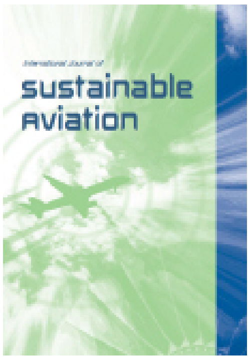


International Journal of Sustainable Aviation

ISSN online: 2050-0475 - ISSN print: 2050-0467
https://www.inderscience.com/ijsa

A fuzzy analytic hierarchy process-based framework for air cargo infrastructure location

Ravi Lakshmanan, Tarun Dhingra, T. Bangar Raju

DOI: 10.1504/IJSA.2024.10062038

Article History:

Received:	23 February 2023
Last revised:	04 July 2023
Accepted:	17 July 2023
Published online:	05 February 2024

A fuzzy analytic hierarchy process-based framework for air cargo infrastructure location

Ravi Lakshmanan

GMR Airports (Singapore) Pte. Ltd.,
135, Cecil Street, Philippines Airlines Building,
#14-01, 069536, Singapore
Email: raveelakshmanan@gmail.com

Tarun Dhingra

Strategic Management,
Jaipuria Institute of Management,
A-32A, Sector 62, Noida, Pin 201309, India
Email: tarun.dhingra@jaipuria.ac.in

T. Bangar Raju*

School of Business,
University of Petroleum and Energy Studies,
Kandoli, Dehradun, Pin 248007, India
Email: bangarraju@gmail.com
*Corresponding author

Abstract: Efficient air cargo infrastructure is crucial for the safe and effective transport of high-value goods, facilitating globalisation and trade. A strategic decision of air cargo infrastructure location can boost airport competitiveness and fit into a multi-modal logistics network. This study presents a decision framework consisting of four primary factors (master planning, environmental impact, techno-economic considerations, and operational aspects), and 30 subfactors. The application of fuzzy analytical hierarchy process (FAHP) helps prioritise these factors and subfactors. Stage 1 consists of finding probable locations followed by its full evaluation in stage 2. In stage 1, 'techno-economic factors', is the topmost priority followed by operational, master planning and environmental factors. In stage 2, the top five subfactors are: 1) compliance with all regulatory/statutory requirements; 2) cargo traffic increase; 3) financial assessment; 4) environmental regulations; 5) business model (airport ownership included) and funding. Practitioners can employ this methodology in a two-stage decision framework.

Keywords: air cargo infrastructure; location decision; MCDM; fuzzy analytical hierarchy process; FAHP; airport.

Reference to this paper should be made as follows: Lakshmanan, R., Dhingra, T. and Raju, T.B. (2024) 'A fuzzy analytic hierarchy process-based framework for air cargo infrastructure location', *Int. J. Sustainable Aviation*, Vol. 10, No. 1, pp.76–98.

Biographical notes: Ravi Lakshmanan holds a postgraduate degree in engineering and PhD in Management. He has been working with the airport industry for the past 32 years out of 46 years of professional experience. His area of interest and expertise includes airport planning, development, project management, operations and maintenance and bidding for airports through PPP model. He is a Visiting Faculty and Guest Lecturer at a few of India's best educational institutions and a member of the Academic Council of Universities.

Tarun Dhingra is a Management Faculty in the area of Strategic Management and General Management with a total experience of 24 years in research, teaching and industry. Currently, he is a Professor- Strategic Management and Dean-Academics, PAN Area Chair-GM and Strategy at Jaipuria Institute of Management, Noida. He has published 85+ papers and case studies in many reputed refereed academic journals (WoS, Scopus, ABDC list) of national and international repute and four books. Under his guidance, ten scholars have successfully completed their doctorate (PhD).

T. Bangar Raju is currently working as a Professor, Transportation Management at University of Petroleum and Energy Studies. He has more than two decades of Experience in industry and academia in the area of transportation management and international trade. He holds a Doctor of Philosophy and Doctor in Business Administration. He has published many papers in reputed journals and is reviewer in maritime, energy and aviation domains.

1 Introduction

In recent years, researchers have shown increased interest in air transport. The air cargo location is a significant area of interest in air transport management and vital link between air transport and cargo operations. Owing to the high value of air cargo (US$ 6 trillion worth of goods), as high as 1/3 of global trade value by all modes of transport (IATA, 2017) although, by volume, it is only 1% of global trade, and air cargo has been an object of research since the last decade.

Air cargo is rapidly becoming a key instrument for critical cargo infrastructure decisions at airports. Cargo traffic through an airport can play a central role in ensuring smooth movement of goods and provide an opportunity for airlines and airports to increase their capacity utilisation, economies of scale, and revenue with a marginal increase in cost. The cargo location decision is a crucial strategy for airports' top and bottom lines.

Over the past century, there has been a dramatic increase in research on air transport, air cargo, and passenger transport. The literature on airfreight is mostly on cargo operations and management, not on infrastructure development, which is an important area of study and needs researchers' attention. The existing body of research on air cargo suggests that the literature concentrates on multiple issues related to passenger transport.

It has been argued that cargo infrastructure at airports should be designed to meet various high-value goods, especially speedy processing, and safe handling, and that the facility should be designed to cater to different types of cargo for example, some may require temperature-controlled storage and transport. Cargo infrastructure consists primarily of a cargo terminal, several aircraft standing for parking freighter aircraft, and the city; the side requires truck bays and truck parking areas. In addition, office areas for freight forwarders, airlines, and regulatory authorities are considered a part of the cargo infrastructure.

Several studies have investigated many criteria to be considered while finalising a suitable location for any infrastructure. These include the cost-benefit of the project, long-term view, unconstrained development in line with air cargo traffic growth operational efficiency, asset utilisation, enabling phased development in line with traffic growth, operational expenditure, satisfied users and stakeholders, the extent of land required and adjacent facilities.

Thus, what is known about the multiple factors and sub-factors of air cargo location decisions is derived from a few primary sources in the last 10–15 years and needs updating. Thus far, there has been little agreement on what constitutes air cargo location decisions, multiple factors and sub-factors, their classification, and relative prioritisation. However, there have been no detailed investigations of this phenomenon. There is a notable paucity of empirical research on locating air cargo facilities at airports by identifying and prioritising factors and subfactors. Few studies have systematically investigated air cargo location decisions and multiple factors and sub-factors in parts, but a comprehensive empirical investigation is a call.

Most studies on air cargo location decisions have only focused on finding some factors and sub-factors but lack a comprehensive examination of identification and prioritisation. The central thesis is that air cargo location decision factors and sub-factors must be identified, categorised, and prioritised.

This study aims to create a framework for locating an air cargo facility at an airport by identifying and prioritising factors and sub-factors.

This study aims to:

1 Develop a framework for identifying and categorising the factors and subfactors of air cargo location decisions.

2 To prioritise these factors using a multi-criterion decision-making approach (MCDM) using the analytical hierarchy process and fuzzy logic (FAHP).

3 To contribute to the theoretical and practical implications of air cargo location factors.

This study aimed to address the following research questions:

Q1 What are the different factors and sub-factors affecting India's air cargo location decisions?

Q2 What is the classification of those factors?

Q3 What are the ranks and priorities of the factors for air cargo location decisions?

