Optimal Airport Selection for Iraq's Infrastructure Development: A TOPSIS Analysis

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ABSTRACT

This study investigates the application of the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method to enhance Iraq's airport infrastructure. The research aims to analyze the performance of major airports based on data collected from the Central Statistical Organization (CSO) of Iraq. A model is proposed to prioritize the airport development projects based on essential criteria, such as aircraft movement (landing and takeoff) and passenger movement (arrivals and departures). The airports are ranked according to the priority they have in infrastructure development, which is linked to their economic growth. In terms of priority, the first is Baghdad International Airport, Basra Airport follows, and Najaf Airport ranks third. Erbil and Sulaymaniyah airports rank lower due to infrastructure limitations and administrative challenges. The research underscores the importance of ongoing investments in airport infrastructure to accommodate the increasing number of passengers and bolster economic expansion.

Keywords-MCDM; TOPSIS; airport development; aviation infrastructure; flight analysis; international travelers; decision support

I. INTRODUCTION

Airports development through Multi-Criteria Decision Making (MCDM) methods is crucial for sustainable and efficient infrastructure growth, which is emphasized by various studies [1]. MCDM is an approach aimed at helping leaders and managers make decisions when facing complex challenges, involving a range of objectives. The former allows different options to be evaluated after being worked out and the best of them to be chosen based on different criteria [2]. MCDM models are utilized to assess performance standards, prioritize investments, and determine optimal strategies for airport development [3-5]. There are various approaches to MCDM problems. One of them is TOPSIS, which solves these problems employing many alternatives.

TOPSIS is an MCDM method for ranking alternatives based on their proximity to an ideal solution. The approach considers each alternative's positive and negative aspects. The ideal solution represents the best possible values for each criterion, while the negative ideal solution represents the worst values [6] .TOPSIS has demonstrated its effectiveness in various fields and showcased its versatility and implementation in straightforward decision-making scenarios. Its successful applications include project selection, supplier evaluation, site selection, supplier selection in manufacturing, assessment of service quality, choice and ranking of renewable energy sources, supply chain management (particularly in green supply chain and sustainable solutions), energy policy selection, renewable energy source ranking, and healthcare industry (specifically in choosing treatments for conditions like acute cerebrovascular disease) [7, 8]. TOPSIS presents multiple advantages and disadvantages in its application. On the advantageous side, TOPSIS offers a practical solution for discrete alternative challenges and is a significant approach to addressing real-world problems. Additionally, TOPSIS reduces the pairwise comparisons required, which makes it applicable to scenarios with numerous alternatives and attributes. Furthermore, its reliance on quantitative or objective data enhances its utility in decision-making. However, TOPSIS also exhibits limitations. It lacks provisions for weighing elicitation, ensuring judgment consistency, and potentially impacting the reliability of outcomes. Moreover, it does not account for the relative importance of distances between alternatives, which could affect the accuracy of rankings [9].

The aviation and air transportation sectors are a vital economic cornerstone in financial development through sustainable and successful growth and reliance on advanced scientific methodologies [10, 11]. The urgent need to focus on these sectors has emerged for developing countries in general and particularly for Iraq, given its significant economic dimensions on a national level. Both sectors are essential to economic progress requiring adequate planning and studies across their domains to achieve real advancement [12]. The aviation sector holds a prominent position in developmental transportation by facilitating the transport of passengers' cargo, baggage, and mail across borders, basin transportation operations, while enhancing international connections. Air transportation is considered a fundamental modern transportation means due to its extraordinary speed, which enables it to cover extensive distances. Supporting this sector leads to the provision of transportation means that meet the requirements of the regular commercial air transport, which holds great economic significance [13].

II. RESEARCH PROBLEM

The challenge addressed in this study revolves around the optimal selection of airports for developing Iraq's infrastructure. This selection should be performed on the basis of strategic investment and development to enhance the country's aviation sector. It includes such tasks as identifying the key criteria and factors for choosing airports that have development priorities. A relevant decision-making technique is introduced to rationalize resource utilization and optimize the related to airport infrastructure development benefits.

III. METHODOLOGY

A. Research Objective

This research is looking for airports, which seem to be already successful, but it is possible for their infrastructure to be improved to respond to further growth. The focus is on additional services and on ameliorating the airplane and air travel experience, while supporting airports become the major nodal points in terms of the air linkage in Iraq.

