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An EFQM-Based Self-Assessment Method for Railway Transportation Service Quality: An Application With Intuitionistic Fuzzy AHP

Gözde YANGINLAR[1], Sait GÜL[2]

ABSTRACT

Service quality is one of the most important issues in railway transportation because it is a concept that positively affects customer satisfaction, customer loyalty, corporate image, and intention to repurchase. The European Foundation of Quality Management (EFQM) Excellence Model provides an opportunity to facilitate the service quality-focused self-assessment efforts of the railway companies. This is the first study that integrates intuitionistic fuzzy theory in the application of the EFQM Model of railway industry in Turkey. As the main contribution, it is aimed to find a dedicatedly special weighting schema for the application of EFQM model in railway transportation. For this purpose, Analytic Hierarchy Process (AHP) is utilized with an integration of intuitionistic fuzzy sets that can reveal the decision-makers' opinions, preferences, and expertise more comprehensively than traditional fuzzy sets can do. Consequently, it is found that the original model should be modified for the railway industry since the weights of all the criteria included in the model are found different than the original ones. The study provides new insights into the long-term benefits of applying the EFQM model as a framework in railway transportation and understanding the associations between the EFQM criteria and railway transportation.

Keywords: EFQM excellence model, Analytic Hierarchy Process, Intuitionistic Fuzzy Sets, Self-assessment, Railway Industry.

JEL Classification Codes: M10, L91, C02

INTRODUCTION

Today, considering the developments in international trade and economic stagnations, there is a need for breakthroughs that will provide a competitive advantage in the railway transportation sector. The latest developments, which occurred in various economic, social, and technological aspects with the effect of globalization, bring some deep changes in railway transportation management models and systems. In today's increasingly competitive environment, it is vital to use modern management techniques and tools in the railway transportation sector, which has a significant share in the transportation system. For that reason, the application of the European Foundation for Quality Management (EFQM) Excellence Model in railway transportation can contribute to the development of cooperation, learning, and benchmarking in the transportation sector while systematically improving the advancement of this system.

Each organization needs to measure its performance in the process of achieving its goals and implementing strategies. In the light of this information, the EFQM model, which helps organizations measure how much progress has been made on the path to organizational excellence and helps them grow steadily, was first developed in Europe in 1998. EFQM model is a general tool for quality management, which is used as a multidimensional framework in all types of businesses. One of the most positive aspects of EFQM is the use of self-evaluation (Tutunc and Küçükusta, 2009). This model offers a roadmap by comparing the current positions of businesses with their ideal positions as well as providing solutions to optimize their current positions. On the other hand, many European enterprises used the EFQM model to evaluate their performance, but they have also encountered problems with the accuracy and consistency of data because the scores obtained from this model are not regulated by industries (Calvo-Mora et al., 2005).

The service quality has an abstract and difficult structure due to its unique "intangibility, the inseparability of production and consumption, and heterogeneity" (Parasuraman et al., 1985). The service

[1] Istanbul Commerce University, Faculty of Business Management, Logistics Management, İstanbul, gyanginlar@ticaret.edu.tr

[2] Bahçeşehir University, Faculty of Engineering and Natural Sciences, Management Engineering Department, Beşiktaş, İstanbul, sait.gul@eng.bau.edu.tr

quality rating must respect its specific properties, which are unrepeatability and impalpability, and their usage at the right time they are provided as well as changeability, which is a significant factor in the conditions of railway transport as well. These peculiarities influence the service quality regarding the constantly increasing requirements (Nedeliakova et al., 2014).

In this study, the application of the EFQM Excellence Model in the railway transportation industry is examined. As the main contribution of the study to the literature, the EFQM is specialized for railway transportation. In the original model as detailed in Section 4, the criteria have equal weights representing their importance such as 10% or 15%. But this general weighting concept cannot satisfy the different requirements of various industries. So, it is here aimed to find a special and appropriate weighting schema for the usage of the EFQM model in railway transportation. For this purpose, the Analytic Hierarchy Process (AHP) which is one of the most popular multiple attribute decision-making (MADM) methods is utilized with an integration of intuitionistic fuzzy sets (IFS) that can reveal the decision-makers' opinions, preferences, and expertise more comprehensively. Fuzzy logic that considers just membership degrees, can provide a limited level of opportunity to deal with the uncertainty and vagueness in decision-making processes. IFSs extend this strength by considering both independent membership and non-membership degrees, also the hesitancy within the decision-makers' preferences can be effectively and extensively modeled. In the data collection step, ten managers of the railway enterprise operating in Turkey were interviewed face-to-face to obtain their individualistic expertise. Data provided by the experts are the linguistic judgments consisting of pairwise comparisons of the EFQM model's criteria.

Fig. 1 shows the flowchart of our proposed IF-AHP method and mathematical details are given in Section 4.

The study is structured as follows: Following the introduction, the second section presents the conceptual framework and literature review of rail transportation and the EFQM Excellence Model. IFSs concept is introduced, and a literature review of IFS is also provided in the third section. The details of IF-AHP method are given in the fourth section. In section 5, IF-AHP application which is conducted for the EFQM model's rail transportation system implementation is examined in Turkey. The final section presents the discussion and conclusions drawn from the study with their practical implications and limitations.

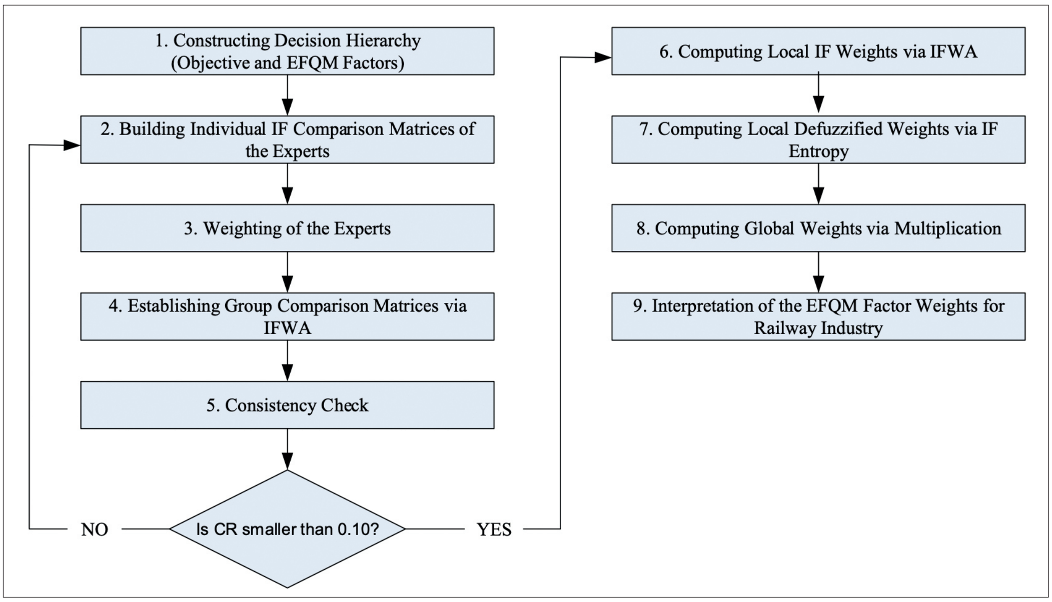

Fig. 1. Flowchart of IF-AHP.

LITERATURE REVIEW: SERVICE QUALITY IN RAILWAY TRANSPORTATION

Railway transportation is a fast-growing sector in developing and developed countries as well as a type of transportation that affects economic and organizational performance. As a result, railway transportation is being given particular attention around the world. Turkey reformed railway transportation policies for the sake of environmental and economic importance. For the liberalization of railway transportation within the scope of improving the service quality and the reconstruction of TCDD (Türkiye Cumhuriyeti Devlet Demiryolları – the State Railways of the Republic of Turkey), the Law on the Liberalization of Turkish Railway Transportation was published on May 1, 2013. In this context, TCDD was identified under two headings, i.e., infrastructure operator and TCDD freight. After TCDD transportation started its activities in 2017, the process of liberalization and opening up to the competition started. In this process, service quality has become the most important criterion.

Banar and Özdemir (2015) indicated that Turkey's railway transportation achieved significant improvement in recent years. Turkey's railway systems are in an important life cycle and are reported to have an environmental impact that compares with that of other countries. Rail transportation in Turkey has shown significant improvement since 1950. Environmental concerns have also been seen in many European Union countries in recent years. In this context, railway transportation's service quality and quality policies take place as a determining factor in the integration of international transportation networks (Babalik-Sutcliffe, 2007).

