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Evaluation of the financial performance of the textile and apparel industry in interval type-2 fuzzy environment

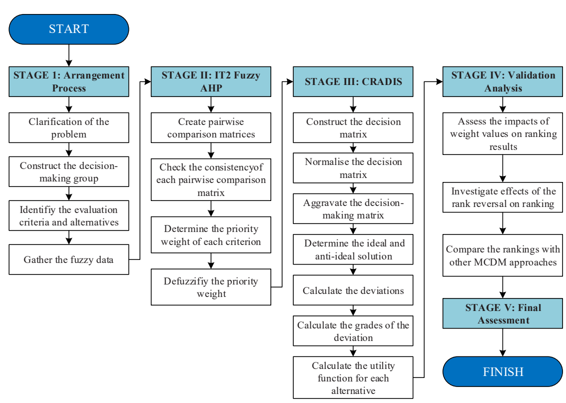
Ömer Faruk Görçün [a,*,1], Mohsin Shabir [b,2], Ahmet Çalık [c,d,3], Özcan Işık [e,4]

[a] Business Administration Department, Faculty of Economics, Administration, and Social Science, Kadir Has University, Cibali Av. Kadir Has St. Fatih, Istanbul 34083, Turkey
[b] School of Economics, Shandong University of Finance and Economics, Jinan, China
[c] Department of Business Administration, Faculty of Economics and Administrative Sciences, Balıkesir University, Bigadiç, Balıkesir, Turkey
[d] Aston Business School, Aston University, Birmingham, UK
[e] Department of Finance and Banking, Faculty of Economics and Administrative Sciences, Sivas Cumhuriyet University, Sivas, Turkey

HIGHLIGHTS

- Introduce a novel model based on interval type-2 fuzzy sets.
- Presenting novel criteria set identified using a mixed approach.
- It deals with financial performance analysis for the textile industry.
- Approving the validity, robustness, and applicability of the approach.

GRAPHICAL ABSTRACT



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ABSTRACT

The Turkish textile and apparel sector plays a crucial role in the national economy through employment, exports, and investment. The financial performance of companies is a key determinant of their sustainability and competitiveness, especially in global markets. The Turkish textile and apparel sector is one of the essential industries in terms of macro-economic indicators such as net foreign exchange inflow, employment and investment. This sector is also one of the critical actors in world trade. A robust performance evaluation model is essential for stakeholders such as investors, creditors, and managers. However, the assessment of firms is a very critical decision involving uncertainty due to various conflicting criteria based on judgements. In this study, an

* Corresponding author.
E-mail addresses: omer.gorcun@khas.edu.tr (Ö.F. Görçün), mohsin.shabir25@gmail.com (M. Shabir), ahmet.calik@balikesir.edu.tr (A. Çalık), ozcanisik@cumhuriyet.edu.tr (Ö. Işık).
[1] ORCID: 0000–0003-3850–6755
[2] ORCID: 0000–0002-1315–8654
[3] ORCID: 0000–0002-6796–0052
[4] ORCID: 0000–0003-2230–8738

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integrated multi-criteria decision-making (MCDM) model including interval type-2 fuzzy hierarchy process (IT2FAHP) and Compromise Ranking of Alternatives from Distance to Ideal Solution (CRADIS) approaches are proposed to assess the financial performance of Turkish textile and clothing firms that are traded in Borsa İstanbul (BİST) in the period from 2006 to 2020. In line with the determined purpose, the arithmetic average of the determined financial ratios during the analysis period covering 15 years is computed to obtain long-term performance indicators. The importance weights of the selected financial criteria for the performance evaluation model are identified by employing the IT2FAHP approach. Then, the firms are ranked according to their financial performances with the CRADIS method. In addition, the results from the sensitivity analysis validate the proposed approach and prove that it is practical. Moreover, practical and managerial implications are discussed based on the results. The results offer valuable insights for strategic decision-making and can support efforts to enhance financial stability in the textile and apparel sector. According to the results, "LUKSK" had the highest long-term financial performance among the 11 companies discussed. This company is followed by BOSSA, YATAS, and ATEKS companies. The alternatives confirm the robustness of the proposed model in maintaining its place in the ranking in 190 scenarios. In addition, the comparative analysis confirms the consistency of the proposed ranking framework.

1. Introduction

The Turkish textile and apparel sector has started to develop rapidly due to export-oriented policies initiated in 1980. The strategic importance of the textile and apparel industry [1] stems from the fact that they largely provide employment, are a producer of export products, and are a contributing sector to Turkey's GDP, as well as their strategic development. According to TUIK data, the industry covered 3 million 773 thousand SMEs in 2024, while this industry carried out 62.6 % of exports and 38.5 % of imports [2]. Its exports reached 1 billion 489.9 million dollars in November, with an increase of 4.3 percent compared to the same period of the previous year [3]. These figures prove that the textile and apparel sector continue to be a critical component of Turkey's industrial production capacity and international trade competitiveness. It has become one of the strategically significant industries of the Turkish economy thanks to the significant investments made in this sector since then [4].

This industry is also among the most economically influential sectors because it significantly contributes to gross domestic product, export and employment [5–8]. Moreover, the foreign currency input provided by the textile and clothing sector contributes to closing the current account deficit, a crucial macroeconomic problem of the country's economy. As of 2020, this industry, where more than 50,000 small and medium-sized firms operate, offers employment opportunities for more than one million people and continues to cooperate with many different sectors, from agriculture to the retail sector in Turkey [9].

Turkey is among the world's top 10 countries concerning the textiles and apparel trade. The WTO (2020) statistics show that Turkey's textiles and apparel exports totalled US$ 11.8 billion and US$ 15.9 billion, respectively. In 2019, Turkey, the world's fifth-largest textile exporter with a global share of 3.9 %, became the world's sixth-largest apparel exporter with a 3.2 % share in the world apparel export [10]. Therefore, analyzing the financial performance of firms operating in this industry, indispensable for the Turkish economy, is vital for its continuous development and long-term survival. However, despite the sector's macroeconomic importance, limited research has focused on evaluating the long-term financial performance of textile and apparel firms using advanced multi-criteria decision-making (MCDM) techniques under uncertainty. Most existing studies address short-term metrics or apply classical models, which lack robustness in handling expert-driven, ambiguous, and long-horizon data structures. This study aims to fill that gap.

In the finance literature, many researchers generally utilize various financial ratios in investigating the financial performance of firms [11–14]. Different financial indicators derived from the financial statements, such as balance sheets and income statements, are frequently used in evaluating the current financial situation and operating results, which allows for analyzing the performance of these firms from different perspectives [15,16].

Consequently, the financial performance evaluation carried out using traditional financial ratios provides highly critical information about the firms to a wide range of interest groups such as managers, bondholders, shareholders, existing and potential investors, lenders, and employees and also can help firms gain sustainable competitive advantage by enabling them to compare their performance with that of their competitors [17,18].

MCDM models are widely employed in assessing the financial performance of firms operating in various economic industries in many countries. For this reason, this paper aims to propose a new assessment model including IT2FAHP and CRADIS approaches for analyzing the financial performance of the publicly traded textile and apparel firms in Borsa Istanbul (BIST) for the period of 2006–2020. The main reason for integrating these two MCDM procedures is to improve the effectiveness of the alternative evaluation process by using the advantages of both techniques below. The main advantages of IT2FAHP can be summarized as follows: i) it is a weighting technique that considers experts' knowledge and experience. Also, it is more flexible and thriving in the problem-solving process compared to traditional AHP and type-1 fuzzy AHP; (ii) it can better handle the uncertainty and vagueness of the pairwise comparison process; and iii) it can quickly reduce the impacts of uncertainty regarding the opinions of experts in the pairwise comparison process. Consequently, the IT2FAHP procedure focuses on experts' opinions in the assessment process and produces more robust results [19–22]. The benefit of CRADIS is as follows: (i) CRADIS, which consists of a unique combination of different MCDM approaches such as ARAS, MARCOS, and TOPSIS, provides a more reasonable solution to the priority ranking problem, (ii) CRADIS uses a more practical, functional and effective approach to identify the best option among relatively existing alternatives, (iii) CRADIS has more flexible application steps than other MCDM methods because its algorithm can apply all types of normalization methods, and (iv) The algorithm that applies the CRADIS procedure, which takes into account the deviation of alternatives from the ideal and anti-ideal solution, produces more consistent ranking results [23,24].

The integration of IT2FAHP and CRADIS methods proposed in this study aims to take advantage of the strengths of both approaches. The IT2FAHP method is a tool that enables more effective handling of uncertainties and variability arising from expert opinions. It has a more flexible and stronger problem-solving ability than traditional AHP and type-1 fuzzy AHP methods. This method reduces uncertainties in evaluating expert opinions, allowing for more consistent and reliable weighing results. Therefore, the choice of IT2FAHP was justified as a strategic choice to meet the uncertainty management requirement of our study, ensuring the reliability of our findings.

The CRADIS method, on the other hand, is an innovative approach that provides flexibility and consistency in ordering alternatives. This method has a structure that combines the advantages of other MCDM methods such as ARAS, MARCOS, and TOPSIS. In addition, sorting by considering the distances to ideal and anti-ideal solutions ensures a high level of accuracy in the results. The fact that CRADIS supports flexible application steps and different normalization methods allows the method to offer a broader range of uses than other sequencing models. For these reasons, the CRADIS method, with its high level of accuracy, has been preferred as a ranking alternative.

The use of this proposed hybrid methodology is aimed at filling the existing gaps in the literature and offering an effective solution. Previous studies have addressed the limitations of traditional decision-making models (e.g., AHP, TOPSIS, and DEA), but the discussion on how to overcome these limitations has been lacking. By integrating IT2FAHP and CRADIS methods, our study brings methodological innovation that yields more effective results in decision-making processes. This effectiveness not only makes a theoretical contribution but also offers a workable solution, giving you hope for improved decision-making in your research and practice. As a result, the choice of the proposed model was carefully justified in terms of the specifics of the methods used and the purpose of the study. This approach has created a long-term and reliable performance evaluation process for the sector and increased the study's originality.

The main contributions of this study can be summarized as follows. First, while the priority weights of the selected financial criteria in previous studies have generally been calculated with MCDM tools such as AHP and FAHP, in this study, they are computed with the IT2FAHP approach, which can better model the uncertainty and vagueness regarding the decision process. Second, the CRADIS approach, a relatively new ranking approach that considers rank reversal, is used for evaluating and ranking the firms' success. Third, unlike many studies in the literature, in this study, the long-term financial performance of firms is assessed by considering 15 years of current data instead of a one-year dataset. Besides, the proposed MCDM framework simplifies the benchmarking analysis by facilitating the understanding of the assessment procedure for decision-makers. Furthermore, integrating IT2F-based AHP and CRADIS methodologies for the textile and apparel industry can be extended to other industries for firm performance analysis.

In light of this context, the central research question guiding this study is: How can a hybrid fuzzy MCDM framework be used to evaluate the long-term financial performance of textile and apparel firms in a way that accounts for expert judgments and uncertainty?

The rest of the paper is organized as follows. The next section reviews the relevant literature on firm performance assessment and studies applying IT2FAHP and CRADIS procedures. Then, the research gap is discussed in the third section. The proposed hybrid methodology is described in the fourth section. The results obtained from the proposed method to evaluate the financial performance of selected firms with data for 2006 and 2020 are presented and discussed in the fifth section. In the next section, an extensive sensitivity check is carried out to analyze the validity of the suggested MCDM framework. Based on the results obtained from the proposed performance assessment framework, the practical and managerial implications of the paper are summarized in the seventh section. Finally, the eighth section gives concluding remarks and future research directions.

2. The research background

In recent years, MCDM tools have been used frequently in measuring, comparing or evaluating the financial or non-financial performance of various companies operating in different sectors of the economy. However, the number of studies specifically applying MCDM methods to the textile and apparel industry remains relatively limited. For instance, Wang et al. [25] used a fuzzy AHP & TOPSIS model to assess manufacturer selection in textile supply chains, while Ulutaş [26] applied Grey AHP and ROV-G to evaluate textile machine selection in Turkish garment factories. Similarly, Raut et al. [27] utilized interpretive structural modeling (ISM) to rank the barriers to sustainable textile and apparel supply chains. Aytekin and Çiftci [28] evaluated the performance of twenty textile and apparel firms in Turkey with the help of the CODAS and MOOSRA methods. These examples demonstrate that MCDM tools are increasingly relevant in this industry but have not been systematically applied to financial performance evaluation over extended periods. A brief review of the literature incorporating financial and non-financial ratios into MCDM models can be given as follows.

