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# Determination of Location Selection Criteria and Their Importance Levels for Air Cargo Companies: A Case from Turkiye

**Ahmet Türk [1], V. Alpagut Yavuz [2*]**

[1] Hatay Mustafa Kemal University, Social Sciences Institute, Hatay, Türkiye. (aahmet.turk@hotmail.com).
[2*] Hatay Mustafa Kemal University, Business Administration Department, Hatay, Türkiye. (vyavuz@mku.edu.tr).

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Corresponding Author: *V. Alpagut Yavuz*

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## Abstract

Air cargo transportation attracts increasing attention among other alternative transportation models in developing countries due to its ability to provide the fastest transportation service to distant locations. A cargo hub, where air cargo companies perform their cargo operations, plays a critical role, especially in service time and cost. In choosing a site for their operations, understanding the importance of many seemingly independent factors/criteria such as airport system and infrastructure, proximity to production and consumption sources, and transportation connections play a critical role in balancing time and cost. Hence, the study aims to determine the location selection criteria of the cargo hub as the operation site of air cargo companies and to rank their importance. For this purpose, the opinions of experts in university and managers of big air cargo companies in Turkiye were collected. In the first stage of the study, the criteria were determined and categorized into four categories by using the Delphi method. In the second stage, the importance levels of the criteria were determined using the G-AHP method. The research findings highlighted "transportation diversity of the region", "proximity to important production resources", and "the structure of existing warehouses" as the most important criteria among others. The importance levels of location selection criteria categories ranked as "Supply, Equipment and Costs", "Transportation Connections", "Consumer" and "External Factors". In summary, findings show that the most important factor affecting the location selection decision is related to the suitability of the airport's infrastructure for cargo operations.

## 1. Introduction

Air cargo transportation has become the fundamental element of the global supply chain with the rapid increase of e-commerce in recent years. The growing interest in the air cargo sector is driven by the global widespread integration of just-in-time (JIT) production and distribution systems, as well as a more open trading regime in international air cargo services offered by air cargo carriers (Yılmaz, 2022: 44) Air cargo volume, which showed a continuous increase except for the global crises in 2009 and 2019-2020, reached 65.5 million tons in 2021 (Statista, 2022). Air cargo has increased its importance in the aviation industry, especially with the role it plays in the distribution of health materials and drugs during the global pandemic process. According to IATA (2022) data, by contributing more than one-third of airline company revenues in 2021, it created an alternative to the decreasing passenger revenues in this period and started to gain importance in company strategies.

Similar developments are observed in Turkiye as well. Thanks to the liberalization in air transportation implemented since 2003, rapid development has occurred in air cargo transportation in Turkiye and the cargo capacity of 302,737 tons in 2003 reached 2,593,450 tons in 2021 with an increase of 757% (GDCA, 2021: 38). According to the FTK (Freight Ton Kilometers) ranking in the latest statistics published by ICAO (2021), Turkiye has continued to rise in the sector over the years, reaching the 8th rank. Estimates are that this growth will continue.

In addition to the advantages of air cargo transportation such as speed, reliability and less exposure to weather conditions, there are disadvantages such as the reflection of operational fees on prices and physical barriers (Yılmaz, 2022: 44). In air cargo transportation, cost minimization is an important factor that each air cargo company develops strategies for, in order to compete. Thus, the relationship and balance between time and cost should be analyzed very carefully. Cargo Hubs (CH), which are closely related to the concepts of time and cost, are known as special facilities that operate as assembly and distribution locations, reduce the number of connections on the network, offer companies the opportunity to benefit from economies of scale and provide access to more locations. These facilities can affect the existence and indirectly the future of the airline company with its advantages such as infrastructure and superstructure installation and facilities, the capacity of the airport, equipment features, proximity to important transportation locations, and production sites.

The network structure that brings the flights departing from various airports together at the airport that is the geographical common point or center of these airports within a certain time period and distributes them from the central point to the surrounding airports in the same way is known as the hub and spoke flight network (Gerede, 2019: 120). The hub and spoke network structure is, in principle, a comprehensive plan designed to ensure that all routes achieve the most efficient system performance (Hsu & Wang, 2013: 258). In this structure, a centrally located institution or facility serves as a collection and distribution point in terms of the importance and capability of its location. The central point where collection and distribution activities take place is known as the CH. In order to take advantage of CHs and to benefit from economies of scale, flows from origin to destination do not use direct/intermediary connection lines and are collected at CHs and sent to destinations via CHs.

The choice of CH location, which is decisive for the performance of cargo transportation activities to be carried out by air cargo companies, has a significant impact on the sustainability of the cargo company, and therefore meticulous and comprehensive research for the selection of the cargo hub is of vital value for this selection process. Through selecting cargo hubs correctly, connection lines are reduced, costs are decreased to lower levels and access to more locations is obtained (Aygün, 2014: 8). Determining the criteria that air cargo companies should consider and evaluate in the selection of CH is a priority issue for making sound decisions.

