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IMPORTANCE LEVELS DETERMINATION OF THE PROBLEMS RELATED TO AIRLINE CARGO LOAD PLANNING USING BY THE AHP METHOD [1]

Master's Student Esra YELKEN [2]

Associate Professor Savaş Selahattin ATEŞ [3]

ABSTRACT

Air cargo transportation has developed continuously from the past to the present and it still continues to develop in this direction. Therefore, air cargo transportation is important both commercially and economically. As the demand in air cargo transportation increases, the issue of load planning has become even more valuable. The aim of this study is to determine the problems studied by academicians in the literature on load planning in Air Cargo Transportation and to discuss them with the employees of the Turkey Airline Cargo Sector and to determine the importance of the problems with the Analytical Hierarchy Process (AHP). The problems were obtained from studies in the literature. In order to determine the importance levels of the problems determined in this direction, the Analytical Hierarchy Process Method was analyzed with the "Expert Choice 11" program. The problems encountered in air cargo transportation are handled with a hierarchical structure consisting of three main criteria and six sub-criteria. As a result of the study, while safety was determined as the most important main criterion, it was seen that weight and balance were the most important sub-criteria. The criterion with the lowest level of importance was determined as accelerating the process. It is thought that the data obtained as a result of the research can be used to determine the investment priority of air cargo companies in terms of efficiency, cost and productivity in load planning. Thus, operational disruptions and possible accidents can be reduced. In future research, the results of this research will be guiding so that air cargo companies can design a safe and reliable load planning process.

Keywords: Air Cargo Transportation, Load planning, AHP

JEL Codes: L91, L93, R42

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[2]Anadolu University, Civil Aviation Management Master's Student with Thesis, yelkenesra@outlook.com (ORCID: 0000-0002-0585-1096)

[3]Associate Professor Eskisehir Technical University, Department of Aviation Management, ssates@eskisehir.edu.tr (ORCID: 0000-0003-2462-0039)

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AHP METODU KULLANILARAK HAVAYOLU KARGO YÜK PLANLAMASINA İLİŞKİN PROBLEMLERİN ÖNEM DÜZEYLERİNİN BELİRLENMESİ

ÖZET

Hava kargo taşımacılığı geçmişten günümüze kadar sürekli olarak gelişme göstermiş ve bu doğrultuda hala gelişmeye devam etmektedir. Bu yüzden hava kargo taşımacılığı hem ticari hem de ekonomik anlamda önem arz etmektedir. Hava kargo taşımacılığındaki talep arttıkça yük planlama konusu daha da değerli hale gelmiştir. Bu çalışmanın amacı, Hava Kargo Taşımacılığında yük planlamasına ilişkin literatürde akademisyenler tarafından çalışılan problemlerin belirlenerek Türkiye Havayolu Kargo sektörü çalışanlarıyla tartışılması ve problemlerin önem derecelerinin Analitik Hiyerarşi Prosesi (AHP) ile belirlenmesidir. Problemler literatürdeki çalışmalardan elde edilmiştir. Bu doğrultuda belirlenen problemlerin önem düzeylerini belirlemek için Analitik Hiyerarşi Proses Yöntemi "Expert Choice 11" programıyla analiz edilmiştir. Hava kargo taşımacılığında karşılaşılan problemler 3 ana kriter ve 6 alt kriterden oluşan hiyerarşik yapıyla ele alınmıştır. Çalışma sonucunda emniyet en önemli ana kriter olarak belirlenirken ağırlık ve denge en önemli alt kriter olduğu görülmüştür. Önem düzeyi en düşük kriter ise sürecin hızlandırılması olarak belirlenmiştir. Araştırmanın sonucunda ortaya çıkan verilerin havayolu kargo işletmelerinin yük planlamada etkinlik, maliyet ve verimlilik açısından yatırım önceliğinin belirlenmesinde kullanılabileceği düşünülmektedir. Böylece operasyon aksaklıkları ve olası kazalar azaltılabilir. Gelecek araştırmalarda havayolu kargo işletmeleri emniyetli ve güvenilir bir yük planlama sürecini tasarlayabilmesi için bu araştırmanın sonuçları yol gösterici olacaktır.