The quality of railway passenger transportation is a complicated issue that requires professional skills based on knowledge and practical experience. Hanna and Drea (1998) and Drea and Hanna (2000) analyzed the service quality in railway passenger transportation in the USA by addressing the cost, timing, comfort, location, and productivity during transportation. Driving quality is one of the primary factors. Maskeliūnaite et al. (2009) measured the quality of service in Lithuanian railway transportation via AHP and made some suggestions for improvement. Sivilevičius and Maskeliūnaite (2010) explained that improvement in service quality depends on the performance of railway terminals and the minimization of losses due to train delays. Lithuanian railway service quality was measured using the AHP method. Brons and Rietveld (2009) specified that customer satisfaction is achieved by increasing the importance of scores that indicate high satisfaction in service quality dimensions. In their framework, it is more effective to focus on quality improvements since the railway operator will have less control over the perceived service quality.

Mirandaa et al. (2018) evaluated the impact of service quality dimensions in railway transportation on customer satisfaction by the SERVQUAL model. It is proved that the combination of comfort and connection in terms of service quality dimensions only provides higher customer satisfaction. Gupta and Datta (2012) offered suggestions for improving the quality of service in Indian rail transportation. The results indicate that passengers are generally dissatisfied with the "extent of waiting"; thereafter, there is a claim for further improvement of the "security" system. Travel-associated facilities and passenger amenities such as refreshment rooms and automated teller machines could be required. Ebolia et al. (2016) proposed a multilevel fuzzy synthetic assessment model to evaluate service quality in railways according to attributes such as cleaning, safety, service, information, comfort, and personnel. In addition to ensuring travel safety in railway passenger transportation, the cleaning of the seats on the trains, cleaning of the toilets, the temperature in the vehicle during travel, the comfort of the windows and doors, and density in the vehicle are also considered.

The European Foundation for Quality Management (EFQM) was established in 1988 to help enterprises gain a competitive advantage in Europe. This foundation aims to create the European quality award as in the case of the American Malcolm Baldridge National Quality Awards – MBNQA (Conti, 2007). Since both are based on a total quality management philosophy, the basic pillars of these awards are fairly similar, but there is some divergence between countries. The main reason for these revisions is adaptations to current business situations. MBNQA has evolved from the quality assurance system to the total quality management system (Tan, 2002). The EFQM model has been revised many times over the years. The first revision was carried out in 1999. In the following years, updates continued, and economic and social adaptation was achieved.

The EFQM Excellence Model has a flexible structure; it is applicable in both public and private sectors, small and large organizations, and in-service and industrial enterprises. The main process in implementation is self-assessment, which is based on a series of attributes and performance indicators when measuring the level of quality. Candidates can be nominated for different quality awards after self-assessment. It is important to conduct an external evaluation by independent experts before the self-assessment report is verified (Calvo-Mora et al., 2018).

EFQM is a nonprescription framework that embodies many approaches to achieving sustainable organizational excellence. Fundamental concepts such as customer orientation, process improvement, results in orientation, the involvement of people, and consistency of processes and facts, leadership, and innovation play a key role in reaching the perfect level of the organization (Rusjan, 2005). New technologies and information systems are vital elements of business strategies. EFQM adapts to information technologies and leads to quality development (Trébucq and Magnaghi, 2017).

EFQM helps businesses adapt quickly to market requirements (Ruiz-Carrillo and Fernández-Ortiz, 2005). It has an integrative feature consisting of operational, strategic, and managerial control processes (Dahlgaard-Park et al., 2001). The strengthening of the relationship between the actors in the supply chain and the increase in quality depend on the generation of synergy and create new opportunities (Daud and Yusoff, 2011). This model offers a perspective-based participatory approach to all actors (suppliers, manufacturers, distributors, customers, etc.) in the supply chain. It acts as a guideline for managers in analyzing the bounds of the company's mission, vision, strategy, and the results it achieves.

Thanks to the scoring procedure, the system assigns specific values and evaluates the current situation of the organization (Madrigal and Lara, 2017). EFQM not only contributes to the development of the enterprises' internal management processes but also provides detailed information about the efficiency of the business (Weske, 2007). Although it defines and evaluates the current situation, it does not provide a specific guide for sectors. It does not classify the areas in which improvement should be primarily made (Rusjan, 2005).

The criteria and sub-criteria of EFQM are classified under nine headings as depicted in Fig. 2 (Moreno-Rodríguez et al., 2013): the first five are defined as "enablers" that are so essential for raising enterprises' performance; the remaining four criteria are classified as "results" which aim to measure the performance of the enterprise (Akyuz, 2015). In this study, Enablers and Results are accepted as the main criteria. So, the general definitions of each sub-criterion are given below, and the sub-sub-criterion is given in Appendix 1.

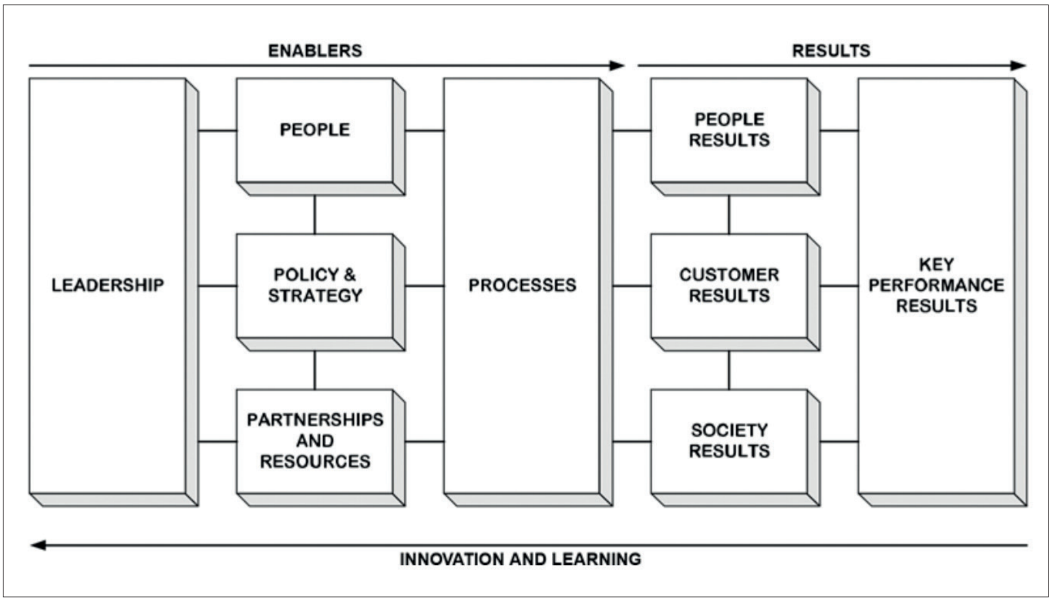

Fig. 2. The EFQM Excellence Model.

- **Leadership**: Excellence in leadership means that leaders create values and systems to provide that they efficaciously execute actions and behaviors.

- **Policy and strategy**: To create an excellent organization, it is essential to create mission, vision, and values with stakeholder-focused policies. Strategy development in a multi-partner, collaborative environment entails the solution to the fundamental dilemma of valuing sustainability.

- **People**: An excellent organization performs the best utilization of its human resources and empowers and awards its "people." In a collaborative context, joint management of cross-border, cross-cultural "people" resources at strategic, tactical, and operational levels are required. People become a crucial component in configuring a cooperative relationship among enterprises with different backgrounds and working styles.

- **Partnerships and resources**: Excellent organizations organize partnerships and resources, including information technologies. Hence, all enterprises' processes and resources assume a vital role in the organization.

- **Processes**: Customer-facing processes add value to the customer in an excellent organization.
- **Customer results**: Excellent organizations realize the best results for their customers and create high levels of customer satisfaction.
- **People results**: Excellent organizations obtain the best results for their people and register high levels of people satisfaction.
- **Society results**: Excellent organizations evaluate the best results for the wider society.
- **Key performance results:** Excellent organizations consistently accomplish the key performance results aligned with their policies and strategies.

Table 1 depicts a picture of EFQM literature. EFQM was integrated with different methods such as fuzzy AHP, fuzzy linguistic modeling, DEMATEL, operations research models, structural equation modeling, hierarchical cluster analysis, maturity models, and canonical correlation analysis. Besides, EFQM has been handled in both production and service industries such as air transportation, thermal power generation, healthcare, electric and electronic, education, tourism, and applications are found in different countries, e.g., India, Greece, Iran, USA, United Kingdom, Spain, Denmark, Portugal, and Netherland.