CH selection is a multi-criteria decision problem, which is described as site/location selection in the literature. Location selection is an important issue that is generally handled within the framework of airport location determination in air transport due to the scope of its consequences and effects. (Martel & Aouni, 1992; Erkan & Elsharida, 2019; Pinto et al., 2020). In studies conducted on this subject in Turkiye; Oktal (1998) proposed a model for the objective evaluation of airport location selection, which has a subjective nature, using numerical data. Akça (2017) conducted a qualitative and quantitative study to develop a scale that allows air traffic controllers to evaluate the suitability of airport locations. Ertunc & Çay (2020) carried out an application study to determine the most suitable areas for airport construction in the provinces of Bayburt and Gümüşhane.

The only study in the literature on the factors considered in air cargo location selection was conducted by Gardiner, Ison, & Humphreys (2005). This is a survey study conducted by 118 non-integrated air carriers in 2005. In this study, they determined that nine factors play an important role in choosing the airport for the cargo activities of the companies. In order of importance, these factors are; night operations, minimizing total costs, airport cargo reputation, local origin-destination demand, the influence of intermediary air cargo agents, airport access, customs clearance times, financial incentives provided by the airport, and shipping time of trucks to main markets. Carrying out operations at night hours and minimizing costs were at the top of the list as extremely important factors. In addition, it has been determined that cost minimization has a great effect regardless of geographical location. Determining the importance of financial incentives as another sub-factor in the airport selection process shows how critical cost management is (Gardiner, Ison, & Humphreys, 2005: 395-396).

A similar study on the subject in Turkiye is the study in which Düztepeliler (2003) examined the home base selection criteria of airline companies and the home base selection criteria of Turkish Airlines for Atatürk Airport. In this study; the question, "According to which criteria was Istanbul Atatürk Airport selected as the home base?" was asked. The answer given was, "No criteria were evaluated for the selection, and Istanbul has become suitable due to the social, cultural, and economic reasons that occur naturally. Although it is suitable for international flights, it is not suitable for domestic flights since it's not a geographical center for Turkiye. This situation can be explained by the fact that the regional development in Turkiye shows great differences and in parallel to this, economic activities are concentrated in a small number of centers (Marmara region and Istanbul). As a result, the absence or very few alternatives in site selection makes detailed analyzes unnecessary for decision-making. However, it is clear from the data that this situation will change rapidly. According to the data of the General Directorate of Civil Aviation for 2021 (2021); Freight traffic consisting of cargo, mail, and baggage increased by 39.8% in domestic cargo transportation in 2021 compared to 2020, while international transportation increased by 34.9%. The increase in air transport traffic along with the increasing number of airports in domestic lines in recent years will create an increasing demand for domestic air cargo transport, causing location selection to be an important decision problem. At this stage, studies to determine the location selection criteria for air cargo companies in Turkiye can provide important contributions.

So far, studies on air cargo in Turkiye has focused on fuel, cargo, fleet planning, and transportation. In these studies; Özger & Oktal (2013) carried out an application study with a new approach proposed for the solution of base layout problems. Derici, Derici, & Karaduman (2015) examined customer preferences in special cargoes. Küçük, Mukanbay & Öztürk (2016) proposed a model for aircraft selection in hazardous goods transportation. Özdoğan (2016) examined the adaptation of modern technology applications in air cargo transit operations.

Considering the studies conducted, it is clear that the CH location selection of air cargo companies has not been sufficiently studied, therefore, this study aims to answer the questions of which criteria should be taken into consideration when selecting the CH location of air cargo companies and how much these criteria should be taken into consideration according to their degree of importance.

Although there are not enough studies on airline cargo companies in the literature, most of these studies focus on fuel, cargo, fleet planning and transportation issues, while very few studies focus on the CH. The difference of this study from the other studies is that the criteria and importance levels taken into account in the site selection process have been investigated by taking into account the views of the academic and industry. From this perspective, the aim of this study is to determine which criteria air cargo carriers take into account when determining the CH airports where they will carry out their operational activities in Turkiye and to classify their importance levels.

## 2. Materials and Methods

The study consists of two stages. In the first stage, interviews were conducted with experts who are competent on the subject, and a list of criteria that air cargo carriers can consider in CH location selection was created. For the criteria list, the Delphi questionnaire was applied to the academicians who are experts in their fields, and the criteria list that the experts agreed upon was determined. In the second stage, the questionnaire containing pairwise comparisons developed to determine the importance of these criteria was evaluated by the managers of the companies operating in the air cargo industry. In the last stage, the evaluations of the company managers have analyzed with the Gray-AHP (G-AHP) method, and the ranking of the criteria according to their importance was determined.

In the first stage of the study, 7 academicians with at least 5 years of academic experience with field knowledge and expertise in aviation participated the study. They were asked to determine, within the scope of their expertise, which criteria air cargo companies should evaluate in the decision of CH location selection. In the second stage of the study, the criteria determined by the experts were evaluated by the companies operating in Istanbul IGA airport and Istanbul Sabiha Gökçen airport, which have the highest concentration of central CH activity in Turkiye to find an answer to the question "Which criterion is more or less important than the others in CH location selection". In this context, managers of 5 companies that serve in two different areas (air cargo operators carrying cargo and doing combined transportation) participated this stage.

