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Research Article / *Araştırma Makalesi*

STRATEGIC DECISION-MAKING FOR AIR CARGO CARRIERS ON FREIGHTER TYPE SELECTION*

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ABSTRACT

The selection of freighter type is one of the strategic decisions that influence the economic sustainability of air cargo carriers, as it creates a serious financial burden, especially in the case of purchasing a freighter. In this context, this study aims to propose a model for air cargo carriers to help them determine the best freighter type in terms of their business models. In this direction, the study is applied criteria including qualitative and quantitative drawn from the related literature and obtained from experts. The AHP method was used to determine criterion weights. TOPSIS and VIKOR methods were employed to select the best alternative freighter type. In addition, consistency tests and sensitivity analysis were performed to test the reliability and validity of the results. Finally, at the stage of determining the best alternative, the results obtained from two different methods were integrated with the Board Count method to obtain a single result. The study reveals A330-200F and B777F as the two best freighter types for the sector-wide result. In addition, while carrier-based results are in parallel with sector-wide results, B747-400 and B777 are in the first two places in line with ACMI provider-based results.

Keywords: *Freighter Type Selection, Air Cargo, Multi-Criteria Approach, AHP-Based TOPSIS-VIKOR, Borda Count Method.*

HAVA KARGO TAŞIYICILARININ KARGO UÇAĞI TİPİ SEÇİMİNDE STRATEJİK KARAR VERME

ÖZET

Kargo uçağı tipi seçimi, özellikle bir kargo uçağının satın alınması halinde ciddi bir mali yük oluşturduğundan hava kargo taşıyıcılarının ekonomik sürdürülebilirliğini etkileyen stratejik kararlardan biridir. Bu bağlamda çalışmanın amacı, hava kargo taşıyıcılarının iş modellerine göre en iyi kargo uçağı tipini belirlemelerine yardımcı olacak bir metodoloji ortaya koymaktır. Bu doğrultuda, çalışmada, literatürden ve uzmanlardan toplanan nitel ve nicel kriterler kullanılmaktadır. Kriter ağırlıklarını belirlemek için AHP tekniği kullanılmıştır. En iyi alternatif kargo uçağı tipini seçmek için ise TOPSIS ve VIKOR tekniklerinden faydalanılmıştır. Çalışmada sonuçların güvenilirlik ve geçerliliğini test

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etmek amacıyla duyarlılık testi ve duyarlılık analizi yapılmıştır. Son olarak, en iyi alternatifi belirleme aşamasında farklı iki yöntemden elde edilen sonuçlar Borda Sayım yöntemi ile bütünleştirilerek tek bir sonuç elde edilmiştir. Çalışmanın sonucunda, sektör geneli için A330-200F ve B777F kargo uçağı tiplerinin en iyi iki kargo uçağı tipi olduğunu görülmüştür. Ayrıca taşıyıcı bazlı sonuçların sektör geneli sonuçlarla aynı paralelde olduğu görülürken kapasite sağlayıcı bazlı sonuçlara göre B747-400 ve B777 ilk iki sırada yer almıştır.

Anahtar Kelimeler: *Kargo Uçağı Tipi Seçimi, Hava Kargo, Çok Kriterli Yaklaşım, AHP Tabanlı TOPSIS-VIKOR, Borda Sayım Yöntemi.*

1. Introduction

In recent years, paralleling global growth, significant growth has been observed in air cargo transportation (Chao & Kao, 2015). This growth and development in air cargo transportation are expected to increase by 4.5-5% annually in the next 20 years (Airbus, 2014; Chao & Li, 2017). An analysis of the data on the Turkish air cargo market reveals that while 1 million 726 thousand tons of cargo were transported in 2009, 3 million 855 thousand tons of cargo were transported in 2018, indicating a growth rate of 9.3% in the last decade (DHMİ, 2019). Istanbul Grand Airport (IGA-Istanbul Airport) has a significant potential to respond to the rapid growth of the air cargo market both in Turkey and the world (UTIKAD, 2019). However, the increase in annual cargo payload capacity is expected to create new needs in the Turkish air cargo market with the completion of the first phase of IGA, which started its operations in 2019 April. Therefore, it is critical for ACMI provider companies, which provide additional capacity to carriers by leasing their aircraft, and carriers, to review their fleets to check whether they can meet the potential needs of the Turkish air cargo market. Unless, they should acquire the right freighters into their fleets to fulfill the need.

Carriers can purchase additional capacity from ACMI providers through aircraft leasing depending on their needs arising from unforeseen circumstances. Because of this strong relationship between carriers and ACMI providers, the ACMI Providers, just like the carriers, aim to select the freighter type that is best for their business strategy by considering the market conditions and operating policies. Unit costs of airline operations can increase if an inappropriate aircraft selection decision is made. The problem of choosing a freighter type is a strategic decision since it has a direct impact on reducing costs and increasing the profit margin (Merkert, 2011, 687; Dozic & Kalic, 2018). While this decision facilitates carriers and ACMI Providers to have a strong position in the market, it also involves the risk of losing their current position. Therefore, it is very important for carriers and ACMI Providers to choose the freighter type that meets their needs at most in line with the specific set of market conditions and operating policies.

Paralleling the growth trend of air transportation industry in recent years, there has been a growing body of research in the literature focusing on aircraft selection. Previous studies carried out on aircraft selection are focused on fleet assignment (Bhadra, 2003; Sherali et al., 2006; Khoo & Teoh, 2014; Ma et al., 2018), fleet planning (Merkert & Hensher, 2011; Dožić & Kalić, 2013; Rosskopf et al., 2014), selection of aircraft to be included in the current fleet (Harasani, 2006; Givoni & Rietveld, 2009; Dožić & Kalić, 2015; Mukanbay et. al.,2016). Apart from the aforementioned studies carried out with different methods in the literature, most research on passenger aircraft selection has been conducted by applying the multi-criteria decision-making (MCDM) methods (Yeh & Chang, 2009; Özdemir et al., 2011; Sun et al., 2011; Gomes et al., 2014; Dožić & Kalić, 2014; Dožić & Kalić, 2015; Bruno et al., 2015; Özdemir & Başlıgil, 2016; Dozic et. al. 2018; Kiracı & Bakır, 2018; Kiracı & Akan, 2020). The aircraft selection studies using the MCDM methods are given in Table 1 in chronological order. When previous studies abovementioned and in Table 1 are examined, it can seen that there are quite limited study on freighter type selection for air cargo carriers (Mukanbay et al., 2016; Ardil, 2021).