Babic & Plazibat [29] have created a model including AHP and PROMETHEE methods to determine the most successful alternative among 12 firms dealing with import and export in Croatia. Zhu [30] used the DEA method to solve the financial performance evaluation problem for Fortune 500 firms. Yurdakul & İç [31] have developed a financial evaluation model that combines the AHP and TOPSIS approaches to assess the performance of 19 Turkish manufacturing firms employing a dataset which covers the 2001–2003 period. Ginevičius & Podvezko [32] have integrated AHP, SAW, COPRAS, and TOPSIS to assess the financial performance of four alternative firms. Ertuğrul & Karakaşoğlu [11] have constructed a hybrid MCDM model consisting of fuzzy AHP and TOPSIS approaches for assessing Turkish cement firms' financial performance. Kung et al. [33] have used a hybrid model that incorporates fuzzy AHP and fuzzy TOPSIS approaches for identifying the best alternative among five firms in Taiwan. Yalcin et al. [12] combined Fuzzy AHP, TOPSIS, and VIKOR with various financial performance indicators to design a performance assessment model for 94 manufacturing firms operating in 7 different sectors registered in Borsa Istanbul in 2007. Moghimi & Anvari [34] have focused on a combination of fuzzy AHP-TOPSIS techniques for evaluating the financial performance of 8 publicly listed cement firms in Iran. Esbouei et al. [35] suggested an integrated MCDM model including AHP, COPRAS, ARAS and VIKOR techniques to assess the financial performance of six automotive firms in Iran. Rezaie et al. [36] have integrated fuzzy AHP and VIKOR methodology to compare the performance level of 27 Iranian cement firms for the period covering the years 2009–2010. Hsu [37] designed a decision-making model to conduct a performance assessment and an efficiency analysis in Taiwan's semiconductor industry in 2010. In his study, the author first determined the efficient and inefficient firms using the DEA approach. Then, he evaluated the operational performance of the two groups of firms (11 efficient and 27 inefficient) by employing the Entropy, VIKOR and improved Grey Relational Analysis (IGRA) methods. Shaverdi et al. [13] have applied MCDM models (e.g. fuzzy AHP and fuzzy TOPSIS) to evaluate and rank Iranian petrochemical firms' financial performance. Adel Alfonso et al. [14] have proposed a model based on the Fuzzy AHP-TOPSIS in choosing the best alternative among 40 Colombian firms in terms of selected three financial indicators for the five years between 2012 and 2016. Dahooie et al. [38] have introduced a new integrated approach based on CCSD, Fuzzy C Means and ARAS to evaluate the performance of 58 manufacturing firms. Neves et al. [39] have developed an integrated model including the generalized method of moments (GMM) estimation approach and data envelopment analysis (DEA) for the evaluation of 213 electricity firms' financial performance in Portugal for the period between 2010 and 2014. Ioan Ban et al. [40] have employed a hybrid MCDM approach comprising an integrated fuzzy AHP and TOPSIS to assess the financial performance of 33 listed manufacturing firms in Romania from 2011–2015. Angilella & Pappalardo [41] have developed a performance assessment model based on Hierarchy Stochastic Multi-Attribute Acceptability (HSMAA) methodology to evaluate the performance of listed energy firms operating in five countries. Aduba [42], using a hybrid approach based on fuzzy AHP and TOPSIS methods, analyzed the performance of the top 18 Japanese construction firms in terms of financial ratios and value-based indicators. İç et al. [43] suggested the AHP-modified VIKOR integrated model for evaluating the financial performance of retail and wholesale trade firms. Biswas et al. [44] presented an integrated framework of LOPCOW and EDAS approaches to analyze the impact of COVID-19 on the performance of 30 listed firms in İndia. Biswas & Joshi [45] used the LOPCOW approach to calculate the weights of performance criteria based on market and accounting indicators and rank 17 IPOs.

2.1. Research gaps

Performance assessment is a vital and complex process that necessitates flexible and analytical methods, as it depends on many conflicting evaluation criteria that directly impact the evaluation process [30]. In today's global world economy, where competition is gaining importance, determining firms' current status in terms of financial and non-financial indicators is a central issue in the current literature [13].

Although non-financial indicators based on environmental and social factors and market-based measures provide strategic information to decision-makers, it takes time to calculate, interpret and understand them, making it difficult to make quick and reasonable decisions. As a result, it is undeniable that taking quick and reasonable decisions provides significant advantages to decision-makers in the markets. Therefore, financial ratios obtained from basic financial statements such as balance sheets and income statements provide vital information not only to firm management but also to credit institutions (banks and other financial institutions) and investors on fundamental issues such as the firm's debt structure, liquidity, profitability, and growth strategies [11, 12]. Besides, financial ratios also provide critical information to decision-makers about the efficiency and productivity of the firm. Consequently, ignoring financial ratios in firm performance analyses may prevent all parties related to the firm from making practical, fast, and reasonable decisions.

Since the textile and apparel industry plays a vital role in developing economies, the ranking problem of this industry has become one of the most critical optimization problems. One of the essential elements that will enable textile and apparel firms to succeed in their markets is establishing appropriate performance measurement systems. In a globalized world economy, there is a need for a decision support system or methodological framework for textile and apparel firms to evaluate their strengths and weaknesses compared to other companies operating in the same industry.

The literature review in the previous section reveals three critical gaps in the previous literature. Previous studies focusing on a short period or a specific year can be considered the first gap. Since such studies make short-term performance assessments of firms or the relevant industry, they are insufficient for long-term performance analysis and are limited in meeting decision-makers needs. The second gap is related to the absence of a study in the literature that integrates the IT2FAHP and CRADIS approach to evaluate the performance of firms in terms of financial ratios. Therefore, proposing a performance evaluation framework that uses the beneficial aspects of both methods contributes to a more comprehensive and practical evaluation of firms in terms of financial ratios. The third and last gap is associated with the absence of studies focusing on performance assessment in the textile and apparel industry, one of the most important industries of the developing economy. As a result, this study proposing a novel integrated model including IT2FAHP and CRADIS methods to analyze the long-term financial performance of companies in the textile and apparel industry provides a more comprehensive framework for meeting decision-makers requirements regarding industry evaluation and performance analysis.

When we evaluate the relevant literature comprehensively, it has been observed that the researchers preferred to apply traditional decision-making approaches, such as AHP, TOPSIS, DEA, and COPRAS, which are the most criticized techniques in the relevant literature. However, these studies did not present a validate evidence on how they overcome these frameworks' drawbacks and structural problems. In addition, although few studies dealt with existing uncertainties with the help of fuzzy approaches, traditional fuzzy set theory was used in these studies. However, the traditional fuzzy set theory may not produce efficient solutions because it can not capture and process highly complicated ambiguities. Also, the literature is scattered, and the focal points of the current works are primarily different. Almost all studies dealt with financial performance analysis, but each study analyzed the financial performance of companies in various industries. However, financial performance indicators are different in each industry, and these indicators may not be proper for firms in different industries. Hence, the findings of these studies may not be generalized to different industries. Though some authors dealt with firms' financial performances in various industries, such as automotive, energy, and cement, there is no study focusing on firms' financial performance in the textile and apparel industry in the relevant literature, according to the authors' information. In addition, there are also some gaps in the practice. The textile and apparel industry practitioners have no reliable, practical and efficient evaluation tool commonly accepted in the relevant industry to assess their financial performance comparatively. Thus, it leads to depriving a road map to improve their companies' financial performance in a highly competitive business environment.

In summary, while numerous studies have explored MCDM applications in various industrial contexts, limited research has focused on the textile and apparel industry, particularly on long-term financial performance under uncertainty. Furthermore, studies employing advanced fuzzy MCDM methods such as IT2FAHP and CRADIS in this domain are virtually nonexistent. This gap highlights the need for a robust, context-specific, and uncertainty-aware performance evaluation framework tailored for this strategically important sector.

2.2. Objectives and motivations of the study

By keeping the existing research and implementation gaps in mind, this paper proposes a novel integrated decision-making model to fill these gaps. This model can also be applied to evaluate the financial performance of the textile and apparel industry firms aside from companies in various industries. In addition to the trustworthiness and robustness of the proposed hybrid model, it can help practitioners to overcome enormously complicated uncertainties in a real-life decision-making environment. Besides, the current work presents a road map for decision-makers in the textile and apparel industry to assess and improve their financial performance in a highly dynamic business environment. Aside from its robust and powerful decision-making framework, it has an efficient procedure that decision-makers can follow without requiring advanced mathematical knowledge.

The components of the proposed performance assessment model combining the IT2FAHP with the CRADIS have been used to cope with various MCDM problems. The IT2FAHP technique, which is employed to calculate the subjective criteria weights, has been incorporated into the solution process of many MCDM problems such as selection of suppliers (Kahraman et al., 2014), an application at multinational consumer electronics company [46], an application in a work wear manufacturing company [47], humanitarian relief organizations in Turkey [48], an actual case application for Turkey [49], an application at Turkish Technic Inc [20]., an application in dry bulk cargo terminals [50], a case study in Nigeria [51], assessment of air quality in urban areas [52], an application at real estate investment trusts in Turkey (Yilmaz et al., 2019), a case study in the Çorum River Basin [53], for selecting sustainable suppliers and order allocation problem [54], for optimization of the renewable energy project portfolio(s) in China [55], selecting green suppliers [22], supplier selection [21], evaluating factors of e learning platforms [56], evaluation of wheat processing plants [57], site selection of nursing homes [58], and vaccine selection [59].

As for the CRADIS technique proposed by [23], the number of studies employing this technique and its extensions or addressing any MCDM problem is relatively low. In the current literature, this technique is utilized in a variety of applications, including a comparison of the energy and environmental performance of countries [60], evaluating macro-economic parameters [61], market assessment [62], tractor ranking [63], green supplier selection [64,65], evaluation of innovation performance of countries [66], selection of internet-of-things service provider [24], performance assessment of end milling processes [67], analysis of bus rapid transit system [68], occupational risk analysis [69], ranking the level of economic freedom of countries [70], and selection of sustainable suppliers [71].

The primary motivation of this study is to fill some critical research gaps identified in the existing literature and to bring a new perspective to sectoral performance evaluation processes. First of all, it has been observed that many studies in the literature are limited to short-term performance analyses and, therefore, are insufficient in terms of long-term evaluation. Our study evaluated the long-term financial performance of companies in the Turkish textile and apparel sector using a 15-year data set. This approach is essential to supporting the sector's sustainable development and providing a more comprehensive analysis.

Secondly, no methodology integrates the IT2FAHP and CRADIS methods into the existing literature. In our study, a new hybrid model was developed that combines the strengths of these two methods. While the IT2FAHP method enables more effective management of uncertainties in decision-making, the CRADIS method offers more consistency and flexibility in ranking alternatives. Thus, the companies' performance evaluation processes were handled using analytical and practical approaches.

Finally, the lack of performance evaluation studies for the textile and apparel sector draws attention. Current studies have generally focused on the automotive, energy, and cement sectors. However, the textile and ready-to-wear sector is not just another industry; it is strategically essential in many macroeconomic indicators of the Turkish economy, such as foreign trade, employment, and investment. Our study aims to fill this gap in the literature by focusing on this vital sector. In addition, this study aims to develop practical solutions for improving sectoral performance by providing a feasible roadmap for decision-makers. In this context, our study fills these critical gaps in the literature and provides a sector-specific, long-term, and sustainable evaluation model for decision-makers and practitioners.

3. Methods

In the following section, some definitions of interval type-2 fuzzy sets are outlined concisely. Additionally, the IT2FAHP and CRADIS methods are elucidated. Ultimately, the propounded research framework is introduced.