This empirical research was a literature review followed by initial exploratory interviews. These factors and sub-factors for air cargo infrastructure location were identified through extensive literature review and planning documents. Initial exploratory interviews were conducted with a mixed population of air cargo experts chosen from cargo operators, freight forwarders, airlines, and airport planners. Based on an extensive literature review and inputs from expert interviews, all the factors and sub-factors responsible for locating an air cargo terminal are listed. Because there are many factors/sub-factors to identify a suitable location for a cargo facility, this is a multi-criteria decision problem. The analytic hierarchy process (AHP) is a widely used multi-criteria decision-making (MCDM) method to measure and rank factors.

This study is the first to identify and prioritise the factors and sub-factors responsible for locating an air cargo infrastructure, and to the best of the researcher's knowledge, there is no study on it as of a date; thus, it fills the gap. The absence of a similar study using MCDM using fuzzy AHP for ranking factors/sub-factors adds to this study's novelty.

The following Section 2 describes previous literature as a research paper or article on air cargo infrastructure and the current planning documents. Section 3 describes the methodology adopted through Fuzzy AHP and the selection of a particular FAHP method. Section 4 presents the results and discussion analysis of the FAHP. Finally, Section 5 presents the conclusions and implications of the study.

2 Literature review

Air cargo is an essential catalyst towards economic development (Kasarda and Green, 2005), and various factors contribute to this. The authors have also brought forward some constraints affecting the same. The impact of air cargo logistics and airport services for an effective supply chain has been discussed in Yuan et al. (2010). Empirical study (Chang and Chang, 2009) brings forth a strong bidirectional relationship between economic growth and air cargo expansion. Air cargo is a significant factor driving the economic growth of the country and region. Relocation and location factors' significance have been deliberated regarding the Polish aviation industry (Capik and Dej, 2018). The prominence of relocation in geography and their impacts on location economy and its consequences is analysed. Multi-agent models were also used in Joubert (2018) to understand the impact of the relocation of a container terminal on various stakeholders. The growth of tourism due to airport relocation has also been envisaged (Ergas and Felsenstein, 2012). Wasesa et al. (2015) describes air cargo centre relocation framework and the conceptual model of the air cargo terminal relocation planning process, which identifies the interdependencies and the contingencies among different aspects of the relocation components. Rodbundith et al. (2019) present air cargo terminal classification of airports in Thailand in his PhD research. Inland inter-modal terminal location criteria for Croatia has been evaluated by Roso et al. (2015). Brătucu et al. (2017) analysed the impact on the regional economic development if a cargo terminal is constructed at this airport. Angelopoulos et al. (2013) in the Master' thesis, identifies factors for relocation of freight operators from major airport to smaller airport as airport's infrastructure, location, quality of services provided, number of passenger flights, tariff weather conditions, the cargo traffic demand, and connectivity with road and rail networks. Ulutaş et al. (2020) dealt with the location selection for the logistics centre using fuzzy methods. This paper identifies the best location of logistics centres based on a varying number of criteria. This study considers 11 criteria and quantitative factors for 12 locations identified and opinions from 8 experts to select the best one. Stević et al. (2015) studied the selection of logistics centre with 3 group criteria and six criteria with a numerical and linguistic variable using AHP for three alternative sites.

Żak and Węgliński (2014) studied ranking of 10 alternative sites for locating the logistic centre in Poland using nine criteria with qualitative and quantitative measures using elimination and choice expressing reality (ELECTRE III/IV) method. By reviewing models, classification, solution methods, and implementations (Farahani et al., 2010) addressed hub position problems. Hubs are facilities that serve as a point of aggregation, connection, and switching for flows between specified sources and destinations. The hub position problem is a newer variation of the traditional facility location problem.

A conceptual framework for selecting the location of the distribution centre in logistics operations is described in Van Thai and Grewal (2005). This framework is based on the geographical area, identification of alternate sites for airports and seaports to be used for inbound and outbound cargo flows, and specific site selection among the identified alternate sites. Owen and Daskin (1998) describe why facility location decisions are a critical element in strategic planning for a wide range of private and public firms and the ramifications of sitting facilities. Klose and Drexl (2005) describes the facility location models for distribution storage. Farahani et al. (2010) reviews recent efforts and development in multi-criteria location problems in three categories: bi-objective, multi-objective and multi-attribute problems and their solution methods. In addition, it provides an overview of various criteria used. This paper also describes location objectives in general. Portugal et al. (2011) proposes a method for identifying and ranking areas that are candidates for truck cargo terminal construction, based on the AHP. This method takes into account position variables, considering accessibility, as expressed by graph theory indicators. The finding is that the terminal's location on the city's outskirts allows for the movement of only smaller trucks into the city by transferring goods from large trucks parked at these terminals so that the movement of large trucks in the city is avoided.

Warehouse problems arising due to airport relocation, the relocation decisions, cost, and benefits analysis from various options available are analysed in Wan et al. (1998). A recent study using the AHP model of the MCDM approach has been deployed to evaluate the air cargo growth (Larrodé et al., 2018). Dožić (2019) reviewed the research papers that used MCDM methodology in the aviation industry, published between 2000 and 2018, totalling 166 papers out of which 40 papers were of airports. Out of these 40 papers, only two papers were cargo related.

Tanriverdi et al. (2022) identifies 18 criteria based on five airport specific aspects viz. location, physical features, performance, costs, and reputation to establish the priority that would be considered by the air carriers in selecting airports for cargo operations. Out of these, the study finds that location and costs are the foremost aspects for the air carriers and the most crucial factors are airport charges and handling charges. Within the air transport literature, publications on airfreight are somewhat limited, and the traditional literature has been concentrated around passenger transport (Merkert et al., 2017). Literature on airfreight is mostly on cargo operations & management but not on infrastructure development.

However, the most popular documents used by airport professionals are Airport Development Reference Manual (ADRM) (IATA, 2019) and Airport Planning Manual (APM) (ICAO, 1987).

ADRM covers the planning parameters and guidelines for all the facilities and infrastructures of an airport, including cargo facilities. Specific design guidelines are also specified in the ADRM. At the same time, APM by ICAO provides planning guidelines for all airport infrastructures, including cargo. APM is in three parts, and these describe master planning, land use and environmental control aspects, and guidelines for consultant/construction services. The Government of India's working group report (Group, 2012) highlighted areas for improvement in the air cargo industry, including operations and infrastructure requirements. The working group was established to suggest policy proposals to address essential issues in India's long-term outlook and future growth potential. The report was based on discussions with all stakeholders in the air cargo industry.

Maynard et al. (2015) of Transportation Research Board under Airport Cooperation Research Program was also referred to in this study.

2.1 Identification of factors affecting the location of a cargo terminal

Based on the literature review mentioned above, including the planning documents practiced by airport professionals, this study identified four factors in level 1 and 30 subfactors in level 2. The factors in Level 1 are techno-economic feasibility (C1), master planning (C2), environmental (C3), and operational factors (C4). Table 1 shows the list of 30 important sub-factors in Level 2, along with the literature. This is briefly explained as follows.

2.1.1 Techno-economic feasibility (C1)

For any project proposal, it is essential to examine whether the project is technically feasible and simultaneously examine the project's financial viability. For the cargo infrastructure considered as a project, the sub-factors identified to examine techno-economic feasibility are as follows:

- technical assessment (geographic location, land requirement, and availability, infra requirement)
- cargo traffic growth
- tax incentives/concessions
- business model (airport ownership includes) and funding
- consultations with stakeholders
- financial assessment (capital expenditure, operating expenditure, and revenue)
- land use and access requirements
- socio economic impact.

2.1.2 Master planning factors (C2)

Master planning is an important planning document for airports that identifies the ideal locations of various facilities. This document shows the location of all facilities and the feasibility of phased expansion to cater to the traffic demand forecast. One of the critical infrastructure/facilities from the business perspective of an airport is the cargo infrastructure.