Table 1: Research on Aircraft Selection Conducted with Various MCDM Methods

Author	Method	Criteria	Alternatives
Yeh & Chang (2009)	Fuzzy MCDM	Technological Advance *(maintenance requirements, pilot adaptability, aircraft reliability, maximum range)*; Social Responsibility *(passenger preference, noise level)*; Economical Efficiency *(operational productivity, airline fleet economy of scale, direct operation cost, purchasing price, consistency with corporate strategy)*	B757-200, A-321, B767-200, MD-82, and A310-300
Özdemir et al. (2011)	ANP	Physical Attributes *(dimensions, security, reliability, suitability for service quality)*; Time *(delivery time, useful life)*; Cost *(purchasing cost, operation and spare cost, maintenance cost, salvage cost)*	A319, A320, B737
Sun et al. (2011)	ELECTRE, SAW, TOPSIS	Max Cruise Speed, MTOW, Available Seat Mile, Cabin Volume per Passenger, Fuel Consumption per Seat Mile	B747-400, B777-200, A340-300
Gomes et al. (2014)	NAIDE	Financial *(acquisition cost, liquidity, operating costs)*; Logistics *(Range, Flexibility, cruising speed, Replacement parts availability, Landing and take-off distance)*; Quality *(comfort, avionics availability, safety)*	The selection of aircraft permitted for regional charter operations are those with a capacity equal to or less than 30 passengers
Dozic & Kalic (2014)	AHP	Seat Capacity, Price, Baggage per passenger, MTOW, Unit costs	Regional Jets: Embraer 190 (ERJ190), CRJ 700, CRJ 900 and CRJ 1000. Turboproplar: ATR 72-500, ATR 72-600 and Bombardier Q400 NG.

Table 1 continue

Dozic & Kalic (2015)	AHP, ESM	Seat Capacity, Price, Baggage per Passenger, MTOW, Unit costs	Regional Jets: Embraer 190 (ERJ190), CRJ 700, CRJ 900 and CRJ 1000. Turboprops: ATR 72-500, ATR 72-600 and Bombardier Q400 NG.
Bruno et al. (2015)	AHP, Fuzzy Set Theory	Economic Performance *(operative costs, aircraft price);* Technical Performance *(speed, autonomy); In-flight Quality (seat comfort, cabin luggage compartment size);* Environmental aspects *(Pollution, Noise)*	Bombardier CRJ1000, Sukhoi SSJ100, Embraer ERJ190
Özdemir & Başlıgil (2016)	Fuzzy ANP	Physical Attributes *(security, Suitability for service quality);* Time *(Delivery time, salvage cost); Costs (operation costs, purchasing cost, operation, and spare cost)*	3 type passenger aircraft selection
Dozic et. al. (2018)	Fuzzy AHP, LFFP	Seat Capacity, MTOW, Range, Purchasing Costs, Maintenance Costs, Total cost per available seat miles, Delivery Time, Payment Conditions, Fleet Commonality, Comfort,	Regional jets: Embraer 190 (ERJ190), CRJ 700, CRJ 900 and CRJ 1000. Turboprops: ATR 72-500, ATR 72-600 and Bombardier Q400 NG.
Kiracı & Bakır (2018)	TOPSIS	Range, Price, Speed, Seat Capacity, Fuel Consumption	A320, A321, B737-800, B737-900ER
Kiracı & Bakır (2018)	AHP, COPRAS ve MOORA	Range, Price, Speed, Seat Capacity, Fuel Consumption, Maximum Payload, Amount of Greenhouse Gas Release	A320, A321, B737-800, B737-900ER
Kiracı & Akan (2020)	IT2FAHP, IT2FTOPSIS	Technical Aspects, Economic Aspects, and Environmental Aspects	Airbus A320neo, Airbus A321neo, Boeing 737 MAX 8, Boeing 737 MAX 9
Ardil (2021)	Entropic TOPSIS Programming, Classical Additive Weighted Model	Range, Maximum Payload, Maximum Takeoff Weight, Maximum Landing Weight	A350F, B777F, B747-8F

The primary source of motivation for this study, which focuses on air cargo transportation, is the fact that the studies on the selection of aircraft with multi-criteria decision-making methods in the literature mostly focus on the airlines engaged in passenger transportation, as seen in Table 1. Therefore, it seems that the research problem of best freighter type selection for air cargo carriers is still valuable for executives of air cargo carriers and related literature since a very limited study on the problem of freighter type selection for air cargo carriers is available in the literature. The present study differs from other studies in terms of its specific focus on the freighter type selection as a multi-criteria decision-making problem. Some criteria (Cargo Capacity, Cost of FTK, Loadability), which were taken into consideration in the selection of freighter type but not included in the literature, were introduced into the literature on aircraft selection by this study. Some of the criteria included in the study were obtained from the literature and the rest were obtained from experts. Finally, all criteria were approved by the experts.

As mentioned before, air cargo carriers operate with two business models in the air cargo industry. The so-called 'carriers' in this study are actively engaged in cargo transportation by freighters. The so-called 'ACMI Provider' offers the additional capacity to the market by renting their freighters to the carriers in line with the demands from the carriers in cases of increasing demand. In this respect, the concept of 'air cargo carrier' is intended for both business models integrally, while the results for carriers and ACMI providers have been discussed separately in business model-based distinctions in the study. In this context, the answers to the following questions were sought:

- What factors affect air cargo carriers' choice of freighter type?
- What are the relative significance levels of the factors affecting the choice of freighter type for air cargo carriers? How do the significance levels of the factors differ according to the business models?
- What is the optimal freighter type for air cargo carriers? How does the optimal freighter type differ according to the business models?

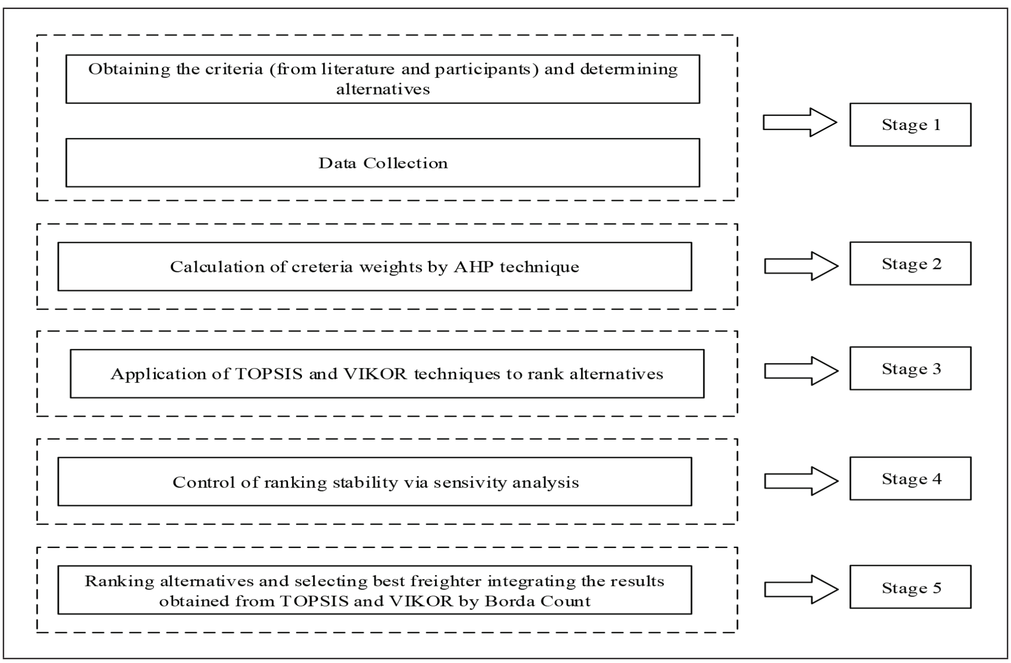
The study is structured as follows: Section 2 introduces the research methodology and proposed model. Section 3 presents the data collection process. Section 4 tells us about results, whilst section 5 includes discussion. Section 6 also includes conclusions, managerial implications, limitations, and future studies.