3.1. Interval type-2 fuzzy sets

Basic definitions for type-2 fuzzy sets (T2FSs) and IT2FSs are presented below [72–74]:

Definition 1. A type-2 fuzzy set $\tilde{\tilde{A}}$ in the universe of discourse, X can be represented by a type-2 membership function $\mu_{\tilde{\tilde{A}}}(x)$, shown as follows:

$$\tilde{\tilde{A}} = \left\{ ((x,u), \mu_{\tilde{\tilde{A}}}(x,u)) | \forall x \in X, \forall u \in J_X \subseteq [0,1], 0 \le \mu_{\tilde{\tilde{A}}}(x,u) \le 1 \right\} \tag{1}$$

where J_X denotes an interval in $[0,1]$.

Definition 2. Let $\tilde{\tilde{A}}$ a type-2 fuzzy set in the universe of discourse X represented by the type-2 membership function $\mu_{\tilde{\tilde{A}}}$. If all $\mu_{\tilde{\tilde{A}}}(x,u) = 1$, then $\tilde{A}$ is called an interval type-2 fuzzy set. An interval type-2 fuzzy set can be regarded as a particular case of a type-2 fuzzy set where:

$$\tilde{\tilde{A}} = \int_{x \epsilon X} \int_{u \epsilon J_X} 1/(x,u) \tag{2}$$

$J_X \subseteq [0,1]$.

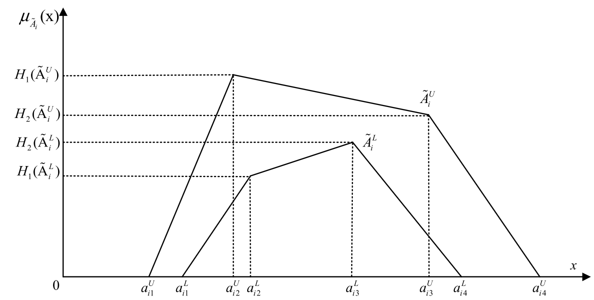

Fig. 1. The membership function of trapezoidal IT2FS.

Definition 3. The upper and lower membership functions of an interval type-2 fuzzy set are type-1 membership functions. Fig. 1 represents a trapezoidal IT2FS $\tilde{\tilde{A}}_i = \left(\tilde{A}_i^U; \tilde{A}_i^L\right) = \left(\left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1\left(\tilde{A}_i^U\right), H_2\left(\tilde{A}_i^U\right)\right), \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1\left(\tilde{A}_i^L\right), H_2\left(\tilde{A}_i^L\right)\right)\right)$ where $\tilde{A}_i^U$ and $\tilde{A}_i^L$ are T1FSs, $a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U$, $a_{i1}^L, a_{i2}^L, a_{i3}^L$ and a_{i4}^L are the reference points of the IT2FS $\tilde{\tilde{A}}_i$, $H_j\left(\tilde{A}_i^U\right); 1 \le j \le 2$ denotes the membership value of the element $a_{i(j+1)}^U$ in the upper trapezoidal membership function $\tilde{A}_i^U$, $H_j\left(\tilde{A}_i^L\right); 1 \le j \le 2$ denotes the membership value of the element $a_{i(j+1)}^L$ in the lower trapezoidal membership function $\tilde{A}_i^L$. $H_1\left(\tilde{A}_i^U\right) \in [0,1], H_2\left(\tilde{A}_i^U\right) \in [0,1]$, $H_1\left(\tilde{A}_i^L\right) \in [0,1], H_2\left(\tilde{A}_i^L\right) \in [0,1]$ and $1 \le i \le n$. To better illustrate the application of interval type-2 fuzzy numbers (IT2FNs) in this study, Fig. 1 demonstrates how linguistic judgments (e.g., "Very Strong") are translated into trapezoidal membership functions with upper and lower bounds. For instance, a linguistic evaluation of "Very Strong" importance between two financial criteria is represented as ((5, 6, 8, 9; 1,1), (5.2, 6.2, 7.8, 8.8; 0.8, 0.8)) to capture the uncertainty in human judgment. These IT2FNs are then used in pairwise comparisons to determine reliable and robust weightings.

In this study, linguistic comparisons made by experts, such as "Very Strong" or "Moderate," are modelled using interval type-2 fuzzy numbers (IT2FNs). These fuzzy numbers allow us to incorporate uncertainty and variability in expert judgments by representing upper and lower membership functions. Fig. 2 illustrates how the linguistic term "Very Strong" is defined using a trapezoidal IT2FN.

As shown in Fig. 2, the IT2FN captures both the central tendency and the uncertainty in expert assessments. This modeling approach is

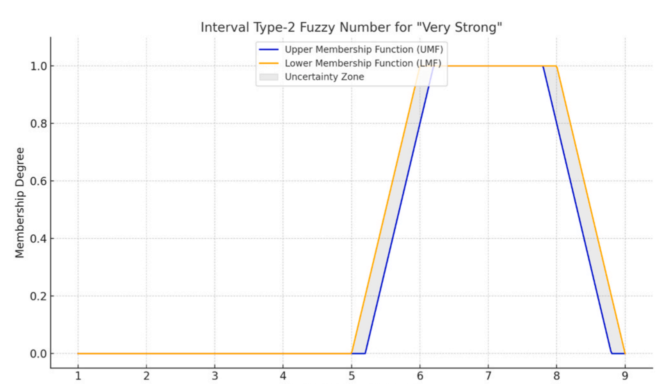

Fig. 2. Representation of the linguistic variable "Very Strong" as an interval type-2 fuzzy number. The shaded region between the upper and lower membership functions illustrates the uncertainty in expert evaluations over the 1–9 importance scale.

Table 1
Linguistic variables for the importance of the criteria [76].

Linguistic variables	Interval type-2 fuzzy numbers (IT2FNs)
Absolutely strong (AS)	(7, 8, 9, 9; 1, 1) (7.2, 8.2, 8.8, 9; 0.8, 0.8)
Very strong (VS)	(5, 6, 8, 9; 1, 1) (5.2, 6.2, 7.8, 8.8; 0.8, 0.8)
Fairly strong (FS)	(3, 4, 6, 7; 1, 1) (3.2, 4.2, 5.8, 6.8; 0.8, 0.8)
Slightly strong (SS)	(1, 2, 4, 5; 1, 1) (1.2, 2.2, 3.8, 4.8; 0.8, 0.8)
Equal (E)	(1, 1, 1, 1; 1, 1) (1, 1, 1, 1; 1, 1)

meet their short-term liabilities. Financial leverage assesses firms' debt utilisation and financial risk. Activity ratios determine the efficiency of firms' asset utilisation in generating income. Profitability measures the capacity of firms to generate earnings when expenses and assets are taken into account. Lastly, growth ratios reflect the long-term financial sustainability and expansion potential of firms.

Sub-Criteria (Third Level): Each main dimension is comprised of specific financial ratios that are utilised as performance measures. In the present research, nineteen financial sub-criteria are considered. These sub-criteria are illustrated in Table 2.

Table 2
Dimensions and indicators to assess financial performance.

Dimension	Performance indicator	Formulation
Liquidity ratio (L1)	Current ratio (L11)	The ratio of current assets to current liabilities
	Quick ratio (L12)	(Current assets−inventories)/Current liabilities
	Cash ratio (L13)	(Cash +marketable securities)/current liabilities
Financial leverage ratio (FL2)	Short-term debt ratio (FL21)	The ratio of short-term debt to total asset
	Long-term debt ratio (FL22)	The ratio of long-term debt to total asset
	Debt ratio (FL23)	The ratio of total debt to total asset
	Debt-to-equity ratio (FL24)	The ratio of total debt to shareholder's equity
	Fixed assets-to-equity ratio (FL25)	The ratio of fixed assets to shareholder's equity
Activity ratio (A3)	Account receivable ratio (A31)	The ratio of total net sales to accounts receivables
	Inventory turnover ratio (A32)	The ratio of costs of goods sold to average inventory
	Accounts payable turnover ratio (A33)	The ratio of purchases on credit to average accounts payable
	Total asset turnover ratio (A34)	The ratio of sales to total assets
Profitability ratio (P4)	Return on assets (P41)	The ratio of net income to total assets
	Return on equity (P42)	The ratio of net income to stockholder's equity
	Net profit margin (P43)	The ratio of net income to sales
Growth ratio (G5)	Asset growth (G51)	$[(\text{Assets}_t - \text{assets}_{t-1})/\text{assets}_{t-1}]\times 100$
	Net sales growth (G52)	$[(\text{Net sales}_t - \text{net sales}_{t-1})/\text{net sales}_{t-1}]\times 100$
	Shareholder's equity growth (G53)	$[(\text{Equity}_t - \text{equity}_{t-1})/\text{equity}_{t-1}]\times 100$
	Net profit growth (G54)	$[(\text{Net profit}_t - \text{net profit}_{t-1})/\text{net profit}_{t-1}]\times 100$

beneficial in financial decision-making contexts where expert judgments may be vague or imprecise, ensuring a more robust and representative weighting process.

3.2. IT2FAHP method

The calculation procedure of the IT2FAHP method is explained as follows:

Step 1: Build the model hierarchical structure. Firstly, a hierarchical structure for the performance measurement problem was designed, consisting of four levels: objective, main criteria, sub-criteria, and firms [75]. The decision hierarchy is structured into the following levels: These levels were specifically tailored to the features of the Turkish textile and apparel industry. The five main criteria—liquidity, financial leverage, activity, profitability, and growth—were selected based on their relevance in assessing long-term financial viability. Expert input was gathered from professionals with industry and financial backgrounds to ensure contextual accuracy in assigning relative weights.

Objective (First Level): The primary objective is to evaluate and rank the financial performance of textile and apparel firms based on selected financial indicators.

Main Criteria (Second Level): Five main financial performance categories (dimensions) were identified through an extensive literature review and expert assessment. The five critical financial performance dimensions identified include liquidity, financial leverage, activity, profitability, and growth groups. Liquidity gauges the ability of firms to meet their short-term liabilities.

Decision alternatives (Last Level): The alternatives represent the firms being evaluated. After filtering firms with incomplete financial data, the final sample includes 11 companies listed on the BIST textile and apparel industry.

Step 2: The experts present the linguistic pairwise comparison matrices for all criteria within the hierarchical systems using the interval type-2 fuzzy scale shown in Table 1, which are subsequently converted into IT2 fuzzy pairwise comparison matrices [22].

Step 3: Each IT2 fuzzy pairwise comparison matrix undergoes a consistency verification. Initially, the components of each IT2 fuzzy pairwise comparison matrix are converted from IT2FNs to crisp values [77]. Then, the consistency of pairwise comparison matrices is checked to see whether the consistency of each pairwise comparison matrix is less than 0.10.

Step 4: The geometric mean of each row is calculated by utilizing Eq. (3),

$$\tilde{\tilde{r}}_i = \left[\tilde{\tilde{a}}_{i1} \otimes \ldots \otimes \tilde{\tilde{a}}_{in}\right]^{1/n} \tag{3}$$

where

$$\sqrt[n]{\tilde{\tilde{a}}_{ij}} = \left(\left(\sqrt[n]{\tilde{\tilde{a}}^U_{ij1}}, \sqrt[n]{\tilde{\tilde{a}}^U_{ij2}}, \sqrt[n]{\tilde{\tilde{a}}^U_{ij3}}, \sqrt[n]{\tilde{\tilde{a}}^U_{ij4}}; H^U_1(a_{ij}), H^U_2(a_{ij})\right), \left(\sqrt[n]{\tilde{\tilde{a}}^L_{ij1}}, \sqrt[n]{\tilde{\tilde{a}}^L_{ij2}}, \sqrt[n]{\tilde{\tilde{a}}^L_{ij3}}, \sqrt[n]{\tilde{\tilde{a}}^L_{ij4}}; H^L_1(a_{ij}), H^L_2(a_{ij})\right)\right)$$

Step 5: Following the computation of the geometric mean for each row, the weights are established by the normalizing procedure. The interval type-2 fuzzy weight of the ith criterion is calculated by using Eq. (4) [46],

$$\tilde{\tilde{w}}_i = \tilde{\tilde{r}}_i \otimes \left[\tilde{\tilde{r}}_1 \oplus \ldots \oplus \tilde{\tilde{r}}_i \quad \oplus \ldots \oplus \tilde{\tilde{r}}_n \quad\right]^{-1} \tag{4}$$

Step 6: The fuzzy weights calculated for each criterion in the previous step are then defuzzified through the center-of-area technique [72] to obtain the crisp weight of each criterion.

$$Defuzzified(\tilde{\tilde{w}}_i) = \frac{\frac{(u_U-l_U)+(\beta_U \bullet m_{1U}-l_U)+(\alpha_U \bullet m_{2U}-l_U)}{4} + l_U + \left[\frac{(u_L-l_L)+(\beta_L \bullet m_{1L}-l_L)+(\alpha_L \bullet m_{2L}-l_L)}{4} + l_L\right]}{2}$$

Step 7: The crisp weight of each criterion are standardized using the Eq. (5).

$$w_i = \frac{Defuzzified(\tilde{\tilde{w}}_i)}{\sum_{i=1}^{n} Defuzzified(\tilde{\tilde{w}}_i)} \tag{5}$$

3.3. CRADIS method

The calculation procedure of the CRADIS method is carried out employing the following steps [63]: This study applies the CRADIS method to rank 11 textile and apparel firms based on 19 financial performance indicators under five dimensions. These indicators are normalized and weighted according to their importance, after which the CRADIS algorithm computes their distances from ideal and anti-ideal solutions. This ranking approach was chosen for its robustness to rank reversal and suitability for complex multi-indicator contexts such as long-term financial assessment.