To create the Delphi questionnaire used in the first stage of the study, the list of criteria covering the topics that can be considered in general was listed by taking into account the relevant literature and expert opinions. Accordingly, the criteria are listed as follows; "Road distance, Railway distance, Seaway distance, Proximity to important consumption sources, Proximity to key production locations, Number of neighboring cities, Structure of warehouses, Airport infrastructure and superstructure, Geographical location, Demographic density, Airport environment Climatic conditions, Airport operating costs".

Then, this list of criteria was sent to academics who are experts in the field to determine the suitability of the criteria, and they were asked to evaluate each criterion in the list by choosing one of the answers as "appropriate, partially appropriate, and unsuitable". Also, it was asked whether there were any suggestions for changes regarding the criteria titles and if there were new criteria suggestions if any. As a result of these evaluations, the list of criteria to be used in the Delphi questionnaire was finalized.

Then, the Delphi questionnaire was created by using the criteria list. The questionnaire containing these criteria was sent back to the independent academic group. At the end of this round the answers given to the questionnaires were evaluated. For this purpose, the 7-point Likert scale evaluations ranging from "strongly disagree" to "strongly agree" for each criterion were coded using numbers from 1 to 7, respectively, and necessary statistics were calculated. The consensus was evaluated by taking into account statistical parameters. Based on this evaluation, it was determined that the experts agreed on the criteria.

As a result of the Delphi study; "proximity to major consumption locations", "the volume of economic activity (industry, trade, import and export) of the region", "population of the nearby region", "nearest airport distance", "transportation diversity of the region", "airport infrastructure and superstructure", "proximity to key production locations", "structure of existing warehouses", "airport operating costs", "geographical location and structure", and "climatic conditions in the airport region" were determined as the criteria for CH location selection. Then, the criteria were grouped under four main criteria categories, taking into account the scope of the criteria.

In the last stage, pairwise comparisons questions were prepared by using the determined criteria to form the AHP questionnaire. In the questionnaire, firstly, four criterion categories were evaluated in six pairwise comparison questions. Then, three criteria in the "Consumer" category were evaluated using three comparison questions. Similarly, the three criteria under the "Transportation Connections" category are in three comparisons; The three criteria under the "Supply, Infrastructure, and Costs" category are in three comparisons; Two criteria under the "External Factors" category were evaluated in one comparison.

The answers given by the air cargo company managers to the survey questions were analyzed by applying the G-AHP steps using the Excel software and the criteria weights were calculated. For the G-AHP calculations, at first the geometric averages of the answers of the five participants were calculated to combine all the evaluations and then using the single evaluation representing the mean group judgement were analyzed.

## 2.1. Methods

There are many Multi Criteria Decision Making (MCDM) methods used to assist decision makers in location selection problems in the literature. MCDM methods include approaches that help the decision maker to make the most appropriate decision, taking into account the effect of multiple and independent factors (Ömürbek, Üstündağ & Helvacıoğlu, 2013: 105).

Some of the popular methods are; Analytical Hierarchy Process-AHP (Rezaian & Jozi, 2016; Vasileiou, Loukogeorgaki & Vagiona, 2017), Preference Sorting Technique by Ideal Solution Similarity-TOPSIS (Sánchez-Lozano, García-Cascales & Lamata, 2016; Chauhan & Singh, 2016), ELECTRE (Dortaj, Maghsoudy, Doulati & Eskandari, 2020), VIKOR (VlseKriterijuska Optimizacija I Komoromisno Resenje) (Tavakkoli, Mousavi & Heydar, 2011), and a multi-method hybrid (Ishizaka, Nemery & Lidouh, 2013) MCDM method.

There are also studies using various methods related to the location selection problem in Turkiye. Aydın, Öznehir & Akçalı (2009) discussed the modeling of the site selection of a hospital planned to be established in Ankara with AHP. Şahin & Altın (2016) conducted an assignment model study for the location selection problem of temporary settlement areas of tent cities to be used after a possible earthquake in Isparta province. Kasak & Erdal (2019) conducted a study using the MOORA method to select the most suitable location for the penitentiary among alternative lands in Sivas province. Balkan (2020) handled the power plant location problem using the ELECTRE method that will provide the best benefit to producers and consumers. Başkurt & Aydın (2020) evaluated criteria using GIS in determining the appropriate location for the establishment of nuclear power plants. Supçiller & Bayramoğlu (2020) examined the wind farm location selection problem with intermittent gray number-based A-GIA and gray EDAS methods. İnağ & Arıkan (2020) solved the problem of site selection of waste collection centers belonging to Çankaya District Municipality using an integrated model with DEMATEL-ANP and mathematical programming methods. Baki (2021) has proposed an approach by applying the Fuzzy COPRAS technique in the analysis of location alternatives of a private hospital.

