scope of science mapping to attain a thematic overview of the field.

4.1. Co-word Analysis

Co-word analysis, also known as the co-occurrence of keywords (van Eck and Waltman 2014), is a type of content analysis that uses the terms in documents to create relationships and extract a research field's conceptual structure (Callon et al. 1983).

Titles, keywords, or abstracts of documents are the analysis units of the co-word analysis (Block et al. 2020). Co-word analysis assumes that a collection of aggregated keywords can reveal underlying themes and that keyword co-occurrences can reveal associations with those themes (Hu and Zhang 2015). We conducted this analysis based on keywords rather than titles and abstracts. Due to being widely agreed that keywords accurately represent the content of a study, we prefer this.

In this section, firstly, we determined the most used keywords in the OET field by performing density visualization. Secondly, we conducted network visualization to show the relationships between those keywords used together. Finally, by using overlay visualization, it has been shown how the keywords and the topics studied in the OET field have changed over time.

In these visualization maps, the distance between two terms can be interpreted as an indication of their relatedness. It is accepted that the closer the words are to each other, the stronger the relationship between them (van Eck and Waltman 2017).

Which terms are mentioned frequently in the OET literature?

The co-word analysis was carried out in the following stages: (1) we downloaded the 399-article data set from the Web of Science as plain text (*.txt file) and uploaded it VOSviewer software. (2) We conduct a keyword co-occurrence analysis by using the author keyword unit. (3) We found that in the 399 articles, 884 separate keywords were used in total. (4) We set a threshold for three appearances as a minimum requirement, which meant that a keyword had to be used at least three times to be included in our analysis. (5) A total of 48 out of 884 keywords meet the criteria.

The colors represent the density of words, ranging from red with the highest density to blue with the lowest density. In addition, the font size reflects how often the words are used. As shown in Figure 4, prominent OET terms include organizational ecology (center), population ecology (lower right), and organizational change (lower left), competition (upper left), and density dependence (upper right).

Which do co-word clusters occur? How do these clusters relate to each other?

Co-word analysis produces a network of themes and their relationships, which represents a field's conceptual structure (Börner et al. 2003). By conducting co-word analysis, VOSviewer provides network visualizations showing the relationship between the most used words

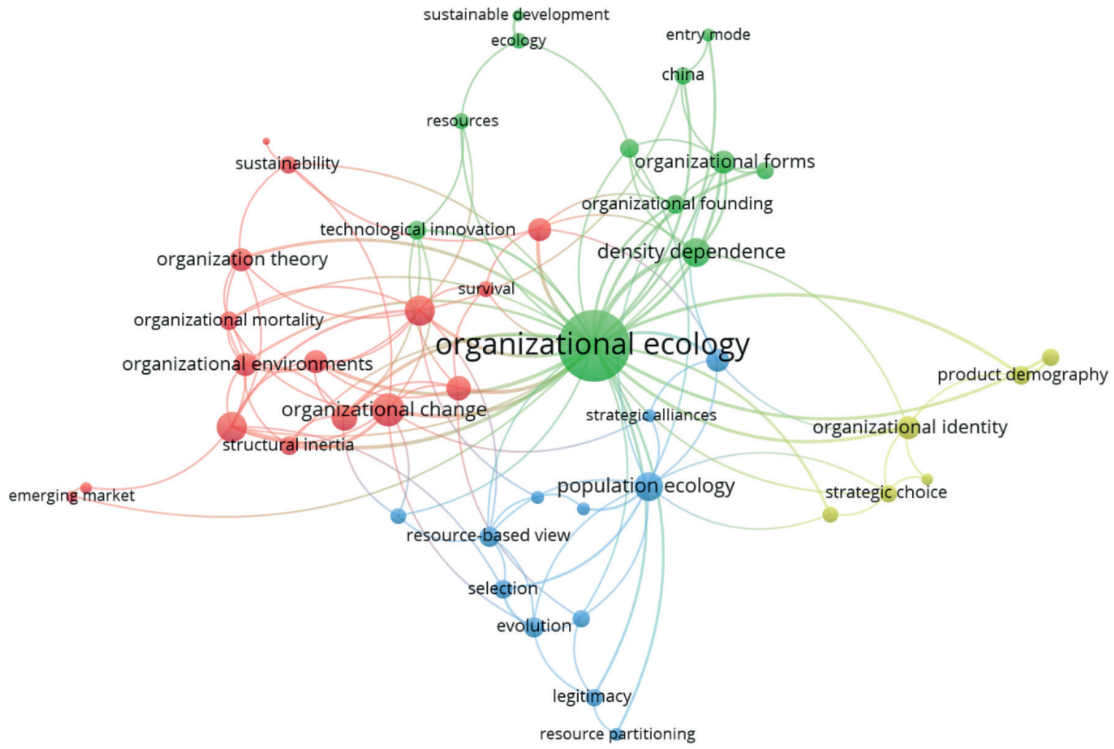

Figure 5 Network visualization of co-word analysis for clustering Notes: Created with VOSviewer based on a sample of N=399 articles (included in Web of Science, color figure online).

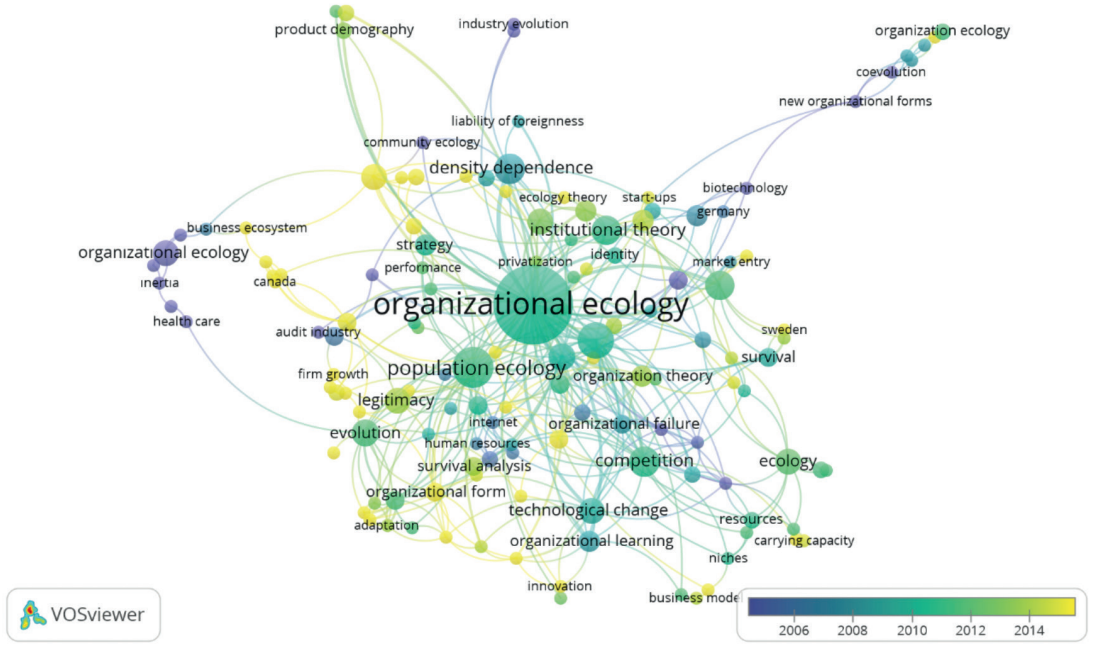

Figure 6 Overlay visualization of co-word analysis Notes: Created with VOSviewer based on a sample of N=399 articles (included in Web of Science, color figure online).

in the field. VOSviewer displays the position of the words in the link (total relationship) network and the total link strength. We can derive our clusters from these links. When words frequently co-occur in documents, it indicates that the concepts they represent are closely related (van Eck and Waltman 2017). The various colors and the positioning of the circles in network are used to cluster the keywords. The network visualization for clustering is shown in Figure 5.