2. Research Methodology

MCDM methods facilitate decision-making by incorporating conflicting criteria into complex decision-making processes systematically and consistently (Sennaroglu & Varlik Celebi, 2018). Multi-criteria decision-making methods are widely used in decision problems for transportation systems. The Analytical Hierarchy Process (AHP) method is one of these most used methods in transportation problems (Mardani et al., 2016, 380). In this study, the AHP method was used to determine the weights of the criteria that the air cargo carriers in the Turkish air cargo sector should consider when determining the best freighter type. The AHP method, developed by Thomas L. Saaty in the 1970s, provides a holistic assessment of qualitative criteria as well as quantitative criteria, taking into account the priorities of decision-makers. As such, the AHP is a powerful multi-criteria decision-making method that is widely used in the solution of decision problems involving many criteria that may contradict one another (Saaty, 1986, 841). In this study, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), developed by Yoon & Hwang (1981) and Kriterijumska Optimizacija Kompromisno Resenje (VIKOR), developed by Opricovic (1998), were also used to reach to the best alternative freighter type based on the criteria weights obtained with the AHP method. While TOPSIS offers a compromise solution approach by identifying the ideal solution and negative ideal solution points and taking the distance of alternatives to these points as the basis, VIKOR can help decision-makers make a final decision on the most appropriate alternative when conflicting criteria are involved by providing a compromising solution to a multi-criteria decision-making problem. The application of these two methods together using different normalizations in the alternative selection phase is critical for the robustness of the study results (Opricovic & Tzeng, 2004).

Numerous studies in the literature analyze various multi-criteria decision-making methods based on selection problems. Some of these studies include only one of these methods, while some include different methods used together. In this study, AHP, TOPSIS, and VIKOR multi-criteria decision-making methods were used. When the literature was reviewed to find out the studies that have applied various methods together, those focusing on AHP-TOPSIS (Gardziejczyk & Zabicki, 2014; Azimifard et al., 2018; Kumar et al., 2018), AHP-VIKOR (Zhu et al., 2015; Soner et al., 2017), and TOPSIS-VIKOR (Azar et al. 2011; Bai & Sarkis, 2018, Fancello et al., 2019) were identified. Although there are many studies applying the couples of AHP and TOPSIS, AHP and VIKOR, and TOPSIS and VIKOR methods together in the literature, no study applying all three of the AHP, TOPSIS, and VIKOR together could be found. In the following section, the data collection procedure of the study is presented.

Figure 1: Proposed Model for the Freighter Selection Problem



3. Data Collection Process

The data collection process of this study which aims to propose a model as in Fig.1 for determining the best freighter type for air cargo carriers in the Turkish air cargo sector, was carried out in two stages. In the first stage, the decision criteria were determined based on a literature review and the opinions of 6 experts. While the experts work in senior management positions in their companies, their average sector experience, and average position experience are respectively 14.6 and 6.6 years. The question "What are the criteria you consider when choosing the freighter type to be included in the fleet?" was asked to the experts via e-mail and answers were obtained on dates between 30 May 2018 and 28 June 2018. A pool of criteria was established in line with the literature and the responses obtained from the experts, and these criteria were evaluated by the researchers in terms of their suitability for the aim of the study. Afterward, a consensus was reached with the researchers on the suitability of the final 12 criteria.

In the second stage of the data collection process, data were collected from the experts on dates between 9 August and 3 October 2018. The experts work at carriers and ACMI providers operating in the Turkish air cargo sector and all air cargo carriers operating in the Turkish air cargo sector were reached in the study.

Based on the methodological flow of the study, a single-level criterion hierarchy was formed, which included 12 criteria, as can be seen in Table 3. It is important to note that the criteria specific to the air cargo business such as cargo capacity, loadability, and cost of FTK were used for the first time in this study in the literature. Thus, the reference of each criterion was stated as a source from literature and experts (Experts were anonymized by researchers by assigning them codes from E1 to E6) for clarifying the original criteria in Table 2.

Table 2: Definitions, Objectives, and References of Decision Criteria

Criteria	Definitions	Objective	References
Range	The maximum distance the aircraft can fly between take-off and landing.	Max	Dozic et al. (2018); Kiracı & Bakır (2018); E4
Aircraft Price	It is the value on which the aircraft is offered for sale by the manufacturer.	Min	Yeh & Chang (2009); Özdemir et al. (2011); Gomes et al. (2014); Dozic & Kalic (2014); Dozic & Kalic (2015); Bruno et al. (2015); Özdemir & Başlıgil (2016); Dozic et al. (2018); Kiracı & Bakır (2018); E5
Speed	The speed of the aircraft per hour during flight (Mach Number)	Max	Sun et al. (2011); Gomes et al. (2014); Bruno et al. (2015); Kiracı & Bakır (2018)

Table 2 continue

Cargo Capacity	The maximum amount of cargo the aircraft can carry for a flight.	Max	E3, E4
Fuel Consumption	The aircraft's hourly fuel consumption with max payload.	Min	Sun et al. (2011); Kiracı & Bakır (2018); E5
MTOW	It is the maximum weight of the aircraft as determined by the manufacturer.	Max	Sun et al. (2011); Dozic & Kalic (2014; 2015) Dozic et al. (2018); E5
Cost of FTK	It is the cost of one ton of cargo carried per kilometer. It is an important indicator that measures the operational cost of the aircraft.	Min	E4, E5
Loadability	This is the case where the cargo can be loaded into the contours of the aircraft. Nose-loading aircraft are preferred in projects and oversize cargoes, but in the case of general cargo transportation, aircraft with pallet utilization can be preferred more easily.	Max	E3, E4
Suitability for the Financial Strength of the Company	The degree to which the financial strength of the operator meets the cost and payment terms of the aircraft to be included in the fleet.	Max	Dozic et al. (2018); E1, E5
Suitability for the Existing Fleet Structure	Whether the type of aircraft that the operator wants to be included in the fleet is included in the current fleet of the operator. The choice of different types of aircraft has disadvantages such as the cockpit crew, technical crew, and new crew, the stock of spare parts, the existing maintenance authorities, and the variable costs they generate.	Max	Dozic et al. (2018); E5
Maintenance Costs	One-year maintenance costs incurred by the operator to keep the aircraft operational.	Min	Dozic et al. (2018)
Suitability for the Planned Destination	The suitability of the aircraft to be included in the fleet to the requirements/conditions (altitude, runway length, airport facilities, maximum noise level, etc.) of the intended destination.	Max	Bhadra (2003); E1, E4