For cargo infrastructure, the sub-factors identified to examine master planning are as follows:

- airport characteristics (primary purpose, annual ATM, number of runways, and airfield infrastructure)

- air cargo volume forecasts for phased development
- expansion flexibility
- compliance with all regulatory/statutory compliances
- various types of cargo handling requirement
- aligns with the master plan of the airport
- environmental factors (C3).

Infrastructure development will have an impact on the environment. Thus, it is essential to identify these impacts and evaluate whether they can be mitigated. Furthermore, the cost of such a mitigation must be included in the project cost. In Brownfield airport development, these impacts are assessed as increased activities add to the existing impact.

2.1.3 Environmental factors (C2)

The sub-factors identified to examine environmental factors are as follows:

- air pollution
- noise pollution
- water quality issues
- the area is within environmentally sensitive zones
- energy conservation measures feasibility
- compliance with environmental regulations
- intermodal transportation.

2.1.4 Operational factors (C4)

Operational factors (C4) are another vital factor to consider in cargo infrastructure projects. Operational factors contribute to the financial viability of a project's capital costs and the facility's operations. For example, restricted operational hours at the airport constrain operation when required by airlines, thereby affecting the throughput. This affects the revenue generated during the operations. Another example is the requirement for skilled human resources for operation and maintenance at a remote airport, which may increase capital costs by adding redundancies and may impact operational costs.

The sub-factors identified to examine the operational factors are as follows:

- unrestricted operational hours
- skilled human resources for ops and maintenance
- minimum transit time for belly cargo
- operational cost and replacement CAPEX
- aircraft refuelling facility

- shared infrastructure for multiple operators
- proximity to passenger terminal apron.

In summary, from the literature review, it can be seen that the published papers on this subject are for specific applications, and the factors considered for the location of warehouses are based on available data and information. To the best of our knowledge, no study has comprehensively identified all the factors and provided a framework with a ranking for the selection of a suitable location for cargo infrastructure. This study aims to fill this gap by enabling airport planners to locate cargo infrastructure. Tanrıverdi et al. (2022) identifies the factors/subfactors affecting airport selection from the perspectives of air cargo carriers. Whereas this study identifies the factors and subfactors for the selection of most appropriate location of air cargo infrastructure at airports among multiple airports/locations.

Table 1 List of factors for identifying a suitable location for cargo infrastructure

Criterion		*Document/literature reference*
C1 – Techno-economic factors		
S1	Technical assessment (geographic location, land requirement, and availability, infra requirement)	International Air Transport Association (2004), ICAO (1987), Maynard et al. (2015), Report (2012)
S2	Cargo traffic growth	International Air Transport Association (2004), ICAO (1987), Chang and Chang (2009)
S3	Tax incentives/concessions	Portugal et al. (2011)
S4	Business model (airport ownership includes) and funding	International Air Transport Association (2004), Maynard et al. (2015), ICAO (1987)
S5	Consultations with stakeholders	International Air Transport Association (2004)
S6	Financial assessment (Capex, Operating expenditure and revenue)	Portugal et al. (2011)
S7	Land use and access requirements	ICAO (1987)
S8	Socio economic Impact	Portugal et al. (2011), Sellner and Nagl (2010)
C2 – Master planning		
S9	Airport characteristics (primary purpose, annual ATM, number of runways, airfield infra)	Maynard et al. (2015)
S10	Community characteristics (population, industries)	Maynard et al. (2015), Ergas and Felsenstein (2012)
S11	Air cargo volume forecasts for phased development	ICAO (1987)
S12	Expansion flexibility	ICAO (1987)
S13	Compliance to all regulatory/statutory compliances	ICAO (1987)

Table 1 List of factors for identifying a suitable location for cargo infrastructure (continued)

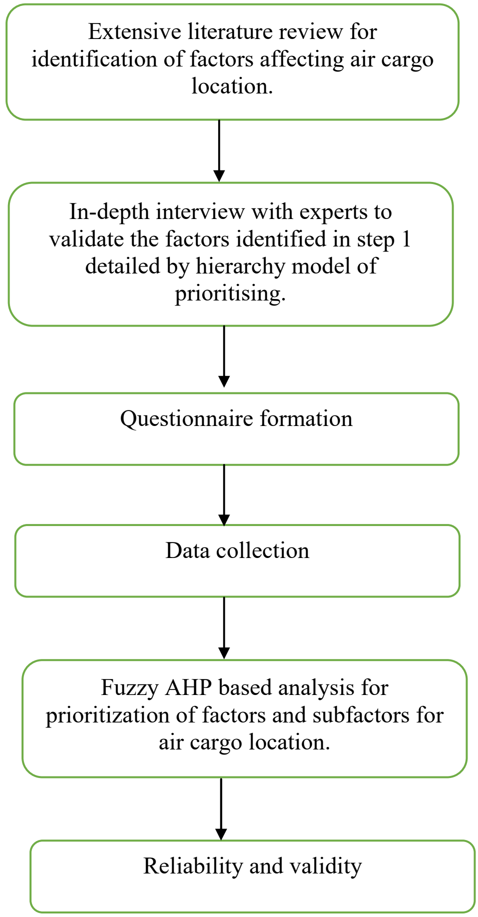
	Criterion	*Document/literature reference*
C2 – Master planning		
S14	Various types of cargo handling requirement	Report (2012), International Air Transport Association (2004)
S15	Aligns with the master plan of the airport	International Air Transport Association (2004)
C3 – Environmental factors		
S16	Air pollution	ICAO (1987), Wolfe et al. (2014)
S17	Noise pollution	ICAO (1987), Wolfe et al. (2014), Thanos et al. (2011)
S18	Water quality issues	ICAO (1987), Carvalho et al. (2013)
S19	Area is within environmentally sensitive zones	Maynard et al. (2015), Boca Santa et al. (2020)
S20	Energy conservation measures feasibility	ICAO (1987), Budd et al. (2015)
S21	Compliance with environmental regulations	ICAO (1987), Boca Santa et al. (2020)
S22	Intermodal transportation	Maynard et al. (2015), Heinitz et al. (2013)
C4 – Operational factors		
S23	Unrestricted operational hours	International Air Transport Association (2004), Report (2012), Portugal et al. (2011)
S24	Distance from other airport or cargo catchment area	Maynard et al. (2015), Wasesa et al. (2015)
S25	Skilled human resources for ops and maintenance	Report (2012)
S26	Minimum transit time for belly cargo	Maynard et al. (2015), Portugal et al. (2011)
S27	Operational cost and replacement CAPEX	Maynard et al. (2015), Portugal et al. (2011)
S28	Aircraft refueling facility	Maynard et al. (2015)
S29	Shared Infrastructure for multiple operators	International Air Transport Association (2004), ICAO (1987), Wasesa et al. (2015)
S30	Proximity to passenger terminal apron	ICAO (1987), Portugal et al. (2011)

3 Research methodology

A detailed description of the research methodology used in this study is shown in Figure 1.

The AHP has been widely used in multicriteria decision-making. The multi-criteria decision problem is broken down into its parts, of which every possible attribute is arranged into multiple hierarchical levels. Then, a pairwise comparison was made within the same level by experts based on their experience and knowledge of the subject.

Figure 1 Research process (see online version for colours)



In the original AHP method by Saaty, human judgments in the pairwise comparison are represented as crisp values; for example, 0 for equal importance and 9 for absolute importance of one over the other.