This study uses a modified version of AHP in implementing the EFQM model in the railway industry. In the literature, few studies are benefitting from MADM approaches. Liu and Ko (2018) utilized fuzzy AHP and found that enablers received 45% while the new results reached 55% importance in the EFQM model applied

Table 1. EFQM Excellence Model's Applications in the Literature

References	Sectors & Organization	Method
Dubey and Lakhanpal (2019)	Indian thermal power generating sector	Structural equation model
Kafetzopoulos et al. (2019).	Greek manufacturing industry	Structural equation model
Paraschi et al. (2019)	Air transportation sectors	Structural equation model
Belvedere et al. (2018)	118 companies	Structural equation model
Calvo-Mora et al. (2018)	116 Spanish companies	Structural equation model
Liu and Ko (2018)	Tourism sectors	Fuzzy analytic hierarchy process
Para-González et al. (2018).	200 medium-sized industrial Spanish firms	Structural equation model
Madrigal and Lara (2017)	Operation of golf courses	Structural equation model
Mesgari et al. (2017)	Healthcare sectors in Iran	Structural equation model
Gómez-López et al. (2016).	168 Spanish private firms	Factor analysis and Kruskal-Wallis Test
Anastasiadou and Zirinogloub (2015)	Greek primary education system	Structural equation model
Ezzabadia et. al. (2015)	Electricity enterprise in Iran	Fuzzy analytic hierarchy process, operations research
Moreno-Rodriguez et al. (2013)	Healthcare sectors	Fuzzy linguistic modeling
Sadeh et al. (2013)	228 Iranian manufacturing firms	Structural equation model
Safari et al. (2012)	Tavanir company in Iran	Canonical correlation analysis
Yousefie et al. (2011)	Iranian companies	Fuzzy analytic hierarchy process, entropy method
Sadeh and Arumugan (2010)	Iranian firms	DEMATEL technique
Sila (2007)	American companies	Structural equation model
Bou-Llusar et al. (2005)	Industrial and services sectors	Structural equation model
Calvo-Mora et al. (2005)	Academic centers in Spain	Partial least squares technique

to the tourism industry. In the original model, the enablers and results have equal weights of 50%. Also, the customer results sub-criterion recorded 23% importance. Ezzabadia et al. (2015) evaluated the EFQM model by integrating fuzzy AHP and operations research in electricity enterprises of Iran. Action plans were prepared with the emphasis on high-priority improvement projects for increasing the quality of business performance evaluation. Yousefie et al. (2011) integrated fuzzy AHP and quality function deployment methodologies for EFQM implementation in the automotive industry and claimed that enterprises can gain market shares and improve operational performance by applying EFQM. By applying DEMATEL in Iranian small-to-medium-sized enterprises, Sadeh and Arumugan (2010) found that leadership has the most efficient criteria having the largest effect on other excellence concepts.

Many studies proposed that industries have characteristics differentiated and they need dedicated EFQM models. In the civil aviation industry, the airport business excellence model version has been implemented at 143 airports worldwide by Paraschi et al. (2019) and the important performance analysis declared that employee results are the most critical success factor for airport excellence, and leadership and operational results are less important than employee results. Madrigal and Lara (2017) suggested that the EFQM operation in the sports industry is effective in improving quality and customer satisfaction. Anastasiadou and Zirinogloub (2015) confirmed that there are relationships among enabler criteria of EFQM with an application in education. As seen from these results, the EFQM applications need industry-specific measures because each industry's service quality evaluation should be based on different priorities of criteria.

The literature review shows there are varying levels of relations among the sub-criteria of EFQM, but these relationships are ignored in the official model. So, these relations are also neglected in this study to build an introductory model of the EFQM application to the railway transportation industry as the first attempt and the main contribution is the determination of the railway-specific importance weights of factors included by the official model. Future research can cope with this assumption of independent criteria.

PRELIMINARIES: INTUITIONISTIC FUZZY SETS

Zadeh (1965) stated that fuzzy numbers are effective tools that can be used in decision-making processes due to the systematic subjectivity in group decision-making problems, uncertainty, and vagueness of human judgments, the necessity of linguistic term usage by decision-makers, etc. Fuzzy set is the general case of set theory and Atanassov's (1986) IFSs provide an extension to the traditional fuzzy sets concept. The basic novelty of IFSs is the consideration of both independent membership and non-membership degrees. This representation style gives an extensive quantification possibility to the decision-makers. Also, the decision-makers' hesitancy levels can be quantified by IFS. The terminology is clarified by the following definitions.

Definition 1. A fuzzy set *A* in the universe of discourse $X = \{x_1, x_2, \dots, x_n\}$ is defined as

$$\tilde{A} = \{ < x, \mu_{\tilde{A}}(x) > | x \in X\} \quad (1)$$

where $\mu_{\tilde{A}} : X \to [0,1]$ is the membership function of $\tilde{A}$. $\mu_{\tilde{A}}(x)$ represents the degree of belongingness of x in $\tilde{A}$.

Definition 2. An intuitionistic fuzzy set (IFS) *A* which is proposed first by Atanassov (1986) and defined on a universe of discourse *X* is expressed as

$$\tilde{A} = \{ < x, \mu_{\tilde{A}}(x) > | x \in X\} \quad (2)$$

where $\mu_A : X \to [0,1]$ and $\vartheta_A : X \to [0,1]$ with the condition $0 \le \mu_A(z) + \vartheta_A(z) \le 1$ for all $x \in X$. .

The numbers $\mu_A(x)$ and $\vartheta_A(x)$ denote membership and non-membership degrees, respectively. The benefit of the binary representation is its ability to model the decision-makers' uncertainty. From constraint $0 \le \mu_A(x) + \vartheta_A(x) \le 1$, it is understood that the total degree of membership and non-membership can be smaller than 1. The remaining represents the degree of hesitation, intuitionistic index, or non-determinacy of x to A (Gupta et al., 2016):

$$\pi_A(x) = 1 - \mu_A(x) - \vartheta_A(x) \text{ where } 0 \le \pi_A(x) \le 1 \quad (3)$$

Smaller $\pi_A(x)$ represents higher certainty of the knowledge about x, and higher $\pi_A(x)$ shows less certain knowledge about x.

Definition 3. The complementary set A^c of A is defined as

$$A^c = \{ < x, \vartheta_A(x), \mu_A(x) > | x \in X\} \quad (4)$$

The summation and multiplication operations in IFS are given as follows (Atanassov, 1986):

$$A \oplus B = \{< x, \mu_A(x) + \mu_B(x) - \mu_A(x) * \mu_B(x), \vartheta_A(x) * \vartheta_B(x) > | x \in X\}$$

$$A \otimes B = \{< x, \mu_A(x) * \mu_B(x), \vartheta_A(x) + \vartheta_B(x) - \vartheta_A(x) * \vartheta_B(x) > | x \in X\} \quad (6)$$

$$n * A = \{< x, 1 - [1 - \mu_A(x)]^n, [\vartheta_A(x)]^n > | x \in X\} \quad (7)$$

Definition 4. Let a triangular IF number (TIFN) be be $\tilde{a} = < (\underline{a}, a, \overline{a}); \mu_{\tilde{a}}, \vartheta_{\tilde{a}} >$. Its membership and non-membership functions are defined as given in equations (8) and (9), respectively (Wu et al., 2018).

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{(x-\underline{a})}{(a-\underline{a})}\mu_{\tilde{a}} & , \quad \underline{a} \le x < a \\ \mu_{\tilde{a}} & , \quad x = a \\ \frac{(\overline{a}-x)}{(\overline{a}-a)}\mu_{\tilde{a}} & , \quad a \le x < \overline{a} \\ 0 & , \quad x < \underline{a} \; or \; x > \overline{a} \end{cases} \quad (8)$$

$$\vartheta_{\tilde{a}}(x) = \begin{cases} \frac{(a - x + \vartheta_{\tilde{a}}(x-\underline{a}))}{(a-\underline{a})} & , \quad \underline{a} \le x < a \\ \vartheta_{\tilde{a}} & , \quad x = a \\ \frac{(x - a + \vartheta_{\tilde{a}}(\overline{a}-x))}{(\overline{a}-a)} & , \quad a \le x < \overline{a} \\ 0 & , \quad x < \underline{a} \; or \; x > \overline{a} \end{cases} \quad (9)$$

Table 2 shows the results of the literature review of IFS applications in the transportation field. It has been determined that studies were carried out in logistics and supply chain management, supply chain risk management, road transportation, maritime transportation, high-speed railway, humanitarian relief logistics, and green supply chain management. To the best of our knowledge, no study examining the EFQM Excellence Model for railway transportation via the intuitionistic fuzzy MADM methods exists in the literature. Thus, this study aims to contribute to the literature in this manner.