In this study, methods that allow quantitative and qualitative evaluations were used. For this purpose, Delphi method was used to determine the criteria related to the subject by applying different perspectives of academicians who are experts in their fields. Then, with the G-AHP method using AHP and Gray numbers, the importance levels of the criteria were determined by the representatives of the air cargo industry and the criteria were ranked in order of importance.

### 2.1.1. Delphi Method

It is a technique in which expert opinions about any problem are obtained systematically. It is mainly used to determine the opinions or judgements about a problem or subject and create consensus among the participating experts or those who represent the target audience (Şahin, 2001: 215-216).

This technique, which was developed by Norman Dalkey & Olf Helmer (1963: 458) for military use within Rand Corporation in the 1950s, is also a planning tool used to predict future trends (Green, 2014: 1).

The Delphi Technique (Linstone & Turoff, 1975: 11), is applied to address complex problems in various fields such as health, technology, environment, and transportation, offer solutions for these problems, making inferences about the future and making decisions (Linstone & Turoff, 1975: 11). It is considered a mixed method because it contains both qualitative and quantitative methods.

According to Dalkey, the Delphi technique has three basic features, these are; confidentiality in participation, statistical analysis of group evaluations, and controlled feedback practices (Şahin, 2001: 216).

Confidentiality in participation is seen as the key to Delphi's success. Accordingly, it is kept confidential to whom the ideas put forward during the research belong. Thus, it is ensured that ideas come to the fore rather than individuals. In this way, the unconditional approval of the views of people who are known and respected in the group is prevented.

Statistical analysis of group assessments refers to the statistical analysis of data after each Delphi questionnaire has been administered. Participants should know well what the statistics used in these analyzes mean.

For controlled feedback, sequential questionnaires are used in the Delphi method. After the statistical analyzes of the surveys are completed, the results, in other words, representing the general tendencies of those who answered the survey, are presented to the participants with the same survey questionnaire. In this way, individuals compare their thoughts with different views and approaches using the results presented to them. The questionnaire used in Delphi studies contains a set of statements, either quantitative or qualitative. A single or different scale can be used for these expressions. The statements to be made in the questionnaire can be determined by the researchers, the participants, or both groups together.

Delphi method can be very functional when air cargo companies need expert opinions on CH location selection. Another point that makes the Delphi method functional is that it provides the researcher with a free range of motion. This technique, which leaves the decision to the researcher on issues such as the number of Delphi rounds, the size of the expert group, the selection criteria, and the rate of agreement, has thus become a method that can be used in many areas. Based on all these reasons, Delphi was used in this study to determine the location selection criteria of air cargo companies.

### 2.1.2. Analytic Hierarchy Process

Analytical Hierarchy Process (AHP) is a multi-criteria decision-making technique that evaluates decision elements in order of hierarchy by pairwise comparison. Qualitative factors are more important than other factors in AHP. However, it is a technique that has the feature of combining qualitative and quantitative factors in evaluation of the alternatives or criteria (Ömürbek, Üstündağ & Helvacıoğlu, 2013: 105).

AHP was developed by Thomas L. Saaty in 1977 to solve complex decision-making problems involving many criteria. AHP aims to solve the problem with its hierarchical analysis and applicability consisting of objectives, criteria, sub-criteria, and options. It is a method with high benefits, dynamism, and a solution to complex decision-making problems (Denizhan, Yalçıner & Berber, 2017: 65)

The main strength of AHP involving many decision-makers is that it processes highly complex and hard decisions more systematically. Constrained logic and constrained conceptual processes make it nearly impossible for decision-makers to incorporate all factors into complex decisions. Decision makers can usually only take into account a subset of decisions, without perceiving the relationship weights and interrelationships of important factors. AHP aims to rationalize complex decision processes by systematizing and synthesizing all possible information for decision making (Handfield et al., 2002: 75-76).

AHP offers an effective and highly understandable approach that allows the integration of qualitative and quantitative factors for decision making. The pairwise comparisons used in the method are an appropriate approach in terms of human perception when making a subjective evaluation (Gülenç & Aydın, 2010: 98).

AHP is used to evaluate factors that are independent of each other at various levels in hierarchical structures (Anık, 2007: 13). In AHP, the problem is structured hierarchically. There is a purpose at the top of the hierarchy and the structure is completed with criteria and alternatives at the bottom, respectively (Felek, Yuluğkural, & Aladağ, 2007: 7).

In order to determine all the criteria that affect the decision process, the opinions of the experts on the subject are used or a survey study is conducted (Dağdeviren, Akay & Kurt, 2004: 132). A decision hierarchy is constructed based on these findings. In the next step, pairwise comparison matrices are created and the decision maker is asked to make pairwise comparisons. Afterward, it is checked whether the comparisons are consistent and if not, the decision maker is requested to reconsider and correct his decision. Then, the relative weights (eigenvector values) are calculated from the pairwise comparison matrices (Aslan, 2005: 5).