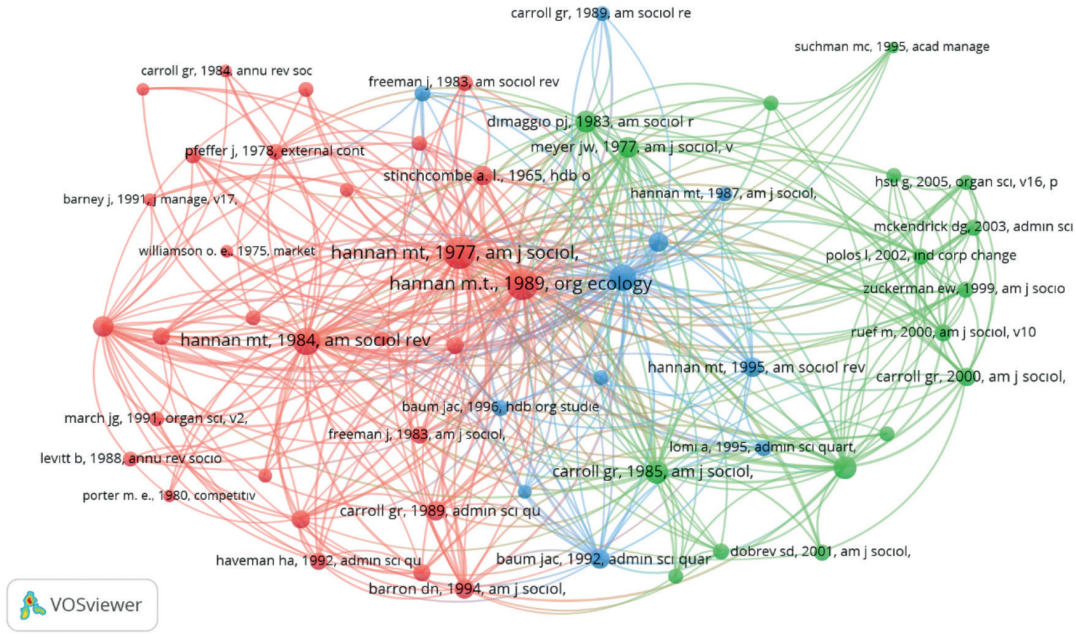

Figure 7 Network visualization of co-citation analysis for clustering Notes: Created with VOSviewer based on a sample of N=399 articles (included in Web of Science, color figure online).

Figure 5 displays the clusters through the relationship networks and the total link strength of the keywords of the articles. Each color in the figure represents a separate cluster. Four clusters have emerged based on the relatedness of the keywords. The red cluster contains keywords related to environmental change issues in general. The green cluster includes the emergence of new organizational types and the entry of new organizations into the existing population within the density dependency logic. The blue cluster focuses on selection mechanisms within the population. Finally, the yellow cluster focuses on the strategic choice issue in organizations' identity constructions.

How do the mentioned terms in the OET literature change over time?

The evolution of the main topics in the field over time can be evaluated using co-word analysis (Liu et al. 2012). VOSviewer offers overlay visualization for this evaluation. With overlay visualization, researchers can track changes in conceptual space created for various periods (Coulter et al. 1998).

We set a threshold for two appearances as a minimum requirement. A total of 147 out of 884 keywords meet threshold. Figure 6 shows the overlay visualization of co-word analysis.

Figure 6 displays the evolution of the keywords used in the period. The early 2000s to the late 2010s are shown with different colors. On the timetable, the color range of visualization begins with purple and progresses to yellow. In the 2010s, the terms with green color are dense on the visualization map. Figure shows that the studies in the field of organizational ecology and the use of terms related to this field became widespread between 2008-2012. It is seen that the number of studies in the field has a decreasing trend after 2014. Relatively old studies of the field use keywords such as new organizational form, organizational failure, first-mover advantage, organizational founding, co-evolution. Organizational ecology, organizational change, population ecology, competition, technological change keywords stand out between the years 2008-2012. Organizational identity, organizational environment, organizational form, strategic choice, innovation are prominent topics after 2014.

4.2. Co-Citation Analysis

One of the citation-based science mapping methods is co-citation analysis (Schröder et al. 2021). Co-citation is an analysis technique that gives images of the most cited works together. Two documents are co-cited when they are both cited by at least one paper in particular (Small 1973). Although it is a citation-based analysis technique, co-citation analysis can determine the thematic similarity between articles in the data set (Kessler 1963).

When two articles earn more co-citations, their citation link strength increases, and they are more likely to be semantically relevant. In other words, the co-citation analysis has been identified as a more accurate measure of thematic similarity (Small 1973). Therefore, when clusters are found through co-citation analysis, thematic clusters are reached as in co-word analysis.

Among most-cited studies, which do co-citation clusters occur? How do these clusters relate to each other?

The citation analysis identifies the most cited studies in the field, and a density visualization was reached on the citation frequencies. This section provides network

Table 10 Summary of the contents of the three co-citation clusters

Clusters Description	No. of pub.	Important publications	Characteristic Terms and Themes	Color
Environmental Change: Adaptation vs. Selection	29	Hannan and Freeman (1977) Hannan and Freeman (1989) Hannan and Freeman (1984) Nelson and Winter (1982) Stinchcombe (1965)	organizational change, technological change, structural inertia, selection, niche width, density dependence, demographic characteristics of organizations (age, size, complexity), organizational evolution, failure, organizational mortality, isomorphism, growth	**red**
Organizational Forms and Identity in Populations	17	Carroll and Hannan (2000) Carroll (1985) DiMaggio and Powell (1983) Meyer and Rowan (1977) Carroll and Swaminathan (2000)	organizational forms, identity, density, species, resource partition, niche width (specialists and generalists), organizational affiliation, isomorphism, legitimacy	**green**
Rising and Falling of the Organization Species	11	Hannan and Carroll (1992) Barnett and Carroll (1987) Baum and Mezias (1992) Hannan et al. (1995) Delacroix and Carroll (1983)	organizational founding, new-entrance/ venture, start-up, organizational decline, organizational failure, organizational mortality, density dependence (competition vs. legitimacy/mutualism), community ecology, population ecology, resource partition, and dependence	**blue**

Notes: We obtained citation counts of the publications from VOSviewer software. As of December 2020, citations are derived from the Web of Science database. In the second column, the five authors with the highest number of citations in a cluster are important authors. In the third column, the given characteristic terms were extracted from the titles, abstract, and introduction section of each publication belonging to a cluster using the methodology described by Waltman and van Eck (2012).

visualization, which depicts the relationships between the most co-cited studies in the OET literature.

Via this visual map, we were able to identify clusters based on the subject's similarity in the field. Co-citation analysis is carried out in three different analysis levels such as publication, journal, author. Since we want to reveal the subject similarity in the field, we performed a co-citation analysis at the publication level.

To conduct co-citation analysis at the publication level, firstly, we downloaded the 399-article data set from the Web of Science as plain text (*.txt file) and uploaded it VOSviewer software. In total, 17235 publications were cited by the 399 articles in our data set. We set the minimum threshold at 30 citations. In total, 57 studies met the threshold. Figure 7 shows the results.

