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# Exploring factors affecting airport selection during the COVID-19 pandemic from air cargo carriers' perspective through the triangular fuzzy Dombi-Bonferroni BWM methodology

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## ABSTRACT

The COVID-19 pandemic has created unexpected demand for air cargo in terms of rapid mobility of critical basic needs. Air cargo carriers aim to maximize their profits by taking advantage of the current demand and using their limited capacity in the right place. At this point, some of the qualifications of the airports in the places where demand plays a crucial role in this decision of the carriers. Thus, evaluating the factors considered in the airport selection for air cargo carriers during the COVID-19 period is curious. This study proposes a triangular fuzzy Dombi-Bonferroni best-worst method (BWM) framework with vast flexibility to establish the priority preferences of factors considered in selecting airports. The fuzzy BWM model becomes a superior decision support system by combining the Bonferroni mean operator's ability to consider interrelationships between attributes and the flexibility of the Dombi operator. In this sense, we highlight eighteen criteria based on five airport aspects: location, physical features, performance, costs, and reputation. Findings reveal that the foremost aspects are location and costs, whereas the most crucial factors are airport charges and handling charges. The study suggests that airports should follow a low-price policy for airport-related charges without compromising their sustainability to have a share of the increasing number of air cargo flights, especially during the COVID-19 period, when airline passenger flights are decreased. The study is crucial in deciding the strategy and policy of air cargo carriers and airports during the pandemic period.

## 1. Introduction

The airline industry is one of the industries that has been deeply affected by the COVID-19 pandemic. The pandemic has led to Flybe Airlines's bankruptcy, Europe's largest regional airline, and many major airlines, such as LATAM, filing for bankruptcy protection (Flightglobal, 2021). The sharp decline in demand for passenger flights with the adverse effects of the pandemic has forced almost all airline companies to land large numbers of passenger aircraft. Hence, the loss caused by the pandemic only for 2020 has reached approximately 492 billion dollars. This figure corresponds to 60% of 2019 revenues and it is estimated that air traffic will not reach 2019 figures before 2024 (Bouwer et al., 2021). Moreover, the inability to use the belly capacities of passenger aircraft has caused the air cargo industry to suffer a severe loss of capacity despite the increasing demand for cargo. Despite the significant

increase in the demand for air cargo transportation, which is the most preferred mode of transportation for urgent needs due to the speed advantage, with the onset of the pandemic, the sector has difficulty in meeting the demand since air cargo carriers have had capacity constraints in terms of limited aircraft in their fleet. According to the report published by IATA in May 2021, the capacity in the air cargo sector is still 14% lower than in 2019 due to the lack of belly cargo capacity. Surprisingly, there is an increase of approximately 10% in the load factor and 50% in the yield compared to normal due to the rise in productivity. As a result, the sector has grown by more than 4.4% compared to the pre-crisis 2019 March figures. This has provided revenue from air cargo, which used to account for around 10–15% in the past, to account for roughly one-third of airline revenues by 2021 (Pearce, 2021).

Some airline companies, looking for ways to respond to the increasing air cargo demand due to the pandemic, have started to

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provide cargo transportation services with some wide-body aircraft that they have grounded to meet the cargo demand and tolerate the loss in passenger income. It is seen that this method, which is applied by some traditional airlines such as Lufthansa Airlines and Turkish Airlines, has a positive effect on the sustainability of these airlines. The figures stated in the 2020 annual report of Turkish Airlines demonstrate this positive effect as an example. According to the report, Turkish Airlines achieved a 61% increase in cargo revenues by using the 50 passenger aircraft that was grounded as a "freighter (derived from passenger and freight)" despite the 66% decrease in passenger revenues due to COVID-19 in 2020 (Turkish Airlines, 2021). However, there is a different case for air cargo carriers that only perform scheduled and non-scheduled cargo transportation. The sudden increase in air cargo demand resulted in carriers seeking to create additional capacity supply but unable to find cargo aircraft. This necessitates the effective and efficient use of existing capacities for the sustainability of these carriers to meet the cargo demand from different routes. In the decision-making process, the adequacy of the airports on the routes where the demand comes from is also essential for the carriers. Further, rival airports on the same routes should also master the factors critical for carriers in this catastrophic process to take the largest share of this capacity with the right policy and strategy.

In this context, the study aims to present proposed multi-criteria decision-making (MCDM) framework that will enable air cargo carriers to make strategic choices among potential airports in evaluating demand from various routes during the COVID-19 pandemic. Accordingly, five main aspects and their 18 factors are obtained from the literature and experts. Afterward, the aspects and factors are prioritized by analyzing with the triangular fuzzy Dombi-Bonferroni mean operators-based best-worst method (TFDBM-BWM) model using data gathered from decision-makers during COVID-19. The study is unique and vital since there is no other study in the literature that deals with the decision of airport selection in terms of air cargo carriers for the pandemic period and it has the quality to provide insight into this decision of strategic selection that carriers make for their sustainability in the era of COVID-19. The study is also expected to provide foresight for air cargo carriers to increase their revenues and market shares by enabling them to use their capacities effectively and efficiently during the pandemic.

Dombi and Bonferroni mean operators can easily manage the interactions between the elements for flexible decisions. Pamucar et al. (2020) argued that consolidating those operators by triangular fuzzy numbers is an effective way for the group decision-making process. BWM, developed by Rezaei (2015), is also an effective and practical MCDM technique with fewer pairwise comparisons than other subjective weighting methods and can achieve more consistent results. Since triangular fuzzy numbers can model ambiguity satisfactorily (Ecer and Tokayesh, 2022), it is a scientific view to integrate the Bonferroni and Dombi operators with triangular fuzzy numbers to cope with challenging multi-criteria problems. As a result, the primary motivation of this paper is to develop the TFDBM-BWM methodology under uncertainty, which is the first time in the literature, to reveal the relative weights of evaluation factors more accurately. Furthermore, this work has the following targets:

- ✓ Identifying the main aspects and factors considered for assessing airports.
- ✓ Exposing the relative importance of the criteria used in the airport selection.

Providing flexible group decision-making, allowing interaction between factors, and eliminating the effect of useless data are the key advantages of the TFDBM-BWM methodology. Motivated by the above issues, below highlights some contributions and novelties of the paper.

- ✓ Generalized Dombi operators allow flexibility in the information aggregation process. Bearing in mind that some famous operators such as the Einstein operator and the Hamacher operator are specific cases of the Dombi operator, in nature, the Dombi operator can be generalized. Since decision-makers are willing to reveal interrelationships between attributes, the Bonferroni mean operator can be a proper tool for this purpose. So, the Bonferroni mean operator can be extended according to the Dombi operations to present the Dombi-Bonferroni mean operator under fuzziness.
- ✓ To improve the outcomes scientifically through the fusion of two well-known aggregating operators and one robust MCDM method.
- ✓ To help air cargo carriers prioritize airport selection criteria through the introduced fuzzy decision support mechanism where the values of the factors are expressed as triangular fuzzy numbers.

The remaining sections of the article proceed as follows: A literature review on airport selection and the fuzzy BWM (F-BWM) method are presented respectively as a subsection in Section 2. In the third section, the introduced methodology of the study is explained, while in the fourth section, it is applied and the results are discussed. The last section includes the subsections of managerial implications, limitations, and future studies, as well as the conclusions of the study.

## 2. Literature review

This paper's literature survey is organized into three subsections: studies on airport selection, MCDM studies performing Dombi and Bonferroni operators, and studies handling the fuzzy BWM (F-BWM) approach.

### 2.1. Studies on airport selection

Scholars have drawn attention to the criticality of air transport and airports in times of disaster crises in the literature (Polater, 2018). Moreover, the decision of airport selection, which has strategic importance for air cargo carriers to use their capacities effectively and efficiently, has been the topic of many studies. In the extant literature, few works examine airport selection in terms of air cargo carriers. Among these very limited studies, Ohashi et al. (2005) analyzed 760 air cargo transfer routes using the multinomial logit model to determine the critical factors affecting the selection of air cargo transfer airports. In their study, which focused on monetary and time cost factors, empirical results presented that air cargo carriers are more sensitive to time costs than monetary costs. Gardiner et al. (2005b) empirically examined the airport selection criteria of air cargo carriers. In the study, night operations and cost criteria were prominent. However, it is contended that the airport marketing criterion has a limited impact. In another study by Gardiner et al. (2005a), it was suggested that air cargo carriers prefer airports with low capacity and night operations restrictions. In addition to these criteria, it was stated that the fee and facility features are critical in the selection of the airport. Kupfer et al. (2016), on the other hand, developed a model for selecting departure-destination airports for all cargo aircraft operations in Europe. In the study, first, the airport selection process was summarized. Then, airport selection was examined under 22-item criteria. Lottia and Caetano (2018), on the other hand,

aimed to analyze the airport selection factors for perishable food exports from Brazil and conducted a sensitivity analysis under simulation in line with the criteria collected from the literature. However, among the studies in the literature, there is no study investigating the airport selection criteria for air cargo carriers, considering the pandemic period. Furthermore, previous studies on airport selection of cargo carriers have not deployed MCDM methods. Complementing these deficiencies mentioned with the current study is remarkable originality and innovation.