8 of the criteria included in the study are quantitative and the remaining four criteria are qualitative. 6[1] quantitative criteria including range, aircraft price, speed, fuel consumption, MTOW, and cargo capacity were obtained from online resources. However, the fuel consumption value of the A310-300 alternative was obtained by consulting about it with E3. The accuracy of all the values obtained from the Internet was also confirmed by the same expert. The values for other quantitative criteria (i.e. maintenance costs and cost of FTK) which have real equivalents in the companies, were expressed on a 0-100 scale, with "0" indicating the worst, and "100" indicating the best value, depending on the real value of the company's interests while maintaining the minimizing and maximizing objectives of the criteria. The values for 4 qualitative criteria were also obtained by the experts with the 0-100 scale.

The freighter types were restricted to pure cargo aircraft called "freighter" operated in the Turkish air cargo market in this study. Thus, five alternative freighter types were identified as A300-600F, A310-300F, A330-200F, B747-400F, and B777F. The reason why these 5 freighter types were determined as alternatives is that they are the freighter types in the fleet of scheduled carriers and ACMI providers in the Turkish air cargo market. The distribution of the alternative freighter types operating in the Turkish air cargo market is shown in Table 3.

Table 3: Status of Freighter Types Owned by Turkish Air Cargo Carriers

Alternatives	Carriers	ACMI Providers
A300-600F	7	-
A310-300F	4	3
A330-200F	11	-
B747-400F	4	5
B777F	5	-

4. Results

The scope of this study, which uses AHP-based TOPSIS-VIKOR methods for the selection of freighter type, consists of 2 carriers and 2 ACMI Providers. Carriers have a business model of transporting the cargoes delivered to them to the desired point in line with the demands of the customers, while ACMI providers have a business model of analyzing the air cargo market and offering the aircraft in their fleets as additional capacity to the carriers in the market. Accordingly, The findings are presented in Table 5 as sector-wide and business model-based (Carrier-based, ACMI Provider-based) to present the results more realistically. Sector-wide results reflect the opinions of all experts in the research. The results obtained separately for the carriers and ACMI providers, which are called business-model based, were obtained by analyzing the opinions of the experts working in the carrier and ACMI provider companies in two separate parts.

1 The data for all the alternatives, except for the A310-300F alternative and the aircraft price criterion for all the alternatives, are available at: https://www.aircraftcompare.com/. The data apart from aircraft price and fuel consumption for A310-300F can be accessed at http://brinkley.cc/AC/a313f.htm

A consistency test was performed separately for each of the obtained binary comparison matrices. The consistency results of the AHP ranged from 0.07550 to 0.0996. Since the consistency values are between 0 and 0.1, the opinions of all decision makers were included in the analysis (Berrittella et al., 2009, 251; Brunelli, 2015, 25). Table 4 summarizes the rankings resulting from the geometric means of the 12 criteria obtained through the AHP method. According to the sector-wide criteria ranking, which indicates the common views of the four companies doing business with 2 different business models, the cost of FTK, suitability for the existing fleet structure, and maintenance costs criteria are the most important criteria for the companies. Regarding the carrier-based criteria ranking, the maintenance costs, cost of FTK, and suitability for the existing fleet structure emerge as the leading criteria. In the assessment made by the ACMI providers, suitability for the financial strength of the company, cost of FTK, and aircraft price criteria stand out as the most important criteria.

At the heart of multi-criteria decision-making problems is the determination of the best alternative for a specific purpose among the alternatives. In this study, which aims to propose a model to determine the best freighter type for air cargo carriers in the Turkish air cargo sector, two different methods (TOPSIS and VIKOR) were used in the alternative-selection stage. The reason for using two different methods at this stage was to achieve a more accurate ranking by allowing the results to be compared. Table 5 shows the three different rankings obtained through both methods for the sector-wide, carrier-based, and ACMI provider-based alternatives.

Table 4: Relative Importance of Criteria

	Sector-Wide		**Carrier-Based**		**ACMI Provider-Based**	
Criteria	**Weights**	**Rank**	**Weights**	**Rank**	**Weights**	**Rank**
Range	0.04	**9**	0.07	**8**	0.02	**11**
Aircraft Price	0.10	**6**	0.07	**6**	0.14	**3**
Speed	0.01	**12**	0.02	**12**	0.01	**12**
Cargo Capacity	0.08	**7**	0.10	**5**	0.05	**8**
Fuel Consumption	0.12	**4**	0.13	**4**	0.09	**7**
MTOW	0.02	**11**	0.02	**11**	0.02	**10**
Cost of FTK	0.15	**1**	0.14	**2**	0.15	**2**
Loadability	0.03	**10**	0.03	**10**	0.03	**9**
Suitability for the Financial Strength of the Company	0.10	**5**	0.07	**7**	0.15	**1**
Suitability for the Existing Fleet Structure	0.14	**2**	0.14	**3**	0.13	**4**
Maintenance Costs	0.14	**3**	0.16	**1**	0.10	**5**
Suitability for the Planned Destination	0.06	**8**	0.04	**9**	0.10	**6**

Table 5:Business Model-Based Ranking Results of TOPSIS and VIKOR Methods

		Sector-Wide				Carrier-Based				ACMI Provider-Based			
	Alternatives	**Si+**	**Si-**	**Ci***	**Rank**	**Si+**	**Si-**	**Ci***	**Rank**	**Si+**	**Si-**	**Ci***	**Rank**
TOPSIS	A300-600F	0.10	0.07	0.41	5	0.09	0.08	0.46	3	0.14	0.11	0.42	5
	A310-300F	0.09	0.08	0.45	4	0.09	0.07	0.45	4	0.12	0.11	0.48	3
	A330-200F	0.05	0.08	0.60	1	0.04	0.12	0.72	1	0.10	0.09	0.48	4
	B747-400F	0.07	0.08	0.54	3	0.12	0.06	0.36	5	0.06	0.14	0.70	1
	B777F	0.08	0.10	0.57	2	0.06	0.11	0.65	2	0.12	0.12	0.51	2
VIKOR	**Alternatives**	**Si+**	**Si-**	**Ci***	**Rank**	**Si+**	**Si-**	**Ci***	**Rank**	**Si+**	**Si-**	**Ci***	**Rank**
	A300-600F	0.88	0.15	1	5	0.70	0.14	0.89	4	0.84	0.15	1	5
	A310-300F	0.73	0.15	0.87	4	0.63	0.10	0.63	3	0.70	0.13	0.77	4
	A330-200F	0.32	0.06	0.08	1	0.24	0.06	0.02	1	0.49	0.09	0.36	2
	B747-400F	0.45	0.14	0.60	3	0.69	0.16	0.99	5	0.18	0.07	0	1
	B777F	0.21	0.10	0.20	2	0.22	0.07	0.05	2	0.40	0.14	0.64	3