Some examples can be given for clarifying the applicability of IF-based MADM methods in various areas. Ar et al. (2020) revealed that the most important criteria are security, visibility, and audit in blockchain technology selection for the logistics industry via incorporating AHP and VIKOR. According to Tavana et al. (2016), the most important criterion that should be considered by the companies making reverse logistics outsourcing decisions is the focus on the core business. Karasan et al. (2018) integrated AHP and TOPSIS approaches under IFS environment to prioritize ten production strategies such as innovation-focused, technology-based, marketing-intensive, customization-based strategies, etc. Şahin and Soylu (2020) proposed a conceptual framework of process management for maritime transportation with IF-AHP. Büyüközkan et al. (2020) showed that digital trust is the most significant dimension in the Turkish airline industry by applying IF-AHP method. Kahraman et al. (2020) prioritize outsource manufacturers by combining IF-AHP and IF-TOPSIS and showed the method's applicability for a global textile firm. Yu et al. (2020) established a computing model combining IF-AHP with a cloud model to evaluate the risk levels of the Chinese electricity retailers. Demir and Koca (2021) used IF-AHP and IF-TOPSIS combined model in selecting the best green supplier for the paper mills in Turkey.

PROPOSED METHODOLOGY

In this study, IF numbers are used to extend AHP (Saaty, 1980) for handling vagueness and ambiguity in the decision processes of experts. IF-AHP can obtain the relative importance of criteria more comprehensively and effectively. When decision-makers make comparisons in a pairwise manner, they may not specify their evaluation with crisp numerical values because of uncertain information. IF-AHP can better work with all aspects of information covered by the expert since it is capable to utilize membership, non-membership, and hesitancy information. The steps of IF-AHP are detailed as follows.

Step 1: Modeling of the decision problem consists of definitions of objective, criteria, and sub-criteria if any exist. The problem hierarchy is constructed here. The objective of the current study is the determination of the EFQM's criteria weights that are specific for railway companies. EFQM's criteria, sub-criteria, and sub-sub-criteria are the elements of the hierarchy which is depicted in Fig. 3. The number of factors is used as the indices. The details of the sub-sub-criteria are given in Appendix 1. The criterion is represented by C_i where i will take a value according to the number of considered criteria, e.g., Enablers is the first main criterion and it is represented by *CI*; Leadership as the first sub-criterion of Enablers is represented by *CI1*; *CI1a* shows the first question of Enabler's Leadership.

Step 2: IF-AHP uses pairwise comparisons in evaluations. Decision-makers are asked to respond to a questionnaire for comparing factors with regard to their industry knowledge and expertise. Each expresses his/her judgment on each factor as a linguistic term. AHP's 9-point evaluation scale is transformed into a 9-point linguistic term set by Abdullah and Najib (2016). The overall scale and their reciprocals for inverse comparisons are shown in Table 3.

Step 3: In group decision making, the group of decision-makers usually have different levels of experience, knowledge, and preferences. This variation among them and their uniqueness is represented by weights that reflect their contribution or reliability in

Table 2. IF-based MADM Methods

Authors	Application area	Techniques used	Aim of the study
Ar et al. (2020)	Logistics management	IF-AHP and VIKOR	Feasibility of blockchain technology in the logistics industry
Büyüközkan et al. (2020)	Air transportation	IVIF-AHP	A new digital service quality model.
Budak et al. (2020)	Humanitarian relief logistics	IVIF-DEMATEL, ANP, and TOPSIS	Real-time location systems technology selection
Niroomand et al. (2020)	Supply chain network design	IF constraint programming	A hybrid approach considering the IF fuzzy objective function
Şahin and Soylu (2020)	Maritime transportation	Triangular IF based Chang's extension method and Gaussian approximation	Conceptual structure of process management for maritime supply chain
Deveci et al. (2019)	Road transportation	Interval-valued IF Quality Function Deployment	Quantitative assessment framework for public bus operators
Memari et al. (2019)	Sustainable supply chain management	IF-TOPSIS	Sustainable supplier selection
Büyüközkan and Göçer (2018)	Logistics and supply chain management	IF-ARAS and AHP	Supplier selection
Büyüközkan et al. (2018)	Sustainable urban transportation	IF Choquet integral	Sustainable urban transportation alternatives selection
Tavana et al. (2018)	Third-party providers	IF-TOPSIS and ANP	Third-party reverse logistics provider selection
Zhang et al. (2018)	Supply chain management	IF entropy weight method	Manufacturing service supply chain optimization problem
Govindan et al. (2016)	Supply chain risk management	Trapezoidal IF ELECTRE TRI-C	Supplier risk assessment
Tavana et al. (2016)	Third-party providers	IF-AHP and SWOT	New method to reverse logistics outsourcing decision making
Wan et al. (2016)	Many companies in various areas	IF preference relations model	RFID technology selection
Govindan et al. (2015)	Green supply chain management	IF-DEMATEL	A method for GSCM practices and performances
Liu et al. (2015)	High-speed railway	Ranking of trapezoidal IF numbers	Investigate high-speed railway accidents.

Table 3. Linguistic term set for the importance of criteria

	TIFNs		Reciprocal TIFNs		
Linguistic Terms	μ			μ	
Equally Important	0.02	0.18	1	0.18	0.02
Intermediate	0.06	0.23	1/2	0.23	0.06
Moderately More Important	0.13	0.27	1/3	0.27	0.13
Intermediate	0.22	0.28	1/4	0.28	0.22
Strongly More Important	0.33	0.27	1/5	0.27	0.33
Intermediate	0.47	0.23	1/6	0.23	0.47
Very Strong Importance	0.62	0.18	1/7	0.18	0.62
Intermediate	0.80	0.10	1/8	0.10	0.80
Extremely More Important	1.00	0.00	1/9	0.00	1.00

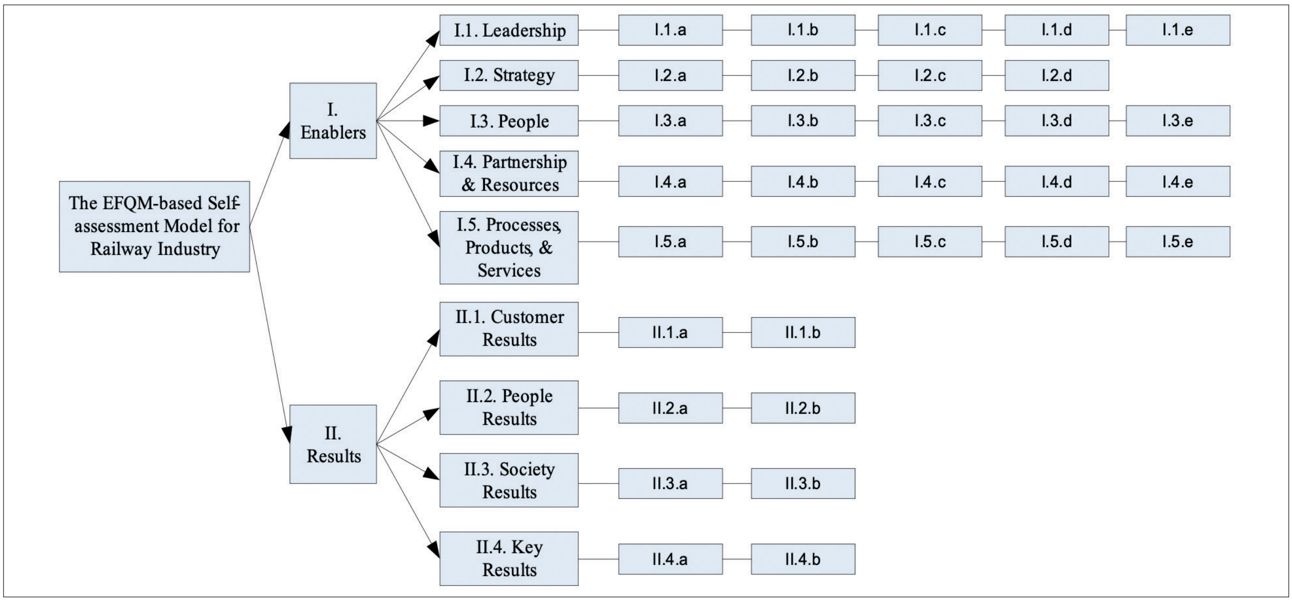

Fig. 3. The hierarchy of EFQM-based self-assessment.