## 2.2. MCDM studies with Dombi and Bonferroni operators

Aggregation operators are promising instruments for combining information in multi-criteria problems. In fuzzy logic, the min and the max operators are frequently preferred due to their superiorities, such as ease of calculation and expansion to a lattice form. The outcome is created by merely one variable, while the other has no effect, which is their main criticism. To eliminate this drawback and construct more flexible decision models, Dombi T-norms and T-conorms have been introduced for fuzzy environments (Pamucar et al., 2020). Dombi operators with various fuzzy extensions (spherical, hesitant, intuitionistic, etc.) were utilized in the extant literature to assess innovation tools in commerce (Jana et al., 2019), choose a suitable investment option (Ashraf et al., 2020), prefer a job (Seikh and Mandal, 2021), prioritize food waste causes (Yaran Ögel et al., 2022), and select emerging technologies firms (Khan et al., 2021), among others. The Bonferroni mean operator was developed to understand the relationship between the elements better and eliminate useless (awkward) data (Bonferroni, 1950). This operator generates a single score function by considering the interconnections between the attributes (Pamucar et al., 2020). Recently, Bonferroni mean operator has been performed for supplier selection (Liu and Liu, 2021; Ecer and Pamucar, 2020), personnel selection (Banerjee et al., 2020), software selection (Deli, 2021), antivirus mask selection (Yang et al., 2021), and cryptocurrency investment decisions (Böyükaslan and Ecer, 2021).

## 2.3. MCDM studies with F-BWM

Transportation is one of the fields in which MCDM techniques are widely employed (Ecer, 2021). When searching the relevant literature, it is possible to encounter various studies that deployed MCDM methods for all transport systems (Aoun et al., 2021; Wan et al., 2021; Pamucar et al., 2021b; Tanrıverdi and Lezki, 2021). Whereas there are already numerous MCDM techniques in the literature as classical or fuzzy-extended, novel MCDM techniques are being developed and existing ones are improved as days pass. As such, employing current MCDM techniques in studies is quite significant in accomplishing more valid results and is also vital to the novelty of the studies. Since fuzzy MCDM techniques allow decision-makers to make meaningful measurements by evaluating through linguistic expressions in uncertain environments (Aytekin et al., 2022), the study, therefore, proposes an enhanced version of the F-BWM method via two known operators to overcome the uncertainties caused by the COVID-19 outbreak and reach the most valid results.

Although there are many studies in different fields and topics in the classical BWM literature, some studies have also been carried out on road transportation (Pamucar et al., 2021a, 2021b; Shabanpour et al., 2018), and air transportation systems (Shojaei et al., 2018; Gupta, 2018; Chakraborty et al., 2020; Rezaei et al., 2017). As of today, however, the

number of F-BWM studies is limited since the method is relatively new. In a study on the selection of sustainable solid waste collection centers, Rahimi et al. (2020) determined the most suitable alternative in a fuzzy environment using BWM-MOORA-GIS hybrid methods and considering environmental, economic, and social factors. In another study performed by F-BWM, Momen et al. (2019) prioritized surgery cancellation factors. Chen et al. (2020) identified and evaluated user activity-oriented service requirements to be integrated into the smart product-service system with the help of rough-F-BWM methods. The proposed methodology provides a workable procedure for mapping critical activities in an intelligent product-service system. In their study investigating the optimal combinations of power plants, Omrani et al. (2018) used different MCDM methods with F-BWM. Mi and Liao (2019) analyzed the proposed methodology, which they developed as a result of their research on the selection of commercial donation insurance products, compared with other MCDM techniques. The proposed methodology has proven to be valid and stable. Patil et al. (2021), who investigated the obstacles to sustainability in human medical supply chains, determined the vital barrier to sustainability as a result of the analysis with F-BWM as inadequate compliance with the guidelines of the World Health Organization (WHO).

Overall, a literature search on the F-BWM highlights that the method has been utilized in different areas and topics. However, there is an insufficient number of papers employing the method in the transportation field. In one of these studies, Tian et al. (2018) utilized F-BWM in their study, aiming to introduce a comprehensive decision support tool for smart bike-sharing programs in China. In another study, Kumar and Anbanandam (2020) investigated sustainability performance in the freight transportation industry. The study revealed the necessary political measures by identifying the obstacles to sustainability. Nevertheless, it can be expressed that Dombi and Bonferroni mean operators-driven F-BWM methodology has not been performed before in the air transport field, which increases the study's originality.

## 3. The TFDBM-BWM model

This study investigates which criteria air cargo carriers should consider directing their scarce resources (aircraft, flight crews, etc.) in the airport selection process with the increasing demand for air cargo during the COVID-19 period. In doing so, at the first stage, a criteria pool is created by combining the criteria on airport selection obtained from literature review, interviews with industry experts, and academicians. Thus, eighteen criteria collected at the first stage are in Table 1. In the second stage, the opinions of experts and academicians are taken to determine which criteria to be included in the study. Besides, the meaningful criteria are brought together under the main criteria at this stage. Considering the frequency of the criteria in the literature and expert opinions, a consensus is reached on the criteria used in the research, as in Table 2. In the third stage, decision-makers consisting of two academics and four air cargo experts are asked to answer the questionnaire and the data collection stage is carried out. In the fourth stage, the criteria affecting the airport selection are prioritized with the proposed approach. Lastly, a sensitivity check is conducted to highlight the effectiveness and practicability of the introduced model.

In the present work, data were gathered from six decision makers consisting of two academics specializing in air cargo in civil aviation management and four experts from the air cargo industry on the date between 10 and 16 August 2021. One of the academics has two years of air cargo industry experience and eight years of academic background,

**Table 1**  
Criteria pool for the proposed framework of airport selection.

Criteria	Morell (2011)	Lottia and Caetano (2018)	Silva and Mota (2022)	Ohashi et al. (2005)	Feng et al. (2015)	(Postorino and Praticò, 2012)	(Alves, ve digerleri, 2020)	Hwang and Shiao (2011)	Onut et al. (2011)	Yuan et al. (2010)	Murphy and Daley (1994)	Tongzon and Sawant (2007)
Airport charge	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Flight Frequency	✓	✓		✓		✓		✓				
Airport stands	✓	✓		✓		✓						
Duty period for customs		✓		✓	✓							
Airport ground access		✓				✓	✓					
Number of competing carriers	✓	✓			✓	✓				✓		
Opportunities for flight connections		✓		✓						✓		✓
Variety of services	✓	✓	✓	✓	✓	✓						✓
Proximity to the import/export area		✓							✓			
The proximity of the feeder or hub airport				✓	✓	✓						
Airport (traffic) density	✓			✓	✓	✓	✓	✓	✓	✓	✓	
Sufficient infrastructure	✓			✓		✓	✓		✓			✓
Facilities and equipment	✓		✓						✓		✓	
Intermodal connections (Railway, Highway, Seaway)							✓		✓			
ULD handling efficiency	✓	✓			✓		✓		✓			✓
Taxi time												
Warehouse/ Freight handling zone efficiency	✓	✓	✓		✓							
Customs efficiency		✓		✓	✓				✓			
Personal relations									✓			
Quick response to the needs of airport users	✓											
Airport security	✓			✓			✓		✓			
Good reputation for cargo damage and delays	✓		✓	✓	✓		✓		✓		✓	
Airport slot allocation	✓				✓					✓		
City location												✓

while the other academic has only 23 years of academic background. The experts from air cargo carriers have 25, 20, 9, and 6 years of industry experience as cargo manager, deputy manager, network planning and cargo schedule manager, and cargo specialist.

The introduced methodology is implemented in nine steps, as illustrated in Fig. 1. The first two steps are to review the existing literature and seek expert opinions to determine the evaluation criteria. Between the 3rd and 6th steps, the F-BWM method is applied to elicit the fuzzy weight values of the criteria. The next step involves aggregating the fuzzy criteria weights with the help of the fuzzy Dombi-Bonferroni mean operator. In Step 8, triangular fuzzy numbers are converted to exact values and the final weight coefficient of all criteria is gathered. Lastly, a sensitivity analysis is performed to investigate the feasibility of the introduced approach.

By handling fuzzy numbers, fuzzy sets give membership values to

linguistic terms. The triangular fuzzy number is one of the most preferred fuzzy numbers in the decision-making area (Ecer, 2022). Below is recalled some key definitions relevant to this paper (Pamucar et al., 2021b).

**Definition 1.**  $F = \{(x, \mu_F(x)), x \in \mathfrak{R}\}$  is termed a fuzzy number and  $\mu_F(x)$  is known as membership function ( $\mu_F(x) \in [0, 1]$ ).