There are many uncertainties in the model of human preferences, and sharp values cannot be assigned to various judgments. The fuzzy set theory allows decision-makers to incorporate immeasurable, unobtained, and incomplete information and unknown facts into the decision model. The extension of the AHP model is fuzzy AHP (FAHP), where fuzzy values represent human judgments. Fuzzy logic is a development tool in artificial intelligence (AI). Human cognition is emulated using fuzzy logic, whereby it seizes possible intermediary digital values. There are some benefits within the imprecise, uncertain, and vague contexts of the MCDM methods and AHP. Combining AHP with fuzzy methods could be an option to overcome the limitations of the AHP method. The evaluation of preferences within appropriate intervals can be performed using a fuzzy AHP process. The fuzzy judgment matrix is derived from these interval results, based on the classical AHP, where rigid value judgement is performed (Afolayan et al., 2020).

FAHP has been applied in broad areas of interest to prioritise or rank various alternatives while analysing business decisions. Biswas et al. (2018) used this method to select the best apparel items for a new garment factory. Khorramrouz et al. (2019) analysed the failure investigation of knowledge-based business plans. Soberi and Ahmad (2016) describe setup time is one of the most expensive costs faced by manufacturing firms and organisations, including optimising setup processes and analysed the setup-time reduction problem. Saad et al. (2016) developed a fuzzy AHP MCDM model for the procurement process to measure the procurement process in the automotive industry. Heinitz et al. (2013) for the risk assessment to General assembly of the satellite. Rahman and Ahsan (2019) analysed the supplier selection and evaluation for ready made garment sector of Bangladesh. Stoltmann et al. (2016) created a multi-criteria investment decision support model for the power industry.

In failure mode and effects analysis (FMEA), three risk factors – severity (S), occurrence (O), and detectability (D) – were evaluated, and a risk priority number (RPN) was obtained by multiplying these factors. Khorramrouz et al. (2019) experts to use linguistic variables for determining S, O, and D for FMEA by applying fuzzy ‘technique for order preference by similarity to ideal solution’ (TOPSIS) integrated with fuzzy analytical hierarchy process (FAHP). A hypothetical case study demonstrated the applicability of the model in FMEA in a fuzzy environment.

Dožić et al. (2018) proposed a fuzzy analytic hierarchy process (FAHP)-based approach to choose aircraft type(s) that best meet the market conditions and airlines’ requirements for known route networks and known forecasted air travel demand by route. Concerning for the different criteria that involve quantitative and qualitative aspects.

Aggregation of individual decisions, rather than deliberation into a consensus, produces better decisions than those of either group deliberation or individual expert judgment based on the following principle (Solomon, 2006):

- The experts, whether they know each other or not, will not know the opinions of others.
- The experts are sufficiently different for the knowledge and perspectives.
- The aggregation process treats each person’s decision similarly, i.e., there are no ‘experts’ or ‘authorities’ whose votes are weighted more heavily than others are.

When averaging the opinions of a large group of diverse, independent, decentralised people, the errors, if any, each of them makes in coming up with an answer, will cancel each other out. Therefore, aggregation without deliberation preserves the information.

3.2 Data collection

This study identified four criteria/factors and 30 subfactors based on documents and literature on cargo infrastructure development. The number of sub-factors under each factor and, thus, in each comparison matrix, is within the limit mentioned in Saaty and Ozdemir (2003).

A matrix for seeking experts’ opinions was prepared for comparison between factors and a comparison between the sub-factors of each factor individually.

Thirty experts were identified, and they included all stakeholders of cargo management, that is, planners, cargo operators, freight forwarders, consultants, and airlines. The experts were contacted via e-mail, forwarded the matrix to them, and guided them in filling up the matrix. There are no clear guidelines for the number of experts to be included in AHP. However, a large sample size is not mandatory to have a large sample (Cheng and Lin, 2002). In this study, 25 of the 30 experts responded that the matrix had been completed. In this study, 25 of the 30 experts responded that the matrix had been completed. The average experience of the 25 experts was 23 years.

The expert provides his opinion/judgement in the comparison matrix in five excel sheets, namely one for factor and four for sub-factors.

The linguistic variables of the experts' judgement were converted to fuzzy triangular numbers. Table 2 presents the linguistic variables and their corresponding triangular fuzzy numbers (TFN). TFN is mostly used for fuzzy numbers.

Table 2 Linguistic variables and their corresponding TFN

Linguistic variables for the importance	*Triangular fuzzy scale*	*Triangular fuzzy reciprocal scale*
Equal	1, 1, 1	1, 1,1
Moderate	1, 3/2, 2	1/2, 2/3, 1
Strong	3/2, 2, 5/2	2/5,1 /2, 2/3
Very strong	2, 5/2, 3	1/3, 2/5, 1/2
Absolute	5/2, 3, 7/2	2/7, 1/3, 2/5

Methodology to derive the weights of factors and sub-factors from experts' judgments is based on Liu et al. (2020). Consistency check was carried out. After calculating the weights of factors and all sub-factors individually, the global weights of the sub-factors are calculated by multiplying the sub-factor weight by the respective weight of the factor and then ranked.

4 Results and discussion

4.1 Crisp values of factors and their ranking

The aggregated and synthesised values of the experts' opinions on the factors in level 1 are shown in Table 3.

Table 3 Aggregated and synthesised values of the experts' opinion on factors

	C1			*C2*			*C3*			*C4*		
C1	1	1	1	1.202	1.461	1.745	1.109	1.35	1.598	0.893	1.061	1.235
C2	0.577	0.690	0.8	1	1	1	0.885	1.066	1.290	0.724	0.846	1.009
C3	0.625	0.740	0.9	0.77	0.937	1.129	1	1	1	0.723	0.865	1.050
C4	0.809	0.942	1.1	0.990	1.180	1.380	0.952	1.155	1.382	1	1	1

Table 3 Aggregated and synthesised values of the experts' opinion on factors (continued)

Factors	*l*	*m*	*u*
C1	1.045	1.202	1.362
C2	0.780	0.888	1.020
C3	0.769	0.880	1.016
C4	0.934	1.064	1.209
Total	3.529	4.036	4.608
Inverse value	0.283	0.247	0.217
Increasing order	0.217	0.247	0.283

The crisp values of the weightage of the factors were derived based on the methodology described above. The results are presented in Table 4.

Table 4 Crisp values of weightage of factors and the ranking of factors in level 1

Factors		*Fuzzy weights*			*Average*	*Normalised crisp values*	*Rank*
C1	Techno economic feasibility (TEF)	0.227	0.298	0.386	0.304	0.297	1
C2	Master planning factors (MPF)	0.169	0.220	0.289	0.226	0.221	3
C3	Environmental factors (EF)	0.167	0.218	0.288	0.224	0.219	4
C4	Operational factors (OF)	0.203	0.264	0.343	0.270	0.263	2

TEF has the highest priority over other factors in stage 1 of the evaluation of many alternative locations initially identified. To evaluate the TEF for the multiple locations identified, the subfactors of TEF were evaluated according to the ranking of these subfactors (TEF1 to TEF8). The crisp values of subfactors TEF1 to TEF 8 are shown in Table 5, which shows that cargo traffic growth has the highest priority, followed by financial assessment, the proposed business model, technical assessment, and others.

4.2 *Crisp values of the sub-factors in level 2*

Table 5 shows the crisp values of the weightage of the sub-factors and their ranking under each factor individually.