Many site selection studies using the AHP method have been identified in the literature. Aydın (2009) evaluated the most appropriate site selection criteria for a hospital to be established in Ankara using the AHP method. In his study, İmren (2011) determined the criteria that have an impact on the process of choosing the most suitable business location in the furniture industry using AHP. Ömürbek et al. (2013) tried to determine the areas where animal husbandry can be made in the province of Isparta using the AHP method. In their study, Uslu, Kızıloğlu, İşlenen & Kahya (2017) proposed a new solution approach in which GIS-based AHP and TOPSIS methods are used together to determine the appropriate site for a newly established primary school. Zaralı, Yazgan & Delice (2018) proposed an integrated approach by combining AHP and VIKOR methods for the Logistics Center planned to be built in Kayseri. Ertunç & Çay (2020) tried to identify suitable areas for airport construction in the provinces of Bayburt and Gümüşhane by using GIS and AHP. Kara, Masri & Kaya (2022) evaluated the validity of the solutions by comparing the results obtained from different methods in determining the location where a supplier company operating in the maritime sector will establish a new branch by using AHP, ARAS, and fuzzy TOPSIS methods integrated. Terme, Çiçek & Kiraz (2022) handled the facility location problem for an industry with Fuzzy AHP and Fuzzy VIKOR methods.

As seen in the above studies, apart from the classical AHP method fuzzy logic and similar approaches are used in the AHP method to evaluate judgments that do not contain certainty and indecision. Within the scope of this study, the uncertainty in the judgments of the evaluators was evaluated using gray numbers based on Gray Relational Analysis in the AHP method.

### 2.1.3. Gray Relational Analysis

Gray Relational Analysis (GRA) is one of the techniques developed by Ju Long Deng in 1982 and based on the gray system theory (Deng, 1989). GRA is a decision-aid method by allowing the ranking and evaluation of the elements of a system and has been applied in many areas including social and economic systems.

A system containing known and unknown data is called a gray system. Fuzzy mathematics usually deals with situations where experts express uncertainty through the membership function (Zareinejad, 2014: 275). Gray Systems Theory is preferred in cases where the number of experts and experience level is low, the data are insufficient or there are few samples and it is not possible to extract the membership function (Zareinejad, 2014: 275).

In this study, Gray numbers on a scale of 5 given in Table 1 were used for the numerical values corresponding to the relative linguistic evaluations of the options.

**Table 1.** Linguistic variables used in the AHP questionnaire

| Linguistic variables | Abbreviation symbol | Corresponding Gray numbers |
|---|---|---|
| Extreme Importance | EMAIL | [8, 10] |
| Very Strong Importance | VSI | [6, 8] |
| Strong Importance | SI | [4, 6] |
| Medium Importance | MI | [2, 4] |
| Equivalent Importance | EI | [12] |

Source: Zareinejad, 2014: 282

Zareinejad's (2014) steps described below are used in calculating the gray relational scores of alternative options;

Step 1: Gray scores ($G_{ij}$) for option $i$ and criterion $j$ can be calculated using Equation 1.

$$Gij = \frac{1}{k}\left[\, G_{ij}^{1} \; + \; G_{ij....}^{2} \; + \; G_{ij}^{k}\right] \qquad (1)$$

Where, $G_{kij}$ indicates that the $k$ decision maker evaluates the $j$ option in terms of the $i$ criterion. This valuation is shown as a gray number $G_{kij} = [^{*}G_{kij}, {}^{*}G_{kij}]$.

Step 2: Construct a gray decision matrix of $G_{ij}$ with linguistic variables defined based on gray numbers (Table 1).

Step 3: To evaluate $m$ options over $n$ criteria, the decision matrix is normalized according to whether the criteria type is profit or cost, as shown in Equation 2.

$$K = \begin{bmatrix} G_{11} & \cdots & G_{1n} \\ \vdots & \ddots & \vdots \\ G_{m1} & \cdots & G_{mn} \end{bmatrix} \qquad (2)$$

a) If the variables are profit (the more the better) Equation 3 is used:

$$G_{ij}^{+} = \left[\frac{{}_{*}G_{ij}}{G_j^{maks}}, \frac{{}^{*}G_{ij}}{G_j^{maks}}\right] \quad G_j^{maks} = maks_{1\le i\le m}\{{}^{*}G_{ij}\} \qquad (3)$$

b) If the variables are in the form of costs (the less the better) Equation 4 is used:

$$G_{ij}^{-} = \left[\frac{G_j^{min}}{{}^{*}G_{ij}}, \frac{G_j^{min}}{{}_{*}G_{ij}}\right] \quad G_j^{min} = min_{1\le i\le m}\{{}_{*}G_{ij}\} \qquad (4)$$

Step 4: Identifying the reference or ideal option based on the type of problem to make the assessment.

Step 5: Calculation of the relative gray coefficient.

The relative gray coefficient between reference options, taking into account the criterion $i$ denoted by $£_{0i(j)}$, is calculated using Equation 5:

$$£_{0i(j)} = \frac{min_i\, min_j\{D_{0i(j)}\} + \rho maks_i\, maks_j\{D_{0i(j)}\}}{D_{0i(j)} + \rho maks_i\, maks_j\{D_{0i(j)}\}} \qquad (5)$$

$$1 \le i \le m, \;\; 1 \le j \le n$$

Where $D_{0i(j)}$ is the Minkowski distance between the reference options considering the $j$ criterion. The technical coefficient ($\rho$) between the reference options is usually 0.5.