Step 1. The decision matrix A is established as shown in Eq. (6):

$$A = [a_{ij}]_{m\times n} \quad = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}; i = 1, 2, \ldots\ldots m; j = 1, 2, \ldots n \tag{6}$$

Where, a_{ij} is the assessment value of i-th alternative in terms of j-th criterion.

Step 2: The decision matrix A is normalized by employing Eqs. (7) and (8) [62]:

$$n_{ij} = \frac{a_{ij}}{a_{jmax}} \text{if the criterion} j \in BFC \tag{7}$$

$$n_{ij} = \frac{a_{jmin}}{a_{ij}} \text{if the criterion} j \in NBFC \tag{8}$$

In Eqs. (7) and (8), BFC and NBFC indicate the beneficial and non-beneficial criteria, respectively.

Step 3: The weighted normalized decision matrix is established via the application of Eq. (9) [23]:

$$v_{ij} = n_{ij} \times w_j \tag{9}$$

where w_j is the weight coefficient of criterion j.

Step 4: Identification of the ideal solution (t_i) and anti-ideal solution (t_{ai}). The ideal and anti-ideal solutions are the largest and smallest values in the weighted normalized decision matrix [63].

$$t_i = maxv_{ij} \tag{10}$$

$$t_{ai} = minv_{ij} \tag{11}$$

Step 5: Computation of deviations from ideal and anti-ideal solutions.

$$d^+ = t_i - v_{ij} \tag{12}$$

$$d^- = v_{ij} - t_{ai} \tag{13}$$

Step 6: Computation of the deviation of the individual alternatives from the ideal and anti-ideal solutions [63].

$$s_i^+ = \sum_{j=1}^{n} d^+ \tag{14}$$

$$s_i^- = \sum_{j=1}^{n} d^- \tag{15}$$

Step 7: Determination of the utility function for each alternative about the deviations from the optimal alternatives.

$$K_i^+ = \frac{s_0^+}{s_i^+} \tag{16}$$

$$K_i^- = \frac{s_0^-}{s_i^-} \tag{17}$$

where s_0^+ denotes the optimal alternative that has the smallest distance from the ideal solution and s_0^- stands for the optimal alternative with the greatest distance from the anti-ideal solution.

Step 8: Ranking the alternatives.

$$Q_i = \frac{K_i^+ + K_i^-}{2} \tag{18}$$

In the last step, the alternatives are ranked based on Q_i values. So, the alternative having the highest value of Q_i is identified as the best option [24].

3.4. Proposed research framework

The existing research has been conducted to gauge and analyse the financial performance of Turkish textile and apparel firms that are traded on the BIST. The developed research framework for addressing the financial performance measurement problem involving experts, criteria, and firm alternatives consisted of four main stages: preparation process, weighting process (IT2F-AHP), firm alternatives ranking process (CRADIS), and validation process of the ranking outcomes. The implementation procedure of the developed research framework is illustrated in the Fig. 3.

4. Case study: Assessing the textile and apparel firms' financial performances

Here, the implementation of the proposed integrated approach is presented by following the basic procedure of the proposed hybrid framework.

4.1. Dataset

In this section, a performance evaluation model including IT2FAHP

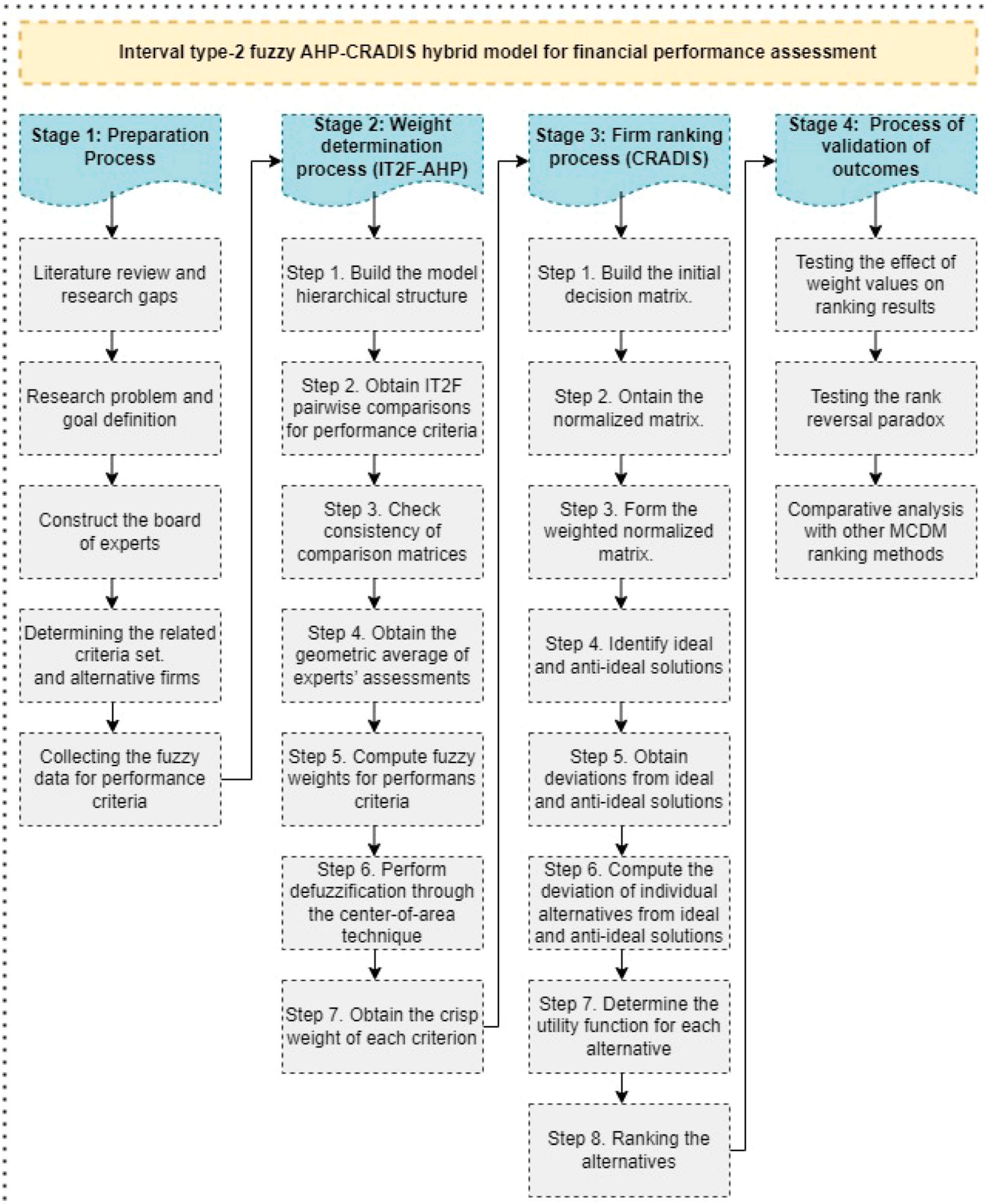

Fig. 3. The proposed hybrid MCDM framework for financial performance assessment.

and CRADIS methods is formed to compare the financial performance of publicly traded Turkish textile and apparel firms. As of the end of 2020, twenty-three firms operate in the BIST textile and apparel industry. However, the firms whose at least one financial ratio could not be calculated are excluded from the dataset containing the 2006–2020 period. As a result, our sample consists of eleven firms. These are Akın Tekstil (ATEKS), Arsan Tekstil (ARSAN), Birko Mensucat (BRKO), Birlik Mensucat (BRMEN), Bossa (BOSSA), Karsu Tekstil (KRTEK), Lüks Kadife (LUKSK), Menderes Tekstil (MNDRS), Söktaş (SKTAS), Yataş (YATAS), and Yünsa (YUNSA).

Following the studies by Ertuğrul & Karakaşoğlu [11], Yalcin et al. [12], Shaverdi et al. [13], and Adel Alfonso et al. [14], this research identified nineteen financial main and sub-criteria for the 15 years between 2006 and 2020. Since the study aims to measure and evaluate long-term financial performance, the initial performance matrix is generated by taking each firm's arithmetic means of the financial ratios. As detailed in Table 2, nineteen financial performance indicators are categorized under five main criteria: liquidity, financial leverage, activity, profitability, and growth. These sub-criteria include widely accepted financial ratios such as the current ratio, return on equity, debt ratio, and inventory turnover ratio. Including these indicators (ratios) in the analysis is based on their relationship with the evaluation of different financial qualities of the financial activities and performances of the enterprises and the frequency of their preference in the relevant literature. The comprehensive set of criteria determines measures that evaluate the enterprises' long-term, medium-term, and short-term financial performances and allows them to be assessed in a thorough and multidimensional manner.

All financial data used in this study were obtained from the FINNET database, a reliable financial reporting platform widely utilized in academic and industry research in Turkey. The dataset includes yearly financial ratios from 2006 to 2020 for publicly traded textile and apparel firms listed on Borsa İstanbul (BIST). Firms with incomplete data during this period were excluded, resulting in a final sample of eleven firms. The arithmetic average of each financial ratio over the 15 years was calculated to construct the initial performance matrix for each company.

As seen in Table 2, nineteen different financial indicators in five separate groups representing liquidity, financial leverage, activity, profitability, and growth are selected for our performance evaluation model as a result of analyzing similar studies in previous literature. All financial indicators used as performance criteria have been collected from the FINNET database, and detailed explanations of these criteria are presented in Table 2. The optimization direction is maximum for the financial ratios shown in Table 2, except for financial leverage ratios.

Following the determination of the financial main and sub-criteria to be used in performance analysis, an associate professor of finance, a bank manager, and a senior executive working in the textile industry are appointed as members of the board of experts to assess the relative importance of financial ratios utilizing pairwise comparisons. As soon as the decision hierarchy is formed, selected performance criteria are weighted with the IT2FAHP method and textile and clothing firms are ranked concerning their performance scores based on the CRADIS method.

Table 3
The pairwise comparison for the dimension.

	L1	FL2	A3	P4	G5
L1	E, E, E	1/VS, SS, SS	1/FS, FS, E	1/AS, FS, 1/FS	E, SS, E
FL2	VS, 1/SS, 1/SS	E, E, E	SS, SS, E	1/FS, FS, 1/FS	SS, E, 1/SS
A3	FS, 1/FS, E	1/SS, 1/SS, E	E, E, E	1/FS, SS, 1/VS	SS, E, 1/SS
P4	AS, 1/FS, FS	FS, 1/FS, FS	FS, 1/SS, VS	E, E, E	AS, 1/SS, AS
G5	E, 1/SS, E	1/SS, E, SS	1/SS, E, SS	1/AS, SS, 1/AS	E, E, E

Table 4
The pairwise comparison of the liquidity ratios.