Anahtar Kelimeler: Hava kargo taşımacılığı, Yük planlama, AHP

Jel Kodları: L91, L93, R42

INTRODUCTION

Air cargo transportation carries about 35% of world trade by value, 52 million metric tons of cargo by volume, and a total of more than 6 trillion US dollars. In particular, air cargo transportation, which came to the agenda with the delivery of Covid-19 vaccines to the world in 2020, is a sector that saves the lives of more than 2.5 million people every year. With the technological solutions and standard procedures used by air cargo transportation in the supply chain, vaccines have been able to be transported over a long distance at storage standards. The increasing volume of e-commerce everyday accounts for an annual volume of 7.4 billion postal package shipments, and air cargo transportation plays an important role in their delivery (IATA, 2021). According to the forecasts made for the future, in terms of ton-kilometer revenue (RTK) growth, air cargo transportation is expected to grow by 4.1% and airmail is expected to increase by an average of 1.7% annually until 2039. Overall, it is estimated that world air cargo traffic will more than double in the next 20 years. It is estimated that the value, which was 264 billion RTK in 2019, will increase to 578 billion RTK in 2039. In addition, it is expected that the number of aircraft in the cargo fleet will increase by 60% and reach 3,260 in the next 20 years (Boeing World Air Cargo Forecast Team, 2020). Limitations due to maximum take-off weight, balance, aircraft body size and restrictions on types of cargo such as hazardous materials are some of the natural obstacles of air cargo transportation. The issue of minimizing fuel consumption is important in terms of carbon footprint, which is always on the agenda. The existence of these limitations requires good

planning of the processes at every stage. There is always the possibility that mistakes made in load planning can lead to large financial losses. A small mistake or loss of time will have big consequences, which will have negative consequences in terms of profitability. When load planning is done correctly, it can provide a competitive advantage in terms of price. It can help to increase delivery capacity and reduce overheads, as well as increase profit margins (OptimoRoute, 2021). The aim of this study is to identify the problems studied by academics in the literature on load planning in Air Cargo Transportation and to discuss them with employees of the Turkish Airline Cargo sector and to determine the importance of the problems with the Analytical Hierarchy Process (AHP). With the data obtained, the importance levels of the criteria were analyzed with the "Expert Choice 11" program.

1. LITERATURE REVIEW

In the literature research conducted on load planning, it has been observed that researchers generally address load planning problems, cargo handling optimization and a number of related problems as a topic. Different methods have been proposed as solutions to these issues. They have usually developed computer-aided programs to these solutions. It is evident from the research that the development of computer-aided programs clearly accelerates the operation. In this respect, the contribution of these programs is great. There are factors to be considered while load planning. Various researchers have tried to find the optimal solution to these factors. The literature review was ordered chronologically with various studies from 1994 to 2021. For example, Richardson, C. J. and others (1994) consider in their work the problem of facilitating the load planning process for military cargo aircraft with the development of a computer-based system. This system is called TALBAS (Transport Aircraft Loading and Balancing System). Thanks to this system, valid cargo arrangements, given a list of goods to be transported, are automatically created, load plans are defined and automatically verified by the user (Richardson, Labbe, Belala, & Leduc, 1994). Another point of attention is the following in the researches; minimizing fuel consumption. For this, Mongeau, M. & Bes, C. (2003), in their articles, they addressed the problem of loading aircraft in order to improve fuel consumption by optimizing freight revenue. For this, six test problems were first created (a list of six containers of different types and various masses to be loaded onto an Airbus A340-300 aircraft). As a result of calculations according to the general formula, they found out how to solve the problem on a computer in ten minutes with ready-made integer linear programming software (Mongeau & Bés, 2003). On the one hand, the fact that this article is aimed at improving fuel consumption provides a versatile advantage. While reducing the expenses of airlines, there has been a situation where more cargo can be transported with less fuel. Another factor that we face is the issue of speed. Fok K., Chun A. Et al. (2004) presented a Web-based application called "CLPA System" with mathematical optimization suggestion to help load planning by considering the top 10 airline cargo companies in the world in their research. For this purpose, they have created a data store by handling historical data. Load planning was carried out using MATLAB and