B. Data Collection

The data for this research were collected from the Central Statistical Organization (CSO) in Iraq. This organization has gained recognition for its dependable provision of thorough and current statistics. The statistics includes essential statistics on aircraft moves (landings and takeoff) and passenger moves (arrivals and departures) at numerous airports in Iraq. It is important to note that the data have been sourced up to the latest update available, ensuring they cover information until 2022. The research and data collection procedures adopted a neutral approach guided by fairness and objectivity without predisposed biases towards a singular airport or region.

C. Methods Used

The study utilized the MCDM, while rating potential airport projects and factors like aircraft and passenger movements were included. TOPSIS has a comparative advantage in case of multi criteria problems, which in turn supported its effectiveness in multi criterion decision-making scenarios. TOPSIS is one of the multiple criteria decision-making methods initially introduced by [14]. This approach operates on the principle that selected alternatives should minimize the distance to the positive ideal solution and maximize the distance from the negative ideal solution, a concept visualized geometrically using Euclidean distance [6]. The positive ideal solution aggregates the best achievable values for each attribute, while the negative one compiles the worst ones. TOPSIS considers both distances by evaluating the relative proximity to the positive ideal solution. In the present study, a priority order for the alternatives is established by comparing the relative distances.

D. Procedure and Application of TOPSIS Method

The TOPSIS method assessed and ranked airports based on their performance scores. This involved formulating a decision matrix, normalizing data, calculating ideal solutions, determining distances from ideal solutions, and ranking alternatives based on their relative closeness to the ideal solution.

1) Procedure

The procedure of this method is [14, 15]:

Step 1: Create a decision matrix:

$$R = [xij]m \times n \tag{1}$$

Step 2: Normalize the decision matrix:

$$\bar{X}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{2}$$

Step 3: Construct the weighted normalized decision matrix:

r_{ij} : normalized decision matrix:

$$v_{ij} = w_j r_{ij} \tag{3}$$

w_j: weight of the *j*th criteria (attribute), under the condition:

$$\sum_{j=1}^{n} w_j = 1 \tag{4}$$

Step 4: Calculate the ideal best $\mathcal{V}_j^+$ and ideal worst $\mathcal{V}_j^-$ values.

If beneficial criteria:

$$\mathcal{V}_j^+ = \max_i(v_{ij}) = \max\{v_{ij}, i = 1, \dots, m\} \tag{5}$$

If cost criteria:

$$\mathcal{V}_j^+ = \min_i(v_{ij}) = \min\{v_{ij}, i = 1, \dots, m\} \tag{6}$$

Step 5: Calculate the distances of each alternative from the positive ideal solution and the negative ideal solution:

$$S_i^{\pm} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - \mathcal{V}_j^{\pm}\right)^2} \tag{7}$$

Step 6: Calculate the relative closeness to the ideal solution (performance score):

$$R_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{8}$$

Step 7: Rank the alternatives. The ranking is done based on the values of R_i. Higher value of the relative closeness has a high rank and hence the better the performance of the alternative. The preference should be ranked in descending order.

2) Application

The TOPSIS method will be demonstrated using an airport selection problem. In this scenario, the set of alternatives includes Baghdad International Airport (BGW), Erbil International Airport (EBL), Sulaymaniyah International Airport (ISU), Basrah International Airport (BSR), and Najaf International Airport (NJF). The evaluation criteria are categorized as aircraft movement (Landing (AL), Takeoff (AT)) and passenger movement (Arrivals (PA), Departures(PD)).

Step 1: Create a decision matrix. The decision matrix is provided in Table I.

TABLE I. DECISION MATRIX

Airport	Aircraft's Movement		Passengers Movement	
	AL	AT	PA	PD
BGW	3,044	3,056	275,091	272,366
EBL	349	355	24,814	28,524
ISU	454	466	18,956	20,961
BSR	598	668	44,904	46,316
NJF	632	647	44,304	42,569
$\sum_{i=1}^{m} X_{ij}^2$	10,350,881	10,547,150	80,629,336,445	79,393,511,670
$\sqrt{\sum_{i=1}^{m} X_{ij}^2}$	3,217	3,248	283,953	281,769

Step 2: Normalize the decision matrix. To normalize the decision matrix, each entry is divided by $\sqrt{\sum_{i=1}^{m} X_{ij}^2}$. The result can be seen in Table II.