In the sector-wide ranking obtained with the TOPSIS, the most suitable freighter type for the sector is A330-200F. In the carrier-based ranking, the A330-200F takes first place, as in the sector-wide ranking. However, the ACMI provider-based ranking differs from the sector-wide and carrier-based rankings. B747-400F, which ranked third and fifth in other rankings, ranked first in the scope of ACMI provider-based TOPSIS results. As indicated by these results, the single freighter type whose rank does not change is B777F, which is the second in three different rankings. It is clear that the sector, carrier, and ACMI provider-based rankings obtained by applying the VIKOR are in line with the TOPSIS results in terms of the alternatives ranked first. The A330-200F was rated as the most suitable freighter type for the sector and carriers, and the B747F for the ACMI providers. According to the TOPSIS results, B777F, which ranks second in all three rankings, maintains its rankings in the sector and carrier-based rankings according to VIKOR results and ranks third in the ranking obtained for the ACMI providers. The A330-200F ranks fourth in the capacity-based ranking in the TOPSIS results but ranks second in the capacity-based ranking according to VIKOR results. Fig. 2 shows the alternative rankings obtained through both MCDM methods.

Although the alternative rankings obtained by the AHP-based TOPSIS and VIKOR methods were parallel to each other, the sensitivity analysis was applied to the results and the effect of the changes in weights on the alternative rankings was also examined. Such robust and stable results make it easier for decision-makers to make the final decision during the selection process. For this purpose, each criterion has the highest weight value once and the lowest weight value once respectively, while the other criteria have the highest and lowest values as well. Thus, with various calculations, different alternative sequences for different sets were obtained. Table 6 presents the criterion weights obtained for the different sets, while Fig. 3 summarizes this in a graphical display. The formula is used to determine the weights; where s is the weight normalization value and m is the number of criteria. The criteria weights are obtained as 1/s, 2/s, 3/s, ..., m-1/s, m/s. In addition, the number of sets is the same as the number of criteria (Ghorabaee et al., 41). In this study using 12 criteria, 12 different weight sets were obtained to follow a specific pattern.

Figure 2: Graphical View of Alternative Rankings

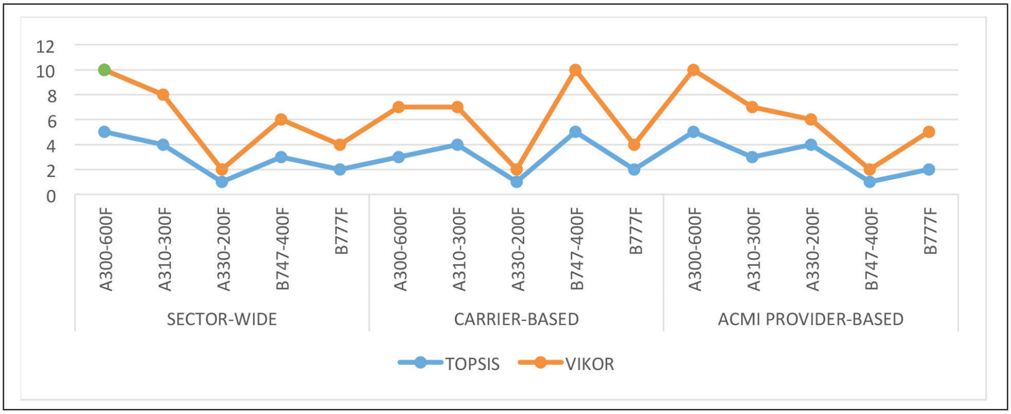


Table 6: Generated Weights for Sensitivity Analysis

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Set1	0.013	0.026	0.038	0.051	0.064	0.077	0.090	0.103	0.115	0.128	0.141	0.154
Set2	0.026	0.038	0.051	0.064	0.077	0.090	0.103	0.115	0.128	0.141	0.154	0.013
Set3	0.038	0.051	0.064	0.077	0.090	0.103	0.115	0.128	0.141	0.154	0.013	0.026
Set4	0.051	0.064	0.077	0.090	0.103	0.115	0.128	0.141	0.154	0.013	0.026	0.038
Set5	0.064	0.077	0.090	0.103	0.115	0.128	0.141	0.154	0.013	0.026	0.038	0.051
Set6	0.077	0.090	0.103	0.115	0.128	0.141	0.154	0.013	0.026	0.038	0.051	0.064
Set7	0.090	0.103	0.115	0.128	0.141	0.154	0.013	0.026	0.038	0.051	0.064	0.077
Set8	0.103	0.115	0.128	0.141	0.154	0.013	0.026	0.038	0.051	0.064	0.077	0.090
Set9	0.115	0.128	0.141	0.154	0.013	0.026	0.038	0.051	0.064	0.077	0.090	0.103
Set10	0.128	0.141	0.154	0.013	0.026	0.038	0.051	0.064	0.077	0.090	0.103	0.115
Set11	0.141	0.154	0.013	0.026	0.038	0.051	0.064	0.077	0.090	0.103	0.115	0.128
Set12	0.154	0.013	0.026	0.038	0.051	0.064	0.077	0.090	0.103	0.115	0.128	0.141