Mosek programs. The load analysis of the approximately 36,000 records in the data warehouse took between 10 and 20 seconds, depending on the analysis performed. Load planning for a single aircraft took about 40 seconds on average on a PC-class server. The result obtained confirmed the feasibility of technical and performance and became an acceptable condition. Airlines handle about 80 to 90 thousand tons of cargo every month. With this cargo volume, it is clear that even the slightest improvement in the load planning process will have a huge impact on overall performance and efficiency (Fok, Chun, & diğerleri, 2004).

In another study, the critical points of load planning were realized again with computer-based analysis. For this, Daçe, A. (2007), in his master's thesis study, the issue of reducing the human factor in loading cargo planes, making the loading closer to ideal values and making the maximum loading were discussed. In this study, loading optimization of A310-304F model cargo aircraft was performed. The aim is to stop the installation from being human-based and to make the safest and most economical installation in less time with a computer solution. The main goal of the solution is to save fuel by bringing the center of gravity closer to the ideal while loading cargo to the aircraft as much as possible. The heuristic solution algorithm for loading optimization has been designed and turned into a computer program in C++. The program decides which cargoes will be loaded and where they will be loaded. The algorithm works according to a method based on weights, where weight constraints are taken into account, rather than a volumetric approach. If we need to think about the advantages gained thanks to the computer installation in the examples, the first of them is flight safety and the prevention of human error. Another advantage is the reduction of fuel consumption by bringing the center of gravity closer to the ideal. The MAC length of the aircraft is 5,8287 m. If we consider this as a percentage, it corresponds to 5.8287 cm for each unit. For an aircraft of this size, approximately for every ten thousand kilometers of flight, a displacement of the center of gravity by 1 cm means a fuel consumption of 50 kg. Thanks to these, both monetary losses will be reduced and air transportation, which is one of the sectors that has the greatest share in the global warming problem that is being discussed today, will be improved (Daçe, 2007). The integer linear programs mentioned earlier have been covered by another researcher at another date. Limbourg, S. Et al. (2012), the goal in their work is the development of a new mixed integer linear program designed to optimally load a set of containers and pallets onto a segmented cargo aircraft. This model also takes into account strict technical and safety restrictions. They also propose a new approach based on the moment of inertia, in addition to the standard goal of optimally positioning the center of gravity. This dual objective means an increase in aircraft efficiency and a reduction in fuel consumption. A fully automated software has been developed to quickly calculate the optimal solutions. Experimental results show that this approach achieves better solutions than manual planning in just a

few seconds. They also proved that it leads to a decrease in pressure on the aircraft structure and a significant improvement in the maneuverability of the aircraft (Limbourg, Schyns, & Laporte, 2012).

Again, in another study, the issue of minimizing fuel consumption was discussed. Chenguang, Y. Et al. (2018), in their research, due to the rapid development of air transportation and the great interest in loading aircraft, a new hybrid algorithm based on two-dimensional chamber packaging with a genetic algorithm (GA) was proposed. The main purpose of this is to ensure minimal fuel consumption and solve the problem of multi-restricted loading of transport aircraft. The optimal result obtained showed that this algorithm can quickly create the best plan for the loading problem related to lower transportation costs. Given the various constraints of air transport loading, a new Hybrid Genetic Algorithm (HGA) has been proposed for the aircraft loading problem. The interest of this algorithm is to facilitate the convergence of cycles by combining the heuristic algorithm of single aircraft loading (HA) with the Genetic algorithm (GA) based on two-dimensional chamber box planning. The high efficiency and applicability of HGA has been proven in the case study. The created optimal loading plan reduces the total fuel consumption and improves transport efficiency, provides better auxiliary options for load planning of transport aircraft (Chenguang, Hu, & Yuan, 2018). It is important to address the problems in load planning. An example of an article that will benefit our research on problems was made by Brandt and Nickel in 2019. The purpose of their work is to provide a large benchmarking dataset for future research by analyzing large-scale world flights and discussing the typical problem structure in practice. The current planning process and the four sub-problems that airlines must solve during this process have been identified. These are: aircraft configuration, construction planning, palletizing, weight and balance issues. Discussion was made by dividing these problems into their sub-branches. They think that it will be useful for the literature for future research to address these problems and create solutions to them.(Brandt & Nickel, 2019).