	L11	L12	L13
L11	E, E, E	1/SS, VS, 1/SS	1/AS, SS, 1/VS
L12	SS, 1/VS, SS	E, E, E	1/VS, 1/FS, 1/FS
L13	AS, 1/SS, VS	VS, FS, FS	E, E, E

Table 5
The pairwise comparison of the financial leverage ratios.

	FL21	FL22	FL23	FL24	FL25
FL21	E, E, E	AS, 1/SS, VS	FS, 1/SS, 1/FS	FS, 1/VS, 1/VS	SS, 1/SS, E
FL22	1/AS, SS, 1/VS	E, E, E	1/SS, 1/SS, 1/VS	1/FS, 1/FS, 1/VS	1/VS, E, 1/VS
FL23	1/FS, SS, FS	SS, SS, VS	E, E, E	1/FS, E, E	1/FS, SS, SS
FL24	1/FS, VS, VS	FS, FS, VS	FS, E, E	E, E, E	E, FS, SS
FL25	1/SS, SS, E	VS, E, VS	FS, 1/SS, 1/SS	E, 1/FS, 1/SS	E, E, E

Table 6
The pairwise comparison of the activity ratios.

	A31	A32	A33	A34
A31	E, E, E	1/SS, SS, VS	FS, E, SS	FS, AS, VS
A32	SS, 1/SS, 1/VS	E, E, E	VS, 1/AS, E	FS, SS, SS
A33	1/FS, E, 1/SS	1/VS, AS, E	E, E, E	E, AS, FS
A34	1/FS, 1/AS, 1/VS	1/FS, 1/SS, 1/SS	E, 1/AS, 1/FS	E, E, E

Table 7
The pairwise comparison of the profitability ratios.

	P41	P42	P43
P41	E, E, E	1/AS, 1/FS, FS	1/FS, SS, 1/FS
P42	AS, FS, 1/FS	E, E, E	FS, VS, 1/AS
P43	FS, 1/SS, FS	1/FS, 1/VS, AS	E, E, E

Table 8
The pairwise comparison of the growth ratios.

	G51	G52	G53	G54
G51	E, E, E	1/FS, 1/FS, 1/VS	FS, 1/AS, 1/SS	E, 1/VS, 1/AS
G52	FS, FS, VS	E, E, E	VS, 1/VS, SS	FS, E, 1/FS
G53	1/FS, AS, SS	1/VS, VS, 1/SS	E, E, E	1/FS, FS, 1/VS
G54	E, VS, AS	1/FS, E, FS	FS, 1/FS, VS	E, E, E

Table 9
Consistency ratio values of pairwise comparison matrices for criteria.

	DM1	DM2	DM3
Main	0.0880	0.0908	0.0911
L1	0.0907	0.0899	0.0916
FL2	0.0796	0.0976	0.0982
A3	0.0951	0.0811	0.0976
P4	0.0734	0.0916	0.0734
G5	0.0690	0.0769	0.0960

Table 10
Aggregated pairwise comparison matrix for main criteria.

	L1	FL2	A3	P4	G5
L1	((1, 1, 1, 1; 1, 1) (1, 1, 1, 1; 1, 1))	((0.481, 0.794, 1.387, 1.710; 1, 1) (0.547, 0.853, 1.326, 1.642; 0.8, 0.8))	((0.754, 0.874, 1.145, 1.326; 1, 1) (0.778, 0.898, 1.114, 1.286; 0.8, 0.8))	((0.362, 0.420, 0.572, 0.693; 1, 1) (0.374, 0.435, 0.552, 0.666; 0.8, 0.8))	((1, 1.260, 1.587, 1.710; 1, 1) (1.063, 1.301, 1.560, 1.687; 0.8, 0.8))
FL2	((0.585, 0.721, 1.260, 2.080; 1, 1) (0.609, 0.754, 1.172, 1.828; 0.8, 0.8))	((1, 1, 1, 1; 1, 1) (1, 1, 1, 1; 1, 1))	((1, 1587, 2.520, 2.924; 1, 1) (1129, 1692, 2.435, 2.846; 0.8, 0.8))	((0.394, 0.481, 0.721, 0.920; 1, 1) (0.411, 0.500, 0.690, 0.872; 0.8, 0.8))	((0.585, 0.794, 1260, 1.710; 1, 1) (0.630, 0.833, 1.200, 1.587; 0.8, 0.8))
A3	((0.754, 0.874, 1.145, 1.326; 1, 1) (0.778, 0.898, 1.114, 1.286; 0.8, 0.8))	((0.342, 0.397, 0.630, 1; 1, 1) (0.351, 0.411, 0.591, 0.886; 0.8, 0.8))	((1, 1, 1, 1; 1, 1) (1, 1, 1, 1; 1, 1))	((0.251, 0.347, 0.550, 0.693; 1, 1) (0.272, 0.365, 0.526, 0.661; 0.8, 0.8))	((0.585, 0.794, 1260, 1.710; 1, 1) (0.630, 0.833, 1.200, 1.587; 0.8, 0.8))
P4	((1.442, 1.747, 2.381, 2.759; 1, 1) (1.502, 1.811, 2.299, 2.674; 0.8, 0.8))	((1.087, 1.387, 2.080, 2.537; 1, 1) (1.146, 1.449, 2.001, 2.436; 0.8, 0.8))	((1.442, 1.817, 2.884, 3.979; 1, 1) (1.513, 1.899, 2.740, 3.681; 0.8, 0.8))	((1, 1, 1, 1; 1, 1) (1, 1, 1, 1; 1, 1))	((2.140, 2.520, 3.434, 4.327; 1, 1) (2.210, 2.606, 3.277, 4.072; 0.8, 0.8))
G5	((0.585, 0.630, 0.794, 1; 1, 1) (0.593, 0.641, 0.769, 0.941; 0.8, 0.8))	((0.585, 0.794, 1.260, 1.710; 1, 1) (0.630, 0.833, 1.200, 1.587; 0.8, 0.8))	((0.585, 0.794, 1.260, 1.710; 1, 1) (0.630, 0.833, 1.200, 1.587; 0.8, 0.8))	((0.231, 0.291, 0.397, 0.467; 1, 1) (0.246, 0.305, 0.384, 0.452; 0.8, 0.8))	((1, 1, 1, 1; 1, 1) (1, 1, 1, 1; 1, 1))

Table 11
Interval type-2 fuzzy and normalized weights of the main criteria.

	Interval Type-2 Weights	Crisp Weights	Normalized Crisp Weights
L1	((0.088, 0.131, 0.236, 0.324; 1, 1) (0.097, 0.140, 0.223, 0.302; 0.8, 0.8))	0.18357	0.17014
FL2	((0.089, 0.136, 0.271, 0.417; 1, 1) (0.098, 0.146, 0.252, 0.377; 0.8, 0.8))	0.21332	0.19771
A3	((0.069, 0.100, 0.191, 0.291; 1, 1) (0.075, 0.107, 0.178, 0.263; 0.8, 0.8))	0.15214	0.14101
P4	((0.181, 0.260, 0.478, 0.692; 1, 1) (0.196, 0.277, 0.447, 0.635; 0.8, 0.8))	0.37773	0.35009
G5	((0.072, 0.104, 0.191, 0.283; 1, 1) (0.078, 0.111, 0.179, 0.258; 0.8, 0.8))	0.15217	0.14104

4.2. Identifying the criteria weights

As mentioned before, the aim of the current research is to compare and analyze the financial performance of firms from textile industry. At the second and third levels of the hierarchical structure, the main dimensions and sub-criteria required for financial performance assessment are defined. Next, a panel of experts was assembled for the purpose of assessing the relative importance of financial ratios using pairwise comparisons. The members of this panel were chosen from a variety of backgrounds, including academia, industry, and banking, with particular attention to ensure the inclusion of expertise from each sector. Specifically, the composition of the panel included a professor of finance, a commercial bank manager, and a senior manager from the textile industry.

Table 12
Interval type-2 fuzzy weights of the sub-criteria.

	Interval Type-2 Local Weights	Interval Type-2 Global Weights
L11	((0.102, 0.141, 0.250, 0.366; 1, 1) (0.110, 0.149, 0.234, 0.335; 0.8, 0.8))	(0.009, 0.018, 0.059, 0.119; 1, 1) (0.011, 0.021, 0.052, 0.101; 0.8, 0.8)
L12	((0.079, 0.115, 0.204, 0.279; 1, 1) (0.087, 0.123, 0.193, 0.261; 0.8, 0.8))	(0.007, 0.015, 0.048, 0.090; 1, 1) (0.008, 0.017, 0.043, 0.079; 0.8, 0.8)
L13	((0.378, 0.511, 0.851, 1142; 1, 1) (0.404, 0.540, 0.805, 1069; 0.8, 0.8))	(0.033, 0.067, 0.201, 0.370; 1, 1) (0.039, 0.076, 0.179, 0.323; 0.8, 0.8)
FL21	((0.087, 0.122, 0.230, 0.349; 1, 1) (0.094, 0.130, 0.214, 0.316; 0.8, 0.8))	(0.008, 0.017, 0.062, 0.146; 1, 1) (0.009, 0.019, 0.054, 0.119; 0.8, 0.8)
FL22	((0.032, 0.044, 0.079, 0.119; 1, 1) (0.034, 0.046, 0.074, 0.108; 0.8, 0.8))	(0.003, 0.006, 0.021, 0.050; 1, 1) (0.003, 0.007, 0.019, 0.041; 0.8, 0.8)
FL23	((0.101, 0.160, 0.309, 0.436; 1, 1) (0.113, 0.172, 0.290, 0.404; 0.8, 0.8))	(0.009, 0.022, 0.084, 0.182; 1, 1) (0.011, 0.025, 0.073, 0.153; 0.8, 0.8)
FL24	((0.202, 0.283, 0.485, 0.649; 1, 1) (0.218, 0.300, 0.460, 0.609; 0.8, 0.8))	(0.018, 0.039, 0.132, 0.271; 1, 1) (0.021, 0.044, 0.116, 0.230; 0.8, 0.8)
FL25	((0.095, 0.132, 0.245, 0.380; 1, 1) (0.102, 0.140, 0.229, 0.342; 0.8, 0.8))	(0.008, 0.018, 0.067, 0.158; 1, 1) (0.010, 0.020, 0.058, 0.129; 0.8, 0.8)
A31	((0.101, 0.149, 0.269, 0.370; 1, 1) (0.111, 0.159, 0.253, 0.345; 0.8, 0.8))	(0.007, 0.015, 0.051, 0.108; 1, 1) (0.008, 0.017, 0.045, 0.091; 0.8, 0.8)
A32	((0.117, 0.174, 0.339, 0.508; 1, 1) (0.128, 0.187, 0.316, 0.463; 0.8, 0.8))	(0.008, 0.017, 0.065, 0.148; 1, 1) (0.010, 0.020, 0.056, 0.122; 0.8, 0.8)
A33	((0.085, 0.119, 0.218, 0.324; 1, 1) (0.092, 0.127, 0.204, 0.295; 0.8, 0.8))	(0.006, 0.012, 0.042, 0.094; 1, 1) (0.007, 0.014, 0.036, 0.078; 0.8, 0.8)
A34	((0.207, 0.293, 0.535, 0.759; 1, 1) (0.223, 0.312, 0.502, 0.702; 0.8, 0.8))	(0.014, 0.029, 0.102, 0.221; 1, 1) (0.017, 0.033, 0.089, 0.185; 0.8, 0.8)
P41	((0.114, 0.152, 0.250, 0.332; 1, 1) (0.121, 0.160, 0.237, 0.313; 0.8, 0.8))	(0.021, 0.039, 0.120, 0.230; 1, 1) (0.024, 0.044, 0.106, 0.199; 0.8, 0.8)
P42	((0.293, 0.375, 0.573, 0.718; 1, 1) (0.310, 0.394, 0.547, 0.684; 0.8, 0.8))	(0.053, 0.097, 0.274, 0.497; 1, 1) (0.061, 0.109, 0.244, 0.435; 0.8, 0.8)
P43	((0.205, 0.267, 0.435, 0.584; 1, 1) (0.217, 0.281, 0.412, 0.546; 0.8, 0.8))	(0.037, 0.069, 0.208, 0.404; 1, 1) (0.043, 0.078, 0.184, 0.347; 0.8, 0.8)
G51	((0.056, 0.070, 0.111, 0.153; 1, 1) (0.059, 0.073, 0.106, 0.143; 0.8, 0.8))	(0.004, 0.007, 0.021, 0.043; 1, 1) (0.005, 0.008, 0.019, 0.037; 0.8, 0.8)
G52	((0.206, 0.281, 0.466, 0.606; 1, 1) (0.221, 0.296, 0.443, 0.573; 0.8, 0.8))	(0.015, 0.029, 0.089, 0.171; 1, 1) (0.017, 0.033, 0.079, 0.148; 0.8, 0.8)
G53	((0.109, 0.147, 0.253, 0.350; 1, 1) (0.117, 0.156, 0.238, 0.325; 0.8, 0.8))	(0.008, 0.015, 0.048, 0.099; 1, 1) (0.009, 0.017, 0.043, 0.084; 0.8, 0.8)
G54	((0.226, 0.287, 0.444, 0.565; 1, 1) (0.238, 0.301, 0.424, 0.536; 0.8, 0.8))	(0.016, 0.030, 0.085, 0.160; 1, 1) (0.019, 0.034, 0.076, 0.138; 0.8, 0.8)