Figure 3: Graphical View of the Generated Weights

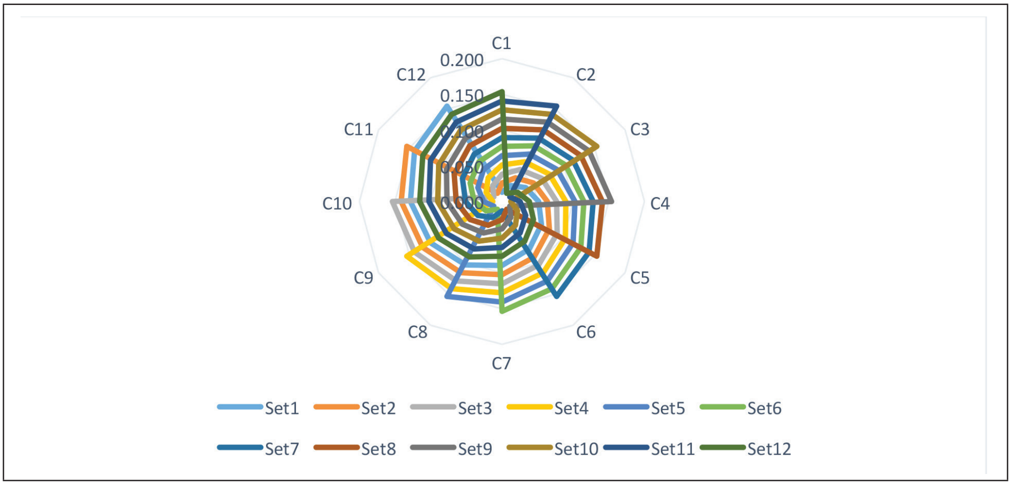


Table 7 shows the results obtained separately for each set in line with the MCDM problem. Furthermore, as a result of the sensitivity analyses carried out separately for each of two MCDM methods used in this study based on sectoral and business models, the distribution of alternatives in different rankings is given in Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8 and Fig. 9. Therefore, it can be said that alternative rankings are sensitive to changes in weight coefficients but the changes in rankings are not very dramatic. Alternatives of A300-600F, A310-300F, and A330-200F take the 5th, 4th and 3rd rankings respectively in general, and the first two rows vary between B747-400F and B777F. Sensitivity analysis shows that the results are partially stable.

Table 7: Ranking Results in line with Different Sets and Methods

		TOPSIS Ranks					VIKOR Ranks				
		A300-600 F	A310-300 F	A330-200 F	B747-400 F	B777F	A300-600 F	A310-300 F	A330-200 F	B747-400 F	B777F
Set 1	Sector-Wide	5	4	2	3	1	5	4	2	3	1
	Carrier-Based	4	3	2	5	1	5	1	2	4	3
	ACMI Provider-based	5	4	3	1	2	5	4	3	1	2
Set 2	Sector-Wide	5	4	2	3	1	5	4	2	3	1
	Carrier-Based	4	3	2	5	1	5	3	2	4	1
	ACMI Provider-based	5	4	3	1	2	5	4	3	1	2

Table 7 continue

Set 3	Sector-Wide	5	4	3	2	1	5	4	2	3	1
	Carrier-Based	5	4	1	3	2	5	3	2	4	1
	ACMI Provider-based	5	4	3	1	2	5	4	2	1	3
		A330-200 F	B747-400 F	B777F	A300-600 F	A310-300 F	A330-200 F	B747-400 F	B777F	A300-600 F	A310-300 F
Set 4	**Sector-Wide**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**2**	**3**	**1**
	Carrier-Based	4	5	1	3	2	5	3	2	4	1
	ACMI Provider-based	5	4	3	1	2	5	4	2	1	3
Set 5	Sector-Wide	5	4	3	1	2	5	4	2	3	1
	Carrier-Based	4	5	1	3	2	5	4	3	2	1
	ACMI Provider-based	5	4	3	1	2	5	4	3	1	2
Set 6	Sector-Wide	5	4	3	1	2	5	4	2	3	1
	Carrier-Based	4	5	1	3	2	3	5	4	1	2
	ACMI Provider-based	5	4	3	1	2	5	4	3	1	2
Set 7	Sector-Wide	5	3	4	1	2	4	5	3	1	2
	Carrier-Based	5	4	3	1	2	4	5	2	1	3
	ACMI Provider-based	5	3	4	1	2	4	5	3	1	2
Set 8	Sector-Wide	4	2	3	1	5	5	4	1	2	3
	Carrier-Based	4	2	3	1	5	4	5	2	1	3
	ACMI Provider-based	4	2	5	1	3	5	4	2	1	3

Table 7 continue

Set 9	Sector-Wide	3	2	4	1	5	4	5	2	1	3
	Carrier-Based	4	2	3	1	5	4	5	3	2	1
	ACMI Provider-based	3	2	5	1	4	4	5	2	1	3
Set 10	Sector-Wide	3	2	4	1	5	4	5	2	1	3
	Carrier-Based	3	1	2	4	5	4	5	2	3	1
	ACMI Provider-based	3	2	4	1	5	4	5	2	1	3
		A330-200 F	B747-400 F	B777F	A300-600 F	A310-300 F	A330-200 F	B747-400 F	B777F	A300-600 F	A310-300 F
Set 11	Sector-Wide	3	2	4	1	5	5	4	2	1	3
	Carrier-Based	3	1	2	4	5	5	4	3	2	1
	ACMI Provider-based	3	2	4	1	5	5	4	2	1	3
Set 12	Sector-Wide	5	4	3	2	1	5	4	3	2	1
	Carrier-Based	5	4	2	3	1	5	4	2	1	3
	ACMI Provider-based	5	4	3	1	2	5	4	3	1	2

The Spearman rank correlation coefficients (spearman's rho) were analyzed to determine whether the results, which were found to be partially stable as a result of the sensitivity analysis, were consistent. Considering Spearman rank coefficients correlation, the correlation between TOPSIS and VIKOR method ranking results is seen as sector-wide: 1.000; carrier-based: 0.900; and ACMI provider-based: 0.700). In this case, it can be said that the results are significantly consistent since there is a high positive correlation between the sector-wide and business model-based results for the two MCDM methods.

In this study, sectoral and business model-based results obtained via MCDM methods were integrated with the Borda Count method to increase the validity of the alternative rankings and to provide more reliable results to the decision-makers. Borda Count reveals a generally acceptable compromise rather than a ranking determined by the majority (Qiu et al., 2016). In the Borda Count method, to obtain the Borda Score, 0 points are given to the last-ranking alternative, and the first-ranking alternative is given a point that is one lower than the total number of alternatives. The other alternatives receive the scores between the lowest score of 0 and the highest score given to the first alternative.

Table 8 summarizes the integrated ranking obtained by Borda Count. Accordingly, the results were integrated and reduced to a single result. This ranking is important in that it provides a more valid, reliable, and strong result. In the last case, the sector-wide ranking, which has the same ranking in both methods, has not changed, alternatives rank in the first two and the last ranks in the carrier-based ranking are the same, however, the A300-600F and A310-300F alternatives with the same score share the 3rd and 4th places. B747-400F and B777F take the first place in the ACMI provider-based ranking, followed by the A330-200F which takes the first place in the sector-wide and Carrier-based rankings.