After the previous study, the important criteria in load planning were discussed by another researchers. The fact that these issues are being addressed by many researchers increases the importance of this issue. Wong, E. And others (2020), in their articles, discussed the issues of real-time visualization, loading optimization, weight balancing and oversized cargo handling. The main reason for this is that these issues are becoming increasingly important due to dynamic loading considerations. Therefore, they have developed a closed-loop dynamic air cargo loading digital twin system that integrates them. For this, a virtual reality system based on the Cave Automatic Virtual Environment (CAVE) is used to visualize and experiment with the installation procedures. This system uses a feedback loop during the capture of sensor data to facilitate decision-making processes on the optimal cargo load plan. The developed optimization model helps planners in determining the optimal location of each ULD in loading into various compartments of an aircraft, taking into account factors such as cargo size and contour, unloading places, weight, separation of dangerous goods and cargo urgency. It also aims to

achieve a tracking and detection system with a feedback loop from physical operations to the digital space for more efficient cargo loading operations. In this way, cargo planners can master complex air cargo load planning. They believe, Cargo assembly and security screening operations with digital twins can be further improved for future developments (Wong, Mo, & So, 2020). In another article, which is quite new, the difficulties of air cargo were mentioned. Sahun, Y. & Bebitowa, F. (2021), mentioned the main challenges in air cargo transportation. One of these difficulties, according to the article, is how to determine the cargo on the plane without exceeding safety restrictions and including profitable aspects. The study deals with the elaboration of the intellectual multi-criteria load optimization model on a multi-leg route based on the newly developed cargo aircraft load planning algorithm. According to the results of the study, the data obtained Intellectual Integrated Multi-Criteria Optimization Model improved the airline staff's ability to make decisions faster and predict the additional load on other flight legs. The successful implementation of the model in airline operations contributes to the improvement of handling service safety and efficiency. Therefore, it supports the acceleration of the return time of the aircraft (Sahun & Bebitowa, 2021).

2. METHOD

The aim of this study is to identify the problems studied by academics in the literature on load planning in Air Cargo Transportation and to discuss them with employees of the Turkish Airline Cargo sector and to determine the importance of the problems with the Analytical Hierarchy Process (AHP). With the data obtained, the importance levels of the criteria were analyzed with the "Expert Choice 11" program.

The research is planned for businesses all over the world that are interested in load planning activities in air cargo. This study was conducted by using the secondary data obtained from the literature review. The research was conducted between October 2021 and November 2021 using the online databases Google Scholar, Semantic Scholar and Ulusal Tez Merkezi. The following words were used as keywords for Turkish literature:

1. "Yük Planlama"
2. "Yük Optimizasyonu"

For the English literature, articles between 2003 and 2021 were searched using the following words:

1. "Air Cargo"
2. "Load Factor"
3. "Load Planning"
4. "Weight and Balance"

Articles containing the problems encountered in Air Cargo load planning were determined as the main universe. Therefore, the sample consists of accessible articles. In addition, the number of people to be interviewed is 5 people. These people only work in the air cargo sector. As a scope of research, only load planning problems for air cargo have been identified. Articles containing load planning problems related to passenger aircraft have not been examined.

The Analytical Hierarchy Process (AHP) is an approach used in decision-making developed by Saaty in 1977. This method offers solutions to decision and prediction problems in multivariate environments. AHP establishes priority weights for alternatives by organizing objectives, criteria and sub-criteria in a hierarchical structure (Bernasconi, Choirat, & Seri, 2010). The form used to structure a decision problem is a hierarchy consisting of three levels. At the highest and first level is the purpose of the decision. At the second level, there are criteria. Finally, the third level consists of alternatives (Saaty & Vargas, 2012).