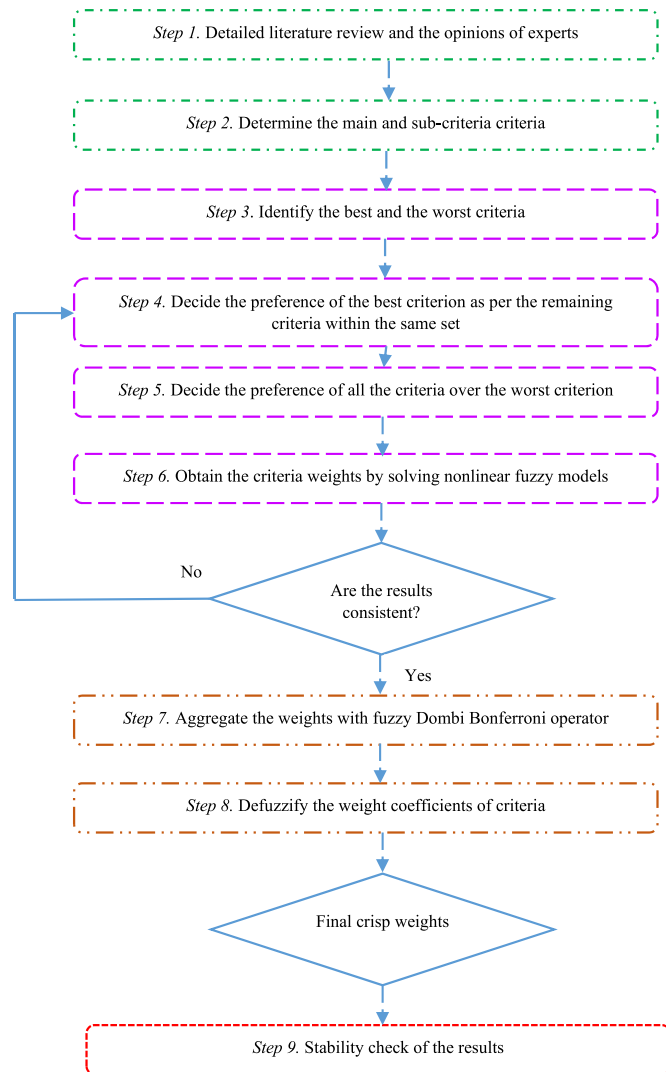
**Definition 2.** Let  $T = (l, m, u)$  be a triangular fuzzy number, where  $l \leq m \leq u$ . The T fuzzy number could be expressed as follows.

$$\mu_T(x) = \begin{cases} 0, & x < l \\ (x - l)/(m - l), & l \leq x \leq m \\ (u - x)/(u - m), & m \leq x \leq u \\ 0, & x > u \end{cases} \quad (1)$$

For the fundamental operational properties of two triangular fuzzy

**Table 2**  
Main criteria and sub-criteria.

Main criteria	Sub-criteria
Airport Location (C1)	Proximity to the import/export area (C11) The proximity of the feeder or hub airport (C12) City location (C13)
Airport Physical Features (C2)	Sufficient infrastructure (C21) Facilities and equipment (C22) Airport ground access (C23) Intermodal connections (Railway, Highway, and Seaway) (C24)
Airport Performance (C3)	ULD handling efficiency (C31) Warehouse/Freight handling zone efficiency (C32) Customs efficiency (C33) Airport (traffic) density (C34) Opportunities for flight connections (C35) Number of competing carriers (C36) Airport slot allocation (C37)
Airport Costs (C4)	Airport charges (C41) Handling charges (C42)
Airport Reputation (C5)	Airport security (C51) Good reputation for cargo damage and delays (C52)



**Fig. 1.** The TFDBM-BWM framework.

**Table 3**  
Fuzzy judgment scale (Ecer and Pamucar, 2020).

Linguistic expressions	Membership function	Consistency index (CI)
Equal importance (EI)	(1,1,1)	3.00
Weak importance (WI)	(2/3,1,3/2)	3.80
Fair importance (FI)	(3/2,2,5/2)	5.29
Very important (VI)	(5/2,3,7/2)	6.69
Absolute importance (AI)	(7/2,4,9/2)	8.04

numbers, the interested researchers are able to view Ecer's (2015) work. After the preliminaries above, a detailed explanation of the TFDBM-BWM methodology steps is given as follows.

- Step 1. Survey the extant literature and seek the thoughts of the decision makers to determine the evaluation criteria and sub-criteria.
- Step 2. Decide the criteria and sub-criteria.
- Step 3. Choose the best and the worst criteria. The best and worst criteria should be selected for both the main criteria and sub-criteria.
- Step 4. Decide the preference of the best criterion (sub-criterion) as per the remaining criteria (sub-criteria) within the same set. Based on linguistic variables in Table 3, Each expert expresses the level of preference of the best criterion over the others.

**Step 5.** Decide the preference of all the criteria over the worst criterion. Similarly, the preferences of all criteria are determined according to the worst criteria.

**Step 6.** Find the triangular fuzzy criteria weights. At first, non-linear fuzzy models are established as per Steps 4 and 5. In Eq. (2),  $w_j = (l_j^w, m_j^w, u_j^w)$ ,  $w_B = (l_B^w, m_B^w, u_B^w)$ , and  $w_W = (l_W^w, m_W^w, u_W^w)$  respectively  $\tilde{w}_j = (l_j^w, m_j^w, u_j^w)$  indicate the fuzzy weight of  $j$ th criterion, best criterion  $C_B$ , and worst criterion  $C_W$ . Moreover,  $l$ ,  $m$ , and  $u$  demonstrate the lower, medium, and upper values, respectively (Ecer and Pamucar, 2020).

$\min \xi^*$

$$\begin{cases} \left| \frac{l_B^w, m_B^w, u_B^w}{l_j^w, m_j^w, u_j^w} - l_{Bj}, m_{Bj}, u_{Bj} \right| \leq (k^*, k^*, k^*) \\ \left| \frac{l_j^w, m_j^w, u_j^w}{l_W^w, m_W^w, u_W^w} - l_{jW}, m_{jW}, u_{jW} \right| \leq (k^*, k^*, k^*) \\ s.t. \left\{ \begin{aligned} \sum_j R(\tilde{w}_j) &= 1 \\ l_j^w &\leq m_j^w \leq u_j^w \\ l_j^w &\geq 0 \\ j &= 1, 2, \dots, n \end{aligned} \right. \end{cases} \quad (2)$$

where  $\tilde{\xi} = (l^{\xi}, m^{\xi}, u^{\xi})$ :  $l^{\xi} \leq m^{\xi} \leq u^{\xi}$  and  $\xi^* = (k^*, k^*, k^*)$ ;  $k^* \leq l^{\xi}$ .

It should be emphasized that the consistency of the results obtained in this step should be checked ( $CR = \xi^*/CI \leq 0.1$ ).

**Step 7.** Aggregate the weight values of the criteria. After solving the model above according to each expert's evaluation, the weight coefficients found are combined using the triangular fuzzy number Dombi-Bonferroni mean (TFDBM) operator (Eq. (3)) at this step. Suppose that  $\tilde{\psi}_j = (\psi_j^l, \psi_j^m, \psi_j^u)$ ; ( $j = 1, 2, \dots, n$ ) be a set of triangular fuzzy numbers in  $\mathfrak{R}$ . Afterward, the TFDBM operator is defined as follows (Pamucar et al., 2020).

$$FDBM^{p,q,\rho}(\tilde{\psi}_1, \tilde{\psi}_2, \dots, \tilde{\psi}_n) = \left( \frac{\sum_{i=1}^n \psi_j^l}{1 + \left\{ \frac{1}{p+q} \frac{n(n-1)}{\sum_{i,j=1, i \neq j}^n \left( p \left( \frac{1-f(\psi_j^l)}{f(\psi_j^l)} \right)^\rho + q \left( \frac{1-f(\psi_j^m)}{f(\psi_j^m)} \right)^\rho \right)} \right\}^{\frac{1}{\rho}}}, \frac{\sum_{i=1}^n \psi_j^m}{1 + \left\{ \frac{1}{p+q} \frac{n(n-1)}{\sum_{i,j=1, i \neq j}^n \left( p \left( \frac{1-f(\psi_j^m)}{f(\psi_j^m)} \right)^\rho + q \left( \frac{1-f(\psi_j^u)}{f(\psi_j^u)} \right)^\rho \right)} \right\}^{\frac{1}{\rho}}}, \frac{\sum_{i=1}^n \psi_j^u}{1 + \left\{ \frac{1}{p+q} \frac{n(n-1)}{\sum_{i,j=1, i \neq j}^n \left( p \left( \frac{1-f(\psi_j^u)}{f(\psi_j^u)} \right)^\rho + q \left( \frac{1-f(\psi_j^l)}{f(\psi_j^l)} \right)^\rho \right)} \right\}^{\frac{1}{\rho}}} \right) \tag{3}$$

where  $f(\tilde{\psi}_j) = (f(\psi_j^l), f(\psi_j^m), f(\psi_j^u)) = \left( \frac{\psi_j^l}{\sum_{i=1}^n \psi_j^l}, \frac{\psi_j^m}{\sum_{i=1}^n \psi_j^m}, \frac{\psi_j^u}{\sum_{i=1}^n \psi_j^u} \right)$  shows fuzzy function.

**Step 8.** Defuzzify the aggregated fuzzy numbers. To obtain crisp weight values of criteria and sub-criteria, this step applies the graded mean integration representation (GMIR) (Eq. (4)) (Pamucar et al., 2020).

$$C(c_j) = \frac{l_j + 4m_j + u_j}{6} \tag{4}$$

where  $l, m,$  and  $u$  are the lower, medium, and upper values of a triangular fuzzy number  $c_j = (l_j, m_j, u_j)$ , respectively.

Step 9. Check the validation of the results. Ultimately, a sensitivity check is realized to demonstrate the applicability of the proposed framework.

**4. Prioritization of criteria used in airport selection and results**

*4.1. Application of the proposed methodology*

Since BWM, which is a pairwise comparison-driven technique, requires fewer calculations than its counterparts like AHP, SWARA, etc. (Zolfani et al., 2022) and obtains more reliable and consistent weight values of criteria (Torkayesh et al., 2021), it is preferred for analysis. Further, the triangle fuzzy extension of this method with the Dombi-Bonferroni mean operator is preferred due to the need for a more flexible evaluation by considering the relations between the criteria.