Step 3: Construct the weighted normalized decision matrix.

The assigned weights to the criteria reflect the careful considerations of decision-makers. For the aircraft movement category, equal importance is placed on both AT and AL, weighing 0.25 each. Similarly, in the passenger movement category, equal weight is given to PD and PA at 0.25 for each. These weight allocations underscore a balanced evaluation approach, emphasizing the significance of both departures and arrivals in aircraft and passenger movements. The decision-makers have meticulously crafted these weightings to ensure a comprehensive and unbiased assessment in the decision-making process.

TABLE II. NORMALIZED DECISION MATRIX

Airport	Aircraft's Movement		Passengers Movement	
	AL	AT	PA	PD
BGW	0.946	0.941	0.969	0.967
EBL	0.108	0.109	0.087	0.101
ISU	0.141	0.143	0.067	0.074
BSR	0.186	0.206	0.158	0.164
NJF	0.196	0.199	0.156	0.151

TABLE III. WEIGHTED NORMALIZED DECISION MATRIX

Weights Wj	**0.25**	**0.25**	**0.25**	**0.25**
Airport	**Aircraft's Movement**		**Passengers Movement**	
	AL	**AT**	**PA**	**PD**
BGW	0.237	0.235	0.242	0.242
EBL	0.027	0.027	0.022	0.025
ISU	0.035	0.036	0.017	0.019
BSR	0.047	0.052	0.040	0.041
NJF	0.049	0.050	0.039	0.038

Step 4: Calculate the ideal best $\mathcal{V}_j^+$ and ideal worst $\mathcal{V}_j^-$ values. The result can be seen in Table IV.

Step 5: Calculate the distances of each alternative from the positive ideal solution and the negative ideal solution. The results can be seen in Tables V and VI.

TABLE IV. POSITIVE AND NEGATIVE IDEAL SOLUTIONS

Airport	Aircraft's Movement		Passengers Movement	
	AL	AT	PA	PD
BGW	0.237	0.235	0.242	0.242
EBL	0.027	0.027	0.022	0.025
ISU	0.035	0.036	0.017	0.019
BSR	0.047	0.052	0.040	0.041
NJF	0.049	0.050	0.039	0.038
$\mathcal{V}_j^+$	0.237	0.235	0.242	0.242
$\mathcal{V}_j^-$	0.027	0.027	0.017	0.019

TABLE V. CALCULATION OF POSITIVE IDEAL SOLUTION

Airport	Aircraft's Movement		Passengers Movement		S_i^+
	AL	AT	PA	PD	
BGW	$(0.237\text{-}0.237)^2$	$(0.235\text{-}0.235)^2$	$(0.242\text{-}0.242)^2$	$(0.242\text{-}0.242)^2$	0.000
EBL	$(0.027\text{-}0.237)^2$	$(0.027\text{-}0.235)^2$	$(0.022\text{-}0.242)^2$	$(0.025\text{-}0.242)^2$	0.428
ISU	$(0.035\text{-}0.237)^2$	$(0.036\text{-}0.235)^2$	$(0.017\text{-}0.242)^2$	$(0.019\text{-}0.242)^2$	0.425
BSR	$(0.047\text{-}0.237)^2$	$(0.052\text{-}0.235)^2$	$(0.04\text{-}0.242)^2$	$(0.041\text{-}0.242)^2$	0.388
NJF	$(0.049\text{-}0.237)^2$	$(0.05\text{-}0.235)^2$	$(0.039\text{-}0.242)^2$	$(0.038\text{-}0.242)^2$	0.390

TABLE VI. CALCULATION OF NEGATIVE IDEAL SOLUTION

Airport	Aircraft's Movement		Passengers Movement		S_i^-
	AL	AT	PA	PD	
BGW	$(0.237\text{-}0.237)^2$	$(0.235\text{-}0.235)^2$	$(0.242\text{-}0.242)^2$	$(0.242\text{-}0.242)^2$	0.433
EBL	$(0.027\text{-}0.237)^2$	$(0.027\text{-}0.235)^2$	$(0.022\text{-}0.242)^2$	$(0.025\text{-}0.242)^2$	0.008
ISU	$(0.035\text{-}0.237)^2$	$(0.036\text{-}0.235)^2$	$(0.017\text{-}0.242)^2$	$(0.019\text{-}0.242)^2$	0.012
BSR	$(0.047\text{-}0.237)^2$	$(0.052\text{-}0.235)^2$	$(0.04\text{-}0.242)^2$	$(0.041\text{-}0.242)^2$	0.045
NJF	$(0.049\text{-}0.237)^2$	$(0.05\text{-}0.235)^2$	$(0.039\text{-}0.242)^2$	$(0.038\text{-}0.242)^2$	0.043

Step 6: Calculate the relative closeness to the ideal solution (performance score). Table VII shows the results.