solving the problem (Koksalmis and Kabak, 2019). By denoting D_k as the group of decision-makers and λ_k as the weights of each D_k, the group aggregation process is executed by utilizing the methodology developed by Boran et al. (2009). They proposed a linguistic evaluation scale for decision-makers' importance levels represented by triangular IF numbers $D_k = (\mu_k, \vartheta_k)$ where $\pi_k = 1 - \mu_k - \vartheta_k$. The scale is given in Table 4. Accordingly, λ_k can be computed with Eq. (10) where $\sum_k \lambda_k = 1$.

$$\lambda_k = \frac{\mu_k + \pi_k \left({}^{\mu_k}/_{(\mu_k + \vartheta_k)} \right)}{\sum_k \left(\mu_k + \pi_k \left({}^{\mu_k}/_{(\mu_k + \vartheta_k)} \right) \right)} \quad (10)$$

Table 4. Linguistic scale for the importance of DMs

Linguistic Scale	*TIFN*
Very Important (VI)	(0.90, 0.05)
Important (I)	(0.75, 0.20)
Medium (M)	(0.50, 0.40)
Unimportant (UNIMP)	(0.25, 0.60)
Very Unimportant (VUNIMP)	(0.10, 0.80)

Step 4: After the construction of IF comparison matrices, preference values in the matrix will be calculated. To do this, it is required to use an aggregation operator because each decision-maker holds his/her specific weight λ_k. Xu (2007) introduced IF weighted averaging (IFWA) operator. As Büyüközkan et al. (2019) stated, IFWA is the most used and practical aggregation operator in literature.

Let Let $R^{(k)} = \left(r_{ij}^{(k)} \right) = (\mu_{ij}^{(k)}, \vartheta_{ij}^{(k)})$ be IF comparison matrix of the k^{th} decision-maker and λ_k be the weight. The individualistic preference values $\left(r_i^{(k)} \right)$ can be calculated by Eq. (11).

$$r_i^{(k)} = IFWA_k\left(r_{ij}^{(k)} \right) = (1 - \prod_j (1 - \mu_{ij}^{(k)})^{\lambda_k}, \prod_j (\vartheta_{ij}^{(k)})^{\lambda_k}) \quad (11)$$

Step 5: The comparisons are based on the individual preferences of decision-makers. The inconsistency level in a comparison matrix should be checked to make a more representative and consistent decision. Saaty (1980) proposed an eigenvector-based consistency measurement which is called CR (consistency ratio). Abdullah and Najib (2016) stated that π hesitancy value of the aggregated IF comparisons can be used while calculating the inconsistency degree of each individualistic comparison matrix. Eq. (12) gives the proposed CR. *n* is the size of the matrix. RI is taken from Saaty (1980)'s Random Index table.

$$CR = \frac{(\lambda_{max} - n)/(n-1)}{RI} = \frac{(\frac{\pi_{ij}^{k}}{n})/(n-1)}{RI} \quad (12)$$

Step 6: Deciding in a group environment requires the fusion of individualistic preference values so that the importance degrees of each criterion or sub-criterion can be determined. IFWA operator can be used again to make this integration.

Let w_i be IF representation of the local weight of factor i, λ_k be k^{th} decision maker's weight and $r_i^{(k)} = (\mu_i^{(k)}, \vartheta_i^{(k)})$ be his/her preference value for each element. Eq. (13) is used for determining the local weights (Xu, 2007).

$$w_i = IFWA_{\lambda_k}\left(r_i^{(1)}, r_i^{(2)}, \ldots, r_i^{(k)}\right) = \lambda_1 r_i^{(1)} + \lambda_2 r_i^{(2)} + \cdots + \lambda_k r_i^{(k)}$$
$$= (1 - \prod_k (1 - \mu_i^{(k)})^{\lambda_k}, \prod_k (\vartheta_i^{(k)})^{\lambda_k}) \quad (13)$$

Step 7: By performing Eq. (13), the aggregated pairwise comparison matrix is formed for each criteria group. To find their local defuzzified weights, Abdullah and Najib (2016) proposed the usage of IF entropy. In this study, the entropy calculation presented by Burillo and Bustince (1996) is used as given in Eq. (14) and (15).

$$\bar{\bar{w}}_i = \pi_i \cdot e^{\pi_i} \quad (14)$$

$$\bar{w}_i = \frac{1 - \bar{\bar{w}}_i}{n - \sum_i \bar{\bar{w}}_i} \quad (15)$$

Step 8: After constructing local weight sets of main criteria and their sub-criteria, the global weights should be determined. They are the distributed weights of main criteria into associated sub-criteria one by one. For example, the weight of Enablers' main criterion will be allocated into its 5 sub-criteria (Leadership, People, etc.) and then, i.e., the weight of Leadership sub-criterion will be allocated into its 5 sub-sub-criteria. The resulting weights of sub-sub-criteria will be called global weights. The local weight of the main criterion and the local weight of its one sub-criterion will be multiplied to reveal the global weight of the interested sub-criterion and so on.

Step 9: Since the aim is to find the specific criteria weights of a new EFQM-based self-assessment model for railway companies to allow them to monitor their service quality level and compare their position within the logistics industry, the global weights that are calculated by IF-AHP approach, should be interpreted and then, are utilized to update the associated weight set of EFQM criteria. As the ultimate result, the EFQM-based self-assessment methodology will be based on the mentioned weights.

A CASE STUDY FROM TURKEY

After introducing the steps of the proposed IF-AHP methodology, the application and results are discussed in this section. A railway company from Turkey is selected to perform the case study. The company focuses on both passenger and cargo transportation. Due to an actual requirement of the company, it was decided to use the proposed method. To deal with the self-assessment problem being discussed within the company, 10 experts were selected for data collection. They were asked to fill out a survey including pairwise comparisons. The survey has 12 main parts. In the first 9 parts, the questions (that are accepted as sub-sub-criteria) of sub-criteria from Leadership to Key Results are evaluated. The survey has 2 parts for the comparison of sub-criteria of Enablers and Results criteria sets, respectively. The last part is about the comparison of Enablers and Results.

As mentioned above, 10 experts were selected from the industry by considering their expertise and knowledge about the management of railway operations. Some of these experts work in the quality management directorate, while others work as directors or deputy directors in the departments of "purchasing, strategy development, information technologies, passenger transportation, freight transportation, personnel and administrative affairs, railway maintenance, and repair". Each has worked for 20 years or more. They are effective in analyzing how railway transportation service quality has changed from the past to the present and evaluating it within the framework of EFQM.

Step 1: The general definition and scope of the interested problem are represented in Fig. 3. Criteria are shown with C_i (i = I and II for Enablers and Results; I1, I2, …, I5, II1, II2, …, II4 for sub-criteria and I1a, I1b, …, II4a, II4b for sub-sub-criteria).

Step 2: All the decision-makers are asked to fulfill the survey which is developed dedicatedly for this specific study. In this step, the opinions of decision-makers are collected by the survey and converted to IF numbers by using the linguistic terms that are depicted in Table 3. Table 5 shows the IF number conversions of comparisons of the first decision-maker (k=1). The other 9 experts' evaluations are not given due to space limitations.

Step 3: Decision-makers are weighted concerning their expertise in railway transportation. These expertise levels will be assessed by using the linguistic term scale and associated conversions of them to IF numbers which are given in Table 4. IF numbers are used in Eq. (10) for computing the decision-makers' weights. Table 6 shows the associated linguistic terms, their IF numbers correspondences, and the weights.