Figure 7 shows the relationship networks and total link strength of the 399 articles in our dataset's most-cited publications. VOSviewer, by default, assigns the items in network visualization to clusters. A cluster is a group of closely related items that are colored differently. Each item is allocated to a single cluster in a network (van Eck and Waltman 2017).

In our analysis, VOSviewer has found three clusters. Of the three clusters, while the red one consists mainly of articles about environmental change and adaptation themes, the green one covers articles focusing on organizational forms and identity in populations. The blue one includes articles rising and falling of the organization species. Details on clusters are given in Table 10.

The red cluster is about what organizations do against environmental changes. In other words, the cluster focus

on the organization-environment relationship. Change is mentioned in cases where organizations operate in a dynamic environment. Technological change is particularly prominent in terms of change. Organizations' responses to change take two different forms: adaptation and selection. Organizations either survive or fail as a result of environmental change. Therefore, organizational change, natural selection, organizational mortality, failure, and evolution are the basic concept set of this cluster. The central concepts of other clusters such as density dependency, niche width, age dependence, size dependence are discussed to explain the organizational change.

The green cluster focuses on intra-population processes in general, particularly on forming organizational forms and identities within the population. In this respect, it consists of concepts under the heading of "organizational forms and identity" about how organizations in a population survive or fail. This cluster includes terms such as organizational species, identity, population density, size, resource partition, niche width (generalist and specialist), population width, penalties, and affiliation.

The blue cluster focuses on the emergence of new organizational species and the extinction of existing ones. It is seen that the concept of "density dependence" is used to explain this phenomenon. When the density in the population is low, the concept of legitimacy and when the density is high, the concept of competitiveness form the basis of explanations on the subject. Organizational founding, density dependence, community ecology, new entrance, organizational decline, organizational failure, organizational mortality are prominent keywords in this cluster. The community and the population are considered two different levels of analysis within the explanatory framework of the theory.

5. Conclusions

The objective of the paper is to overview OET literature. We present a comprehensive picture of the OET literature through bibliometric analysis, which examined the general overview and the evolution of OET literature between 1975 and 2020, based on articles in the WoS database. To accomplish the purpose of the study, we apply performance analysis (quantitative overview of the dataset and citation analysis), co-word analysis, and co-citation analysis. While this is not the first attempt to conduct a comprehensive and systematic review of academic OET research, it is the first strive to map an orderly conceptual and intellectual structure by applying bibliometric techniques.

Our results on the quantitative dataset indicate a fluctuating view of the number of articles over the years since OET literature dated back 1970s suggesting that the field is becoming more mature in the 1990s. The most influential papers can be traced around the 1990s. The top three influential publications in the data set are Baum and Oliver (1991), O'reilly and Tushman (2008), and Haveman (1993). The journals *Administrative Science Quarterly*, *Organization Science*, and *Organization Studies* published the most article on the topic. We also find that authors such as Carroll, van Witteloostuijn, Barnett, Boone, Dobrev, and Lomi published ten or more articles according to our dataset. The USA is a prominent country in terms of publication numbers. 55.38 % of all publications in our dataset are from this country. Canada (9.52%), England (9.27%), and Netherland (9.02%) follow the USA. The top universities with the highest publication number are Stanford University, the University of Chicago, and the University of California Berkeley.

The citation analysis results on publications show that Hannan and Freeman (1977, 1989, 1984) and Hannan and Carroll (1992) are the most-cited ones. In addition, the most cited journals are Administrative Science Quarterly, American Journal of Sociology, and Strategic Management Journal.

While this study aims to have a general review of the OET literature, we intend to have an inventory of past research to direct future research by using bibliometric techniques such as co-citation and co-word analysis. The results of both analyses overlap in terms of thematic clusters. These overlapping ***clusters*** (and prominent keywords in these clusters) are ***organizational change*** (technological change, niche width, age, size, organizational evolution, co-evolution), ***organizational forms*** (new organizational form, identity, species, resource partition, organizational affiliation, isomorphism, legitimacy), and ***organizational founding*** (new-entrance, new venture, start-up, first-mover advantage) ***and mortality*** (organizational decline, organizational failure, density dependence). In the light of our research findings, we can propose some research questions to link previous research to direct future research, specifically in OET literature.

- How do technological changes affect organizations?
- How did unexpected global situations like the COVID-19 pandemic affect the pace of organizational change?
- What type of new organizational forms has been revealed in the unestimated future era?
- How the new organizational forms have been legitimized?
- What kind of new ventures have been triggered by future trends?
- What lessons can be drawn from failed organizations in the certain industries?
- Are there any cases of organizational extinction in the pandemic?
- What type of advantages do start-ups gain when they first enter an organizational population?

As with any research design, this approach is not without limitations. Some limitations are a consequence of the nature of the bibliographic databases and the bibliometric technique per se:

1. The bibliometric analysis was restricted to data retrieved from the WoS online database since it provides the information required to conduct a bibliometric analysis. In future studies, different sources of literature (e.g., Scopus) can be used simultaneously to overcome this limitation.

2. Only articles from peer-reviewed journals were included in this study, potentially restricting access to other results.

3. The weakness of the co-citation analysis results in evidence from frequently cited articles, while less frequently cited documents may have less impact on the research.

The results of the analysis via a bibliometric analysis provide some evidence that research streams have detectable characteristics. Since co-citation analysis and bibliographic coupling are citation-based techniques, it gives an idea about the chronology of evolution in the field. While co-citation analysis reveals the change historically, bibliographic coupling identifies new trends in the field. For this reason, in future research, the bibliographic coupling can be used to detect recent thematical trends in the field. It is hoped that the results presented in this paper will encourage and facilitate new OET research in the future.

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Evaluating Marketing and Trendy Topics from Marketing Managers' Perspective: Do the Work of Marketing Academicians 'Make Sense' to Marketing Managers?*

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ABSTRACT

This study aims to reveal how the new concepts and marketing practices, which have recently been trendy topics in the marketing literature, are perceived by the marketing managers as the target audience practitioners. The research is exploratory and adopts a phenomenological method. With purposeful sampling, data were obtained from 14 marketing managers through semi-structured in-depth interviews and analyzed with the grounded theory approach. Research findings show that marketing knowledge has two important effects on marketing managers: the interaction between academic knowledge and marketing practitioners and the interaction among marketing practitioners. Education – especially post-graduate education – is an important element that determines the direction of this interaction. While the practitioners with post-graduate degrees keep less distance with academic knowledge, the ones without post-graduate degrees use marketing with basic tools like price, promotion and underestimate knowledge. Having academic knowledge is seen as an important means of status and social discrimination in the relationship among marketing managers. As an original finding of the study, academic language is the tool that most clearly reveals this distinction. Although the distance between theory and practice is preserved despite the critical literature in this field, the individual requests of managers towards knowledge allow this gap to be diminished..

Key Words: : Marketing, Trendy Topics, Marketing Managers, Practice of Topics, Education, Theory-Practice Gap.

JEL Classification Codes: M30, M31, M39, M121

1. INTRODUCTION

More than half a century has passed since the 1950s, the concept of marketing was introduced. Developing technology, the disappearance of market boundaries, and changing competition conditions in line with changing consumer preferences (Appadurai, 1990) have also revealed new marketing concepts. Especially with the flow of information accelerated by technological developments, the spread of new concepts is also gaining momentum. These concepts, which academics in Turkey follow closely or have to follow, generally consist of concepts ‹imported› from other countries and included in literature by adopting in Turkish.