Table 8:Integrated Ranking Results for Borda Count Method

		TOPSIS Ranking	TOPSIS Score	VIKOR Ranking	VIKOR Score	BORDA Score	BORDA COUNT Ranking
Sector-Wide	**Alternatives**						
	A300-600F	5	0	5	0	0	5
	A310-300F	4	1	4	1	2	4
	A330-200F	1	4	1	4	8	1
	B747-400F	3	2	3	2	4	3
	B777F	2	3	2	3	6	2
Carrier-Based	**Alternatives**						
	A300-600F	3	2	4	1	3	3-4
	A310-300F	4	1	3	2	3	3-4
	A330-200F	1	4	1	4	8	1
	B747-400F	5	0	5	1	1	5
	B777F	2	3	2	3	6	2
ACMI Provider-Based	**Alternatives**						
	A300-600F	5	0	5	0	0	5
	A310-300F	3	2	4	1	3	4
	A330-200F	4	1	2	3	4	3
	B747-400F	1	4	1	4	8	1
	B777F	2	3	3	2	5	2

5. Discussion

In this section, the results of the study are discussed with the literature. One of our most significant results that emerged from the analysis is that although they have different business models air cargo carriers consider a stronger emphasis on cost-oriented criteria than the criteria for aircraft characteristics due to the cost structure of the aviation industry. The cost of FTK criterion appears to be relatively more important than the other 11 criteria for all air cargo carriers operating. This finding broadly supports the results of other studies in the literature. Prior studies on aircraft selection have noted the importance of cost. In this direction, Dozic & Kalic (2018) found that the criteria of the purchase and maintenance cost under the main criterion of cost are one of the most important criteria. The main criterion of economic performance was ranked first in terms of relative importance with a great rate of 0.62 compared to the other three main criteria in the study conducted by Bruno et al. (2015). In another study by Yeh & Chang (2009), in parallel with other studies, criteria such as maintenance requirements, operational productivity, airline fleet economy, and purchasing price, which directly affect the costs of businesses, came first in terms of their relative importance levels. The fact that the criterion of cost of FTK and other cost-oriented criteria emerged as the most important criteria in this study show also what executives of air cargo carriers give importance to. This result supported by previous studies on aircraft selection was evaluated as an expected result for the air cargo industry operating with a low-profit margin.

Applying the TOPSIS and VIKOR methods together after employing the AHP method, this study found no significant difference between the results of two separate MCDM ranking methods. For all air cargo carriers, A330-200F was identified as the best freighter type sector-wide. The fact that the A330-200F is the most widely used freighter type by carriers in the Turkish air cargo industry, with a total of 11 freighters, is in line with the sector-wide results of the study (Table 5). On the other hand, when a business model difference is considered, the carrier-based results overlap with the sector-wide result and the most suitable freighter type for carriers is A330-200F. When the results obtained for ACMI providers are considered, the best freighter type is B747-400F. Regarding the freighter types used by the ACMI providers in the sector (5 B747-400F and 3 A310-300F), the results obtained for the ACMI Providers coincide with the current situation in the sector, just like the sector-wide and carrier-based results. ACMI providers supply aircraft by leasing them to carriers. An example of this is Turkish Airlines' rental of some of the B747-400Fs belonging to ACT Airlines. Carriers, which are more dominant in the Turkish air cargo industry compared to the ACMI providers, have an important effect on the sector-wide results. Therefore, it can be said that ACMI providers tend to include freighter types in their fleets that can best meet the market conditions and the needs of carriers as well as their financial situation in the selection of freighter types for their fleets. In addition, when the integrated results obtained by the Borda Count method are considered, the freighter which is thought to best meet the sectoral requirements are B777F, A330-200F, and B747-400F. Regarding the freighter types used by the ACMI providers in the sector (5 B747-400F and 3 A310-300F), the results obtained for the ACMI Providers coincide with the current situation in the sector, just like the sector-wide and carrier-based results. ACMI providers supply aircraft by leasing to carriers. An example of this is Turkish Airlines' rental of some of the B747-400Fs belonging to ACT Airlines. Carriers, which are more dominant in the Turkish air cargo sector compared to the ACMI providers, have an important effect on the sector-wide results. Therefore, it can be said that ACMI providers tend to include freighter types in their fleets that can best meet the market conditions and the needs of carriers as well as their financial situation in the selection of freighter types for their fleets. In addition, when the integrated results obtained by the Borda Count method are considered, the freighter which is thought to best meet the sectoral requirements are B777F, A330-200F, and B747-400F. These freighter types were also found to stand out in terms of the cost of FTK criterion which is in the first place in terms of importance among the criteria considered in the selection of freighter types. According to the results of Borda Count, B777F was found to be one of the best freighter types for the sector. The B777F is a newer generation freighter compared to the other freighter types in the fleets of the companies operating in the sector, thus offering cost advantages to the companies. In this respect, although this is a new freighter that the Turkish air cargo industry has just met, it was found that its advantages are recognized by the companies in the sector. Experts stated that this freighter type is potential aircraft that can meet the needs and expectations of the Turkish air cargo sector. Another result indicates that the B747-400F, which is the only freighter type among the alternatives that can transport very large cargoes, especially in project-based transports, provides an important advantage in terms of loadability criterion by means of nose-loading. Finally, when the whole analysis is taken into consideration, it is seen that the decision makers will not have any problems with the alternatives that are in the last two places in their decision process. However, they should be careful in their evaluations of some alternatives in which the ranks are variable.

6. Conclusion

This study presents a proposed model to help air cargo carriers determine the best freighter type. Accordingly, the results of the study are reached in four steps. In the first step, the criteria for the research problem (as 8 quantitative and 4 qualitative) are determined and the criteria weights of these criteria are calculated by employing AHP, which provides an opportunity to weight the qualitative and quantitative criteria together. In the second step, the alternative freighter rankings are obtained for air cargo carriers based on their business models as air cargo carriers and capacity providers, and sector-wide by applying the TOPSIS and VIKOR methods. In the third step, the sensitivity analysis is performed to ensure the robustness and stability of the results. In the last step, the Borda Count method is used to consolidate and validate the results of the proposed model obtained from the second step.

As a result of the study, the cost of FTK, suitability for the existing fleet structure, and maintenance costs are the most important criteria. Among the alternative freighter types, the B777F, A330-200F, and B747-400F have emerged as the best alternatives for the Turkish air cargo industry. The most remarkable conclusion of the study is that the carriers and ACMI providers consider cost factors and efficiency as the main agenda items for the freighter type choice in the air cargo industry, where business is carried out with high costs. The managerial implications and limitations and suggestions for future studies are given under the following sub-sections.

6.1. Managerial Implications

Selection of the right freighter type among alternatives in line with demand amount and demand type is one of the strategic decisions of air cargo carriers which can provide a competitive advantage in the long-term for them (Kiracı & Akan, 2020). Accordingly, this study can be counted as a guide that will enable carriers and ACMI providers to make the best freighter selection among alternatives in the context of managerial implications.

The managerial implications of the current study can be summarized as follows: The relative importance of the criteria and the alternative rankings based on different business models as carriers and ACMI provider makes this study highly valuable in terms of executives involved in the decision-making process of freighter type selection. This study is expected to have key importance as a roadmap to be considered by companies in making decisions on allocating resources in line with their business model and strategies.