In order to create the IT2 fuzzy pairwise comparison matrices, evaluations are provided between five main criteria and nineteen sub-criteria. Pairwise comparison matrices created by experts employing the scale given in Table 1 are presented in Table 3 for the main criteria and Tables 4–8 for sub-criteria. To eliminate inconsistencies in decision-makers judgments, the steps described in Section 3.2 are followed, and it is concluded that the experts' judgments in the pairwise comparison process are consistent, as shown in Table 9. As a result, the fact that calculated consistency ratios are less than the threshold value of 0.1 affirms that computed weights for criteria and sub-criteria are acceptable. Afterwards, pairwise comparison matrices are aggregated using Eq. (3) and presented in Table 10 for the main criteria. Then, using Eq.

Table 13
Crisp and normalized weights of the sub-criteria.

	Defuzzified Weights	Normalized Weights
L11	0.0469	0.1966
L12	0.0370	0.1552
L13	0.1546	0.6482
FL21	0.0524	0.1752
FL22	0.0180	0.0603
FL23	0.0673	0.2250
FL24	0.1048	0.3502
FL25	0.0566	0.1893
A31	0.0412	0.1934
A32	0.0538	0.2525
A33	0.0348	0.1632
A34	0.0833	0.3909
P41	0.0941	0.1996
P42	0.2125	0.4509
P43	0.1647	0.3495
G51	0.0174	0.0900
G52	0.0699	0.3621
G53	0.0389	0.2015
G54	0.0668	0.3464

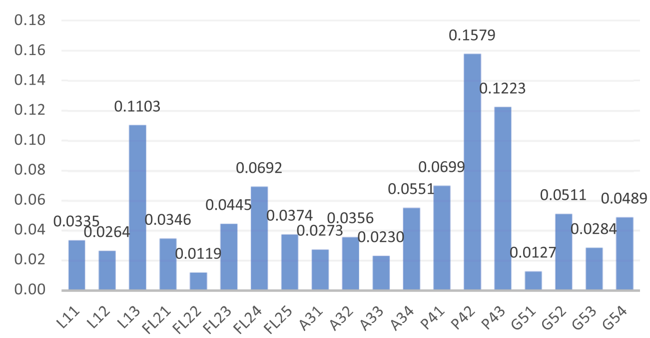

Fig. 4. Crisp weight for sub-criteria.

(4), the IT2F weights of the criteria and sub-criteria are calculated and described in Table 11 for IT2F values and the defuzzified values in Table 12, respectively. Finally, the crisp criteria weights are computed by performing the defuzzification process in Eq. (5) above and displayed in Table 13.

According to the weighting results presented in Table 11, the main criterion representing profitability ratios is the most crucial performance criterion, with a weight of 0.35009. This main criterion is followed by the financial leverage (0.19771), liquidity (0.17014), growth (0.14104) and activity (0.14101) main criteria, respectively.

When the weighting results presented in Fig. 4 as well as Table 13 are analyzed in terms of sub-criteria, it is revealed that return on equity is an essential criterion for performance evaluation (0.15786), followed by net profit margin ratio (0.12234) and cash ratio (0.11028) that come in the second and third ranks, respectively.

4.3. Evaluating the financial performance of textile firms by the CRADIS method

The initial performance matrix for the application procedures of the CRADIS method is established and given in Table 14.

Following constructing the initial performance matrix, this matrix is normalized by employing Eqs. (7) and (8). The normalized decision matrix is shown in Table 1.

In the next step, the weighted-normalized-performance matrix is computed by multiplying the corresponding weights (w_j) with each element of the normalized performance matrix. Table 16 indicates the weighted-normalized-performance matrix. As indicated at the bottom of Table 16, each criterion's minimum and maximum values in the weighted-normalized-performance matrix are computed to obtain ideal

Table 14
Initial performance matrix.

	L11	L12	L13	FL21	FL22	FL23	FL24	FL25	A31	A32	A33	A34	P41	P42	P43	G51	G52	G53	G54
ATEKS	1.60	0.81	15.02	0.19	0.08	0.27	0.73	0.70	5.84	3.58	7.14	0.61	1.06	2.55	0.07	0.11	0.09	0.12	2.79
ARSAN	0.98	0.54	10.50	0.36	0.07	0.43	0.55	0.67	3.87	3.54	12.34	0.52	1.41	1.93	0.04	0.10	0.11	0.11	0.76
BRKO	1.29	0.72	2.36	0.34	0.15	0.49	0.51	0.57	2.65	2.84	8.41	0.56	−4.50	−9.28	−0.12	0.03	−0.06	0.06	1.90
BRMEN	1.09	0.61	9.36	0.36	0.23	0.59	0.41	0.74	2.53	4.64	8.20	0.36	−7.06	−18.53	−0.59	0.01	−0.17	0.02	−1.28
BOSSA	1.77	1.06	14.45	0.30	0.19	0.49	0.52	0.54	4.21	3.63	6.59	0.71	3.48	7.40	0.05	0.08	0.10	0.10	1.06
KRTEK	1.70	1.10	21.20	0.34	0.25	0.58	0.42	0.46	3.05	4.59	9.19	0.80	−1.63	−5.69	−0.03	0.10	0.11	0.01	−1.34
LUKSK	2.37	1.41	19.95	0.15	0.63	0.41	0.59	0.70	3.12	3.46	10.68	0.43	2.42	5.64	0.07	0.23	0.18	0.24	−1.44
MNDRS	1.37	0.73	13.72	0.41	0.12	0.53	0.46	0.47	10.55	2.78	6.47	0.86	1.37	0.76	0.01	0.14	0.15	0.01	−1.17
SKTAS	1.19	0.53	13.70	0.31	0.37	0.68	0.32	0.71	6.21	3.05	4.58	0.52	−3.15	−18.00	−0.07	0.12	0.10	0.03	0.29
YATAS	1.27	0.60	10.91	0.50	0.16	0.66	0.34	0.37	6.11	2.46	3.36	1.08	3.93	8.20	0.03	0.16	0.12	0.19	0.30
YUNSA	1.12	0.60	2.99	0.63	0.05	0.68	0.32	0.29	3.34	2.95	6.73	1.14	1.98	6.21	0.01	0.08	0.11	0.05	−3.30

Table 15
Normalized performance matrix.

	L11	L12	L13	FL21	FL22	FL23	FL24	FL25	A31	A32	A33	A34	P41	P42	P43	G51	G52	G53	G54
ATEKS	0.67	0.57	0.71	0.80	0.66	1.00	0.44	0.41	0.55	0.77	0.58	0.53	0.27	0.31	1.00	0.46	0.49	0.52	1.00
ARSAN	0.41	0.38	0.50	0.43	0.76	0.64	0.58	0.44	0.37	0.76	1.00	0.45	0.36	0.24	0.52	0.43	0.63	0.46	0.27
BRKO	0.54	0.51	0.11	0.45	0.36	0.55	0.63	0.51	0.25	0.61	0.68	0.49	−1.15	−1.13	−1.75	0.12	−0.36	0.27	0.68
BRMEN	0.46	0.43	0.44	0.43	0.23	0.46	0.78	0.39	0.24	1.00	0.66	0.32	−1.80	−2.26	−8.26	0.06	−0.97	0.09	−0.46
BOSSA	0.75	0.75	0.68	0.51	0.28	0.56	0.61	0.54	0.40	0.78	0.53	0.62	0.89	0.90	0.70	0.35	0.56	0.44	0.38
KRTEK	0.72	0.78	1.00	0.46	0.22	0.47	0.76	0.63	0.29	0.99	0.74	0.70	−0.41	−0.69	−0.38	0.42	0.60	0.04	−0.48
LUKSK	1.00	1.00	0.94	1.00	0.09	0.66	0.54	0.42	0.30	0.75	0.87	0.38	0.62	0.69	0.98	1.00	1.00	1.00	−0.52
MNDRS	0.58	0.52	0.65	0.38	0.44	0.51	0.68	0.62	1.00	0.60	0.52	0.75	0.35	0.09	0.17	0.60	0.84	0.03	−0.42
SKTAS	0.50	0.38	0.65	0.49	0.15	0.40	0.99	0.41	0.59	0.66	0.37	0.46	−0.80	−2.20	−0.95	0.53	0.58	0.11	0.11
YATAS	0.54	0.43	0.51	0.31	0.33	0.41	0.93	0.78	0.58	0.53	0.27	0.95	1.00	1.00	0.39	0.69	0.67	0.81	0.11
YUNSA	0.47	0.43	0.14	0.24	1.00	0.40	1.00	1.00	0.32	0.64	0.55	1.00	0.50	0.76	0.09	0.33	0.64	0.21	−1.18

Table 16
Weighted normalized performance matrix.

	L11	L12	L13	FL21	FL22	FL23	FL24	FL25	A31	A32	A33	A34	P41	P42	P43	G51	G52	G53	G54
ATEKS	0.02	0.02	0.08	0.03	0.01	0.04	0.03	0.02	0.02	0.03	0.01	0.03	0.02	0.05	0.12	0.01	0.02	0.01	0.05
ARSAN	0.01	0.01	0.05	0.01	0.01	0.03	0.04	0.02	0.01	0.03	0.02	0.02	0.03	0.04	0.06	0.01	0.03	0.01	0.01
BRKO	0.02	0.01	0.01	0.02	0.00	0.02	0.04	0.02	0.01	0.02	0.02	0.03	−0.08	−0.18	−0.21	0.00	−0.02	0.01	0.03
BRMEN	0.02	0.01	0.05	0.01	0.00	0.02	0.05	0.01	0.01	0.04	0.02	0.02	−0.13	−0.36	−1.01	0.00	−0.05	0.00	−0.02
BOSSA	0.03	0.02	0.08	0.02	0.00	0.02	0.04	0.02	0.01	0.03	0.01	0.03	0.06	0.14	0.09	0.00	0.03	0.01	0.02
KRTEK	0.02	0.02	0.11	0.02	0.00	0.02	0.05	0.02	0.01	0.04	0.02	0.04	−0.03	−0.11	−0.05	0.01	0.03	0.00	−0.02
LUKSK	0.03	0.03	0.10	0.03	0.00	0.03	0.04	0.02	0.01	0.03	0.02	0.02	0.04	0.11	0.12	0.01	0.05	0.03	−0.03
MNDRS	0.02	0.01	0.07	0.01	0.01	0.02	0.05	0.02	0.03	0.02	0.01	0.04	0.02	0.01	0.02	0.01	0.04	0.00	−0.02
SKTAS	0.02	0.01	0.07	0.02	0.00	0.02	0.07	0.02	0.02	0.02	0.01	0.03	−0.06	−0.35	−0.12	0.01	0.03	0.00	0.01
YATAS	0.02	0.01	0.06	0.01	0.00	0.02	0.06	0.03	0.02	0.02	0.01	0.05	0.07	0.16	0.05	0.01	0.03	0.02	0.01
YUNSA	0.02	0.01	0.02	0.01	0.01	0.02	0.07	0.04	0.01	0.02	0.01	0.06	0.04	0.12	0.01	0.00	0.03	0.01	−0.06
Max.	0.03	0.03	0.11	0.03	0.01	0.04	0.07	0.04	0.03	0.04	0.02	0.06	0.07	**0.16**	0.12	0.01	0.05	0.03	0.05
Min.	0.01	0.01	0.01	0.01	0.00	0.02	0.03	0.01	0.01	0.02	0.01	0.02	−0.13	−0.36	**−1.01**	0.00	−0.05	0.00	−0.06

Table 17
Results of the CRADIS approach.