An important purpose of academic research in the marketing literature is to suggest marketing strategies that marketing practitioners can benefit from and to contribute to the development of the business world. However, recent literature covers how marketing knowhow is transferred (Aydin & Terpstra, 1981; Simonin, 1999), what the definition/concept of marketing should be (Levy, 2002; Lusch, 2007; Wilkie & Moore, 2007; Brooksbank et al., 2010; Keelson, 2012) or how marketing practices are interpreted by marketing academics (Levy, 2002; Gök & Hacıoğlu, 2010; Brooksbank et al., 2010; Bolajoko et al., 2013; Zeithaml et al., 2020). One of the studies trying to understand the marketing managers' conceptual perspective towards marketing concepts is Contreras & Ramos (2016)›s quantitative study. The authors reveal that marketing is reduced to a tactical dimension and perceived as promotional activities. Webster et al. (2005) reflected senior managers' perspective that marketing functions are disembodied. They are now embedded in product engineering and field sales as they are closer to the consumer.

This article aims to reveal how the new concepts and marketing practices, which have recently been included as trendy topics (can also be defined as "hot" topics in academic conversations) in the marketing literature, are perceived by the marketing managers, as target practitioners. In line with this, we will try to question

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* The first round results of this study were presented at the 22nd Marketing Congress.

the dimensions of the relationship that practitioners have with academic knowledge through marketing concepts. Although it is stated that academic knowledge is not visible to practitioners and marketing education is significant (Levy, 2002; Brooksbank et al., 2010), clarifying the question of how practitioners define this invisibility and in which areas they experience it is crucial.

The pursuit of this study, unlike the literature, is to understand the direct response of concepts in real life and practical evaluation of theory by practitioners who use them by directly asking them. The manifestation of marketing knowledge in concepts and activities (Akaah et al., 1988) has become a divergent approach in the abstract marketing literature and elaboration of marketing managers› practices is generally based on the interpretation of marketing academics. The reflection of these elaborations on marketing managers is uncertain. Accordingly, bringing out an explicit point of view of practice will contribute to the marketing literature and will also be an opportunity for indiscipline evaluation.

In the data collection process due to the emphasis on the importance of marketing education, the inclusion of education as a factor has come up and thus the sense of marketing education on the use of concepts has also been examined in the study.

2. Literature review

2.1. Development of Marketing Concepts and Trendy Topics

Discussions in the field of marketing start from what marketing is and bring its functions, scope, and activities to the agenda. The most important shift in the marketing perspective is from the distribution of products and services to the distribution of intangible elements such as ideas and values; from the distribution of physical elements to mental elements; from economy to non-economic issues, and from entrepreneurship to social activities (Bartels, 1974). At the core of all these discussions, there are concepts, topics, and definitions that will form the basis of marketing (Bolajoko et al., 2013). This will also utilize a framework to understand the development of marketing discussions with a spectrum encouraging trendy concepts.

One of the first marketing definitions accepted in the marketing literature presents a corporate perspective in which all marketing activities are integrated and coordinated, and as a result, these activities are blended with other corporate functions aiming to ensure long-term profitability as a basic goal of production (Felton, 1959). Shortly after Keith (1960) centered on customers, not the company, and described this as a marketing revolution. Examination of the difference between marketing and sales (Levitt, 1960), marketing mix elements (Borden, 1964), and the social aspect of marketing (Kotler & Zaltman, 1971) have advanced the definition of marketing.

In the 1990s, the concept of market orientation (Kohli & Jaworski, 1990; Narver & Slater, 1990; Jaworski & Kohli, 1993) was introduced, and academic discussions highlighted how the marketing concept should be applied. Eventually, value-based marketing emphasized that the companies aimed to make a profit by creating value within the framework of long-term relationships (Slater, 1997; Doyle, 2000).

The digital revolution, which left its mark on the marketing world in the 2000s, accelerated the flow of information and started a new era for both the academy and the business world. In this period, new concepts like digital marketing, which offers a new field and tool especially in the implementation of marketing activities (Bala & Verma, 2018; Desai, 2019), relationship marketing (Steinhoff et al., 2019; Steinhoff & Palmatier, 2021), experiential marketing (Lin, 2019; Soliha et al., 2021), mobile marketing (Narang & Shankar, 2019), social media marketing (Saravanakumar & SuganthaLakshmi, 2012; Dwivedi et al., 2015; Jacobson et al., 2020; Wibowo et al., 2021), content marketing (Kee & Yazdanifard, 2015; Koiso-Kanttila, 2004), event marketing (Gupta, 2003; Wood, 2009), agile marketing (Poolton et al., 2006; Accardi-Petersen, 2011; Hagen et al., 2018; Moi & Cabiddu, 2021), visual hammer (Ries, 2013), pop- up shop stores (Marciniak & Budnarowska, 2009), non -marketing (Akın, 2014; Memiş, 2017), new concepts such as brand love (Carroll & Ahuvia, 2006; Batra et al., 2012; Roy et al., 2013), microblogging (Yazdanifard et al., 2011) have emerged in the marketing literature. These concepts also demonstrate a more glimpse perspective instead of a holistic one conducing academicians to specialize in their theoretical discussions.

As marketing escalates its importance in social context enriching concepts and topics, it also becomes generic (Bolajoko et al., 2013). For this reason, the evaluation of the perspectives of the managers working in the field of marketing will also enable us to determine how much of the intellectual accumulation is reflected in practice. The presence or absence of these trendy concepts in practice will also reveal the value, pertinence, and the ‹necessity› of these concepts.

2.2. Practice of Marketing Concepts

Discussions on whether marketing is a science or not have brought different evaluations in terms of practice and theory. Taylor (1965) mentioned that the development of rich conceptual schemes should turn into usefulness that allows marketing managers to see the results of their decisions, and this usefulness should change the patterns in the market environment.

Marketing studies are considered a science through the process of theoretical contribution and art through practice (Taylor, 1965: 53). While Bartels (1983) mentions that the outcomes of education should be attributed to the relationship between academia and business, he resides marketing to empirical research. Years later, Simkin (2000) is concerned that marketing is not a science and ends his discussion with the following statement: "The basic marketing toolkit is applied differently and requires more than minor "tweaking" to tackle the characteristics of many industrial business-to-business products, target markets, and even marketing managers." (p. 158). This approach has justified the treatment of marketing as a discipline (Akaah et al., 1988). For this reason, the application of marketing know-how manifests itself in the concepts and activities in the discipline (Akaah et al., 1988).

The fluid-structure of marketing and micro-theoretical discussions provoked the gap between marketing practitioners and marketing literature (knowhow). Recent discussions refer to the fact that marketing academics are irrelevant to the process, confusion about the definition of marketing complicates the work of marketing managers resulting in a deterioration in marketing discipline (McDonald, 2009). The top of marketing mind issues is generally borrowed from different fields impeding discipline-specific knowledge and discussions are forced to adapt to a theory instead of focusing on the stakeholder problems augmenting the gap between practice and theory (Zeithaml et al., 2020). The use of the most appropriate marketing theory to the problem encountered in practice is the point where marketing knowledge is put into practice (Carson & McCartan-Quinn, 1995). For this reason, the development of a marketing practice approach for problem-solving is an important evaluation point in the reflection of the academic discussions to practice (Hunt, 2007; Zeithaml et al., 2020).

3. Methodology

The aim of this study is to examine how the trendy concepts in marketing literature are understood and applied in the business world, and therefore we address to shed light on this field of marketing literature from a different perspective. Thus, we direct to present a discipline evaluation to both practitioners and academicians working in this field of marketing in addition to the relations between academia and practice.

The study is designed as exploratory research, and the qualitative research method was used to examine the subject in depth. Qualitative research supports the nature of exploratory studies by enabling researchers to delve deeper into the subject on the basis of the participants within the research field. The exploratory nature of this study helps both to understand how current marketing concepts are evaluated by managers as practitioners and to obtain representative feedback on academic education.