Table 5 Crisp values of the weightage of sub-factors at level 2 and their ranking

TEF1	Technical assessment (geographic location, land requirement and availability, infra requirement)	0.121	4
TEF2	Cargo traffic growth	0.157	1
TEF3	Tax incentives/concessions	0.119	5
TEF4	Business model (airport ownership includes) and funding	0.139	3
TEF5	Consultations with stakeholders	0.117	6
TEF6	Financial assessment (capex, operational expenditure, and revenue)	0.155	2
TEF7	Land use and access requirements	0.101	7
TEF8	Socio economic impact	0.090	8

Table 5 Crisp values of the weightage of sub-factors at level 2 and their ranking (continued)

MPF1	Airport characteristics (primary purpose, annual ATM, number of runways, airfield infra)	0.115	6
MPF2	Community characteristics (population, industries)	0.088	7
MPF3	Air cargo volume forecasts for phased development	0.151	2
MPF4	Expansion flexibility	0.150	3
MPF5	Compliance to all regulatory/statutory compliances	0.214	1
MPF6	Various types of cargo handling requirement	0.138	5
MPF7	Aligns with the master plan of the airport	0.143	4
EF1	Air pollution	0.136	3
EF2	Noise pollution	0.110	7
EF3	Water quality issues	0.129	4
EF4	Area is within environmentally sensitive zones	0.180	2
EF5	Energy conservation measures feasibility	0.114	6
EF6	Compliance to environmental regulations	0.206	1
EF7	Intermodal transportation	0.125	5
OF1	Unrestricted operational hours	0.115	5
OF2	Distance from other airport or cargo catchment area	0.109	7
OF3	Skilled manpower for ops and maintenance	0.149	2
OF4	Minimum Transit time for belly cargo	0.140	3
OF5	Operational cost and replacement capex	0.153	1
OF6	Aircraft refuelling facility	0.117	4
OF7	Shared Infrastructure for multiple operators	0.103	8
OF8	Proximity to passenger terminal apron	0.113	6

4.2.1 Stage 1: evaluation

Assuming that the best location for the same air cargo catchment area must be chosen from among four alternate sites at two different airports. TEF evaluation will begin with rank 1 subfactor, cargo traffic growth, and in this example, we've made the assumption that this parameter is significantly lower in location D than other locations and is therefore excluded from further consideration. For the remaining three locations, the evaluation continued for other subfactors from ranks 2 to 8. Table 6 displays the evaluation matrix for stage 1, along with a brief analysis of the parameters for the next remaining three locations. The subfactors ranked 6, 7, and 8 were taken into consideration and did not have a go/no-go status. Additionally, marginal variances are not considered when making a decision at this stage of evaluation; the only significant differences are.

Table 6 Evaluation matrix for stage 1 (see online version for colours)

Subfactors and their ranking		*Location A*	*Location B*	*Location C*	*Location D*
TEF1	Technical assessment (geographic location, land requirement and availability, infra requirement) Rank 4	Fulfils	Land available is insufficient as it interferes with existing facilities	Land available is insufficient but can be acquired	
TEF2	Cargo traffic growth Rank 1	Same for A and B		More than A and B	
TEF3	Tax incentives/concessions Rank 5	No	No	Yes	
TEF4	Business model (airport ownership includes) and funding Rank 3	Assumed as same assumptions for locations A, B and C			
TEF5	Consultations with stakeholders Rank 6	Done	Done	Done	
TEF6	Financial assessment (capex, operational expenditure, and revenue) Rank 2	Less than location B and C			
TEF7	Land use and access requirements Rank 7		Same for all		
TEF8	Socio economic impact Rank 8		Same for all		

Note: Location deleted for stage 2 evaluation.

4.2.2 *Stage 2: evaluation of locations A, B and C*

The three remaining sites will be analysed in depth using the global ranking of all the subfactors combined rather than the ranking among the factors in level 1.

To view the ranking of the subfactors at level 2 combined with all subfactors, that is, all the 30 subfactors together, the global weightage is calculated by multiplying the respective factor (level1) weight and its sub-factor (level 2) weights. For example, to calculate the global weights of TEF1 to TEF8, the weight of TEF (Table 5) is multiplied by the weight of TEF1 to TEF8 in Table 7. In this case, global weight of TEF 2 is 0.2965 X 0.157 = 0.0465. Similarly, the global weights of all the subfactors are calculated and tabulated in Table 7, along with the local ranking. Based on the global weightage, the global ranking is obtained, as shown in Table 7.

All three shortlisted locations, A, B, and C will be thoroughly assessed using the global ranking of the subfactors in Table 7.

Table 7 Summary of local ranking and global ranking

Factors at level 1 and their weightage		*Sub factors at level 2*	*Local weights*	*Local ranking*	*Global weights*	*Global ranking*
Techno-economic feasibility (TEF) 0.2965	TEF1	Technical assessment (geographic location, land requirement and availability, infra requirement)	0.121	4	0.036	10
	TEF2	Cargo traffic growth	0.157	1	0.0465	2
	TEF3	Tax incentives/concessions	0.119	5	0.035	11
	TEF4	Business model (airport ownership includes) and funding	0.139	3	0.041	5
	TEF5	Consultations with stakeholders	0.117	6	0.035	12
	TEF6	Financial assessment (capex, operational expenditure, and revenue)	0.155	2	0.0459	3
	TEF7	Land use and access requirements	0.101	7	0.030	19
	TEF8	Socio economic impact	0.090	8	0.027	26
Master planning factors (MPF) 0.2208	MPF1	Airport characteristics (primary purpose, annual ATM, number of runways, airfield infra)	0.115	6	0.025	27
	MPF2	Community characteristics (population, industries)	0.088	7	0.019	30
	MPF3	Air cargo volume forecasts for phased development	0.151	2	0.033	13
	MPF4	Expansion flexibility	0.150	3	0.033	14
	MPF5	Compliance to all regulatory/statutory compliances	0.214	1	0.047	1
	MPF6	Various types of cargo handling requirement	0.138	5	0.030	17
	MPF7	Aligns with the master plan of the airport	0.143	4	0.032	15
Environmental factors (EF) 0.2101	EF1	Air pollution	0.136	3	0.030	20
	EF2	Noise pollution	0.110	7	0.024	29
	EF3	Water quality issues	0.129	4	0.028	23
	EF4	Area is within environmentally sensitive zones	0.180	2	0.039	7
	EF5	Energy conservation measures feasibility	0.114	6	0.025	28
	EF6	Compliance to environmental regulations	0.206	1	0.045	4
	EF7	Intermodal transportation	0.125	5	0.027	24

Table 7 Summary of local ranking and global ranking (continued)

Factors at level 1 and their weightage		*Sub factors at level 2*	*Local weights*	*Local ranking*	*Global weights*	*Global ranking*
Operational factors (OF) 0.2634	OF1	Unrestricted operational hours	0.115	5	0.030	18
	OF2	Distance from other airport or cargo catchment area	0.109	7	0.029	22
	OF3	Skilled manpower for ops and maintenance	0.149	2	0.039	8
	OF4	Minimum transit time for belly cargo	0.140	3	0.037	9
	OF5	Operational cost and replacement capex	0.153	1	0.040	6
	OF6	Aircraft refuelling facility	0.117	4	0.030	16
	OF7	Shared infrastructure for multiple operators	0.103	8	0.027	25
	OF8	Proximity to passenger terminal apron	0.113	6	0.029	21

Number 1 priority under global ranking is compliance to all regulatory /statutory compliances. If all the three locations under consideration are compliant, they will be ranked same at this stage. If any location does not confirm with all regulatory/statutory compliance, there are two possibilities to deal with it.