Firm	s_i^+	K_i^+	s_i^-	K_i^-	Q_i	Rank
ATEKS	2.3881	0.9808	19.8156	0.8372	0.9090	4
ARSAN	2.5367	0.9734	19.6670	0.7882	0.8808	5
BRKO	3.2252	0.9393	18.9785	0.6199	0.7796	10
BRMEN	4.3038	0.8859	17.8999	0.4646	0.6753	11
BOSSA	2.3317	0.9836	19.8720	0.8575	0.9205	2
KRTEK	2.8017	0.9603	19.4020	0.7137	0.8370	8
LUKSK	2.3034	0.9850	19.9003	0.8680	0.9265	1
MNDRS	2.5909	0.9707	19.6128	0.7717	0.8712	7
SKTAS	3.1825	0.9414	19.0212	0.6283	0.7849	9
YATAS	2.3471	0.9828	19.8566	0.8519	0.9173	3
YUNSA	2.5617	0.9722	19.6420	0.7805	0.8763	6
A_0	1.9994		20.2043			

and anti-ideal solutions.

By employing Eqs. (10)–(18), the results of the CRADIS procedure are obtained. The results of the CRADIS procedure and the rankings of firms are given in Table 17. Based on the results in Table 17, LUKSK is identified as the best alternative in terms of long-term performance. Furthermore, BOSSA, YATAS, and ATEKS are other successful alternatives compared to the others. It is also concluded that BRMEN is the alternative with the lowest financial performance.

5. Robustness check

Sensitivity analysis verifies the robustness, consistency, and usefulness of the developed decision tool [44,78,79]. In this section, three cases are considered to analyze the sensitivity of the proposed performance model. In the first case, the effects of various weight values on the initial ranking results are assessed. In the second case, the influences of the rank reversal issue on the initial ranking are tested. In the last case, the introduced decision model's results are compared with those of other MCDM approaches.

The findings of the robustness and validity tests provide extremely valuable managerial and policy implications for decision-makers and practitioners of the small and medium-sized textile and apparel industry. The consistency and stability of the ranking results under many scenarios, including extreme ones, confirmed that the textile companies considered, including companies such as LUKSK, maintained their long-term financial performance and effectiveness. This valuable insight enables decision-makers in the relevant industry to adopt the identified financial strategies and practices or to compare themselves with firms with high financial performance and adopt appropriate policies. The decision-making procedure developed in this study may be helpful for investment analysts, corporate strategists, and policymakers who aim to identify firms that demonstrate superiority and resilience in terms of financial performance in the relevant industry.

5.1. Assessing the impacts of various weight values on rankings results

The influence of changing criteria weight values was assessed by employing 190 scenarios in which the weight values of all criteria were modified [79]. For example, the weight value of the first criterion was reduced between 10 % and 100 % in each of the first ten scenarios until its weight value reached 0 %, whereas the values of the remaining

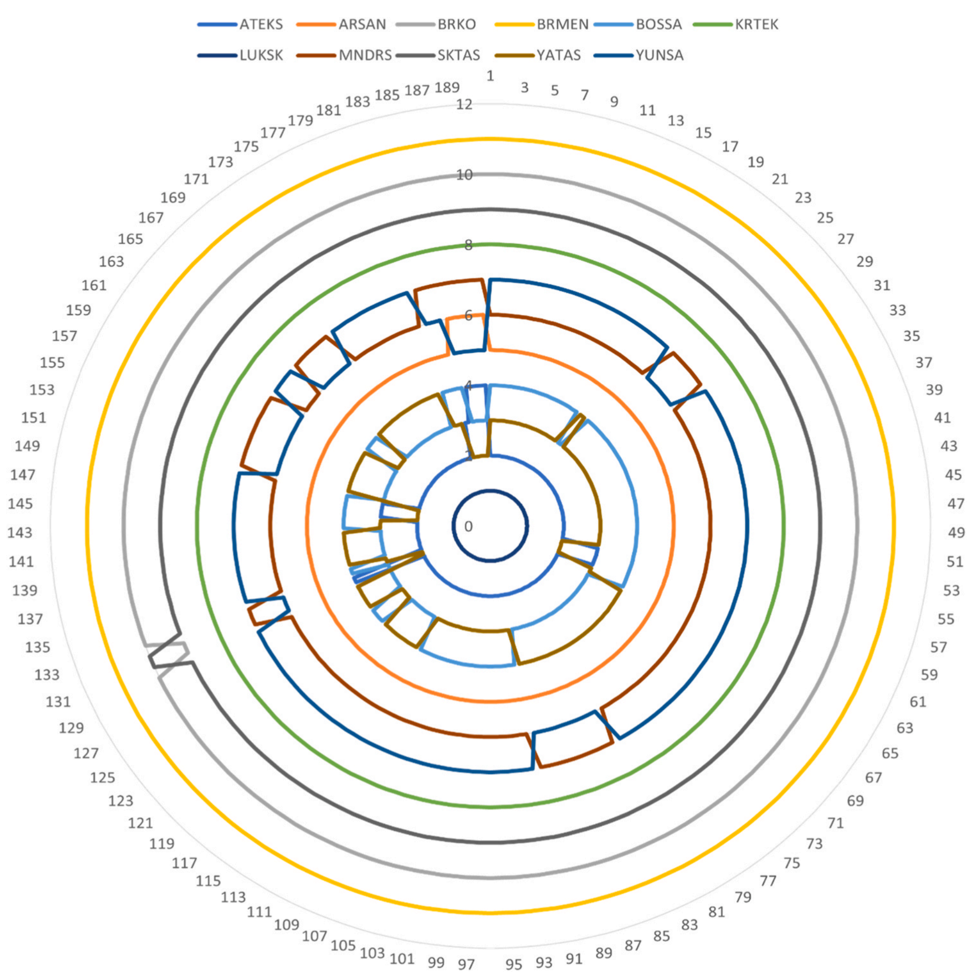

Fig. 5. Changes in the ranking of firms depending on the changes in criteria weights.

weights were proportionally adjusted to meet the condition that $\sum_{j=1}^{19} w_j = 1$. The same calculations were repeated in the remaining scenario groups. In this way, ten scenarios were generated for each criterion to obtain new weight values of the criteria.

As shown in Fig. 5, LUKSK, identified as the best option employing the developed model, is also the best alternative for all 190 scenarios. Similarly, BRMEN and KRTEK have remained in the same ranking position for 190 scenarios. The ranking positions of alternatives BRKO and SKTAS have been changed in only two scenarios, while the ranking performance of ARSAN has never changed except for eight scenarios. Alternatives YATAS and MNDRS have shown the same ranking performance for 87 and 44 scenarios, respectively. Furthermore, it was observed that there existed slight changes, which cannot influence the ranking positions of other alternatives. Consequently, the results certify that the suggested approach is stable and consistent, confirming the developed methodology's consistency, stability, and robustness.

Although the proposed decision-making model is stable, reliable, and robust, some procedural limitations and structural problems should be considered. First, it compares pairs of criteria to model and manage IT2FAHP uncertainties, making it possible to include subjective and biased attitudes in decision-making. Second, the fact that the arithmetic mean is still used to unify assessments of fifteen-year financial ratios can hide short-term fluctuations critical to specific investment decisions.

Each line on the chart corresponds to a specific firm, where the relative stability or fluctuation in rank across scenarios is visually depicted. Firms whose lines remain flat across scenarios indicate strong robustness in their performance ranking, whereas minor volatility (e.g., for ARSAN or BRKO) is shown with subtle variations in line elevation. The color-coded lines allow for tracking individual firm behaviour under different weighting structures. This visual tool demonstrates that the proposed ranking model is not sensitive to moderate weight changes, which supports the model's credibility and validity.

5.2. Effects of the rank reversal issue on the ranking

To investigate the influences of adding or removing an alternative is of paramount importance for assessing the resistance of the proposed decision-making framework to the rank reversal problem. In this paper, whether the proposed performance evaluation tool is resistant to the rank reversal problem was investigated in two experimental cases. To this end, each alternative was eliminated once to check for rank reversal in the first case, and then each alternative was added one by one to control rank reversal in the second case [80].

A total of 10 scenarios were generated for the alternative addition case based on the number of firms. In the first scenario, performance ranking was obtained for the dataset, including ATEKS and ARSAN. After that, other companies were included in the dataset one by one, and new ranks were obtained according to performance evaluation scores.

The results from the scenarios regarding the alternative addition case are given in Table 18 and Fig. 5. When the ranking results in Fig. 5 were analysed; it was deduced that any firm's line did not cross that of other firms in any scenario. Therefore, this finding reveals that the relative performance rankings of firms have not changed.

Table 18
Ranking results based on adding firms one by one.

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10
ATEKS	1	1	1	2	2	3	3	3	4	4
ARSAN	2	2	2	3	3	4	4	4	5	5
BRKO		3	3	4	5	6	7	8	9	10
BRMEN			4	5	6	7	8	9	10	11
BOSSA				1	1	2	2	2	2	2
KRTEK					4	5	6	6	7	8
LUKSK						1	1	1	1	1
MNDRS							5	5	6	7
SKTAS								7	8	9
YATAS									3	3
YUNSA										6

Next, we have formed 11 scenarios for the alternative elimination case, as indicated in Table 19 as well as in Fig. 6. In each scenario, a firm was eliminated from the existing dataset, and it was examined whether there was any change in the relative ranking of the remaining firms. According to the results shown in Fig. 7, it was observed that the line of any firm did not cross the line of other firms, which proved that the relative performance rankings of the firms had remained the same in each scenario.

5.3. Comparison with other MCDM approaches

In the third phase of testing the validity of the suggested framework, a comparative analysis is carried out, along with five other MCDM tools: MABAC [81], MAUT [82], PIV [83], SAW [84], and PSI [85]. Fig. 8 demonstrates the comparative analysis results, which include the final rankings. Fig. 6 shows that LUKSK is ranked as the best firm by all the considered performance analysis techniques. Moreover, all MCDM methodologies show that the ranking performance of some alternatives, such as BOSSA, YATAS, ATEKS, SKTAS, BRKO and BRMEN, are the same. Nevertheless, it is also observed that there are minor changes in the ranking performance of the remaining four firms that do not change the overall results. In conclusion, the results from the comparative analysis show the high consistency of the initial results.

6. Discussion, practical and managerial implications

This section highlights the discussion and practical and managerial implications depending on the results of the developed approach.

In both developed and developing economies, the textile and apparel industry meets one of the most basic needs of modern society and provides input to help the continuity of production in other economic sectors. The textile and apparel industry needs a practical and powerful performance evaluation approach to measure and evaluate its current performance concerning financial ratios globally, where sustainable competitive advantage becomes more important.

Our study suggests a combined MCDM framework to compare the firms in terms of financial performance indicators providing the highest benefits for all textile and apparel industry stakeholders. The hybrid MCDM model suggested in this study has five practical contributions as follows:

- The IT2FAHP procedure is integrated with the CRADIS procedure and applied to prioritizing firms operating in the textile and appeal industry for the first time in the literature. In conclusion, the suggested decision-making tool provides a methodological frame for the existing decision-makers in textiles and apparel.
- This study's suggested performance assessment tool is a hybrid framework with the potential to provide very successful results. Hence, it can also be applied to decision-making issues in different economic industries.
- The results of sensitivity control prove that the suggested MCDM framework resists the rank reversal issue.
- Our study also presents a new and updated criteria set consisting of 19 financial performance criteria in 5 dimensions to the existing literature. Therefore, the criteria set based on an extensive literature review can also be considered by practitioners who want to perform performance analysis in non-financial sectors of the economy. It can also guide future researchers who will work on this subject.
- The suggested MCDM framework allows us to evaluate various criteria of different dimensions together and reach accurate and reasonable conclusions.