As a data collection method, the phenomenological in-depth interview technique was used to enable participants to express their experiences and opinions (Pollio et al., 1997). The aim of the phenomenological interview is that the participants freely make sense of their own experiences and reveal their subjective approaches (Hopkinson & Hogg, 2006). Accordingly, the researchers were in the field with the list of dimensions to be discussed within semi-structured interviews, but the participants were allowed to guide the interviews.

The profile of the participants participating in the research is shown in Table 1.

The purposive sampling method was used to determine the participants participating in the research. In this context, in the first stage of the data collection, we contacted via email marketing and/or sales executives working in private sector companies operating in Izmir and doing a master's with non-thesis degree (post-graduate) in Business Administration or Marketing Management programs in Izmir. Master's with non-thesis programs address private sector practitioners and for graduation, instead of a thesis, they accomplish a project including research in their program specialization. Course programs were adapted to their working hours. As follows, these programs are means to bridge marketing academic knowledge and practice so that our motivation to include them in sampling. In-

[1] Whether to receive a master's with non-thesis degree in Business Administration or Marketing.

Table 1. Demographic Profile of Participants

Participants (P)	Gender (F: Female, M: Male)	Education[5]	Interview Duration (min.)	Position in the Company
P1	F	Master with Non-Thesis	46:10	General Secretary of the Board of Directors (Sales-Marketing Department)
P2	M	Master with Non-Thesis	42:01	Izmir Regional Sales Chief
P3	F	Master with Non-Thesis	25:17	Marketing And Corporate Relations Specialist
P4, 5	F, F	Master with Non-Thesis	37:52	Sales-Marketing Manager, Agency Operations Manager
P6	M	Master with Non-Thesis	38:42	Turkey Sales and Marketing Executive
P7	M	Master with Non-Thesis	46:28	Izmir Regional Dealer Manager
P8	F	Master with Non-Thesis	44:35	Marketing Manager
P9	F	Graduate	46:59	Assistant Product Manager
P10	M	Graduate	48:10	Company Manager
P11	F	Graduate	38:04	Product Manager
P12	F	Graduate	41:04	Turkey Sales Director / Marketing Manager
P13	M	Graduate	53:23	Sales Representative
P14	F	Graduate	35:46	Marketing Expert

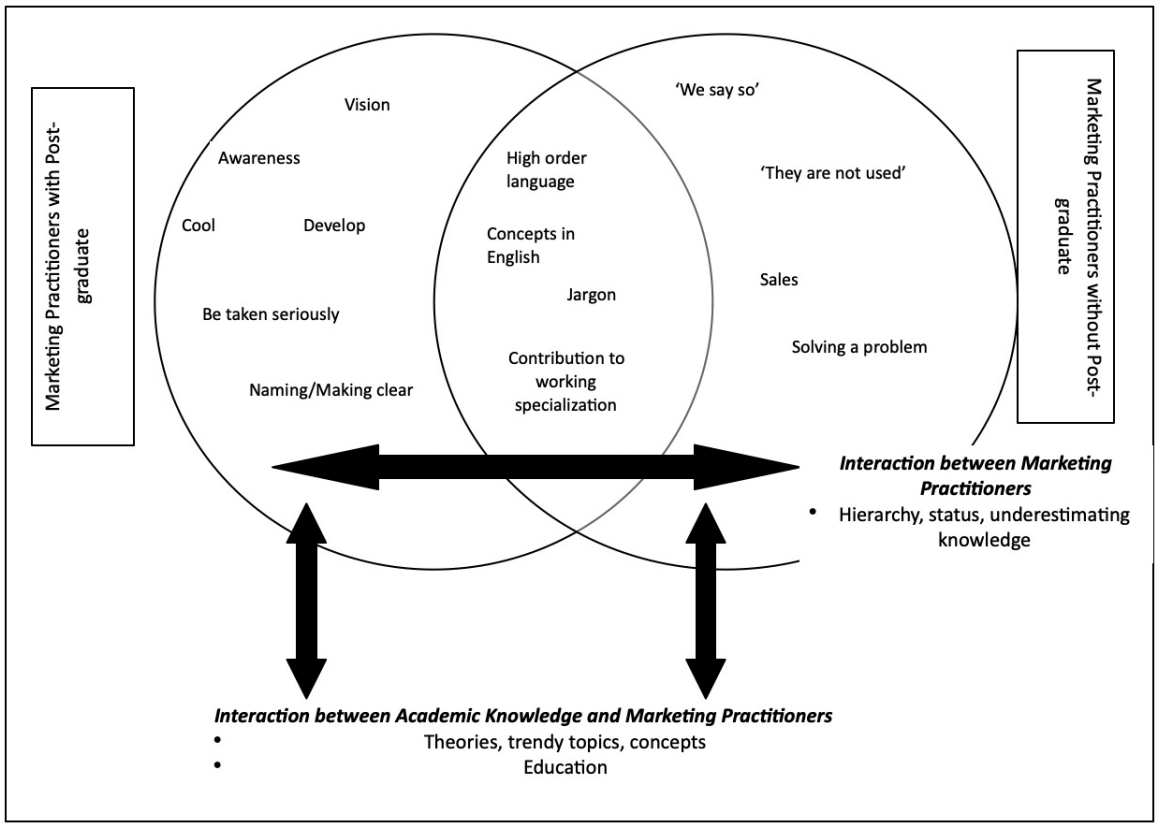

Figure 1. Representation of Focus Concepts and Interaction Expressed Around Marketing Concepts by Participants with and without Postgraduate Education

depth interviews were conducted with the volunteer participants. The criterion in the selection of the sample is to reach the marketing managers of the companies that are active in the consumer/industrial market. At this stage, we interviewed 8 marketing managers till we revealed the 'patterns' at the data saturation point of adding nothing new with new data (Mason, 2010). In this process, the most important factor affecting the views of the participants on marketing concepts was education. The fact ideas of our participants with post-graduate are reflected in the findings as their proximity to current and fundamental concepts, knowing the content of the concepts, and using these concepts greatly to affect their ‹vision› in their working life. For this reason, in the second stage of the study, we aim to answer the question of ‹How do marketing managers who do not have a post-graduate approach to these concepts?›. At this stage of the data collection process, interviews were held with people who did not have a post-graduate in the aforementioned fields. Interviews were held with 6 marketing managers fitting this criterion, and after the interviews, we followed the grounded theory approach in coding the data allowing the text to guide the researchers instead of predetermined themes (Graneheim & Lundman, 2004).

4. Findings

On the academic side of marketing, the discussions about determining and meeting consumer needs, ensuring the long-term ‹existence› of the company in the market, increasing profitability, and directing the development of activities, plans, strategies, or tactics in this direction (Taylor, 1965; Bass, 1993) are taking place, these are turning into tools for practitioners in the market. These actors are intermediates by turning academic knowledge into practice for business purposes and contributing to academia with their outcomes.

Our findings reflect two angles: The interaction between academic knowledge and practitioners and among practitioners through academic knowledge. In Figure 1, we illustrate the basic concepts of our findings. These two angles are discussed with a blend of education as an important threshold value that changes the perspective.

4.1. Findings Between Academic Marketing Knowledge and Practitioners

Recently the news titled 'Professor, no one is reading you!' (https://t24.com.tr/haber/profesor-hic-kimse-sizi-okumuyor,298153) called attention to the willing/unwilling disconnection of communication/ interaction between academics and non-academics and within the academy itself. It was provoking to think about education, practice, and theory and serve as a motivation to study. Our findings contribute to this discussion in terms of post-graduate education with a declaration: ***'Maybe they don't read but they listen'***.