1 non-compliant location is eliminated from the consideration if such compliance is a major one which cannot be made compliant

2 taken to the next step for evaluation if it can be made compliant with estimated cost for making it compliant.

Even if just one site is being taken into consideration, it must still be reviewed to ensure compliance with this subfactor. The estimated traffic growth is given priority number two. All three locations can be considered to have the same rating if there are no appreciable differences between them, and the following assessment can then be made. Number 3 priority is financial assessment, in terms of capital expenditure, operational expenditure, and revenue. This assessment is to be conducted on a long-term basis.

The inputs to the financial assessment, priority 3, are as follows: -

- Business strategy was ranked 5. One choice is for the airport operator to decide only to build the structure with all utilities included and lease it to a cargo operator who provides all the systems and equipment required to run the facility. Another choice is for the airport operator to build all the facilities and necessary infrastructure and run the facility by themselves. The third option would be to build all the facilities and engage an cargo operator to run the facility. Capex, operational expenses, and revenue vary among the three alternatives mentioned. Such a study will assist in determining the most appropriate business strategy for airport operators.

- Operational cost and replacement capex ranked 6, coupled with skilled manpower availability ranked 8. This also depends on the business model adopted.
- Compliance to environmental regulation, ranked 4, and if the location is within the environmentally sensitive zone, ranked 7, might have cost implications depending on the location.
- Technical assessment was ranked 10, including land availability and cost, if required to acquire or make it available. Infrastructure required to determine the capex, in turn, the operational expenditure. The cost of construction for two or more possible locations may vary depending on the soil conditions, ground profile, and access requirements for cargo inflow and outflow, and the cost of bulk utilities also contributes to the capex.
- Tax incentives/concessions, rank 11 if different between two or more locations will affect financials.
- Cargo volume at various years, ranked 13, will have an impact on the assessment of infrastructure required at different phases of development as the infrastructure will be developed in phases in tandem with traffic growth, thus incurring capex at the right time, optimising operational expenditure and funding.
- Assessment of flexibility to expand seamlessly, ranked 14, with minimum relocation of existing infrastructure, thus avoiding capital, operational impact, and revenue loss. Applicable when comparing two or more locations.
- To the extent possible, the location should match the existing master plan of the airport, ranked 15, in order not to hinder operations during cargo infrastructure development, avoiding relocation of the existing infrastructure, etc.
- The minimum time for belly cargo, ranked as 9, is a preferred parameter if the dominant cargo throughput is through passenger aircraft. Consultation with stakeholders, ranked 12, with the infrastructure planned to ensure there were no difficulties during operations by taking their suggestions into the development. This may not have any impact on the ranking of the locations but must be considered while assessing the location.

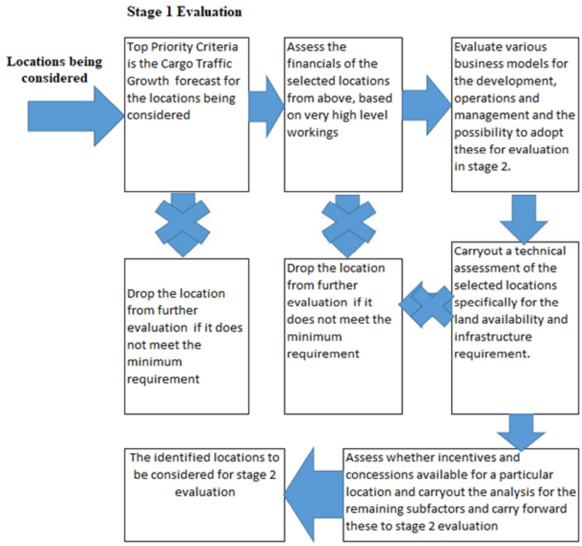
From the above, it can be seen that once the possible alternative locations are evaluated for subfactors, that is, conformance to compliances and cargo traffic growth, the locations that pass these evaluations will be taken up for subfactor ranked 3, that is, financial assessment, which requires inputs from other subfactors until subfactor ranked 15. The evaluation of additional subfactors from priorities 16 to 30 is necessary, but they have no bearing on the chosen location.

Based on the above, among the several locations identified in stage 1, the optimal location earns the highest rating in the financial assessment (priority 3 of the subfactor).

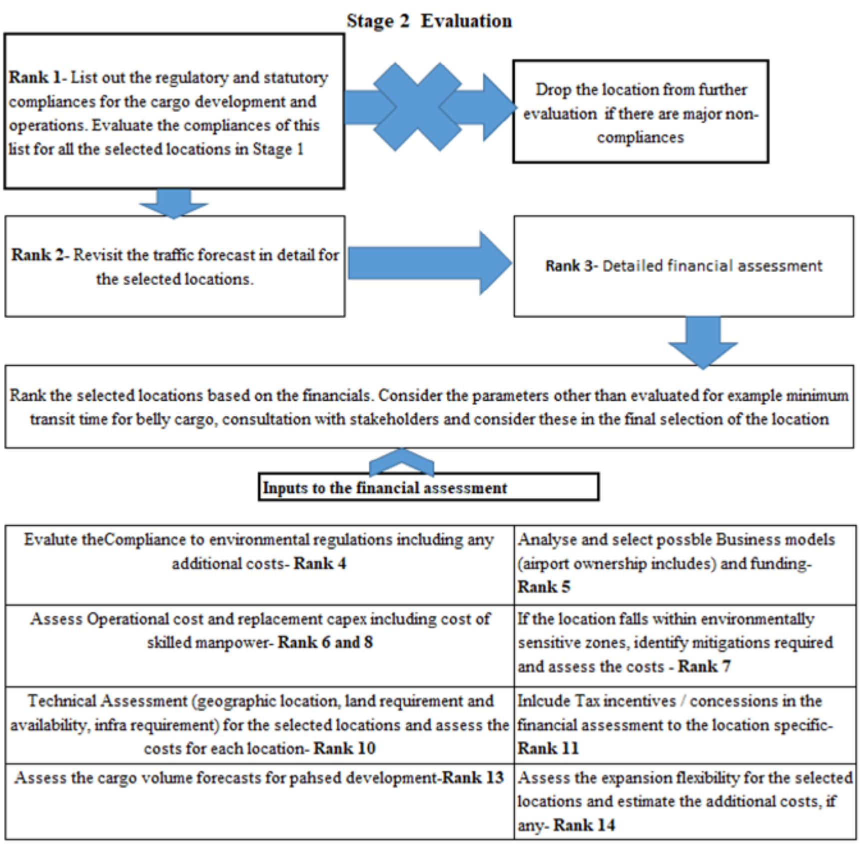
Sensitivity analysis was carried out by varying the weight of the number one ranked factor TEF from its assessed weighting of 0.296. Weightage from 0.1 to 0.9 was assigned for TEF and corresponding weightage for the other factors was calculated.

The two-level stage approach is depicted in Figure 2(a) and Figure 2(b).