Table 5. Converted TIFNs of evaluations of Expert 1

	I1a		I1b		I1c		I1d		I1e	
I1a	0.02	0.18	0.62	0.18	0.8	0.1	0.8	0.1	0.8	0.1
I1b	0.18	0.62	0.18	0.02	0.33	0.27	0.33	0.27	0.33	0.27
I1c	0.1	0.8	0.27	0.33	0.02	0.18	0.27	0.33	0.27	0.33
I1d	0.1	0.8	0.27	0.33	0.33	0.27	0.02	0.18	0.33	0.27
I1e	0.1	0.8	0.27	0.33	0.33	0.27	0.27	0.33	0.02	0.18

	I2a		I2b		I2c		I2d	
I2a	0.02	0.18	0.33	0.27	0.27	0.33	0.33	0.27
I2b	0.27	0.33	0.02	0.18	0.33	0.27	0.22	0.28
I2c	0.33	0.27	0.27	0.33	0.02	0.18	0.22	0.28
I2d	0.27	0.33	0.28	0.22	0.28	0.22	0.02	0.18

	I3a		I3b		I3c		I3d		I3e	
I3a	0.02	0.18	0.33	0.27	0.27	0.33	0.27	0.33	0.27	0.33
I3b	0.27	0.33	0.02	0.18	0.33	0.27	0.27	0.33	0.33	0.27
I3c	0.33	0.27	0.27	0.33	0.02	0.18	0.33	0.27	0.33	0.27
I3d	0.33	0.27	0.27	0.33	0.27	0.33	0.02	0.18	0.33	0.27
I3e	0.33	0.27	0.27	0.33	0.27	0.33	0.27	0.33	0.02	0.18

	I4a		I4b		I4c		I4d		I4e	
I4a	0.02	0.18	0.27	0.33	0.33	0.27	0.27	0.33	0.27	0.33
I4b	0.33	0.27	0.02	0.18	0.33	0.27	0.02	0.18	0.02	0.18
I4c	0.27	0.33	0.27	0.33	0.02	0.18	0.27	0.33	0.27	0.33
I4d	0.33	0.27	0.02	0.18	0.33	0.27	0.02	0.18	0.27	0.33
I4e	0.33	0.27	0.02	0.18	0.33	0.27	0.33	0.27	0.02	0.18

	I5a		I5b		I5c		I5d		I5e	
I5a	0.02	0.18	0.02	0.18	0.33	0.27	0.33	0.27	0.02	0.18
I5b	0.02	0.18	0.02	0.18	0.33	0.27	0.33	0.27	0.27	0.33
I5c	0.27	0.33	0.27	0.33	0.02	0.18	0.33	0.27	0.27	0.33
I5d	0.27	0.33	0.27	0.33	0.27	0.33	0.02	0.18	0.27	0.33
I5e	0.02	0.18	0.33	0.27	0.33	0.27	0.33	0.27	0.02	0.18

	II1a		II1b	
II1a	0.02	0.18	0.33	0.27
II1b	0.27	0.33	0.02	0.18

	II2a		II2b	
II2a	0.02	0.18	0.33	0.27
II2b	0.27	0.33	0.02	0.18

	II3a		II3b	
II3a	0.02	0.18	0.33	0.27
II3b	0.27	0.33	0.02	0.18

	II4a		II4b	
II4a	0.02	0.18	0.33	0.27
II4b	0.27	0.33	0.02	0.18

	I1		I2		I3		I4		I5	
I1	0.02	0.18	0.33	0.27	0.33	0.27	0.33	0.27	0.33	0.27
I2	0.27	0.33	0.02	0.18	0.27	0.33	0.33	0.27	0.33	0.27
I3	0.27	0.33	0.33	0.27	0.02	0.18	0.33	0.27	0.33	0.27
I4	0.27	0.33	0.27	0.33	0.27	0.33	0.02	0.18	0.27	0.33
I5	0.27	0.33	0.27	0.33	0.27	0.33	0.33	0.27	0.02	0.18

	II1		II2		II3		II4	
II1	0.02	0.18	0.33	0.27	0.02	0.18	0.02	0.18
II2	0.27	0.33	0.02	0.18	0.02	0.18	0.02	0.18
II3	0.02	0.18	0.02	0.18	0.02	0.18	0.02	0.18
II4	0.02	0.18	0.02	0.18	0.02	0.18	0.02	0.18

	I		II	
I	0.02	0.18	0.27	0.33
II	0.33	0.27	0.02	0.18

Table 6. Weights of DMs

k	*Linguistic Term*	*TIFNs*		λ_k
1	VI	0.9	0.05	0.1101
2	VI	0.9	0.05	0.1101
3	I	0.75	0.2	0.0917
4	I	0.75	0.2	0.0917
5	I	0.75	0.2	0.0917
6	VI	0.9	0.05	0.1101
7	VI	0.9	0.05	0.1101
8	M	0.5	0.4	0.0645
9	VI	0.9	0.05	0.1101
10	VI	0.9	0.05	0.1101

Step 4: IFWA operator (Eq. 11) is used for obtaining the preference values of the criteria. For each comparison matrix, IFWA operator will be performed. Table 7 shows the preference values determined for the first decision-maker. For all the others, preference values are calculated in the same fashion.

Step 5: All the consistencies of decision-makers are checked via Eq. (12). A comparison matrix is consistent when its CR value is smaller than 10%. At the end of the consistency analysis, all the matrices are found ready for further steps.

Step 6: Group decision as the integration of different decision-makers' comparison matrices is realized by using Eq. (13) which is an application of IFWA. For illustration purposes, Table 8 shows the preference values for the sub-sub-criteria of Strategy. By combining these values, their local weights can be calculated as given below.

$$\mu_{I2a} = 1 - \prod_k \left(1 - \mu_{I2a}^{(k)}\right)^{\lambda_k} = 1 - [(1 - 0.1175)^{0.1101} * (1 - 0.0584)^{0.1101} * (1 - 0.1041)^{0.0917} * (1 - 0.0547)^{0.0917} * (1 - 0.1145)^{0.0917} * (1 - 0.0798)^{0.1101} * (1 - 0.823)^{0.1101} * (1 - 0.0052)^{0.0645} * (1 - 0.0218)^{0.1101} * (1 - 0.0405)^{0.1101} = 0.0701$$

$$\vartheta_{I2a} = \prod_k \left(\vartheta_{I2a}^{(k)}\right)^{\lambda_k} = (0.5494)^{0.1101} * (0.5389)^{0.1101} * (0.7008)^{0.0917} * (0.6197)^{0.0917} * (0.5254)^{0.1101} * (0.5691)^{0.1101} * (0.6423)^{0.0645} * (0.4915)^{0.1101} * (0.4535)^{0.1101} = 0.5584$$

Similarly, weights of remaining 3 factors are (0.0753, 0.5291) for *wI2b*, (0.0775, 0.5301) for *wI2c*, and (1, 0) for *wI2d*. All IF number representations of local weights are depicted in Table 9.

Step 7: Entropies of all criterion sets are computed and then, these entropies are processed to find the crisp local weights. As an illustration, the entropies and crisp weights related to the factors under Strategy are given below. For entropies, Eq. (14) is performed.

Table 7. Preference values of Expert 1

	μ	ν		μ	ν
I1a	0.4728	0.3206	II1a	0.0452	0.7169
I1b	0.1613	0.4003	II1b	0.0362	0.7329
I1c	0.1111	0.5603			
I1d	0.1277	0.5361		μ	ν
I1e	0.1194	0.5480	II2a	0.0452	0.7169
			II2b	0.0362	0.7329
	μ	ν			
I2a	0.1175	0.5494		μ	ν
I2b	0.1026	0.5516	II3a	0.0452	0.7169
I2c	0.1026	0.5516	II3b	0.0362	0.7329
I2d	0.1034	0.5252			
				μ	ν
	μ	ν	II4a	0.0452	0.7169
I3a	0.1395	0.4972	II4b	0.0362	0.7329
I3b	0.1476	0.4863			
I3c	0.1556	0.4757		μ	ν
I3d	0.1476	0.4863	I1	0.1635	0.4653
I3e	0.1395	0.4972	I2	0.1476	0.4863
			I3	0.1556	0.4757
	μ	ν	I4	0.1313	0.5083
I4a	0.1395	0.4972	I5	0.1395	0.4972
I4b	0.0905	0.4256			
I4c	0.1313	0.5083		μ	ν
I4d	0.1195	0.4549	II1	0.0495	0.4915
I4e	0.1277	0.4450	II2	0.0405	0.5025
			II3	0.0089	0.4701
	μ	ν	II4	0.0089	0.4701
I5a	0.0905	0.4256			
I5b	0.1195	0.4549		μ	ν
I5c	0.1395	0.4972	I	0.0362	0.7329
I5d	0.1313	0.5083	II	0.0452	0.7169
I5e	0.1277	0.4450			

$$\bar{\bar{w}}_{I2a} = \pi_{I2a} * e^{\pi_{I2a}} = 0.3715 * e^{0.3715} = 0.5387$$

$$\bar{\bar{w}}_{I2b} = \pi_{I2b} * e^{\pi_{I2b}} = 0.3956 * e^{0.3956} = 0.5875$$

$$\bar{\bar{w}}_{I2c} = \pi_{I2c} * e^{\pi_{I2c}} = 0.3924 * e^{0.3924} = 0.5809$$

$$\bar{\bar{w}}_{I2d} = \pi_{I2d} * e^{\pi_{I2d}} = 0 * e^{0} = 0$$

To find final weights, Eq. (15) is used.