"[Trends] I don't think it's possible for me to reach every single one of them completely, but [with post-graduate] at least I read a book at work or look at a book about a concept I've heard at school, at least I try. you can't sit down and study everything because then you cannot work, maybe we don't know a lot of things in detail, like you, you know, many terms of marketing are your skills. For you, it is a skill, not knowledge. Well, it is not possible for us to be like that, but if we heard of its existence at least once, we opened it and looked and what was it? What's in it? So, we can go back again" (P1)

"[With post-graduate] You start not looking at things the same way, especially if you work in the same industry for a long time, it starts to go blind. You start doing the same things involuntarily. When you learn something, when you add something new, you want to apply it too, and this is already reflected in your success. The brand is renewed, the brand identity is revived" (P 3)

Post-graduate guides managers in adopting new approaches and implementing them. While the dynamic structure of working life makes it difficult for practitioners to follow the academic literature, continuing education facilitates the adoption of new concepts to the extent that they match the work done. Thus, as long as they continue their education, they ensure that the practical theory that comes with the concepts such as the content, application, results and difficulties of the concepts are taken together and enable them to deal with the application with a holistic approach when they go into practice.

"This is the best part of the training we have received. The education we receive overlaps with our work at this point. At school, they say us to make people dream so we come here to learn how to make people dream and we put it into sentences here somehow." (P5)

4.1.1. Approaches to Marketing and Dealing with Marketing Concepts

Postgraduate education is effective in creating awareness of the importance of marketing activities, while enabling participants to understand what marketing really is. Therefore, it also helps them develop

a critical perspective on the general functioning of the marketing concept in Turkey and their performance.

"In Turkey, it is something like ımm, in companies like us, marketing is just memo pad, fair preparation is like a billboard" (P1)

"Are we doing marketing? We question this every time after the course. It creates a very interesting perception." (P4)

While postgraduate education is a real 'vision' element for the participants, it helps them to adopt more innovative approaches and develop a perspective that aims to 'take it further'. Therefore, marketing activities are more of a *purpose*.

"What interests me is the movements that can be captured in real-time, that is, being able to catch the consumer at that moment, being able to respond at that moment on social media. There are software related to this that work in the background, maybe to apply them, to surprise the consumer. To collect and analyze that information of the consumer and send a message to him as soon as he is at that moment. For example, there is beacon technology, so when you pass by the store, if Bluetooth is on, you can catch it and there is a special discount for you. I think this is the point to come. But there is not enough awareness about it, and we cannot implement it now. I'm just reading, so we can't do that right now." (P3)

Participants without post-graduate, on the other hand, focus more on the effectiveness of marketing. It shows that they have a perspective of how marketing works but from a selling concept (Keelson, 2012) that they treat it more as a ***tool*** focusing on 'earnings'.

"Sales and marketing in Turkey are the same, you know, sales-marketing, sales- marketing. Actually, sales are different, marketing is different. It starts with marketing, maybe the first step is promotion, relationship with sales, and relationship with marketing. That's my perception because marketing is a bit of perception management." (P13)

"[…] Marketing is all about perception management for me, I mean. After the sale .. The important first step is sales, but of course, you still need visuals and the necessary instruments to reach the consumer in order to create a perception while making the sale." (P11)

"I can't say that things won't change if scientific research reaches us, but it might change, but as I said, I'm not sure if it will create such an incredible effect and move it to a completely different point. I don't think it will be like that" (P9)

Participants with post-graduate education know and use basic concepts such as 'social media marketing', 'relationship marketing' and they know concepts such as 'visual hammer', which can be considered a trendy topic. They also express their unfamiliarity with the concepts that they don't know. Besides, they develop 'awareness' of some new trendy marketing concepts (guerrilla marketing, content marketing, etc.) in the blogs they follow, in line with their academic interest in post-graduate education. On the other hand, participants without post-graduate education focus on the content required by their job description. Therefore, concepts matter if they provide practical benefits like solving a problem or increasing sales (Hunt, 2007; Zeithaml et al., 2020).

"[Asking green marketing] Can you explain? [Explained]. Unfortunately, we did not have such studies. Why not? It's beautiful. We want to turn to social responsibility projects a little bit to create the perception there again in terms of marketing. It's a different project, but it's still like a branch of marketing." (P11)

The main difference between the two groups is 'vision'. The basic distinction here is the above-mentioned 'instrumentality' and 'purposiveness'. This is fed by the approach to marketing. Because how marketing is discussed determines how marketing concepts are discussed. While the participants with post-graduate education apply the trends and follow the results for improvement of work, the participants without post-graduate education deal with the trends to solve the problems they observe.

"[Marketing concepts] I think they will work as long as they solve a problem." (P11)

"I think one of the most important things in the marketing trends right now is to use more active sense organs and we are directing workers to launch this to the end customer, and the customers like it. Previously, when purchasing a [product name], people only looked at the year, but now they wonder about the taste and smell, they ask about it, and we started to move in this direction, we saw that it works." (P2)

"R: For example, there is a concept called content marketing.

P12: speak more of this term. to We use it as the market. We have our own concepts within ourselves, as I said, everyone determines a concept according to their own needs. Or it sets a slogan. These can obviously differ from company to company. In other words, each company can organize a slogan according to itself."

"R: How did you learn about beacon technology?

P3: We use this term more as 'speak to the market' [said in English]. We have our own concepts within ourselves, as I said, everyone determines a concept according to their own needs."

While the threshold created by education sheds light on the reality that the concept of marketing does not show a fixed structure and is constantly changing, it also enables them to understand the depth of marketing. Therefore, marketing trends and concepts represent the 'alive' feature of marketing. However, the instrumental importance of marketing welcomes marketing concepts as 'unnecessary'.

"Some concepts are very similar to each other. Even I have a hard time separating them. I don't think I know it very well, because when you don't really apply those concepts start to resemble each other in a way. It also makes you a little unhappy, you know, am I not enough? Got a lot of terms and can't seem to catch it? Or you are worried that your job does not improve you, but at the same time it is a good thing. After all, you see that this sector, that is, the ***field, is not dead and is constantly alive,*** *so the emergence of something new, in a way, also directs the brands to work. In other words, when a marketer reads these, he wants to apply it in his industry and that term somehow comes into our lives over time.* ***So, we are being renewed in the same way****." (P3)*

"I mean, if there is such a thing, we can say, ' Oh yes, this is the company, I saw it from that advertisement' and create familiarity in those matters, but is the concept very important? I don't think it matters that much, frankly. In other words, it may not be so important for us to appear using that concept. But it is of course very good to be known, it is a plus for everyone, but it is not a must." (P12)

"[…] [by knowing the concept] You can at least search for this word as a source of information. If you enter 'respond quickly to my customer', you will not find it easy on the internet. But these names, these top headings actually make it easier for us to access information. At least we can search by that name. […] So, imagine a main street and you are going. Yes, you can go, but if there are no signs, you will not know where and how many kilometers are left. So yes 40 km. I guess I have a long way to go, yes, but when he shows you it, I think you can go much more comfortably, safely, and knowingly." (P1)

Realization of marketing activities comes to life in line with the goals of the managers but in two directions. While the participants with post-graduate education get ahead of the market with an attitude that sees 'beyond marketing', participants without post-graduate education operate with the aim of 'saving the day'.