TABLE VII. RELATIVE CLOSENESS CALCULATION

Airport	S_i^+	S_i^-	$S_i^+ + S_i^-$	R_i
BGW	0.000	0.433	0.433	1.000
EBL	0.428	0.008	0.436	0.018
ISU	0.425	0.012	0.437	0.027
BSR	0.388	0.045	0.433	0.104
NJF	0.390	0.043	0.433	0.099

Step 7: Rank the alternatives. Table VIII shows the ranking of the considered airports.

TABLE VIII. ALTERNATIVE RANKING

Airport	R_i	Rank
BGW	1.000	1
EBL	0.018	5
ISU	0.027	4
BSR	0.104	2
NJF	0.099	3

IV. RESULTS AND DISCUSSION

The results were derived by applying the TOPSIS methodology and are presented in Table VIII and Figure 1. Table VIII illustrates the final ranking of airports based on their relative performance. These rankings were determined by systematically evaluating each airport against predefined criteria. Figure 1 provides additional visual support to the results portrayed in Table IX. This comprehensive analysis helps better understand each airport's performance and facilitates informed decision-making in selecting the most suitable airport.

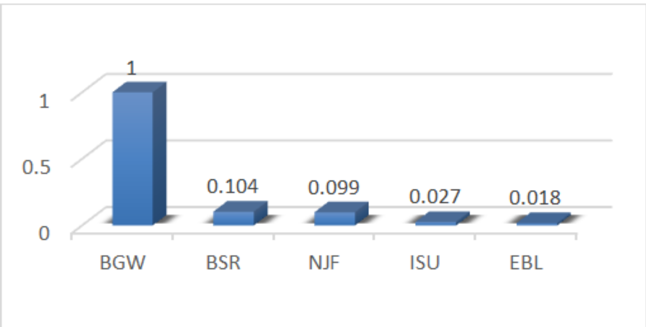

Fig. 1. Airport's relative performance ranking.

Baghdad airport stands first in the ranking, given its strategic location as the capital of Iraq and the main point of entry for aviation transport. Baghdad has a variety of aviation services and facilities that draw passengers and aircraft. When it comes to Basra Airport, it is in second place owing to its significant contribution to Iraq's economics through southern Iraq's oil industry and transportation. It is vital as a point of entry for goods and external services. Najaf Airport is in the third place being one of the significant places of worship for religious individuals and tourists. However, Erbil and Sulaymaniyah airports and their respective rankings in the fourth and fifth place might be due to several factors, one of which is their limited infrastructure. This administrative challenge may affect their capacity to handle increased aircraft and passenger traffic, which constitute obstacles in raising service quality, technology, and financing to positively influence their evaluation.

V. CONCLUSION

The Multi-Criteria Decision Making (MCDM) method and particularly the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) approach, were applied to assess and group airports according to aircraft movements and passenger flux, providing valuable findings for developing air transportation systems. The ratings acquired for airports, namely Baghdad International Airport, Erbil International Airport, Sulaymaniyah International Airport, Basrah International Airport, and Najaf International Airport, present a comprehensive picture of their performance in regulating aircraft operations and passenger movements.

According to the results, Baghdad International Airport has reached the top rank, emphasizing its high performance in supervising aircraft movements and passenger flow. On the contrary, Erbil International Airport was ranked lower and some areas that need improvement were proposed.

The following research should develop the valuation criteria, consider new factors, and expand the scope to other regional airports. Continuously developing air transportation infrastructure is vital for satisfying the ever-rising passenger demands and the country's economic growth.

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REFERENCES

[1] J. D. Gonzalez-Ruiz, E. A. Duque, and J. C. Restrepo, "Clean Development Mechanism in Airports: The Colombian Case," in *21st International Symposium on Advancement of Construction Management and Real Estate*, K. W. Chau, I. Y. S. Chan, W. Lu, and C. Webster, Eds. New York, NY, USA: Springer, 2018, pp. 481–490.