To set the priorities of airport selection factors, firstly, decision-makers decide the best and worst criteria and their importance concerning other factors, utilizing linguistic judgments presented in Table 3. Consequently, the linguistic expressions of experts are highlighted in Table 4.

After the linguistic judgments given in Table 4 are converted into triangular fuzzy numbers utilizing Table 3, the F-BWM models based on these TFNs are formed. For instance, fuzzy models can be built for six experts to achieve the fuzzy values of weights of main aspects, as presented in Table 5.

The fuzzy weights of the main aspects and their sub-factors are calculated. For example, the triangular fuzzy weights computed concerning the main aspects for Expert 1 are as follows.

$$w_{E1-C1} = (0.3148, 0.3666, 0.3666) w_{E1-C2} = (0.2053, 0.2435, 0.2551)$$

$$w_{E1-C3} = (0.1291, 0.1672, 0.1860) w_{E1-C4} = (0.1291, 0.1672, 0.1860)$$

$$w_{E1-C5} = (0.0690, 0.0763, 0.0763) \xi^* = (0.8074, 0.8074, 0.8074)$$

The consistency ratio (CR) calculated is 0.1 (0.8074/8.04), which highlights that the result is acceptable. As a result, the fuzzy weights computed for each expert are indicated in Table 6.

To aggregate six different weighting results, as emphasized before, the TFDBM operator (Eq. (3)) is handled in this work. Put it differently, the TFDBM operator is utilized to aggregate the six fuzzy weight values. In the next step, Eq. (4) is performed to obtain defuzzified optimal local values of the criteria weights. As in Table 7, the global weight values of the sub-criteria are determined by multiplying the local values of the factors with the weight values of the aspects.

Based on the results gathered, five main aspects are ranked as C1, C4, C2, C3, and C5. Further, C13 is the most significant factor in the C1 aspect. Similarly, C21, C37, C41, and C51 are the most important factors in the C2, C3, C4, and C5 dimensions, respectively. Overall, C41 is decided as the most crucial factor in this paper, followed by C42, C51, and C52. According to the empirical findings, however, C36, C35, and C33 are the factors with the least importance.

*4.2. Empirical findings and discussion*

The results of the study are discussed in this section. The results reached by the proposed framework employed in this study are depicted in Table 8. Significant aspects and factors in the proposed framework can also be expressed as factors that put airports that want to attract the limited capacity of air cargo carriers ahead of their competitors. The ‘‘airport location,’’ which has the highest weight value (0.2844) among the five main criteria, is the most significant aspect affecting the airport selection decisions of air cargo carriers during the COVID-19 process. Accordingly, air cargo carriers mainly consider airport location criteria to be sustainable by using their capacities effectively and efficiently (Zhang, 2003; Gardiner et al., 2005b). With the weights of 0.2674, 0.

**Table 4**  
Linguistic judgments of the experts.

Expert	BO vector of the main aspects							OW vector of the main aspects								
	Best	C1	C2	C3	C4	C5	Worst	C1	C2	C3	C4	C5				
Expert1	C1	EI	WI	FI	VI	AI	C5	AI	AI	VI	VI	EI				
Expert2	C1	EI	VI	VI	FI	VI	C5	VI	WI	WI	VI	EI				
Expert3	C1	EI	FI	FI	WI	FI	C2	FI	EI	WI	FI	WI				
Expert4	C4	VI	WI	AI	EI	AI	C5	WI	WI	FI	AI	EI				
Expert5	C1	EI	FI	FI	WI	VI	C5	VI	FI	FI	VI	EI				
Expert6	C3	WI	WI	EI	WI	FI	C4	FI	FI	VI	EI	WI				
	BO vector of the "location" aspect							OW vector of the "location" aspect								
	Best	C11	C12	C13			Worst	C11	C12	C13						
Expert1	C11	EI	WI	FI			C13	FI	EI	EI						
Expert2	C13	WI	FI	EI			C12	WI	EI	FI						
Expert3	C13	VI	FI	EI			C12	WI	EI	VI						
Expert4	C11	EI	WI	FI			C13	FI	WI	EI						
Expert5	C11	EI	FI	WI			C12	FI	EI	FI						
Expert6	C11	EI	FI	WI			C12	FI	EI	WI						
	BO vector of the "physical" aspect							OW vector of the "physical" aspect								
	Best	C21	C22	C23	C24		Worst	C21	C22	C23	C24					
Expert1	C21	EI	VI	FI	FI		C22	VI	EI	FI	WI					
Expert2	C21	EI	WI	FI	WI		C23	VI	FI	EI	FI					
Expert3	C21	EI	FI	WI	EI		C22	FI	EI	WI	FI					
Expert4	C22	WI	EI	AI	FI		C23	VI	AI	EI	WI					
Expert5	C21	EI	WI	FI	WI		C23	FI	WI	EI	WI					
Expert6	C24	FI	FI	WI	EI		C22	WI	EI	FI	FI					
	BO vector of the "effectiveness" aspect							OW vector of the "effectiveness" aspect								
	Best	C31	C32	C33	C34	C35	C36	C37	Worst	C31	C32	C33	C34	C35	C36	C37
Expert1	C37	VI	FI	AI	WI	FI	AI	EI	C36	VI	FI	FI	AI	FI	EI	AI
Expert2	C37	VI	FI	VI	WI	FI	VI	EI	C36	VI	FI	WI	AI	FI	EI	VI
Expert3	C34	FI	FI	VI	EI	VI	FI	WI	C35	FI	FI	FI	VI	EI	WI	FI
Expert4	C37	WI	WI	FI	VI	AI	VI	EI	C35	AI	AI	VI	FI	EI	FI	AI
Expert5	C34	FI	FI	WI	EI	VI	VI	WI	C35	WI	WI	WI	VI	EI	WI	VI
Expert6	C33	WI	FI	EI	WI	VI	VI	FI	C35	VI	FI	VI	FI	EI	WI	FI
	BO vector of the "cost" aspect							OW vector of the "cost" aspect								
	Best	C41	C42						Worst	C41	C42					
Expert1	C41	EI	WI						C42	WI	EI					
Expert2	C41	EI	WI						C42	WI	EI					
Expert3	C42	WI	EI						C41	EI	WI					
Expert4	C42	WI	EI						C41	EI	WI					
Expert5	C42	FI	EI						C41	EI	FI					
Expert6	C41	EI	WI						C42	WI	EI					
	BO vector of the "image" aspect							OW vector of the "image" aspect								
	Best	C51	C52						Worst	C51	C52					
Expert1	C51	EI	WI						C52	WI	EI					
Expert2	C51	EI	FI						C52	FI	EI					
Expert3	C51	EI	FI						C52	FI	EI					
Expert4	C52	WI	EI						C51	EI	WI					
Expert5	C52	FI	EI						C51	EI	FI					
Expert6	C51	EI	WI						C52	WI	EI					

1765, and 0. 1619, the airport location is followed by "airport costs," "airport physical features," and "airport performance," respectively. Obviously, the airport's physical features and performance have very close weights. Sub-criteria and overall rankings are given in Table 9. According to Table 9, the sub-criteria of "airport charges" and "handling charges under airport costs" share the first two places and are at the forefront among all sub-criteria, which demonstrates the importance that carriers operating in a high-cost industry attach to costs (Gardiner et al., 2005b). "Airport security" and "a good reputation for cargo damage and delays" share the 3rd and 4th place, respectively, with weights of 0.08, whereas "city location" and "proximity to the import/export area" each with weights of 0.07 is ranked as 5th and 6th. However, "connecting flight opportunities" and "number of competing airlines" are the least considered sub-criteria with their relative weights of 0.01 in the decision-making process of airport selection.

4.2.1. Airport location

The study reveals that airport location is one of the first aspects that carriers consider in the airport selection process during the COVID-19 pandemic period. This shows that airport location is quite crucial for air cargo carriers. Gardiner et al. (2005b), in their study of airport selection of freighter operators, explored that airport location is the first criterion that draws their attention in the decision of carriers. The main reason for airport location to come to the fore in the airport selection process for the period during and before the pandemic can be expressed as the fact that the carriers have many airport options. In other words, air cargo carriers have an opportunity to choose among the airports in better locations since there are no passenger flights and the airports are available for slots during the COVID-19 pandemic. This aspect includes city location, proximity to the import/export area, and proximity of feeder or hub airport as sub-criteria. The importance of airport location factors in the airport selection decision of the carriers results from the effect of these criteria on the cost. Due to the high-cost characteristics of