4.1.2. Naming Things "Already" Implemented

Practitioners in marketing, whether they have a post-graduate education or not, have to fulfill their responsibilities by making the necessary decisions in the context of their job descriptions. Therefore, the concepts developed by the marketing literature only make sense for the actors who use them. Marketing activities are already carried out and if you are operating in the market environment, there will be practices that you need to maintain within the existing order and system. However, the awareness gained through post-graduate education develops an understanding that reveals the value of the concepts. By the way, we stress 'post-graduate education' to indicate proximity to marketing literature.

"I'm doing something, but it's like doing it instinctively, without knowing what it's called. Or I do it because I think it's right. Now I can name the things I do […] As you learn, you realize that there is an incredible work behind it, an incredible effort. So, it is not an easy thing." (P1)

"Knowledge sometimes creates this awareness: Oh yes, I used it here, I can say that I have had created it then. That's why it's definitely a plus for me. Once my vision is developing" (P4)

On the other hand, managers who have a distance from marketing knowledge have an attitude that concepts are 'unnecessary'. The striking result of this situation is that the marketing activities of the participants in this profile are carried out in a narrower framework and will only serve to complete the requirements of the job, that is, reflect the awareness of 'fulfilling the task'. Therefore, the marketing literature has difficulties in reaching such actors, due to the nature and attitude of the actors, or even cannot reach them.

"Imm we do marketing activities, as you mentioned, without using those concepts in daily life. In other words, we do not necessarily have to use that marketing concept to be able to engage in marketing activities. We have a Facebook at our disposal right now, we have followers, everyone has a circle of friends, there is Instagram, there is Linkedin, if we want to share something about that, when there is something new about our company, we can share it there and show it to everyone." (P2)

"How can I say Turkish equivalents since they are mostly in a foreign language? I haven't come across those terms very often. And yes, I realize things that I see in accounting

and finance courses. You know, again in Turkish, but in marketing, it seems to be a little more different. It helps to understand what you mean when you read an article, but there is no time to think about it when running an operation in daily life. Or yes, we are not saying that we are doing guerrilla marketing right now. It may be done, but it is not done under that term in general." (P9)

4.2. Findings among Practitioners through Academic Knowledge: Negotiation of Status in Hierarchy with Academic Knowledge, and Language in Workplace

Language has been a prominent element, especially in terms of marketing concepts and has shed light on different approaches. Using marketing concepts in ***practice***, in professional working life brings out these different interactions:

- Among managers with and without a post-graduate education (managers with post-graduate degree may be subordinate or superior, upper hierarchical relationship)
- Between participants who have and/or have no post-graduate degree and other marketing managers (horizontal relationship)

Another function in which language acts as a separator is the balance between ***academia and practice*** positioning academic knowledge in a higher status.

While the participants with post-graduate degrees develop attention to using these marketing concepts correctly and appropriately, they show a more comfortable attitude in expressing that they do not know the concepts they have heard for the first time. In an approach where marketing is accepted as the goal, it is not a problem for them to say, 'I do not know', since the main thing is to 'learn'.

For participants with post-graduate degrees, since language is a tool to 'show oneself', it manifests itself more as 'pretending to know' or expressing 'not using' rather than expressing that they do not know. It is evident in the contradiction between their body language and narratives with diminishing usage rate of concepts in conversations (Wilkie & Moore, 2007) and critics of 'there is repetition in academia, not in practice'.

"It's more of us here, actually relationship marketing is the heart of our company, the truth of the matter. The reason I'm still involved in sales at work is relationship marketing." (P1)"

"[About relationship marketing] It is inviting our customers, that's like a marketing technique. Factory tour, total participation in surgeries, surgery with another doctor using our product. [bringing out experiential marketing in conversation] I don't say that we do this. I call it relationship marketing because it's about the distributor and the distributor's affiliate doctor." (P11)

"[Giving some examples of marketing concepts] I've heard of these concepts, of course. We use it at work. We are launching a new product these days and we always say 'marketing', 'marketing' (laughs)." (P11)

*"As I follow these [marketing concepts such as relational marketing, visual hammer] as I have said a lot, I especially follow documents or publications in English, and I **have definitely heard the name** pop- up marketing, in the form of visual hammer, is very new English concept.." (P10)*

Pretending to know is a basic coping strategy in conversations like these. This is because the capability of using academic language and trendy concepts in conversations offers managers the opportunity to 'differentiate themselves from others' like between managers or in a subordinate-superior relationship. Therefore, it carries individuals in a relatively 'advantaged' position in the eyes of managers or their colleagues compared to others in the workplace. The most basic indicator of visibility is to use new marketing trends at the right place and time, in the right way.

*"These concepts we use here **make you look cooler** like that in business life. For example, in one of my last meetings, they gave us training. It is customer segmentation, so what are the factors that affect marketing, these are the things we always use in the field and pay attention to, but when you get up and say something in the academic language here and there, everyone turns to look at you. 'How do you know?' You say that I had this education, I graduated [post-graduate] from the marketing department, or the person who gave this education gets up and says to you, 'Of course, you have a master's degree in this department." (P2)*

*"P3: [Learning the concepts through education] When you use the word he [managers at the workplace] uses technically, you make the other party feel **that you know the job. The other party takes you more seriously.***

R: Has there been a change in behavior?

*P3: Yes. In my interview experience, of course, he already feels it when meeting with someone in my field, and the interviewer **doesn't even extend the interview too***

much, especially in the interviews you have for the first time like HR. *He asks you a few questions, starting with what the difference between sales and marketing is, when you use a few terms there, apart from the classic answers, 'Yes, you know this job, you have developed yourself very well', the other party already makes you feel and does not extend it 'Okay enough, you know', I've had it." (P3)*

"If I don't know those terms in a meeting, I feel uncomfortable because I'm in the meeting at that time, I don't have the opportunity to research at that moment and I get nervous because I may not fully understand what you mean. Or I worry that I won't be able to give an adequate answer." (P9)

"[If you say a new marketing concept to someone who doesn't know] When they hear that, they say 'Yes, yes, let's do that, you're right,' but you can feel from the sentences that he does know nothing about it. If he was in competition with you and what you said was hostile to him, if he felt that it was revealing his ignorance, you were dead (laughs). Every sentence you make about him will come back negatively to you (laughs)" (P5)

Thus, marketing trends enable employees to be visible and respected in the working environment, and by creating an advantage over employees who do not know the trends. Working culture, in this context, actually separate individuals who have post-graduate degree as most of the practitioners have graduate degrees. This condition reaches to peak to make practitioners feel 'disturbed' when they do not know the concepts or trends.

The effort of the participants with post-graduate degrees to use marketing trends and concepts correctly enables them to realize the 'errors' in discourse and develop critical discussions towards language.

"[Academy and business] I don't think it reflects it exactly. Especially if the staff does not have academic knowledge such as a master's degree, there are actually strategies that they apply with their experience, foresight and talent without knowing what their name is. Maybe it's true, but when they explain it, they use the wrong terms. Since I have my master's education, I can use the right term in the right strategy as much as I can, but still, when you give a break, you become dull again. Because in fact, they use the right thing wrong, so you have to accept that wrong as right over time. They say this is this for us and you can't actually explain it there because it has been named that way for years." (P3)

"Concepts are definitely misused. In this society, we are already emptying ourselves for every profession. In other words, we have even already emptied the concepts of sales and marketing. Sales and marketing get mixed up a lot. Hot sales, marketing, strategy, these concepts are all intertwined. Maybe something will happen if we can find new words or if those of us who receive this education today can put these concepts into place in a decade or in 15 years and use them appropriately. […] There are so many wrongs out there. In order for us to eliminate these, maybe the academy needs to provide education for practice." (P5)

Another prominent situation regarding language is that employees create a 'higher end order language' among themselves and this upper language manifests itself with marketing concepts. This suggests that this situation encourages a 'status' structure. It creates a given class distinction by setting a threshold between employees.