Figure 2 (a) Stage 1: evaluation (b) Stage 2: evaluation (see online version for colours)



(a)



(b)

5 Conclusions

Global supply chains have had a significant impact because of the COVID-19 pandemic, and the air cargo business has been under pressure for the past few years. Ground infrastructure at airports is vital and plays an important role in both the development of a country's economy and the creation of job opportunities. It has been found that airports' air cargo businesses are more resilient than other businesses. One of the main considerations is to create a competitive infrastructure that can handle varying freight volumes based on the present and future demand. However, this requires strategic decisions that consider several aspects. The first step in establishing a business is selecting a location for the facility; this choice requires careful consideration of a wide range of intricate aspects and proactive planning. The purpose of this study was to conduct an in-depth analysis of a variety of elements, including technical and economic considerations, as well as environmental and operational concerns. Before this study and analysis, it was difficult to identify how to prioritise the many different criteria and subfactors that need to be considered when choosing the location of the cargo facility. The Fuzzy AHP methodology reveals that consideration of techno-economic factors should be given priority in stage 1 and compliance with all regulatory/statutory requirements in stage 2 of selecting the suitable location. These findings improve understanding of and allow the planners to prioritise the elements and subfactors that go into making a decision on the location of a cargo facility, taking into account the many different options that are available. Identifying the components and subfactors, as well as receiving feedback from various stakeholders in order to prioritise them based on a fuzzy approach are two of the most important strengths of this study. During the process of generating a full project report and feasibility assessment, this research might be helpful in offering planners' criteria to follow when analysing the cargo facility location.

6 Limitations and future scope of the study

The study's conclusions, which include those related to techno-economic factors, master planning, environmental factors, and operational factors, are specific to India. Because the study is focused on India, its findings cannot be generalised to other countries. The study could be replicated in other nations with possibly different constraints regarding Techno-Economic factors, Master planning, Environmental factors, and Operational factors. Future research may broaden the study's scope and methodology. Any researcher can use the study's existing literature in a different country context; instead, the results can be contrasted. To prioritise the selection parameters, they could utilise quantitative and qualitative methods like analytic network process (ANP) and TOPSIS.

References

Afolayan, A.H., Ojokoh, B.A. and Adetunmbi, A.O. (2020) 'Performance analysis of fuzzy analytic hierarchy process multi-criteria decision support models for contractor selection', *Scientific African*, Vol. 9, p.e00471, doi:https://doi.org/10.1016/j.sciaf.2020.e00471.

Airport Planning Manual of 1987.

Angelopoulos, Panagiotis and Leivo P. (2013) 'Drivers and barriers for relocation of freight operators to smaller airports'.

Biswas, T.K., Akash, S.M. and Saha, S. (2018) 'A fuzzy-AHP method for selection best apparel item to start-up with new garment factory: a case study in Bangladesh', *International Journal of Research in Industrial Engineering*, Vol. 7, No. 1, pp.32–50, doi:https://doi.org/10.22105/riej.2018.111802.1034.

Boca Santa, S.L., Ribeiro, J.M.P., Mazon, G., Schneider, J., Barcelos, R.L. and Guerra, J.B.S.O.d.A. (2020) 'A green airport model: Proposition based on social and environmental management systems', *Sustainable Cities and Society*, Vol. 59, p.102160, doi:https://doi.org/10.1016/j.scs.2020.102160.

Brătucu, G., Dincă, G., Dincă, M.S. and Palade Zamfirache, A. (2017) 'Opportunity of constructing a cargo terminal – case study Brașov International Airport, Romania', *Transylvanian Review of Administrative Sciences*, No. 50E, pp.38–53, doi:https://doi.org/10.24193/tras.2017.0003.

Budd, T., Budd, L. and Ison, S. (2015) 'Environmentally sustainable practices at UK airports', *Proceedings of the Institution of Civil Engineers – Transport*, Vol. 168, No. 2, pp.116–123, doi:https://doi.org/10.1680/tran.13.00076.

Capik, P. and Dej, M. (2018) *ReLocation of Economic Activity*.

Carvalho, I.d.C., Calijuri, M.L., Assemany, P.P., Silva, M.D.F.M., Moreira Neto, R.F., Santiago, A.d.F. and de Souza, M.H.B. (2013) 'Sustainable airport environments: a review of water conservation practices in airports', *Resources, Conservation and Recycling*, Vol. 74, pp.27–36. doi:https://doi.org/10.1016/j.resconrec.2013.02.016.

Chang, Y-H. and Chang, Y-W. (2009) 'Air cargo expansion and economic growth: finding the empirical link', *Journal of Air Transport Management*, Vol. 15, No. 5, pp.264–265, doi:https://doi.org/10.1016/j.jairtraman.2008.09.016.

Cheng, C-H. and Lin, Y. (2002) 'Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation', *European Journal of Operational Research*, Vol. 142, No. 1, pp.174–186, doi:https://doi.org/10.1016/s0377-2217(01)00280-6.

Dožić, S. (2019) 'Multi-criteria decision making methods: application in the aviation industry', *Journal of Air Transport Management*, Vol. 79, p.101683, doi:https://doi.org/10.1016/j.jairtraman.2019.101683.

Dožić, S., Lutovac, T. and Kalić, M. (2018) 'Fuzzy AHP approach to passenger aircraft type selection', *Journal of Air Transport Management*, Vol. 68, pp.165–175, https://doi.org/10.1016/j.jairtraman.2017.08.003.

Ergas, Y. and Felsenstein, D. (2012) 'Airport relocation and expansion and the estimation of derived tourist demand: the case of Eilat, Israel', *Journal of Air Transport Management*, Vol. 24, pp.54–61, doi:https://doi.org/10.1016/j.jairtraman.2012.06.005.

Farahani, R.Z., SteadieSeifi, M. and Asgari, N. (2010) 'Multiple criteria facility location problems: a survey', *Applied Mathematical Modelling*, Vol. 34, No. 7, pp.1689–1709, doi:https://doi.org/10.1016/j.apm.2009.10.005.

Heinitz, F., Hirschberger, M. and Werstat, C. (2013) 'The role of road transport in scheduled air cargo networks', *Procedia - Social and Behavioral Sciences*, Vol. 104, pp.1198–1207, doi:https://doi.org/10.1016/j.sbspro.2013.11.216.

IATA (2017) *Value of Air Cargo Connectivity*, Geneva.

IATA (2019) *IATA ADRM*, 11th ed., IATA.

ICAO (1987) *Airport Planning Manual (APM)*.

International Airports Council (2019) *AIR CARGO GUIDE ACI-NA Air Cargo Committee*, September [online] https://airportscouncil.org/wp-content/uploads/2020/03/Air-Cargo-Guide.pdf (accessed 2 January 2023).

Joubert, J. (2018) *Evaluating the Relocation of an Urban Container Terminal*, pp.197–210, doi:https://doi.org/10.1002/9781119425526.ch12.

Kasarda, J.D. and Green, J.D. (2005) 'Air cargo as an economic development engine: a note on opportunities and constraints', *Journal of Air Transport Management*, Vol. 11, No. 6, pp.459–462, doi:https://doi.org/10.1016/j.jairtraman.2005.06.002.

Khorramrouz, F., Pourmahdi Kajabadi, N., Rahiminezhad Galankashi, M. and Mokhatab Rafiei, F. (2019) 'Application of fuzzy analytic hierarchy process (FAHP) in failure investigation of knowledge-based business plans', *SN Applied Sciences*, Vol. 1, No. 11, doi:https://doi.org/10.1007/s42452-019-1394-3.

Klose, A. and Drexl, A. (2005) 'Facility location models for distribution system design', *European Journal of Operational Research*, Vol. 162, No. 1, pp.4–29, doi:https://doi.org/10.1016/j.ejor.2003.10.031.