**Table 5**  
F-BWM models formed to decide the fuzzy weight coefficients of the main aspects.

Expert 1 (C1–C5)→mink s.t	... ..	Exper6 1(C1–C5)→mink s.t
$\left\{ \begin{array}{l} \left  \frac{w_1^l}{w_2^l} - 0.67 \right  \leq k.u_2; \left  \frac{w_1^m}{w_2^m} - 1 \right  \leq k.m_2; \left  \frac{w_1^u}{w_2^u} - 1.5 \right  \leq k.l_2; \\ \left  \frac{w_1^l}{w_3^l} - 1.5 \right  \leq k.u_3; \left  \frac{w_1^m}{w_3^m} - 2 \right  \leq k.m_3; \left  \frac{w_1^u}{w_3^u} - 2.5 \right  \leq k.l_3; \\ \left  \frac{w_1^l}{w_4^l} - 2.5 \right  \leq k.u_4; \left  \frac{w_1^m}{w_4^m} - 3 \right  \leq k.m_4; \left  \frac{w_1^u}{w_4^u} - 3.5 \right  \leq k.l_4; \\ \left  \frac{w_1^l}{w_5^l} - 3.5 \right  \leq k.u_5; \left  \frac{w_1^m}{w_5^m} - 4 \right  \leq k.m_5; \left  \frac{w_1^u}{w_5^u} - 4.5 \right  \leq k.l_5; \\ \left  \frac{w_2^l}{w_5^l} - 3.5 \right  \leq k.u_5; \left  \frac{w_2^m}{w_5^m} - 4 \right  \leq k.m_5; \left  \frac{w_2^u}{w_5^u} - 4.5 \right  \leq k.l_5; \\ \left  \frac{w_3^l}{w_5^l} - 2.5 \right  \leq k.u_5; \left  \frac{w_3^m}{w_5^m} - 3 \right  \leq k.m_5; \left  \frac{w_3^u}{w_5^u} - 3.5 \right  \leq k.l_5; \\ \left  \frac{w_4^l}{w_5^l} - 2.5 \right  \leq k.u_5; \left  \frac{w_4^m}{w_5^m} - 3 \right  \leq k.m_5; \left  \frac{w_4^u}{w_5^u} - 3.5 \right  \leq k.l_5; \end{array} \right.$		$\left\{ \begin{array}{l} \left  \frac{w_1^l}{w_2^l} - 1.5 \right  \leq k.u_2; \left  \frac{w_1^m}{w_2^m} - 2 \right  \leq k.m_2; \left  \frac{w_1^u}{w_2^u} - 2.5 \right  \leq k.l_2; \\ \left  \frac{w_1^l}{w_3^l} - 1.5 \right  \leq k.u_3; \left  \frac{w_1^m}{w_3^m} - 2 \right  \leq k.m_3; \left  \frac{w_1^u}{w_3^u} - 2.5 \right  \leq k.l_3; \\ \left  \frac{w_1^l}{w_4^l} - 0.67 \right  \leq k.u_4; \left  \frac{w_1^m}{w_4^m} - 1 \right  \leq k.m_4; \left  \frac{w_1^u}{w_4^u} - 1.5 \right  \leq k.l_4; \\ \left  \frac{w_1^l}{w_5^l} - 2.5 \right  \leq k.u_5; \left  \frac{w_1^m}{w_5^m} - 3 \right  \leq k.m_5; \left  \frac{w_1^u}{w_5^u} - 3.5 \right  \leq k.l_5; \\ \left  \frac{w_2^l}{w_5^l} - 1.5 \right  \leq k.u_5; \left  \frac{w_2^m}{w_5^m} - 2 \right  \leq k.m_5; \left  \frac{w_2^u}{w_5^u} - 2.5 \right  \leq k.l_5; \\ \left  \frac{w_3^l}{w_5^l} - 1.5 \right  \leq k.u_5; \left  \frac{w_3^m}{w_5^m} - 2 \right  \leq k.m_5; \left  \frac{w_3^u}{w_5^u} - 2.5 \right  \leq k.l_5; \\ \left  \frac{w_4^l}{w_5^l} - 2.5 \right  \leq k.u_5; \left  \frac{w_4^m}{w_5^m} - 3 \right  \leq k.m_5; \left  \frac{w_4^u}{w_5^u} - 3.5 \right  \leq k.l_5; \end{array} \right.$
$\begin{aligned} & (w_1^l + 4.w_1^m + w_1^u)/6 + (w_2^l + 4.w_2^m + w_2^u)/6 + \\ & (w_3^l + 4.w_3^m + w_3^u)/6 + (w_4^l + 4.w_4^m + w_4^u)/6 + \\ & (w_5^l + 4.w_5^m + w_5^u)/6; \\ & k \geq 0; \\ & w_j^l \leq w_j^m \leq w_j^u; \forall j = 1, 2, \dots, 5 \\ & w_j^l, w_j^m, w_j^u \geq 0; \forall j = 1, 2, \dots, 5 \end{aligned}$		$\begin{aligned} & (w_1^l + 4.w_1^m + w_1^u)/6 + (w_2^l + 4.w_2^m + w_2^u)/6 + \\ & (w_3^l + 4.w_3^m + w_3^u)/6 + (w_4^l + 4.w_4^m + w_4^u)/6 + \\ & (w_5^l + 4.w_5^m + w_5^u)/6; \\ & k \geq 0; \\ & w_j^l \leq w_j^m \leq w_j^u; \forall j = 1, 2, \dots, 5 \\ & w_j^l, w_j^m, w_j^u \geq 0; \forall j = 1, 2, \dots, 5 \end{aligned}$

the aviation industry, air cargo transportation stands out as the costliest mode of transportation. This causes air cargo transportation to be preferred in the last place by customers who do not have an urgent shipment to send. Hence, carriers consider the location of the airports to which they will arrange flights to better meet the demands of their customers in return for the fee they receive. Because city location, proximity to the import/export area, and proximity of feeder or hub airport can have a cost-increasing or reducing role by affecting origin-destination demand (Min et al., 1997). Due to the location of the city in which they are located, airports close to the world's important trade centers can be preferred among alternatives. Tanrıverdi and Lezki (2021) stated that the high competitiveness and potential of Istanbul Airport, and therefore of Turkey, in the context of air cargo is due to the city's location. Particularly during the COVID-19 pandemic, in which the demand for air cargo increased significantly, airports' proximity to the import/export area is also able to provide carriers a chance to improve their trading volume and profit by allowing them to cooperate closer with freight forwarders and general sale agents and thus to expedite the cargo flow (Romero-Silva and Mota, 2022). Moreover, unlike airline passenger transportation in air cargo transportation, aircraft can return empty from the airports they fly to. The proximity of the airport location to the import/export area increases the probability of returning aircraft fully. This is critical in terms of increasing the incomes of the carriers and decreasing freight transportation costs, especially during COVID-19. The airport's proximity to a feeder or hub airport not only offers customers different options but also contributes to the carrier's effective and efficient use of its capacity by ensuring that their aircraft return full. Another noteworthy lesson to be drawn from this aspect is that airport location factors have a critical role in the safe, reliable, and efficient distribution of vaccines and the delivery of primary and urgent needs in crisis periods such as COVID-19 (Jahani et al., 2022; Reuters, 2021; Polater, 2018).

**4.2.2. Airport costs**

Airport costs are one of the most important factors that reduce the competitiveness of air transportation than other transportation modes. Therefore, air cargo carriers try to minimize costs in their business processes by prioritizing cost factors to be sustainable. This also influences the decision of airport selection by carriers. Airport charges are paid to airport operators by carriers in return for using services offered

such as runway, parking, airport infrastructure, and air traffic control. Airport handling charges, on the other hand, are paid to ground handling companies or airport operators by carriers in return for transportation of the cargo delivered to the airport from aircraft and transferring it to bonded warehouses, loading the cargo on the aircraft before flight, and the pushback or towing services received (Chao and Hsu, 2014). Considering the ranking of all aspects and sub-criteria of this study, airport costs and the sub-criteria of airport charges and handling charges have a significant role in the decision of airport selection by carriers during COVID-19 that can be said. Airport charges and handling charges, which vary in the airport context, have an extremely decisive role in the airport selection process for air cargo carriers that want to use their capacities effectively and efficiently. The fact that Gardiner et al. (2005b) found the "minimizing overall cost" factor in the second place, is significant evidence in terms of showing that the cost aspect is always important regardless of which period before or after COVID-19. Even so, it can be said that COVID-19 has made all the stakeholders of the air transport industry, especially the carriers, more sensitive in terms of costs. This result presents significant signs that airports and ground handling companies, the two essential stakeholders of the air cargo industry, did not reduce their fees to have a share of air cargo flights, or beyond that, they may have increased their fees to survive during the COVID-19 process. The latter possibility looks stronger as some stakeholders of the air transport industry, including airports, have notified their respective national governments of their need for financial support in the form of loans, grants, other cash, or fee waivers (Macilree and Duval, 2020). The reason behind this is the sharp decrease in the revenues of airport operators and ground handling companies as a result of the fact that airline passenger flights, which constitute a large part of air transport during the COVID-19 pandemic period, came to a standstill. Additionally, carriers pay more attention to costs in airport selection to minimize losses during COVID-19 conditions. It would be appropriate for airports to pursue pricing policies similar to passenger airlines (Tavalaei and Santalo, 2019; Humphreys et al., 2009) for air cargo carriers during the COVID-19 pandemic to attract carriers that attach importance to cost to the airports. In other words, airports should follow a policy that includes lower prices on airport cost elements for carriers by applying the logic of scale economy. This can allow airports to be capacity-effective and sustainable with a high traffic volume and revenue from air cargo carriers that hold more flights than passenger airlines