"[The use of marketing concepts] Frankly, the automotive sector is not a structure with a very high level of education. Sales consultants are either high school or university graduates. But we are not a structure that has a great command of jargon, especially in terms of marketing-sales, and follows them in an academic sense. We speak within ourselves (in the company) using these jargons from the academy, yes, but apart from that, there is nothing clear that I can say we use such things specifically within the company. Because this is all about the level of education and whether he understands what you are saying when you say it. In other words, if the person in front of you will not understand when you use this jargon, you will say it in Turkish and put it into practice in a way that he can understand." (P10)

"The people we are dealing with are not very conscious, frankly. I do not go to them with the concept of marketing anyway, I go with advertising, promotion, etc. This is the way they go and since they are not very well-equipped due to the sector, of course, I cannot offer a clear recommendation on a strategy, but other than that, we use marketing concepts a lot." (P4)

"I studied marketing [post-graduate education], but I can't go directly to my sales team and tell them what I saw in the course here. Because the language used here is very different, the language used in the field is very different. Here, I use a Turkish translation of it, at school the language used is an academic language, but the language used in business life is a different language, so you just said that this is one of the most important differences between business life and academia. You change it and explain it to your team in an understandable language." (P2)

This situation 'equalizes' managers, regardless of education level, against actors such as 'other' employees and even the consumer group. In addition to all these dimensions, the academy, which represents the 'ideal' in language, is seen as an element that includes all managers and all other stakeholders.

The language used as 'jargon' among practitioners turns into a 'high end language' framing the relationship between theory and practice and creating a 'natural barrier' between practitioners and academics.

"The biggest difference I see is that in all academic studies there is a lot of repetition. In other words, I am reading some articles, for example, I am reading a similar paragraph, a similar explanation may have taken place in three or four places. It doesn't happen again in real life. So, we don't have that much time. We don't have time to repeat so much, make very long sentences or give too many details at work. In real life, we try to act with short sentences, short sentences as much as possible, which is reflected even in our speech, in general with shorter sentences and fast sentences. We don't talk too much about details. I think that gap in reaching the conclusion is longer in academics, of course, but since we have less time in real life, I always say, how nice it would be if we could summarize academic articles (laughs)." (P1)

Academy is a 'reliable' alternative to the internet for managers. In terms of presenting 'approved', 'checked' information, it is a more valid source compared to the internet environment full of 'false' and 'copy-paste' information. However, due to the nature of the academy, repetitions and long narratives relatively lose their functionality in the agile market structure.

"How CRM came into our lives as we used it like many concepts used in theory. Those who are concepts today will be part of our lives twenty years later. New concepts emerge with technology. In theory, it is presented in the article as if it is on it, but then as people start to use it and begin to function, they turn it into a positive or negative perception. […] Yes, someone has to write those theories, they have to name those concepts. It needs to be worked on. Swedish scientists[2] have to be real so that new trends we can apply twenty years from now, new markets and new words." (P5)

"There is scientific research on the one hand, and a constantly changing field factor on the other. I am also a little against this: as a result of scientific research, don't say that this is useful, it is an effective application in terms of marketing, it is a useful application, we did research, and the figures show this part. Because there is a field variable there! The human factor. People can do an experiment and hundred times they may do the same movement but different in hundred and first. It is due to field variability. Therefore, in the academic part, I think the field factor can be forgotten. It can be acted as pure research. In business life, on the contrary, academic studies can be left in the background, and direct action is taken in line with the feedback from the field. But that also has to be mixed somewhere." (P2)

The detailed structure of the academy conflicts with the practical need of the application, which reinforces the distance between the practice and theory. It is even seen as 'unnecessary' for managers who instrumentalize marketing.

5. Conclusion and Discussion

Research findings reveal that marketing practitioners develop unique interactions with academic knowledge and unique interaction among themselves through academic knowledge. Figure 1 reveals the prominent elements in this interaction and the factors that are effective in this interaction. As the tendency to view marketing as a firm function increase, so does the perception that marketing concepts are useful (Akaah, 1988). While the results of the research support this finding, it is seen that this belief is stronger for the participants with post-graduate degrees creating awareness about the usefulness of concepts at this point (Stephens et al., 2010).

Especially postgraduate education is the threshold in providing the relationship between theory and practice. The savvy of 'necessary concepts' is thus an indicator of this threshold discriminating between post-graduate and graduate degrees (Wilkie & Moore, 2007). Gamble et al. (2011) reveal that marketing managers and marketing academics still use a different language and jargon which creates a gap between marketing academics and practitioners. Despite the studies raising awareness about the gap between practice and theory, it can be said that this gap still endures. The gap decreases for managers with a post-graduate degree in marketing, and managers converge to the academic language. Contrary to Brooksbank et al. (2010)'s self-styled marketing experts due to fast 'fads' of marketing, the university was prioritized as a source of information for our study offering an opportunity to reach practitioners, as the main stakeholders of the marketing academy.

[2] 'Swedish scientist' is a joke here. This concept is used in advertisements (especially toothpaste advertisements) in Turkey's 1990s as experts as a promotional tool. Years later, people started to make fun of it with questions like 'What was the deal with them?', 'Why did we trust them?', especially on social media.

Another question that comes to mind at the end of this study is whether practitioners should be close to academic language. This study approaches this question from the point of view that they should. Marketing concepts should be relevant to social life and create social awareness (Gamble et al., 2011). While education is the area where marketing practitioners approach academia, what the academy can do to fill this gap is the subject of another study. Therefore, as Levy (2002) states, it is understood that education acts as a bridge between theory and practice.

Companies generally start to implement marketing when they transform from a start-up to a medium-sized business, and they evaluate it as nothing but the cost (Carson & McCartan-Quinn, 1995). In today's competitive world, although the importance of marketing is emphasized, from a practice perspective, it is not well-understood. Therefore, knowledge is not enough to turn into action. It is thought that this is because marketing is not accepted as a professional discipline (Hunt, 2007). Research findings reveal that some marketing managers question their positions and job descriptions and show that managers who have developed awareness of marketing are more collaborative in searching, learning, and using the right information. The effort of participants with the post-graduate degrees to learn the academic equivalent of the strategies they currently apply and to 'name' them also shows that academic knowledge reflects real life and adds value to practitioners (Stephens et al., 2010). However, theory-practice matching is experienced when managers show individual efforts to make it. Therefore, it is important to discuss a system structure that will ensure the sustainability of theory-practice harmony.

The most basic criticism of academic knowledge is that it is not reflexive to the market environment. In a competitive environment where quick decisions must be made, the 'repetitive' structure of academic knowledge and the lack of time flexibility in the field keep practitioners away from marketing knowledge. At this point, it is possible to comment that the functioning of the academic literature is not market oriented. Therefore, the definitions generally reflect the ideal to reach but have difficulties and barriers to be realized.

Marketing managers negotiate their status and power based on academic knowledge among themselves. The desire to have an education and get a post-graduate degree is a social situation in which managers distinguish themselves by confirming that they know - especially confirmation from their superiors - and by highlighting their education in the group. It creates an identity negotiation process (Creed & Scully, 2000). Therefore, having academic knowledge becomes a criterion of status and respect within the group (Bowles & Gelfand, 2010) and this shows that marketing knowledge creates a side value for practitioners. The pros of this situation are that it may be the main motivator for the post-graduate degree but on the other hand, it may hinder the sustainability of the link between theory and practice.

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