Larrodé, E., Muerza, V. and Villagrasa, V. (2018) 'Analysis model to quantify potential factors in the growth of air cargo logistics in airports', *Transportation Research Procedia*, Vol. 33, pp.339–346, doi:https://doi.org/10.1016/j.trpro.2018.10.111.

Liu, Y., Eckert, C.M. and Earl, C. (2020) 'A review of fuzzy AHP methods for decision-making with subjective judgements', in *Expert Systems with Applications*, Vol. 161, Elsevier Ltd., https://doi.org/10.1016/j.eswa.2020.113738.

Maynard, M.C., Cocanougher, D., Walter, M., Brimble, D., Webber, R., Janisse, M., Freidheim, R. and Kitty Miller, R. (2015) *Guidebook for Air Cargo Facility Planning and Development*, National Academies of Sciences, Engineering, and Medicine, The National Academies Press, Washington, DC, https://doi.org/10.17226/21906.

Merkert, R., Van de Voorde, E. and de Wit, J. (2017) 'Making or breaking – key success factors in the air cargo market', *Journal of Air Transport Management*, Vol. 61, pp.1–5, doi:https://doi.org/10.1016/j.jairtraman.2017.02.001.

Owen, S.H. and Daskin, M.S. (1998) 'Strategic facility location: a review', *European Journal of Operational Research*, Vol. 111, No. 3, pp.423–447, doi:https://doi.org/10.1016/s0377-2217(98)00186-6.

Portugal, L.d.S., Morgado, A.V. and Júnior, O.L. (2011) 'Location of cargo terminals in metropolitan areas of developing countries: the Brazilian case', *Journal of Transport Geography*, Vol. 19, No. 4, pp.900–910, doi:https://doi.org/10.1016/j.jtrangeo.2010.11.005.

Rahman, M.M. and Ahsan, K.B. (2019) 'Supplier selection and evaluation by fuzzy-AHP extent analysis: a case study RMG sector of Bangladesh', *International Journal of Engineering and Management Research*, Vol. 9, No. 1, pp.41–48, doi:https://doi.org/10.31033/ijemr.9.1.5.

Report, Working Group (2012) *Air Cargo Logistics in India Ministry of Civil Aviation*, Government of India, New Delhi, India.

Rodbundith, T., Suthiwartnarueput, K. and Pornchaiwiseskul, P. (2019) 'A study of criteria for air cargo terminal classification model', *International Journal of Logistics Systems and Management*, Vol. 33, No. 4, pp.543–567, https://doi.org/10.1504/IJLSM.2019.101797.

Roso, V., Brnjac, N. and Abramovic, B. (2015) 'Inland intermodal terminals location criteria evaluation: the case of Croatia', *Transportation Journal*, Vol. 54, No. 4, p.496, doi:https://doi.org/10.5325/transportationj.54.4.0496.

Saad, S.M., Kunhu, N. and Mohamed, A.M. (2016) 'A fuzzy-AHP multi-criteria decision-making model for procurement process', *International Journal of Logistics Systems and Management*, Vol. 23, No. 1, p.1, doi:https://doi.org/10.1504/ijlsm.2016.073295.

Saaty, T.L. and Ozdemir, M.S. (2003) 'Why the magic number seven plus or minus two', *Mathematical and Computer Modelling*, Vol. 38, Nos. 3–4, pp.233–244, doi:https://doi.org/10.1016/s0895-7177(03)90083-5.

Sellner, R. and Nagl, P. (2010) 'Air accessibility and growth – the economic effects of a capacity expansion at Vienna International Airport', *Journal of Air Transport Management*, Vol. 16, No. 6, pp.325–329, doi:https://doi.org/10.1016/j.jairtraman.2010.04.003.

Soberi, M.S.F. and Ahmad, R. (2016) 'Application of fuzzy AHP for setup reduction in manufacturing industry', *Journal of Engineering Research and Education*, January, Vol. 8, pp.73–84.

Stević, Ž., Vesković, S., Vasiljević, M. and Tepić, G. (2015) *The Selection of the Logistics Center Location using AHP Method*, pp.86–91 [online] http://logic.sf.bg.ac.rs/wp-content/uploads/Papers/LOGIC2015/ID-15.pdf (accessed 2 January 2023).

Stoltmann, A., Bućko, P. and Jaskólski, M. (2016) 'Multi-criteria investment decision support model using fuzzy analytic hierarchy process (F-AHP) method for power industry', *Zeszyty Naukowe Wydziału Elektrotechniki i Automatyki Politechniki Gdańskiej*, Vol. 47, No. 47, pp.179–182 [online] https://www.infona.pl/resource/bwmeta1.element.baztech-5cf50ce3-f317-4372-83e6-294bf1524ef8 (accessed 2 January 2023).

Tanrıverdi, G., Ecer, F. and Durak, M.Ş. (2022) 'Exploring factors affecting airport selection during the COVID-19 pandemic from air cargo carriers' perspective through the triangular fuzzy Dombi-Bonferroni BWM methodology', *Journal of Air Transport Management*, Vol. 105, p.102302, doi:https://doi.org/10.1016/j.jairtraman.2022.102302.

Thanos, S., Wardman, M. and Bristow, A.L. (2011) 'Valuing aircraft noise: stated choice experiments reflecting inter-temporal noise changes from airport relocation', *Environmental and Resource Economics*, Vol. 50, No. 4, pp.559–583, doi:https://doi.org/10.1007/s10640-011-9482-x.

Ulutaş, A., Karakuş, C.B. and Topal, A. (2020) 'Location selection for logistics center with fuzzy SWARA and CoCoSo methods', *Journal of Intelligent & Fuzzy Systems*, Vol. 38, No. 4, pp.4693–4709, doi:https://doi.org/10.3233/jifs-191400.

Van Thai, V. and Grewal, D. (2005) 'Selecting the location of distribution centre in logistics operations: a conceptual framework and case study', *Asia Pacific Journal of Marketing and Logistics*, Vol. 17, No. 3, pp.3–24, doi:https://doi.org/10.1108/13555850510672359.

Wan, Y., Cheung, R.K., Liu, J. and Tong, J.H. (1998) 'Warehouse location problems for air freight forwarders: a challenge created by the airport relocation', *Journal of Air Transport Management*, Vol. 4, No. 4, pp.201–207, doi:https://doi.org/10.1016/s0969-6997(98)00024-6.

Wasesa, M., Rahman, M.N., Rizaldi, A. and Mashuri (2015) 'Relocating a multiple-tenants logistics center: lesson learned from an air cargo terminal relocation project', *Procedia Manufacturing*, Vol. 4, pp.139–145, doi:https://doi.org/10.1016/j.promfg.2015.11.024.

Wolfe, P.J., Yim, S.H.L., Lee, G., Ashok, A., Barrett, S.R.H. and Waitz, I.A. (2014) 'Near-airport distribution of the environmental costs of aviation', *Transport Policy*, Vol. 34, pp.102–108, doi:https://doi.org/10.1016/j.tranpol.2014.02.023.

Yuan, X-M., Low, J.M.W. and Ching Tang, L. (2010) 'Roles of the airport and logistics services on the economic outcomes of an air cargo supply chain', *International Journal of Production Economics*, Vol. 127, No. 2, pp.215–225, doi:https://doi.org/10.1016/j.ijpe.2009.08.005.

Żak, J. and Węgliński, S. (2014) 'The selection of the logistics center location based on MCDM/A methodology', *Transportation Research Procedia*, Vol. 3, pp.555–564, doi: https://doi.org /10.1016/j.trpro.2014.10.034.