Step 6: In calculating the relative gray score, the relative gray score of an option $i$ considering the reference choice is calculated using Equation 6:

$$\gamma_{0i} = \sum_{j=1}^{n} \frac{1}{n} £_{0i(j)} \qquad (6)$$

2.1.4. G-AHP

The main steps of using the G-AHP approach are as follows (Zareinejad, 2014: 279-281):

Step 1: Defining the problem: In the first step, the purpose of the problem, decision criteria, and decision alternatives are defined.

Step 2: Establishing the hierarchical structure: The hierarchical structure of the problem is created based on the defined purpose, criteria and alternatives of the problem.

Step 3: Creation of the pairwise comparison matrix: This stage involves creating the pairwise comparisons and pairwise comparison matrix in each row of the hierarchy to respond to the fulfillment of the objective or meet their requirements. Each element of this matrix is a gray number (Equation 7).

$$K = \begin{bmatrix} G_{11} & \cdots & G_{1n} \\ \vdots & \ddots & \vdots \\ G_{m1} & \cdots & G_{mn} \end{bmatrix} = \begin{bmatrix} [{}_{*}G_{11}, {}^{*}G_{11}] & \cdots & [{}_{*}G_{1n}, {}^{*}G_{1n}] \\ \vdots & \ddots & \vdots \\ [{}_{*}G_{m1}, {}^{*}G_{m1}] & \cdots & [{}_{*}G_{mn}, {}^{*}G_{mn}] \end{bmatrix} \qquad (7)$$

Step 4: Normalizing the pairwise comparison matrix (Equations 8,9,10):

$$K*=\begin{bmatrix} G*_{11} & \cdots & G*_{1n} \\ \vdots & \ddots & \vdots \\ G*_{m1} & \cdots & G*_{mn} \end{bmatrix}$$

$$=\begin{bmatrix} [{}_*G*_{11},{}^*G*_{11}] & \cdots & [{}_*G*_{1n},{}^*G*_{1n}] \\ \vdots & \ddots & \vdots \\ [{}_*G*_{m1},{}^*G*_{m1}] & \cdots & [{}_*G*_{mn},{}^*G*_{mn}] \end{bmatrix} \quad (8)$$

$${}_*G*_{ij}=\left[\frac{2({}_*G_{ij})}{\sum_{i=1}^{m}{}_*G_{ij}+\sum_{i=1}^{m}{}^*G_{ij}}\right] \quad (9)$$

$${}^*G*_{ij}=\left[\frac{2({}^*G_{ij})}{\sum_{i=1}^{m}{}_*G_{ij}+\sum_{i=1}^{m}{}^*G_{ij}}\right] \quad (10)$$

## 3. Result and Discussion

As a result of the Delphi questionnaire, the criteria agreed upon by the experts were gathered in four main categories, taking into account the subject of each criterion. These criteria categories are as follows;

Consumer: This category includes “proximity to major consumption locations”, “the volume of economic activity (industry, trade, import, and export) of the region”, and “population of the nearby region”.

Transportation Connections: This category includes “nearest airport distance”, “transportation diversity of the region”, and “airport infrastructure and superstructure”.

Supply, Infrastructure, and Costs: This category includes “proximity to key production locations”, “structure of existing warehouses”, and “airport operating costs”.

External Factors: This category includes “geographical location and structure” and “climatic conditions in the airport region”.

**Table 2.** Pairwise Comparisons of Criteria Categories

| | Consumer | Transportation Connections | Supply, Infrastructure, and Costs | External Factors |
|---|---|---|---|---|
| Consumer | | (SI, EI) | (MI) | (VSI, SI, SI) |
| Transportation Connections | (SI, VSI, VSI, VSI) | | (VSI, SI, EI, EI) | (EMI, VSI, SI, EI, EI) |
| Supply, Infrastructure, and Costs | (SI, SI, VSI, EMI, EMI) | (SI, VSI) | | (VSI, VSI, VSI, SI, EI, EI) |
| External Factors | (MI, SI, VSI) | (MI) | | |

Pairwise comparison questions were asked using the AHP questionnaire for the four criteria categories and sub-criteria determined. In the first questionnaire, four criterion categories were evaluated in six pairwise comparison questions. Then, three criteria in the Consumer category were evaluated using three comparison questions. Similarly, the three criteria under the Transportation Connections are in three comparisons; The three criteria under the Supply, Infrastructure, and Costs criteria are in three comparisons; Two criteria under the External Factors were evaluated in comparison. The participant evaluations for the main criteria category are given in Table 2 as an example. Similarly, pairwise comparisons of sub-criteria were recorded for each group.