Table 8. Preference values of Experts for sub-sub-criteria of Strategy

	λ_1 =	0.1101	λ_2 =	0.1101	λ_3 =	0.0917	λ_4 =	0.0917	λ_5 =	0.0917
	μ	ν	μ	ν	μ	ν	μ	ν	μ	ν
I2a	0.1175	0.5494	0.0584	0.5396	0.1041	0.7008	0.0547	0.6071	0.1145	0.6197
I2b	0.1026	0.5516	0.1007	0.4222	0.0386	0.7850	0.0846	0.4874	0.0748	0.5625
I2c	0.1026	0.5516	0.0832	0.4575	0.2641	0.5488	0.0518	0.5742	0.1096	0.5742
I2d	0.1034	0.5252	0.0667	0.5254	0.3590	0.4535	0.0443	0.5370	0.0698	0.5212

	λ_6 =	0.1101	λ_7 =	0.1101	λ_8 =	0.0645	λ_9 =	0.1101	λ_{10} =	0.1101
	μ	ν	μ	ν	μ	ν	μ	ν	μ	ν
I2a	0.0798	0.5254	0.0823	0.5691	0.0052	0.6423	0.0218	0.4915	0.0405	0.4535
I2b	0.0653	0.5494	0.0601	0.5806	0.0052	0.6423	0.1007	0.4222	0.0832	0.4575
I2c	0.0798	0.4742	0.0066	0.5677	0.0052	0.6423	0.0218	0.4915	0.0262	0.5050
I2d	0.0405	0.4535	1.0000	0.0000	0.0052	0.6423	0.0218	0.4915	0.0474	0.4355

Table 9. Aggregated local weights of all factors

	μ	ν
I1a	1.0000	0.0000
I1b	1.0000	0.0000
I1c	1.0000	0.0000
I1d	1.0000	0.0000
I1e	1.0000	0.0000

	μ	ν
I2a	0.0701	0.5584
I2b	0.0753	0.5291
I2c	0.0775	0.5301
I2d	1.0000	0.0000

	μ	ν
I3a	0.0881	0.4579
I3b	0.1029	0.4403
I3c	1.0000	0.0000
I3d	0.0917	0.4590
I3e	0.0914	0.4556

	μ	ν
I4a	0.1114	0.4682
I4b	0.0778	0.4649
I4c	0.1038	0.4369
I4d	0.1233	0.4324
I4e	0.1267	0.4409

	μ	ν
I5a	0.1011	0.4638
I5b	0.1052	0.5034
I5c	0.1007	0.4491
I5d	0.1354	0.4320
I5e	0.1089	0.4417

	μ	ν
II1a	0.0341	0.7234
II1b	0.0243	0.7365

	μ	ν
II2a	0.0262	0.7269
II2b	0.0346	0.7170

	μ	ν
II3a	0.0237	0.7186
II3b	0.0223	0.7197

	μ	ν
II4a	0.0265	0.7198
II4b	0.0208	0.7229

	μ	ν
I1	0.0950	0.4634
I2	0.0956	0.4879
I3	0.0987	0.4688
I4	0.1470	0.4255
I5	1.0000	0.0000

	μ	ν
II1	0.0285	0.7277
II2	0.0278	0.7237
II3	0.0522	0.7183
II4	0.0403	0.7420

	μ	ν
I	0.0429	0.4100
II	0.0673	0.3814

$$\overline{w}_{I2a} = \frac{1-\overline{w}_{I2a}}{n-\sum_i \overline{w}_i} = \frac{1-0.5387}{4-(0.5387+0.5875+0.5809+0)} = \frac{0.4613}{2.2930} = 0.2012$$

$$\overline{w}_{I2b} = \frac{1-0.5875}{2.2930} = 0.1799\ ;\ \overline{w}_{I2c} = \frac{1-0.5809}{2.2930} = 0.1828;\ \overline{w}_{I2d} = \frac{1-0}{2.2930} = 0.4361$$

The resulting weights are introduced in Table 10.

Step 8: In this step, the local weights of each criterion (Table 10) are multiplied by their parent sub-criteria weights and criteria weights to extract global weights. For example, the calculation regarding the global weights of sub-sub-criteria of Strategy is given below.

Local weight of Enablers (C_I): $\overline{w}_I = 0.5574$

Local weight of Strategy (C_{I2}): $\overline{w}_{I2} = 0.1561$

Global weight of Strategy: $w_{I2} = \overline{w}_{I2} * \overline{w}_I = 0.1561 * 0.5574 = 0.0870$

Global weight of C_{I2a}: $w_{I2a} = \overline{w}_{I2a} * \overline{w}_{I2} * \overline{w}_I = 0.2012 * 0.0870 = 0.0175$

Global weight of C_{I2b}: $w_{I2b} = \overline{w}_{I2b} * \overline{w}_{I2} * \overline{w}_I = 0.1799 * 0.0870 = 0.0157$

Global weight of C_{I2c}: $w_{I2c} = \overline{w}_{I2c} * \overline{w}_{I2} * \overline{w}_I = 0.1828 * 0.0870 = 0.0159$

Global weight of C_{I2d}: $w_{I2d} = \overline{w}_{I2d} * \overline{w}_{I2} * \overline{w}_I = 0.4361 * 0.0870 = 0.0380$

Step 9: Based on all experts' evaluations, the final weights are calculated as a group decision. According to the results of integrated preferences, the proposed EFQM-based self-assessment model's criteria weights may now be interpreted. Table 11 summarizes the main criteria and sub-criteria weights of the official EFQM and proposed model.

In the proposed model, Enablers representing the management aspects of the railway transportation company get higher importance in general, since its weight increased from 50% to 55.74%. Therefore, Results as the performance measure of the company's business

Table 10. Global weights of all factors

Main Criteria	Local Weights	Sub-Criteria	Local Weights	Global Weights	Sub-Sub-Criteria	Local Weights	Global Weights
Enablers	0.5574	Leadership	0.1328	0.0740	I1a	0.2000	0.0148
					I1b	0.2000	0.0148
					I1c	0.2000	0.0148
					I1d	0.2000	0.0148
					I1e	0.2000	0.0148
		People	0.1561	0.0870	I2a	0.2012	0.0175
					I2b	0.1799	0.0157
					I2c	0.1828	0.0159
					I2d	0.4361	0.0380
		Strategy	0.1413	0.0788	I3a	0.1329	0.0105
					I3b	0.1298	0.0102
					I3c	0.4657	0.0367
					I3d	0.1378	0.0109
					I3e	0.1338	0.0105
		Partnership and Res.	0.1460	0.0814	I4a	0.2320	0.0189
					I4b	0.1788	0.0146
					I4c	0.1761	0.0143
					I4d	0.1980	0.0161
					I4e	0.2151	0.0175
		Proc., Prod., & Services	0.4238	0.2362	I5a	0.1961	0.0463
					I5b	0.2519	0.0595
					I5c	0.1759	0.0415
					I5d	0.1993	0.0471
					I5e	0.1768	0.0418
Results	0.4426	Customer	0.2450	0.1084	II1a	0.4981	0.0540
					II1b	0.5019	0.0544
		People	0.2424	0.1073	II2a	0.5009	0.0537
					II2b	0.4991	0.0536
		Society	0.2530	0.1120	II3a	0.5002	0.0560
					II3b	0.4998	0.0560
		Key	0.2595	0.1149	II4a	0.5016	0.0576
					II4b	0.4984	0.0572

activities lost some importance. At first sight, it seems that the management activities are accepted as more important than the outputs of their results. But the consideration of the weights of sub-criteria may give a different and more realistic view. In fact, sub-criteria of Leadership, Strategy, People, and Partnership and Resources lost weights ranged between 1% and 3% and it seems all the lost slides to the sub-criterion of Products, Processes, and Services. Railway transportation experts gave more importance to services provided by the companies than other aspects of management. Actually, since railway transportation is a service itself, this finding points out an inevitable phenomenon of it. The general EFQM model is designed to be used in any industry. So, there are no industry-specific implications of it until now. Transporting goods and/or people requires an emphasis on processes and services. Otherwise, the customers can be lost to the competitor(s) as companies and other transportation modes like maritime, truck, or airway. To keep the goods and people safe and delivering

Table 11. Comparison of original and proposed models' weight sets

Main Criteria	Original Weights	Proposed Weights	Difference	Sub-Criteria	Original Weights	Proposed Weights	Difference	Rank
Enablers	0.50	0.5574	0.0574	Leadership	0.10	0.0740	-0.0260	9
				People	0.10	0.0870	-0.0130	6
				Strategy	0.10	0.0788	-0.0212	8
				Partnership and Res.	0.10	0.0814	-0.0186	7
				Proc., Prod., & Services	0.10	0.2362	0.1362	1
Results	0.50	0.4426	-0.0574	Customer	0.10	0.1084	0.0084	4
				People	0.15	0.1073	-0.0427	5
				Society	0.10	0.1120	0.0120	3
				Key	0.15	0.1149	-0.0351	2

the service with a top-quality involving timely delivery are among the basic expectations and requirements of customers.