The study's managerial implications can be summarised as follows:

Table 19
Ranking results obtained by removing a firm.

	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11
ATEKS		4	4	4	3	4	3	4	4	3	4
ARSAN	4		5	5	4	5	4	5	5	4	5
BRKO	9	9		10	9	9	9	9	9	9	9
BRMEN	10	10	10		10	10	10	10	10	10	10
BOSSA	2	2	2	2		2	1	2	2	2	2
KRTEK	7	7	8	8	7		7	7	8	7	7
LUKSK	1	1	1	1	1	1		1	1	1	1
MNDRS	6	6	7	7	6	7	6		7	6	6
SKTAS	8	8	9	9	8	8	8	8		8	8
YATAS	3	3	3	3	2	3	2	3	3		3
YUNSA	5	5	6	6	5	6	5	6	6	5	

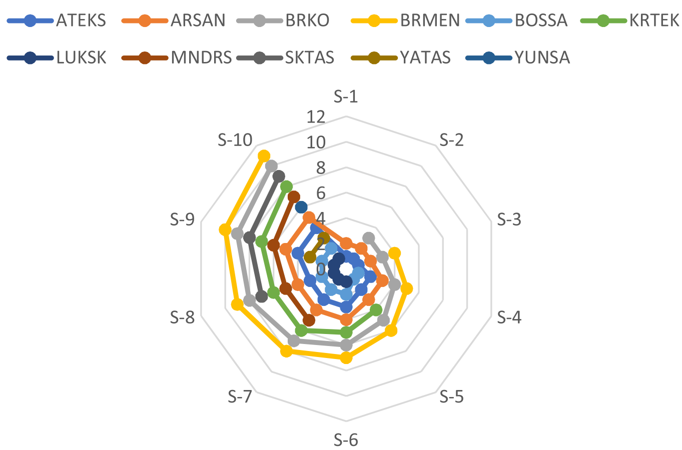

Fig. 6. Rank of firms based on adding firms one by one.

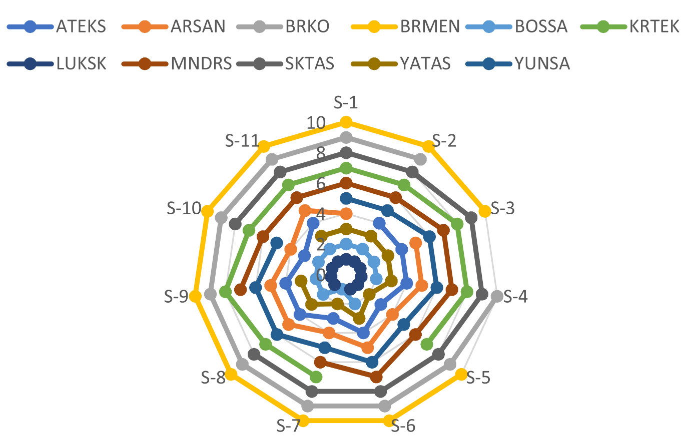

Fig. 7. Rank of firms based on the removal of a firm.

- The research findings presented in this work make a substantial contribution to the existing body of knowledge on evaluating and enhancing financial performance in the textile and apparel sector. The long-term financial performance indicators employed in the study facilitate companies in identifying their strengths and weaknesses, thereby enabling them to conduct more effective strategic planning processes. Specifically, the significance of critical financial criteria, such as profitability, liquidity, and debt management, underscores the areas that require companies' focus with respect to resource management and operational efficiency. This, in turn, provides companies with valuable insights and the capacity to make well-informed decisions.
- The study's methodological framework fosters greater systematicity and data-orientation in corporate performance management processes. For instance, a textile enterprise with a consistently high debt ratio, such as BRMEN, can consider these findings and results to develop new strategies and practices, such as debt restructuring, or to secure external equity financing to stabilize its financial leverage. On the contrary, textile enterprises such as LUKSK or BOSSA, which have a high level of liquidity and profitability, can use the analysis in this study to find foreign investment or loans with their stakeholders on more favourable terms. The companies' senior managers can compare their performance with the averages of the financial performance and effectiveness of the companies in the sector and determine the inadequacies and gaps in their performance by considering their results. It provides a more transparent and clearer basis for decisions related to budgeting capital and assets, mergers, and capacity expansion, which will allow comparisons between long-term data, such as 15 years, and short-term financial volatilities and the long-term performance of firms. These methodologies empower managerial personnel to comprehensively analyse and enhance their organisations' financial positions. To illustrate, enterprises with elevated debt ratios can optimise their liquidity management by prioritising debt restructuring strategies. Moreover, more efficacious decisions regarding resource allocation can be made, and investment planning processes can be enhanced through the utilisation of performance evaluation outcomes.
- The findings presented herein provide a framework for companies within the sector, enabling them to gauge their performance in relation to sector averages and delineate strategic directions. By acquiring knowledge from the practices of successful entities, firms can gain a competitive advantage. Furthermore, the study offers guidance on the formulation of long-term strategies necessary for achieving financial sustainability across the sector.
- This work provides substantial implications for both sectoral and managerial contexts. This model provides strategic value beyond firm-level analysis in the Turkish context, where the textile and apparel industry accounts for a significant share of exports,

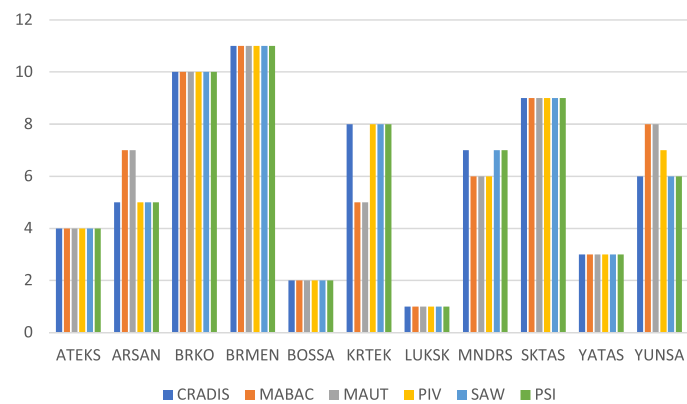

Fig. 8. Comparison with the other five MCDM tools.

employment, and SME activity. Regional development agencies, trade unions, and investment promotion bodies can use the model's firm rankings and performance outputs to support industrial clustering strategies, grant allocation, or sustainability certification mechanisms. The availability of a robust, uncertainty-aware evaluation framework also supports evidence-based policy formulation aligned with Turkey's broader economic transformation agenda. It enhances our comprehension of firms' financial circumstances and furnishes invaluable information for policymakers and regulators within the industry. The findings will play a pivotal role in developing sectoral reporting standards, thereby augmenting financial transparency and reinforcing market mechanisms. In this context, the study's findings constitute a valuable resource for fostering sustainable growth in the sector and enhancing competitive advantage.

- The findings of this work have the potential to facilitate the process of strategic decision-making on the part of creditors and investors, both in the short and long term. Furthermore, the proposed methodology can be utilised by decision-makers in the field of textiles and apparel as a decision support system when deliberating matters pertaining to import, export, production, and investment activities.
- The developed hybrid model provides a framework for policymakers, facilitating enhanced comprehension of the competitiveness and efficiency of textile and apparel firms. The proposed framework enables a comparative analysis of performance metrics, including those based on financial indicators. This is significant in light of the Turkish textile and apparel industry, which is one of the nation's most dynamic sectors in terms of gross added value, export income, employment, and regional development, as observed in numerous developing economies.

7. Conclusions

The textile and apparel industry, which contributes significantly to the industrialization efforts of the Turkish economy, is one of the leading sectors in Turkey. The contributions of the textile and apparel sector to the national economy in three critical areas: gross domestic product, export and employment, reveal that this sector is a vital industry for the Turkish economy. In today's changing and developing conditions, the performance of the textile and apparel industry should be analyzed and evaluated systematically in terms of various evaluation criteria.

This study makes several original contributions to the performance evaluation literature. First, it integrates the IT2FAHP and CRADIS methods to form a novel hybrid framework, which addresses expert judgment uncertainty and ensures stable ranking outcomes. Second, it applies this model to the textile and apparel industry, which is underrepresented in financial performance research despite its economic significance in Turkey. Third, using 15-year longitudinal financial data offers a more comprehensive view of firms' strategic positioning, a perspective often missing in existing short-term evaluations.

In this study, the financial performance of the textile and apparel industry firms in Turkey is assessed with an integrated MCDM model encompassing IT2FAHP and CRADIS approaches. For this purpose, financial ratios that reflect the financial performance of firms in the 15 years covered by the analysis are identified considering the available literature. In this context, five financial indicators are employed as the main criteria for the performance evaluation model. These indicators are liquidity, financial leverage, activity, profitability and growth ratios. The financial performance rankings derived from the CRADIS method revealed that LUKSK outperformed all other firms, consistently maintaining the top position across all validation scenarios. BOSSA, YATAS, and ATEKS followed closely behind, while BRMEN exhibited the lowest financial performance. Its resistance to rank reversal in all 21 addition and elimination scenarios confirmed the proposed hybrid model's validity. Moreover, 190 simulations testing criteria weight variations demonstrated that the top firms' ranks remained unchanged, reinforcing the approach's stability. Also, nineteen financial criteria are formed as sub-criteria depending on the main financial criteria. Then, pairwise comparisons of all criteria affecting the goal are constructed. Inconsistencies in pairwise comparisons are found to be insignificant and fuzzy weights of the performance criteria are computed using the IT2FAHP procedure.

The results obtained from the IT2FAHP method reveal that the profitability ratio is the main criterion that has the highest impact on performance evaluation. This result is like previous studies in the literature. However, our profitability ratio result differs from some previous studies. Consequently, the order of main criteria in their priority weights is profitability ratio>financial leverage ratio>liquidity ratio>growth ratio> activity ratio. Among sub-criteria, return on equity, net profit margin, and cash ratio are ranked top three. Following the determination of criteria weights through the IT2FAHP method, long-term financial performance evaluation of firms is carried out using the CRADIS method. In other words, firms are ranked from the best to the worst by applying the CRADIS procedure. Given the results from CRADIS, LUKSK has ranked the best option among all firms. BOSSA takes second place, while YATAS takes third place. BRMEN also takes the last place.

The rankings obtained from the CRADIS method highlight that LUKSK consistently ranks as the top-performing firm across all dimensions, suggesting strong and stable financial health. BOSSA and YATAS also perform well, particularly in profitability and liquidity metrics. On the other hand, BRMEN ranks the lowest, primarily due to weak profitability and high financial leverage. These findings underscore the varying degrees of financial resilience among firms in the sector and demonstrate the ability of the proposed model to distinguish firms based on holistic, long-term financial criteria.

Nevertheless, this study has certain limitations. The evaluation is restricted to publicly traded firms in a single industry, and thus, the generalizability of findings to other sectors remains limited. Additionally, the subjective judgments used in pairwise comparisons may still reflect bias, even with fuzzy logic techniques. The reliance on historical financial data also excludes forward-looking market conditions or qualitative insights.

For future research, similar models can be applied to different industries or extended with environmental, social, and governance (ESG) criteria to form a more holistic performance framework. Moreover, alternative fuzzy environments such as hesitant or intuitionistic fuzzy sets may be tested for more complex decision-making scenarios.

This study includes a hybrid MCDM model with the IT2FAHP and the CRADIS methods for performance evaluation. In future studies, other MCDM techniques such as MAIRCA, COBRA, MARA, EATWOS, and MARCOS can also be employed for this goal. Besides, future studies can expand the research topic by adding market performance and financial indicators. Finally, decision makers' judgments may be addressed in different fuzzy environments, e.g. hesitant, intuitionistic, and Pythagorean.

In summary, this study contributes both theoretically and practically by introducing a robust and replicable hybrid MCDM model, expanding the literature on long-term financial performance evaluation under uncertainty, and providing a practical decision-support tool for stakeholders in the Turkish textile and apparel sector.

CRediT authorship contribution statement

Ömer Faruk Görçün: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Mohsin Shabir:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization. **Ahmet Çalık:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Conceptualization. **Özcan Işık:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

We inform you that we have no conflict of interest, and we have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Data availability

Data will be made available on request.

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