**Table 6**  
Fuzzy and crisp weight values of main aspects and factors as per each expert.

Aspect/factor	Expert		
	#1	#2	#3
C1	(0.3148,0.3666,0.3666)	(0.3133,0.3951,0.4492)	(0.2652,0.2757,0.3449)
C2	(0.2053,0.2435,0.2551)	(0.1109,0.1113,0.1122)	(0.1340,0.1340,0.1743)
C3	(0.1291,0.1672,0.1860)	(0.1109,0.1113,0.1113)	(0.1330,0.1401,0.1885)
C4	(0.1291,0.1672,0.1860)	(0.2301,0.2726,0.3300)	(0.2452,0.2707,0.3474)
C5	(0.0690,0.0763,0.0763)	(0.1113,0.1113,0.1147)	(0.1330,0.1411,0.1885)
	CR=0.10	CR=0.08	CR=0.01
C11	(0.3004,0.4258,0.5512)	(0.2471,0.3419,0.3419)	(0.1923,0.1923,0.1923)
C12	(0.3058,0.3268,0.3268)	(0.1897,0.2625,0.2625)	(0.2512,0.2512,0.2512)
C13	(0.2509,0.2509,0.2509)	(0.3142,0.4454,0.4454)	(0.4357,0.5614,0.6574)
	CR=0.05	CR=0.05	CR=0.03
C21	(0.4108,0.4115,0.4762)	(0.2192,0.2917,0.3280)	(0.2200,0.3119,0.3119)
C22	(0.1347,0.1397,0.1779)	(0.2188,0.2917,0.3277)	(0.1328,0.1838,0.1838)
C23	(0.2154,0.2390,0.2988)	(0.1311,0.1458,0.1460)	(0.1730,0.2394,0.2394)
C24	(0.1707,0.1802,0.2340)	(0.2188,0.2914,0.3277)	(0.2394,0.3119,0.3119)
	CR=0.04	CR=0.00	CR=0.05
C31	(0.0995,0.1222,0.1359)	(0.1025,0.1367,0.1548)	(0.1306,0.1638,0.2013)
C32	(0.0812,0.0964,0.1033)	(0.0856,0.0911,0.1605)	(0.1306,0.1638,0.2013)
C33	(0.0505,0.0665,0.0854)	(0.0629,0.0809,0.1179)	(0.1058,0.1234,0.1595)
C34	(0.2532,0.2532,0.2571)	(0.1709,0.2704,0.2704)	(0.1931,0.2111,0.2338)
C35	(0.0811,0.1564,0.1638)	(0.0877,0.0925,0.0933)	(0.0722,0.0722,0.0874)
C36	(0.0505,0.0557,0.0588)	(0.0615,0.0684,0.0684)	(0.0838,0.0922,0.1079)
C37	(0.2384,0.2679,0.2679)	(0.2332,0.2734,0.2769)	(0.1306,0.1638,0.2013)
	CR = 0.10	CR = 0.09	CR = 0.04
C41	(0.9413,0.9413,1.2933)	(0.9413,0.9413,1.2933)	(0.7059,1.0588,1.0588)
C42	(0.8622,0.9413,1.4050)	(0.8622,0.9413,1.4050)	(0.7094,1.0588,1.0588)
	CR = 0.00	CR = 0.00	CR = 0.00
C51	(0.9413,0.9413,1.2933)	(0.7826,1.0435,1.0435)	(0.7826,1.0435,1.0435)
C52	(0.8622,0.9413,1.4050)	(0.4174,0.5217,0.5217)	(0.4174,0.5217,0.5217)
	CR = 0.00	CR = 0.00	CR = 0.00
	<i>Expert</i>		
	#4	#5	#6
C1	(0.1201,0.1266,0.1351)	(0.2510,0.3059,0.3059)	(0.1929,0.2532,0.2893)
C2	(0.1064,0.1479,0.2087)	(0.1317,0.1707,0.1905)	(0.1935,0.2529,0.2893)
C3	(0.0951,0.1343,0.1719)	(0.1236,0.1707,0.1897)	(0.1935,0.2529,0.2899)
C4	(0.4824,0.4824,0.4941)	(0.2201,0.2850,0.2987)	(0.1158,0.1266,0.1288)
C5	(0.0951,0.1028,0.1150)	(0.0826,0.0953,0.0953)	(0.0860,0.1263,0.1735)
	CR = 0.08	CR = 0.03	CR = 0.00
C11	(0.3142,0.4454,0.4454)	(0.3064,0.4084,0.4585)	(0.3142,0.4454,0.4454)
C12	(0.2471,0.3419,0.3419)	(0.1833,0.2041,0.2041)	(0.1897,0.2625,0.2625)
C13	(0.1897,0.2625,0.2625)	(0.3059,0.4084,0.4581)	(0.2471,0.3419,0.3419)
	CR = 0.05	CR = 0.05	CR = 0.01
C21	(0.2590,0.2996,0.3546)	(0.2369,0.3359,0.3359)	(0.1554,0.1554,0.2213)
C22	(0.3853,0.4170,0.4170)	(0.1863,0.2578,0.2578)	(0.1573,0.1660,0.2037)
C23	(0.1014,0.1175,0.1263)	(0.1430,0.1979,0.1979)	(0.2865,0.3166,0.4079)
C24	(0.1414,0.1703,0.1976)	(0.1863,0.2578,0.2578)	(0.31130.3253,0.4031)
	CR = 0.05	CR = 0.06	CR = 0.04
C31	(0.1760,0.1883,0.1929)	(0.0769,0.0919,0.0919)	(0.2063,0.2063,0.2250)
C32	(0.1754,0.1844,0.2077)	(0.1038,0.1270,0.1295)	(0.1105,0.1247,0.1537)
C33	(0.1134,0.1415,0.1415)	(0.1141,0.1507,0.1531)	(0.2063,0.2063,0.2381)
C34	(0.0867,0.0867,0.0915)	(0.1885,0.2353,0.2353)	(0.1769,0.1769,0.2031)
C35	(0.0500,0.0554,0.0620)	(0.0743,0.0965,0.0965)	(0.0713,0.0754,0.0958)
C36	(0.0867,0.0867,0.0915)	(0.0670,0.0830,0.0972)	(0.0619,0.0619,0.0823)
C37	(0.2588,0.2588,0.2588)	(0.2055,0.2454,0.2479)	(0.1105,0.1247,0.1537)
	CR = 0.08	CR = 0.08	CR = 0.05
C41	(0.7059,1.0588,1.0588)	(0.8276,1.0345,1.0345)	(0.9413,0.9413,1.2933)
C42	(0.7094,1.0588,1.0588)	(1.5517,2.0690,2.0690)	(0.8622,0.9413,1.4050)
	CR = 0.00	CR = 0.00	CR = 0.00
C51	(0.7431,1.0514,1.0514)	(0.9949,1.0010,1.0010)	(0.9413,0.9413,1.2933)
C52	(0.7044,1.0514,1.1147)	(1.5015,2.0020,2.4874)	(0.8622,0.9413,1.4050)
	CR = 0.00	CR = 0.00	CR = 0.00

during the pandemic by tolerating this disadvantage from the pricing policy.

#### 4.2.3. Airport physical features

The four sub-criteria of the airport physical features are between the 8th and 12th places in the overall ranking of the criteria influencing the airport selection process of the carriers. This finding demonstrates parallelism with some works (Gardiner et al., 2005b; Jou et al., 2011). Such a finding means that carriers attribute considerable importance to having sufficient cargo infrastructure, intermodal connections,

sufficient facilities and equipment for cargo, and airport ground access during the COVID-19 pandemic. For example, the fact that having temperature-controlled cold storage for the necessity of keeping the vaccines between 2 and 8 °C in order not to spoil due to the criticality of the vaccines can affect the airport selection decision of the carriers during the pandemic process (Zhan et al., 2022). This example underlines the importance of airport facilities and equipment factors in the pandemic process. Considering that cargo flights take place more than passenger flights during the outbreak period, it is inevitable for carriers to prefer a better airport in terms of physical features if it is financially

**Table 7**  
The weight coefficients of the aspects and factors.

Aspects	Aggregated fuzzy weights	Global weights
C1	(0.1992,0.2269,0.2567)	0.2844
C2	(0.1205,0.1396,0.1669)	0.1765
C3	(0.1073,0.1286,0.1544)	0.1619
C4	(0.1944,0.2113,0.2423)	0.2674
C5	(0.0789,0.0860,0.1036)	0.1098
Factors		
C11	(0.2289,0.2976,0.3305)	0.0691
C12	(0.1868,0.2172,0.2238)	0.0564
C13	(0.2383,0.2990,0.3279)	0.0719
C21	(0.2052,0.2379,0.2752)	0.0384
C22	(0.1661,0.1918,0.2128)	0.0311
C23	(0.1436,0.1654,0.1922)	0.0269
C24	(0.1733,0.2024,0.2351)	0.0325
C31	(0.1082,0.1197,0.1360)	0.0186
C32	(0.0939,0.1037,0.1298)	0.0161
C33	(0.0893,0.1013,0.1215)	0.0153
C34	(0.1461,0.1625,0.1752)	0.0251
C35	(0.0597,0.0722,0.0813)	0.0103
C36	(0.0562,0.0590,0.0687)	0.0097
C37	(0.1609,0.1757,0.1909)	0.0276
C41	(0.6921,0.7871,0.9544)	0.1964
C42	(0.7596,0.9233,1.1403)	0.1962
C51	(0.7088,0.7931,0.9129)	0.0826
C52	(0.6513,0.7875,1.0119)	0.0759

**Table 8**  
Relative weights of five pillars.

Main Criteria	Weight	Rank
Airport Location	0.2844	1
Airport Physical Features	0.1765	3
Airport Performance	0.1619	4
Airport Costs	0.2674	2
Airport Reputation	0.1098	5

convenient when choosing the airport among many options.