[2] S. A. Khan, A. Chaabane, and F. T. Dweiri, "Multi-criteria decision-making methods application in supply chain management: A systematic literature," in *Multi-Criteria Methods and Techniques Applied to Supply Chain Management*, V. Salomon, Ed. London, UK: IntechOpen, 2018, pp. 3–34.

[3] Z. Turskis, J. Antucheviciene, V. Kersuliene, and G. Gaidukas, "Hybrid Group MCDM Model to Select the Most Effective Alternative of the Second Runway of the Airport," *Symmetry*, vol. 11, no. 6, Jun. 2019, Art. no. 792, https://doi.org/10.3390/sym11060792.

[4] N. Meireles de Souza, M. Hazin Alencar, and A. Teixeira de Almeida Filho, "Multi-criteria model of runway pavement inspection policy using delay time modelling," in *International Conference on Systems, Man, and Cybernetics*, Banff, AB, Canada, Oct. 2017, pp. 3340–3343, https://doi.org/10.1109/SMC.2017.8123145.

[5] C. M. Silva, S. R. Granemann, P. Guarnieri, and G. L. Da Silva, "Measuring the Attractiveness of Cities to Receive Investments in

Regional Airport Infrastructure," *Mathematics*, vol. 10, no. 10, Jan. 2022, Art. no. 1734, https://doi.org/10.3390/math10101734.

[6] R. Rahim *et al.*, "TOPSIS Method Application for Decision Support System in Internal Control for Selecting Best Employees," *Journal of Physics: Conference Series*, vol. 1028, no. 1, Mar. 2018, Art. no. 012052, https://doi.org/10.1088/1742-6596/1028/1/012052.

[7] K. Palczewski and W. Sałabun, "The fuzzy TOPSIS applications in the last decade," *Procedia Computer Science*, vol. 159, pp. 2294–2303, Jan. 2019, https://doi.org/10.1016/j.procs.2019.09.404.

[8] N. Vafaei, R. A. Ribeiro, and L. M. Camarinha-Matos, "Data normalisation techniques in decision making: case study with TOPSIS method," *International Journal of Information and Decision Sciences*, vol. 10, no. 1, pp. 19–38, Jan. 2018, https://doi.org/10.1504/IJIDS.2018.090667.

[9] M. A. Alsalem *et al.*, "Systematic Review of an Automated Multiclass Detection and Classification System for Acute Leukaemia in Terms of Evaluation and Benchmarking, Open Challenges, Issues and Methodological Aspects," *Journal of Medical Systems*, vol. 42, no. 11, Sep. 2018, Art. no. 204, https://doi.org/10.1007/s10916-018-1064-9.

[10] N. Osman Aden, "Air Transportation and Socioeconomic Development: The Case of Djibouti," in *2nd International Conference on Robotics Systems and Vehicle Technology*, Xiamen, China, Dec. 2020, pp. 89–94, https://doi.org/10.1145/3450292.3450307.

[11] "للاحصاء المركزي الجهاز - النقل," *Authority of Statistics and Geographic Information Systems*. https://cosit.gov.iq/ar/2015-11-23-08-05-11.

[12] D. Dimitriou, "Air transport economic footprint in remote tourist regions," in *Mobilities, Tourism and Travel Behavior: Contexts and Boundaries*, L. Butowski, Ed. London, UK: IntechOpen, 2018, pp. 143–158.

[13] R. Higgoda and M. W. Madurapperuma, "Dynamic Nexus between Air-Transportation and Economic Growth: A Systematic Literature Review," *Journal of Transportation Technologies*, vol. 9, no. 2, pp. 156–170, Mar. 2019, https://doi.org/10.4236/jtts.2019.92010.

[14] R. M. Zulqarnain, M. Saeed, N. Ahmad, F. Dayan, and B. Ahmad, "Application of TOPSIS Method for Decision Making," *International Journal of Scientific Research in Research in Mathematical and Statistical Sciences*, vol. 7, no. 2, pp. 76–81, Apr. 2020.

[15] A. M. Qureshi and A. Rachid, "Comparative Analysis of Multi-Criteria Decision-Making Techniques for Outdoor Heat Stress Mitigation," *Applied Sciences*, vol. 12, no. 23, Jan. 2022, Art. no. 12308, https://doi.org/10.3390/app122312308.