3. FINDINGS AND ANALYSIS

The problems focused on in the examined articles are listed as can be seen in Table 1. As a result, criteria were determined in accordance with the problems identified. Three problems were identified as the main Criteria. These are: Minimum Cost, safety and aircraft configuration. Two sub-criteria have been determined for these main criteria. The sub-criteria for minimum cost include minimum fuel consumption and acceleration of the load planning process. The sub-criteria for safety, weight and balance, include the human factor. The sub-criteria for the aircraft configuration consist of the maximum payload loading and the placement plan of the ULDs. Then, the Analytical Hierarchy Process (AHP) method was applied with these criteria.

Table 1. Problems in the Literature

	Problems That Are Concerned	(Mongeau & Bès, 2003)	(Fok, Chun, & diğerleri, 2004)	(Daçe, 2007)	(Souffriau, Berghe, Demeester, & Causmaecker, 2008)	(Limbourg, Schyns, & Laporte, 2012)	(Lurkin & Schyns, 2015)	(Chenguang, Hu, & Yuan, 2018)	(Brandt & Nickel, 2019)	(Wong, Mo, & So, 2020)	(Sahun & Bebitowa, 2021)
1	Acceleration of The Load Planning Process		**X**			**X**				**X**	**X**
2	Maximum Payload Loading	**X**		**X**	**X**					**X**	
3	Safety				**X**						**X**
4	Minimum Fuel Consumption	**X**		**X**			**X**	**X**			
5	Aircraft Configuration								**X**		
6	Weight And Balance			**X**	**X**	**X**	**X**		**X**	**X**	
7	Minimum Cost						**X**				
8	Human Factor			**X**							

9	Placement Plan of The Ulds	**X**						**X**		**X**				**X**							**X**
10	Palletizing													**X**							

For the criteria, interviews were conducted using the structured interview technique with "load master" i.e. "load planners" from air cargo employees in Türkiye. First of all, a scale has been prepared for pairwise comparison (Table 2). The criteria and sub-criteria included in the study are stated in the content of the scale. Then, an explanation of each element in the study is given and an example of how to implement the application is shown. Decisively, the participants were then asked to compare the criteria among themselves. In line with this scale, the opinions of the people who participated in the interview were evaluated. In accordance with the answers, the geometric mean of the scores given to the criteria was calculated by taking their weights and the importance levels were determined in the "Expert Choice 11" program. The scale 1-9 proposed by Saaty was used for scaling (Table 3).

Table 2. Scale

ANA KRİTERLER KARŞILAŞTIRMASI																	
Hava kargo yük planlama yaparken sizce aşağıdaki kriterlerden hangisi daha önemlidir? İkili karşılaştırma yaparak ugun kutucuğa 'X' işareti koyunuz.																	
A	Tamamen Önemli		Çok Fazla Önemli		Fazla Önemli		Biraz Önemli		Eşit Önemli	Biraz Önemli		Fazla Önemli		Çok Fazla Önemli		Tamamen Önemli		**B**
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Minimum Maliyet																		Uçak Konfigürasyonu
Minimum Maliyet																		Emniyet
Uçak Konfigürasyonu																		Emniyet

Table 3. Scale Used in Pairwise Comparison of Criteria (Saaty & Vargas, 2012)

Point	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Important	Experience and judgment, strongly favor one activity over another
5	Strong Importance	Experience and judgment, strongly favor one activity over another
7	Very Strong Importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute/Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Immediate values between above scale	When compromise is needed

While the purpose of the problem, which is the first stage of the model, is included in creating a hierarchical structure, the second stage includes evaluation criteria and the third stage includes sub-criteria related to them (Figure 1).

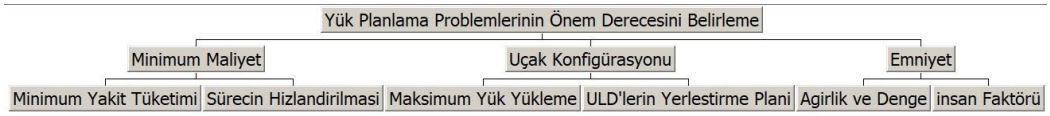

Figure 1. Hierarchical Structure

In the application part, firstly, the decision matrix formed by comparing the 3 main criteria in pairs is given in Figure 2. According to the answers given to the scale, weighting was calculated for each criterion. Accordingly, safety is one of the most important problems with a weight coefficient of 0.699. This is followed in turn by the aircraft configuration with a weight coefficient of 0.237 and a minimum cost of 0.064. If the inconsistency value is less than 0.10, the operations performed are seen as consistent. Thus, since the inconsistency value of the operations performed here is 0.09, these results are considered consistent.