**4.2.4. Airport performance**

Airport performance is the fourth foremost main criterion after airport physical features. Airports become more competitive than rival airports that handle cargo in the same catchment zone through the opportunity to quickly flow cargo in ground operation processes (Boonekamp and Burghouwt, 2017). It is about the performance of airports, and our results regarding this aspect and its sub-criteria, however, reveal that criteria from this aspect are not a priority in airport choice decisions of carriers during the COVID-19 period. The sub-criteria under this aspect is in the last place in the overall ranking. Among the criteria from this aspect, airport slot allocation is the most essential criterion in this study. Contrary to our results regarding the COVID-19 pandemic, slot availability, compliance of the noise upper limit determined by airport authority with the standards of the aircraft planned by the carrier, and the airport's approach to allowing night flights typically make this criterion significant. Especially, non-integrated carriers attach importance to night flights. The necessity of leaving the Asian continent at night for carriers operating in Asian markets to arrive in Europe in the morning makes night-time slots vital (Kupfer et al., 2016). Supporting this, Gardiner et al. (2005a,b), in their study conducted on airport selection of air cargo carriers, also revealed that night flights are vital for North American and European carriers. Additionally, due to the sharp decline in air traffic during the COVID-19 period, the European Union Commission temporarily reduced the obligation to fly at least 80 percent to 40–50 percent for airlines to maintain their historic slot rights for the period during COVID-19 (Soone, 2020). This means that the carriers do not have slot problems during the pandemic process and confirms our study's ranking of the "airport slot allocation" factor. Accordingly, regarding our results, airport (traffic) density, ULD handling efficiency,

**Table 9**  
Relative weights of factors.

Sub-Criteria	The main criterion to which it belongs	Weight	Rank
Airport charges	Airport Costs	0.1964	1
Handling charges	Airport Costs	0.1962	2
Airport security	Airport Reputation	0.0826	3
Good reputation for cargo damage and delays	Airport Reputation	0.0759	4
City location	Airport Location	0.0719	5
Proximity to the import/export area	Airport Location	0.0691	6
The proximity of the feeder or hub airport	Airport Location	0.0564	7
Sufficient infrastructure	Airport Physical Features	0.0384	8
Intermodal connections (railway, highway, and seaway)	Airport Physical Features	0.0325	9
Facilities and equipment	Airport Physical Features	0.0311	10
Airport slot allocation	Airport Performance	0.0276	11
Airport ground access	Airport Physical Features	0.0269	12
Airport (traffic) density	Airport Performance	0.0251	13
ULD handling efficiency	Airport Performance	0.0186	14
Warehouse/freight handling zone efficiency	Airport Performance	0.0161	15
Customs efficiency	Airport Performance	0.0153	16
Opportunities for flight connections	Airport Performance	0.0103	17
Number of competing carriers	Airport Performance	0.0097	18

warehouse/freight handling zone efficiency, customs efficiency, opportunities for flight connections, and the number of competing carriers are less considered by air cargo carriers in the COVID-19 process. The drivers mentioned directly related to the slot allocation approaches of the airport authority. Airport authorities already plan slot allocations to make the airport operations/traffic as efficient as possible. On the other hand, while these criteria typically increase the attractiveness of an airport for carriers, as a result of the decrease in flights due to the restrictions and the reduction in the demand for airports, it is not needed to consider factors of airport performance during the COVID-19 pandemic, when the mobility at the airports is already relatively low.

**4.2.5. Airport reputation**

Sub-criteria of airport reputation are ranked 3rd and 4th in the overall ranking, which depicts parallelism with the results of Gardiner et al. (2005b) and Kupfer et al. (2016). Our results indicate that airport security and a good reputation for cargo damage and delays are among the pioneer factors that carriers consider in their decision-making processes on airport choice during the COVID-19 pandemic. Carriers are responsible for delivering the cargo undamaged, safely, and on time without being lost. Otherwise, the image of carriers in customers' eyes will likely be damaged. This will negatively affect the sustainability of the carriers. Especially for the COVID-19 pandemic process, when criticality of transporting vaccines for people struggling with the disease by air (Martins and Cró, 2022), and the criticality of transporting essential foods due to disruptions in the food supply chain (Barman et al., 2021) since lock-downs were experienced, are considered, the importance of these factors can be understood clearly (Dube et al., 2021). Therefore, carriers prefer rival airports in case of a possible weakness in terms of airport reputation criteria, regardless of how affordable the airport charge is.

**4.3. Sensitivity check**

In this paper, analysis of the gathered results is conducted by a twofold sensitivity analysis. To achieve this, first, it is presented the analysis of the dependence of the gathered outcomes on the change of p,

$q$ , and  $\rho$  parameters. In the second stage of the sensitivity check, the weights produced by the proposed model and the F-BWM approach are compared.

To determine the final weight values of evaluation criteria, in this work, the values of the parameters  $p$ ,  $q$ , and  $\rho$  are initially handled to be one (i.e.,  $p = q = \rho = 1$ ). However, there is no obstacle for scholars to prefer various  $p$ ,  $q$ , and  $\rho$  parameter values if they wish to deal with more complex calculations. In light of this idea, as presented in Appendix A, a total of 117 experiments in four scenarios are carried out. In the first scenario (S1), the parameter  $\rho$  takes values in the range of [2, 30], whilst both the values of  $p$  and  $q$  are assumed to be 1. For the second scenario (S2), the values of  $p$  take values in the range of [2, 30], whereas the values of  $\rho$  and  $q$  are accepted as 1. Similarly, the values of  $q$  take values in the range of [2, 30], whilst for the values of  $\rho$  and  $p$  are assumed to be 1 in the third scenario (S3). In the last scenario (S4), the effect of changing  $p$ ,  $q$ , and  $\rho$  parameters simultaneously on the outcomes is investigated ( $\rho, p, q \in [2, 30]$ ). In real applications, though the researchers choose the parameter values of  $p$ ,  $q$ , and  $\rho$  as per their preferences, as mentioned above, it is suggested those values to be one to take the internal connections between factors into account. Further, this choice can provide ease of calculations. Fig. 2 reveals that the ranking orders of evaluation criteria remain the same when three parameters have various values. Although there are small differences in weight values of criteria when the parameters are changed, this does not influence on the significance ranking.

Concerning the above analysis, it can be easily concluded that the parameters  $p$ ,  $q$ , and  $\rho$  have no effect on criteria importance ranking. In sum, C41, C42, and C51 are the foremost factors, whereas C36, C35, and C33 are the least significant criteria, respectively. The sensitivity check demonstrates that the ranking of the criteria is consistent for all scenarios, emphasizing that the results from the analyzes are reliable and useable and that the methodology utilized is suitable for the air transport field.

Second, in the context of the sensitivity analysis, The F-BWM methodology (Ecer and Pamucar, 2020) is also considered for testing the reliability of the results obtained with the proposed model. In other words, criteria weights are again calculated using the same data through F-BWM. Afterward, the criteria weights rankings derived via both approaches are compared. As seen in Fig. 3, some apparent dissimilarities in the criteria rankings draw attention. The ranking of the top four most essential criteria (C41, C42, C51, and C52) as well as the 11th (C37) and 12th (C23) crucial criteria differ as per these approaches' outcomes. Obviously, regarding the proposed approach, the foremost criteria are C41, C42, C51, and C52, while the most critical criteria concerning F-BWM are C42, C41, C52, and C51, respectively. Further, the results of the proposed framework reveal that the essential criteria in the 11th and 12th rankings are C37 and C23, whereas the F-BWM decides that the criteria in the indicated rankings are C23 and C37, respectively. Even though some aggregation operators (Hamacher, Einstein, Choquet, etc.) have a nonlinear formation, they transact by accepting that the criteria are independent of each other. However, in most cases, decision-makers require to include inter-criteria relationships in their analyses. In such cases, Bonferroni mean operator can consider the interactivity among criteria. On the other hand, the Dombi operator can make the information aggregation operation much more flexible thanks to its general t-conorm and t-norm features (Liu et al., 2017). Consequently, thanks to the Bonferonni and Dombi operators, the model proposed in this study catches the relationships between the evaluation criteria and aid in making more flexible decisions than the F-BWM approach, meaning that the proposed model's results are more credible and acceptable than F-BWM. Finally, providing flexible decision-making and incorporating relations between criteria into calculations are vital advantages and novelties of the framework employed.

### 5. Conclusion

The present study serves as a framework that integrates the superiorities of the Bonferroni mean operator and Dombi operator with the BWM method for airport selection under a fuzzy environment. To achieve dynamic decision-making, the Bonferroni mean and generalized Dombi operators are used to aggregate criteria value coefficients obtained from F-BWM. When setting priorities for a real-world problem, the main advantages of this model are that it considers the interaction between factors and offers a flexible decision support system. The study comprehensively evaluates the airport selection criteria from the perspective of air cargo carriers for the COVID-19 period. As a result of comprehensive research and opinions of decision-makers, the five pillars of the airport location, airport costs, airport physical features, airport performance, and airport reputation, as well as their 18 sub-criteria, are determined as crucial factors affecting the airport selection process of carriers in this period. All of these are evaluated by six decision-makers from the aviation sector. The collected data is analyzed through the TFDBM-BWM framework, and the priority of the criteria is reached.