In addition, the COVID-19 pandemic crisis has shown that air cargo transportation is an indispensable and most important mode of transportation, especially in times of crisis. In this period, some amount of the demand for air cargo that increased sharply could not be met with the existing freighters in the fleets due to capacity constraints. In this direction, many airlines have preferred to increase their cargo capacities with "phreighters" by converting their passenger aircraft to cargo aircraft. In this context, it is expected that carriers and ACMI providers will tend to include freighters in their fleets, which will enable them to respond to sharp demands most effectively and efficiently, considering the criteria found important in this study in terms of being prepared for such large-scale crises.

6.2. Limitations and Suggestions for Future Studies

Airlines can take different perspectives from different departments in strategic decisions such as aircraft selection (Dožić et al., 2018). Air cargo carriers also follow a similar way in making this strategic decision for freighter selection. In this direction, different opinions of experts from different positions contributing freighter selection process were taken in this study. The study is limited to opinions of different positions and departments from academia and air cargo carriers operating in the Turkish air cargo sector. The application of the proposed model for air cargo industries of different countries is important in terms of the generalization of the results.

As a follow-up to this study which focuses on the choice of freighter type, it would be useful to carry out other studies that deal with the subject from different perspectives. In this study, the authors discussed the selection of freighter types based on the sector-wide and business models. In the future, case analysis studies may focus on a cargo company operating on certain lines by analyzing which freighter types are effective and efficient for the flight network of that company. Additionally, the study is limited to classical multi-criteria decision-making approaches. New methods are emerging in the scientific community as the MCDM area continues to grow. The proposed method can be expanded in future work to accommodate many fuzzy settings, including intuitionistic, fermatean, spherical, reluctant, etc. As an alternative to AHP, relatively newer weighting methods such as BWM and FUCOM can also be used in future studies. Last, future studies can be carried out as in-depth investigations, including perspectives from shippers and freight forwarders.

Declaration of competing interest

The authors declare that there is no conflict of interest relating to the publication of the paper.

Contributions of Authors to the Article

The contribution rate of each researcher is equal in the study.

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Appendix: Ranking Distribution of Alternatives Related to Sensitivity Analysis

Figure 4: Stability of Ranking of Sector-Wide Results in Different Sets for TOPSIS

Figure 5: Stability of Ranking of Sector-Wide Results in Different Sets for VIKOR

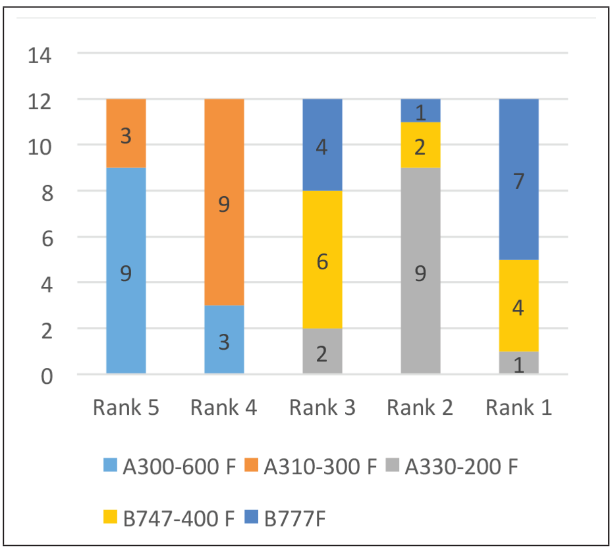


Figure 6: Stability of Ranking of Carrier-Based Results in Different Sets for TOPSIS

Figure 7: Stability of Ranking of Carrier-Based Results in Different Sets for VIKOR

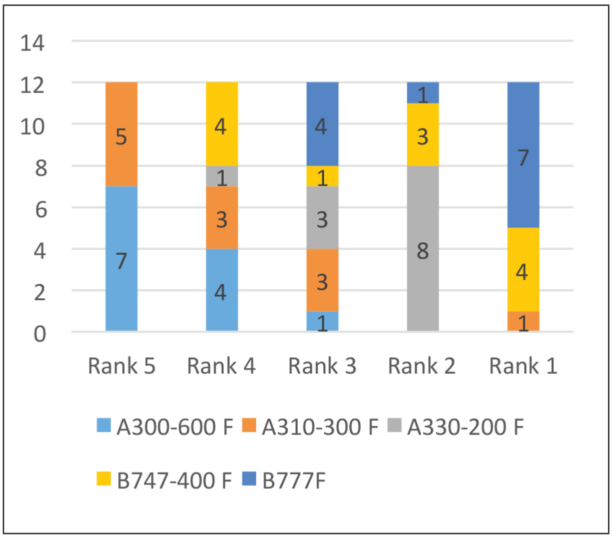


Figure 8: Stability of Ranking of ACMI Provider-Based Results in Different Sets for TOPSIS

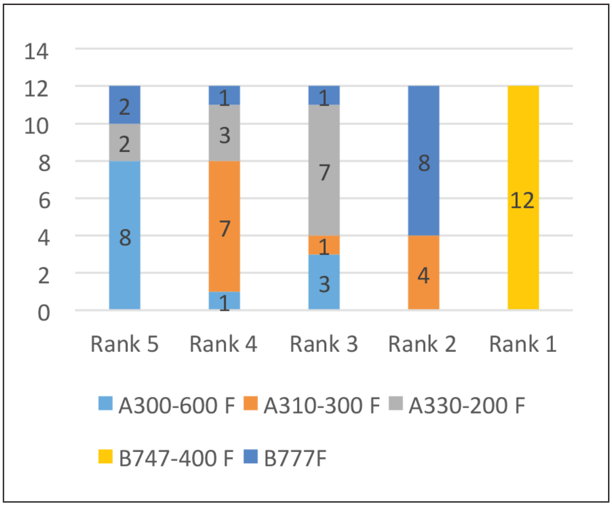
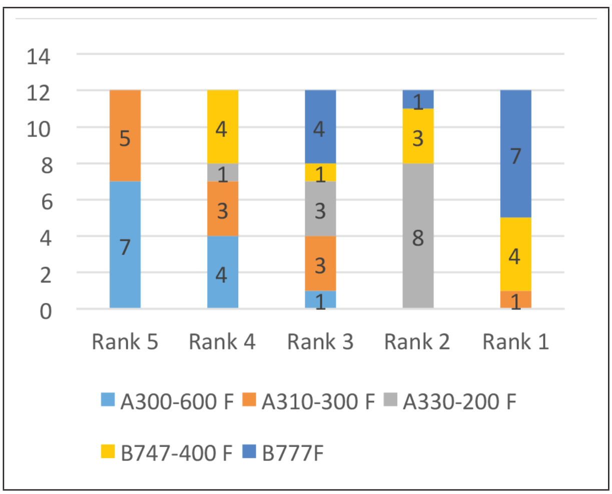


Figure 9: Stability of Ranking of ACMI Provider-Based Results in Different Sets for VIKOR



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