**Table 3.** Gray Matrix of Criteria Categories

| | Consumer | Transportation Connections | Supply, Infrastructure, and Costs | External Factors |
|---|---|---|---|---|
| Consumer | [1,000; 1,000] | [0.331; 0.490] | [0.203; 0.294] | [0.891; 1,348] |
| Transportation Connections | [2,040; 3.026] | [1,000; 1,000] | [0.891; 1.414] | [1.906; 3.141] |
| Supply, Infrastructure, and Costs | [3.397; 4,932] | [0.707; 1.123] | [1,000; 1,000] | [3.086; 4.804] |
| External Factors | [0.742; 1.123] | [0.318; 0.525] | [0.208; 0.324] | [1,000; 1,000] |

All the answers given to the survey questions were analyzed by applying the G-AHP steps using the Excel software and the criteria weights were calculated. At first, the geometric mean of the answers of the five participants were calculated for combining the opinions and obtaining the group evaluation. For this purpose, the gray matrix was created by using the calculations defined in the 3rd step of the method. As an example, Table 3 presents the pairwise comparison gray matrix evaluations for the criteria categories.

Then, the calculations in the 4th step of the method were applied and the normalized gray matrix was obtained. Table 4 shows the normalized gray matrix generated for the criteria categories.

**Table 4.** Normalized Gray Matrix of Criteria Categories

| | Consumer | Transportation Connections | Supply, Infrastructure, and Costs | External Factors |
|---|---|---|---|---|
| Consumer | [0.116; 0.116] | [0.120; 0.179] | [0.076; 0.110] | [0.104; 0.157] |
| Transportation Connections | [0.236; 0.351] | [0.364; 0.364] | [0.334; 0.530] | [0.222; 0.366] |
| Supply, Infrastructure, and Costs | [0.394; 0.572] | [0.257; 0.409] | [0.375; 0.375] | [0.359; 0.559] |
| External Factors | [0.086; 0.130] | [0.116; 0.191] | [0.078; 0.122] | [0.116; 0.116] |

Finally, the gray significance levels of the criteria were calculated by applying the calculations defined in the 5th step of the method. Table 5 shows the gray importance levels calculated for the criteria categories.

**Table 5.** Gray Importance Levels of Criteria Categories

| | Gray Importance Levels | Crisp Importance Levels |
|---|---|---|
| Consumer | [0.104; 0.140] | 0.122 |
| Transportation Connections | [0.289; 0.403] | 0.346 |
| Supply, Infrastructure, and Costs | [0.346; 0.479] | 0.413 |
| External Factors | [0.099; 0.140] | 0.119 |

All the steps described above were first applied to all group comparisons, starting with combining the geometric averages of the answers of the five participants to reach the evaluation of the criteria under each group among themselves. Thus, the importance levels of the criteria under each main criterion group were calculated. The overall importance levels of all criteria were calculated by multiplying the importance levels of the main criteria groups with the within-group importance levels of each criterion. The results obtained after these procedures are presented in Table 6.

**Table 6.** G-AHP Questionnaire Results

| Groups | Grey Importance | Crisp Importance | Faktörler | Grey Importance | Crisp Importance | Internal Ranking | Normalized Weights | Global Ranking |
|---|---|---|---|---|---|---|---|---|
| Consumer | [0.104; 0.140] | 0.122 | Proximity to major consumption | [0.349; 0.486] | 0.417 | **1** | 0.051 | 8 |
| | | | The volume of economic activity of the region | [0.285; 0.429] | 0.357 | 2 | 0.044 | 9 |
| | | | Population of the nearby region | [0.186; 0.266] | 0.226 | 3 | 0.028 | 11 |
| Transportation Connections | [0.289; 0.403] | 0.346 | Nearest airport distance | [0.142; 0.197] | 0.169 | 3 | 0.059 | 6 |
| | | | Transportation diversity of the region | [0.528; 0.724] | 0.626 | **1** | 0.217 | **1** |
| | | | Airport infrastructure and superstructure | [0.170; 0.240] | 0.205 | 2 | 0.071 | 5 |
| Supply, Infrastructure and Costs | [0.346; 0.479] | 0.412 | Proximity to key production locations | [0.410; 0.585] | 0.498 | **1** | 0.205 | 2 |
| | | | Structure of existing warehouses | [0.300; 0.424] | 0.362 | 2 | 0.149 | 3 |
| | | | Airport operating costs | [0.115; 0.165] | 0.140 | 3 | 0.058 | 7 |
| External Factors | [0.099; 0.140] | 0.119 | Geographical location and structure | [0.387; 0.521] | 0.681 | **1** | 0.081 | 4 |
| | | | Climatic conditions in the airport region | [0.181; 0.244] | 0.320 | 2 | 0.038 | 10 |

The data presented in Table 6 show the importance levels of the main criteria categories, the importance levels of the sub-criteria within each category, and the importance levels of all 11 criteria in comparison to each other. According to these results;

Based on the crisp importance levels of the four main categories; “Supply, Infrastructure and Costs” is the factor with the highest importance among the categories with 41.2%, “External Factors” category stands out as the factor with the least important among all criteria categories with 11.9%.