Figure 2. Comparison of Main Criteria

After comparing the main criteria, a comparison was also made for the sub-criteria (Figure 3). Accordingly, the problem that received the most attention was the weight and balance problem with a value of 0.629. In other problems, the placement plan of the ULDs is ranked by a weight coefficient of 0.198; minimum fuel consumption is 0.054; maximum load loading is 0.040; human factor is 0.070; acceleration of the process is 0.011.

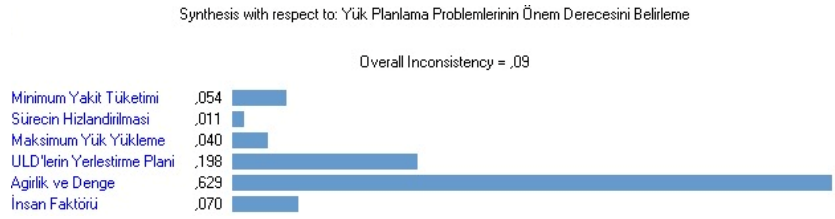

Figure 3. Comparison of Sub-Criteria

The final significance levels are given in table 4.

Table 4. Ultimate Significance Levels

Main Criteria	Main Criteria Weight	Sub-Criteria	Sub-Criteria Weight	Ranking
Safety	0,699			
		Weight and Balance	0,629	1
		Human Factor	0,070	3

Aircraft Configuration	0,237			
		Maximum Payload Loading	0,040	5
		Placement Plan of The Ulds	0,198	2
Minimum Cost	0,064			
		Minimum Fuel Consumption	0,054	4
		Acceleration of The Load Planning Process	0,011	6

CONCLUSIONS AND RECOMMENDATIONS

The aim of this research is to determine the importance of the problems in the literature related to load planning in air cargo by discussing them with aviation employees. The obtained data were analyzed with the "Expert Choice 11" program using the Analytical Hierarchy Method.

First of all, a literature review was conducted for the problems encountered in load planning, and 3 main criteria and 2 sub-criteria were determined for each of them. Randomly selected people working as Load Masters in air cargo in Türkiye were interviewed and weighted for the criteria. According to the results obtained, it has been determined that the most important main criterion in load planning is safety. This is followed by the aircraft configuration and the minimum cost, respectively. In this direction, the most important consideration for safety was the weight and balance criteria, while the placement plan of the ULDs for the aircraft configuration and the minimum fuel consumption for the minimum cost were. The fact that the consistency ratio for the analysis is 0.09 increases the accuracy of the study.

The criteria determined consist of the most talked about problems in the literature. Therefore, it is thought that determining the final importance of these will be important for load planners and provide convenience. Paying more attention to these criteria will reduce the adverse situations or accidents that will be experienced, and will create a safer and reliable load planning process. In addition, these criteria are actions aimed at shortening the total load planning process. While incorrect calculations or applications slow down the process, the more attention is paid to these criteria, the likelihood of undesirable situations will decrease.

It is thought that the data obtained as a result of the research can be used to determine the investment priority of airline cargo enterprises in terms of efficiency, cost and efficiency in cargo planning. Thus, operational disruptions and possible accidents can be reduced. In future studies, the results of this research will be a guide for airline cargo operators to design a safe and reliable load planning process.

In this study, only the load planning process in air cargo was taken into account. In future studies, the criteria here can be increased more or the problems encountered in the load planning process for passenger aircraft can be addressed. It will be more effective to determine the problems by

interviewing the people working in load planning here. The use of different or integrated methods for future studies will contribute to the enrichment of the literature. In addition, this model can also be taken into account in load planning processes in other transport sectors.

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