This empirical study on the evaluation of airport selection criteria for air cargo carriers in a strategic way during the COVID-19 pandemic reveals that airport location and airport costs are the key determinants. Further, the findings indicate that airport performance and airport physical features do not affect the decision process of carriers regarding airport selection enough in this period. Obviously, the aviation industry is among the industries most affected by the devastating pandemic. Although cargo carriers are not affected by the adverse conditions of the pandemic as much as passenger carriers, regardless of passenger or cargo, costs are always considered as the first criterion of air transportation for any strategic selection. The results of the studies carried out on airport selection in terms of cargo or passenger carriers before the pandemic and the results of this study, which investigated the airport selection criteria for cargo carriers within epidemic conditions, also support the importance of costs. Apart from costs, the study highlights airport location and airport reputation factors. For carriers that try to respond to the sharply increasing demand with their current capacity effectively and efficiently during the outbreak period, there is no slot availability problem after the drop in passenger flights. For this reason, although the bargaining power of carriers is high compared to airports, carriers have flexibility in choosing the optimal airport for them in terms of location. Airport security and a good reputation for cargo damage or delays are prerequisites for carriers. In another conclusion, airports with weaknesses in terms of security and cargo damage are not among the options that can be said. In these challenging times, when the importance of air cargo is felt, compromising these criteria means that carriers directly risk their sustainability.

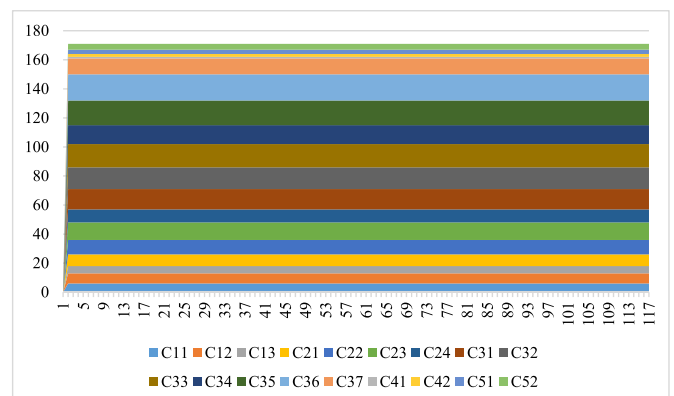


Fig. 2. Effect of diverse  $p$ ,  $q$ , and  $\rho$  parameters on rankings.

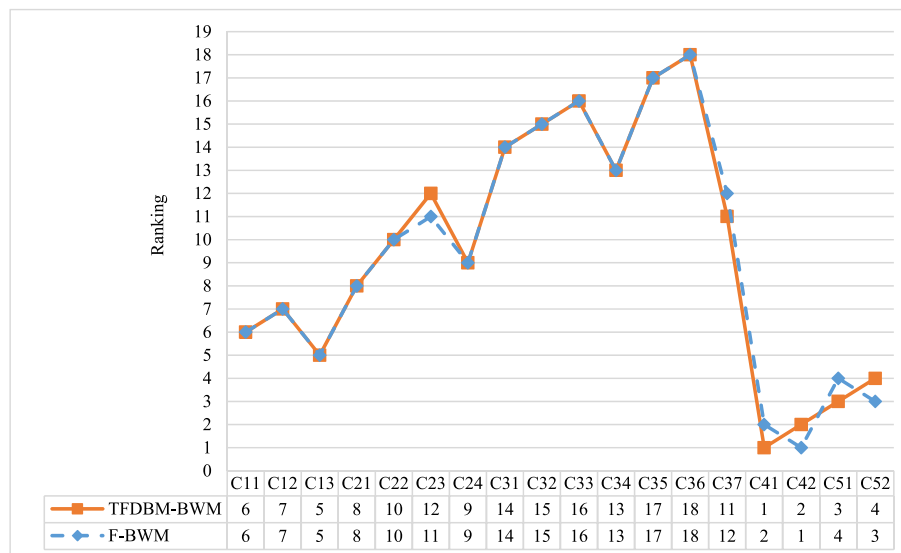


Fig. 3. Criteria rankings of the proposed model versus F-BWM.

5.1. Managerial implications

Within the framework of managerial implications, the paper guides both air cargo carriers and airport operators. The study can be counted as a guide that will enable air cargo carriers to make the optimal strategic selection among airports during the pandemic period. Besides, it presents empirical findings showing which strategic moves should be made by airport operators aiming to attract air cargo carriers. The way to realize these strategic moves is to understand the characteristics of air cargo carriers.

Within the scope of the study, air cargo carriers should consider airport location and airport costs at most for the airport selection process during the age of COVID-19 since they must use their limited capacity in the right way for their sustainability. It has been observed that carriers attribute almost the same importance to these two factors. Whereas the airport location means new demands and revenues for the carriers, the low charges expected from the airports show the efforts of the carriers to minimize their costs during the era of COVID-19. In this direction, air cargo carriers have paid attention to low airport and handling charges while selecting airports among alternatives in good locations that have been idle due to the pandemic. Furthermore, many passenger airlines which lost during this period made a strategic move to generate some income and started carrying cargo with freighters.

In this context, it is expected that the most crucial steps airport operators will take to attract air cargo carriers will be in cost criteria. It is understood that airport operators need to lower their prices to attract freighters and freighters during the pandemic. At this point, one can see that airports with suitable locations and low prices will attract the attention of carriers during the pandemic period if they also meet other basic requirements for cargo carriers. The price policies of such airports, therefore, have strategic importance. Airports should follow a low-pricing policy without compromising their sustainability to have a share of the increasing air cargo flights, especially in this period when airline passenger flights are decreasing. Zuidberg (2017) researched the factors affecting the airport's profitability and revealed that the volume of cargo handled at the airport does not affect airport profitability. On the contrary, the demand for basic humanitarian needs increases significantly during periods leading to humanitarian crises such as pandemics. Depending on these conditions, it can be expressed that the increase in air cargo demand due to the urgency of meeting these needs during such periods ensures airport profitability. Besides, airports should increase their awareness and knowledge about cargo in this pandemic period, where the importance of cargo transportation is rising. At the same time, they should improve their

marketing activities and convey to the carriers what kind of services they offer, unlike competing airports, how financially convenient these services are, and why they should be preferred over the competitors in their region. Gardiner et al. (2005b) asserted that the efficiency of airport marketing in airport preferences of carriers is 39%. This proves the necessity of airports to improve themselves in marketing. In sum, airports should adapt to changing conditions to attract and retain carriers.

5.2. Limitations and future studies

This paper also has some limitations and suggestions. First, the paper is limited to the perceptions of a certain number of experts. Undoubtedly, the empirical findings are shaped by the decision-makers' insights, capacities, experiences, and inclinations, which is the limitation of the study. In decision support systems based on subjective weighting methods like the proposed framework, in other words, various linguistic evaluations by different decision-makers are likely to have an impact on the results. Hence, the results cannot be generalized. Secondly, this study is limited to the most significant five aspects and eighteen factors that air cargo carriers consider in airport selection as a single stage. In the future, two-stage empirical studies can be carried out considering the alternative selection in line with the proposed model. In this direction, MCDM methods that allow alternative selection and ranking can be used in the second stage of the study, or that can be used in both stages can be preferred. Third, the study is limited to the F-BWM method, which provides decision-making under uncertainty. Since the MCDM field is constantly developing, new methods are taking their place in the scientific world. Future work can be carried out by extending the proposed approach to various fuzzy environments such as intuitionistic, fermatean, spherical, hesitant, etc. Additionally, other weighting methods can be performed instead of BWM. Future studies can also reach more generalizable results by investigating the criteria of air cargo carriers influencing airport selection during the pandemic period with quantitative methods. Finally, future work can include extensive research involving shippers, freight forwarders, and regulators.

Author statement

Gökhan Tanrıverdi: Writing, literature review part, introduction, discussion, references, Fatih Ecer: Writing and research methodology, formal analysis, sensitivity analysis, review & editing, Mehmet Şahin Durak: Conceptualization, original draft preparation, review and editing, All authors have read and agreed to the published version of the manuscript.

**Appendix A. The influence of various  $p$ ,  $q$ , and  $\rho$  parameters on the ranking of sub-criteria**

Scenario	Sub-criteria																		
	Rank	C11	C12	C13	C21	C22	C23	C24	C31	C32	C33	C34	C35	C36	C37	C41	C42	C51	C52
S1	Current	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = 1; \rho = 2$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = 1; \rho = 3$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = 1; \rho = 4$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = 1; \rho = 5$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = 1; \rho = 6$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = 1; \rho = 7$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
$p = q = 1; \rho = 30$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4	
S2	$q = \rho = 1; p = 2$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$q = \rho = 1; p = 3$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$q = \rho = 1; p = 4$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$q = \rho = 1; p = 5$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$q = \rho = 1; p = 6$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$q = \rho = 1; p = 7$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$q = \rho = 1; p = 30$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
S3	$p = \rho = 1; p = 2$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = \rho = 1; p = 3$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = \rho = 1; p = 4$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = \rho = 1; p = 5$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = \rho = 1; p = 6$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = \rho = 1; p = 7$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = \rho = 1; p = 30$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
S4	$p = q = \rho = 2$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = \rho = 3$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = \rho = 4$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = \rho = 5$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = \rho = 6$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = \rho = 7$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	...	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4
	$p = q = \rho = 30$	6	7	5	8	10	12	9	14	15	16	13	17	18	11	1	2	3	4

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