The importance levels of the criteria within each category shows that; the most important sub-criterion among the main criteria category “Consumer” is “proximity to major consumption locations” with 41.7%. In this group, “population of the nearby region” criterion is the least important one with 22.6% compared to the other two criteria

The sub-criterion, which has the highest degree of importance in the "Transportation Connections" category, is the "transportation diversity of the region" criterion with a rate of 62.6%. Among this group, the one that has less importance compared to the other two criteria with a rate of 16.9% is the "nearest airport distance" criterion.

Within the “Supply, Infrastructure and Costs” category, the most important sub-criterion is “proximity to key production locations” with 49.8%. The "airport operating costs" criterion is the one that has less importance compared to the other two criteria with a rate of 14% in this category.

The “geographical location and structure” criterion has the highest degree of importance with a rate of 68% in the “External Factors” category. The criterion with less importance is "climatic conditions in the airport region" with a rate of 32%.

According to the normalized weights of 11 sub-criteria of 4 main categories; it is seen that the most important criterion among all is “transportation diversity of the region” with a rate of 21.7%. On the other hand, the criterion with the least important among all criteria was evaluated as “population of the nearby region” with a rate of 2.8%.

Within the scope of the findings, “Supply, Infrastructure and Costs” and “Transportation Connections” criteria emerge as criteria that should be emphasized when choosing CH locations for air cargo companies. For air cargo businesses, some of the 11 sub-criteria under the 4 main criteria determined in this study are generally similar to the criteria considered in the selection of the location of the businesses. These criteria are as follows; “transportation diversity of the region”, “the volume of economic activity of the region”, “proximity to key production locations”, “proximity to major consumption locations”, “geographical location and structure”, “population of the nearby region”. In contrast, the criteria: “structure of existing warehouses”, “airport infrastructure and superstructure”, “nearest airport distance”, “airport operating costs”, “climatic conditions in the airport region” are specific to air cargo transportation. Among the 11 sub-criteria determined within the scope of the study, the "transportation diversity of the region", "proximity to key production locations" and "structure of existing warehouses" criteria are the three criteria with the highest level of importance, and that air cargo companies should pay the most attention when choosing CH location.

A similar study found in the literature on the location selection decision of air cargo companies belongs to Gardiner et al. (2005). The most important criterion determined in this study was "performing the operations at night hours and minimizing the costs" at the selected location. When the findings of this study are compared with their findings; it is seen that there is a parallelism between the criteria of "airport operating costs" and "minimizing the total costs", and the criteria of "transportation diversity of the region" and "access to the airport". However, the importance of these criteria varies in each study. The main difference between the two studies is their study is done within the scope of location selection at the global level. Whereas, this study constrains the location selection decision within one country which is Turkiye. This focus contains valuable insights for application, since the geographical structure of Turkiye contains great diversity, and the regional production and consumption levels are different due to the uneven distribution of demographics. From this point of view, the criteria of “proximity to production sources” and “geographical conditions” differ from the findings in the literature, and in this respect, they offer a contribution to the literature. From another point of view, as an explanation it can be stated that Turkiye’s significant regional development differences are the reason why these criteria come to the fore.

## 4. Conclusion

The air cargo transportation has many advantages compare to the other transportation modes with its defining features such as speed, security, safety, and transportation service to the distant locations. In particular, companies that prefer the collect-distribute network system, aiming to achieve their activities most efficiently and embracing profit maximization, need a comprehensive analysis for airports with a collect-distribute network system. Collect-distribute network structure has strategic importance for air cargo companies. Factors that are closely linked to the company's existence, are the efficiency of operations and cost management, and determine the company's strategy and decisions. With this priority, this study was conducted for the determination of the CH location criteria and importance levels of air cargo companies in Turkiye. The main limitation of the study is that the number of air cargo companies participating in the study does not allow the results to be quantitatively representative of the entire industry. On the other hand, it can be said qualitatively that the companies for which data is collected in practice are the most important companies operating in Turkiye and that other companies follow their practices, providing sufficient information on sector representation.

The most important criterion for air cargo companies in choosing a location is that the airport should be structurally suitable for cargo operations. Thus, it can be stated that airport equipment is at the forefront of the issues that companies performing air cargo operations in Turkiye. In this study, both production and consumption balance came to the fore as criteria close to each other with the industrialization rate. From this point of view, it can be deduced that the companies that will choose a location as an air cargo company in Turkiye should make a location selection considering the industrialization and agricultural geography.

The results of the research highlight the operational suitability of airport conditions in the location selection decision of air cargo companies. From this point of view, the equipment and operations of the new airports to be built should increase the diversity of services and support the convenience of cargo operations. Since this is the first exploratory study on this subject in Turkiye, it would be beneficial for the sector to examine the site selection criteria and priorities for air cargo operations by repeating the study with a wider participation in future studies with an increase in the number of airports that allow air cargo operations.

## Ethical approval

Ethical approval for this study was obtained from Social Sciences and Humanities Scientific Research and Publication Ethics Board at Hatay Mustafa Kemal University (07/03/2022-No.24).

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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