From Table 11, it is observed that weights of many sub-criteria (6 out of 9; 4 out of 5 Enablers criteria, and 2 out of 4 Results criteria) were diminished for an EFQM application in the railway industry. The only weight increment in Enablers criteria was observed in Processes, Products, and Services by 13.62%. Customer and Society sub-criteria of Results also increased their weights by only 0.84% and 1.20%. It is obvious that the total lost weights were shifted to the three aforementioned sub-criteria and Services earned the biggest part of the pie with an increase of 13.62%. It can be interpreted that the railway experts gave due credit to Services sub-criteria.

According to these findings, it is evident that the weights of the official EFQM are not completely appropriate for the railway industry. Industries have different features, paradigms, expectations, and characteristics. The original model's equal weighting methodology should be updated by considering the distinctive requirements of the industry. As a quality self-assessment tool, the EFQM model should be modified according to the specific requirements of railway transportation service. Adjustment of the weighting schema can be a good starting point. Then, if required, definitions, concepts, or questions in EFQM can be updated according to the specifications of railway transportation.

CONCLUSIONS

In today's intensely competitive environment, EFQM has become a strategic issue, as it is an effective concept in choosing the best management tool for a business. EFQM is a concept that develops strategic capabilities and plays a key role in achieving sustainable competitive advantage.

Service quality is one of the most important issues in railway transportation because it is a concept that positively affects customer satisfaction, customer loyalty, corporate image, intention to repurchase, and operational efficiency. The quality of railway transport directly affects whether passengers travel by train and how often they travel by train. Therefore, it is important to take steps to improve the service quality of railway operators. EFQM model also provided an opportunity to consider the justification of the existing solutions of local authority activity in railway transportation. EFQM may authorize railway transportation managers to determine how local authority processes influenced the achievement of positive results and outcomes for passengers.

The purpose of this study is to build a modified EFQM-based self-assessment model for allowing railway companies to evaluate their service quality levels, provide relevant data on the continuous improvement process, and lead the way to higher levels of quality. This is the first attempt to conduct a case study in the Turkish railway industry using the IF-AHP method for EFQM model implementation. This study pointed out interesting results related to the gaps identified during the railway transportation and EFQM literature review and contributed toward improving railway service quality, thus encouraging the identification of solutions that lead to continuous improvement.

In this study, IF-AHP method which provided the relative importance of criteria was used to analyze the problem more comprehensively and effectively. We preferred to employ an intuitionistic version of AHP because this version is more inclusive than traditional fuzzy sets. In the original fuzzy definition, an expert can just provide a positive idea represented by a membership function. But intuitionistic fuzzy sets consider both positive and negative evaluations of the expert and represent these ideas with membership and non-membership degrees, respectively. AHP is a very famous and highly cited MADM method, and its power comes from its practicality and usability in any decision problem requiring subjective judgments of the experts. To increase its ability regarding the human judgment evaluations, we conducted an AHP analysis under IFS environment. Another power of AHP is its ability to assess the consistencies of the experts.

We developed a dedicated questionnaire for this study and took the EFQM model's elements as attributes. Then, the questionnaire was fulfilled by eleven railway experts in a face-to-face meeting. The collected data were analyzed by IF-AHP and the attribute weights were revealed. As can be seen in Table 11, all the weights we found are different than the original EFQM model's weight set. As a result, it has been determined that the importance of the Enablers has increased by 5.74% in total. It means the management aspects in the railway transportation companies should be improved as a quality dimension. It is observed that the results of management activities are admitted as more important than their outputs. Also, the highest change (its weight is increased from 10% to 23.62%) occurred in the Process, Production, and Services attribute. In contrast, the sub-criteria of Leadership, Strategy, People, and Partnership, Resources lost weight and it is obvious that all these losses have shifted to the sub-criterion of Products, Processes, and Services. This finding is very important because transportation activity is a service and management efforts should always be focused on service quality. So, the proposed EFQM model for the railway industry is reflecting this idea: processes and services will take the first position in any improvement plan because the customer's focus will be on service quality.

A country's development depends on the importance given to relations with transportation infrastructure so that the railway transportation service quality is expected to further improve by increasing the resources allocated to the railway infrastructure in Turkey. Turkey is located at the junction where international trade and logistic activities function among Europe, the Balkans, the Black Sea, the Caucasus, Central Asia, North Africa, and the Middle East. With the acceleration of economic growth and international trade, located in the Silk Road and the Spice Road route in the historical process, the importance of Turkey in the railway transportation undertaking act as a bridge between the East and West is further increased. Despite Turkey owned to having a huge advantage in strategic and geopolitical position, it is not a sufficient factor to be an international logistics center. Rail transportation is so critical regarding Turkey's transformation into an international logistics center. First of all, railway transportation should be provided as integration by sea, road, and air transportation for being an international logistics center. Railway transportation is one of the most important modes of transportation to realize intermodal transportation effectively and efficiently. In this context, a consideration that should be given to improving the quality of railway transportation services and infrastructure will strengthen the potential of becoming an international logistics center. These developments will provide an opportunity for Turkey about being a center country in the world and not a transit country.

The options for future research are wide. Firstly, a comprehensive analysis of air, sea, road, and railway transportation could be included to find the importance of general service quality measures for the logistics industry of a country. Secondly, the question that needs to be addressed is which transportation mode is more important regarding quality for being an international logistics center. This study has three basic limitations, one is related to the fact that the railway experts invited stay in Turkey; the judgment and thinking of these experts can contradict those of railway transportation experts in other countries. The second one is the assumption of the non-existence of influences/relations among criteria. Rather than using a version of the AHP, Analytic Network Process (ANP) can be performed.

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Appendix 1. The sub-sub-criteria included by the hierarchy of the EFQM Model.

(I1) Leadership

(I1a) Leaders develop the mission, vision, values and ethics and act as role models.

(I1b) Leaders define, monitor, review and drive the improvement of the organization's management system and performance.

(I1c) Leaders engage with external stakeholders.

(I1d) Leaders reinforce a culture of excellence with the organization's People.

(I1e) Leaders ensure that the organization is flexible and manages change effectively.

(I2) Strategy

(I2a) Strategy is based on understanding the needs and expectations of both stakeholders and the external environment.

(I2b) Strategy is based on understanding internal performance and capabilities.

(I2c) Strategy and supporting policies are developed, reviewed and updated to ensure economic, societal and ecological sustainability.

(I2d) Strategy and supporting policies are communicated and deployed through plans, processes and objectives.

(I3) People

(I3a) People plans support the organization's strategy.

(I3b) People's knowledge and capabilities are developed.

(I3c) People are aligned, involved and empowered.

(I3d) People communicate effectively throughout the organization.

(I3e) People are rewarded, recognized and cared for.

(I4) Partnership and resources

(I4a) Partners and suppliers are managed for sustainable benefit.

(I4b) Finances are managed to secure sustained success.

(I4c) Buildings, equipment, materials and natural resources are managed in a sustainable way.

(I4d) Technology is managed to support the delivery of strategy.

(I4e) Information and knowledge are managed to support effective decision making and to build the organizational capability.

(I5) Processes, products and services

(I5a) Processes are designed and managed to optimize stakeholder value.

(I5b) Products and Services are developed to create optimum value for customers.

(I5c) Products and services are effectively promoted and marketed.

(I5d) Products and services are produced, delivered and managed.

(I5e) Customer relationships are managed and enhanced.

(II1) Customer results

(II1a) Perception.

(II1b) Performance indicators.

(II2) People results

(II2a) Perception.

(II2b) Performance indicators.

(II3) Society results

(II3a) Perceptions.

(II3b) Performance indicators.

(II4) Key results

(II4a) Key outcomes.

(II4b) Key indicators.