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Overview of Airport Location Selection Methods

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Abstract

Finding the location of a facility is a vital decision for a decision maker. Such a decision represents the success of association. Several techniques have been evolved in this field, resulting in a number of methods to find the most efficient location. The issue of airport location selection is considered a strategic planning issue of the system of transportation and it should be handled according to the comprehensive domain of the system. The covering problem in airport location is reviewed. Searches have been made in English scientific journals for the period between 1969 to 2017 using web science search engines for all data bases, science technology and only searching for titles pertaining to airport site selection while ignoring all papers containing other facilities. The taxonomy of the methods of selecting airport location and discussing their drawbacks was then proposed in a method which avoided the weak points of the previous approaches to improve the quality of solutions.

Keywords: facility location, airport site selection, ranking approach, optimization approach.

1. INTRODUCTION

The acquisition of funding for airport construction is complex, the time of implementation is long, and the facility must function for a very long time. An optimal location is selected considering the changing states to which the facility may have to alter in the future. Facility position issues in relationship with the importance of travelling and arrival time have garnered enthusiasm from decision makers and business analysts. The first ever spatial survey was performed in 1929 by Hotelling , who is well-known for the precept of minimal comparison, which suggests that competitive companies with technologies of transport generally tend to establish at the middle of market which involves linear flow of goods from Supplier to the other end customer (Yang et al. 2016). Several studies have been presented to determine and select the best solution to the airport location problem from past to present. Bambiger and Vandersypen (1969) primarily applied qualitative multi-criteria evaluation to the airport location issue (Yang et al. 2016), followed by Neufville and Keeney in 1972, who carried out studies on airport location and performed multi-attribute utility (MAU) method to assess two alternative airport locations near Mexico City (Min & Wu 1997). Then, Keeney (1973) and Howard (1974) used mathematical decision evaluation methods focusing on airport location (Yang et al. 2016). Keeney (1973) used a decision analytic model to assess procedures. The attributes were adjusted to represent impacts after some time. Probability density functions and a utility capacity were surveyed over the six characteristics (cost, noise levels, access time, safety, social disturbance, and capacity of the airport facilities). Paelinck (1977) used an adaptable strategy for a multi-criteria examination with augmentations that give its outcomes a more level realism and apply it to the instance of the area of anew airport. Horner (1980), who applied the location-allocation algorithm technique to review the location of airports and airstrips in Ireland, considered distance minimization with respect to population distribution. The author found difficulties in accumulating acceptable data, mainly inside the grid-square form required for Tornqvist. Saatcioglu (1982) used three approaches of programming models to determine airport site location with different attributes for each model, the first being used to determine the least number of airports depending on the passengers number, and the remaining two models being used to find the optimal airport location type. Although it included several characteristics, the approach was constrained to a single period, single objective issue (Min & Wu 1997). Neufville (1990) used an approach which provides insurance against risks and was associated with a strategy to cope with uncertainties. Martel (1992) evolved a procedure relying on the fixation of goals regarding each criterion introduced in the PROMTHTEE outranking method. The satisfaction function would be built by the decision maker for every deviation from the fixed goals. Min (1994) considered the multiple and contradictory goals nature of the airport location issue. Although he used an Analytic Hierarchy Process (AHP) method with cost/benefit trade-offs and carried out the analysis of sensitivity, but the model therewith constrained to a single-period. Liangcai Cai (1996) considered the method of the analytic hierarchy process (AHP) combined with technology systems of experts to select the location of an airport. Min & Wu (1997) commentated on de Neufville and Keeney (1972) as they did not consider the potential financial profits related to each alternative, significant cost related to clean-up, restitution, insurance and time sensitivity related to cost variation volume and pollution levels. They commentate on Min (1994) because his model was constrained to a single-period, uncapacitated location problem.

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To control some of those flaws, they developed a dynamic, multi-objective, mixed integer programming model and considered the criteria of cost, noise, economics and accessibility time to the airport. An optimal solution would be gained by including explicit limits which can adequately manage with capacity and financial constraints which previous approaches of MAU or AHP could not do. Janic & Reggiani (2002) found the same outcomes when applying three methods of multi-criteria decision making, including AHP, Simple Additive Weighting (SAW) and the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) on seven preselected airports as potential locations to select the new hub airport for a hypothetical European Union (EU) airline which is supposed to work in the liberalized EU air transport market. It used the same technique to define the different criteria weights for each procedure. Kleij & Hulscher (2003) studied the comparisons between alternative locations for the Amsterdam Schiphol airport. They considered the uncertainties of the information and joined the AHP and Monte Carlo rules and permitted alternative comparisons relying on ecological and morphological aspects. They used this approach because of modeling uncertainty during the assessment of the variations. Similarly, different criteria, including financial, planning of land use, operational conditions, environmental and sustainable development, were used in order to determine the consequences of different sites but with a different technique of multi-criteria analysis (MCA) (I.K. Panagopoulos et al. 2003). Again, Ballis (2003) made a case study of airport site selection on the island of Samothraki based on the MCA technique using a new approach relying on analysis of the relevant criteria. The author built his decision on the engineering rules of the study-team staff and the assessors of the authority involved. Then, applying AHP method with the previous used criteria, both rules resulted in the same airport location. At every stage, there were three approvals required from local authorities, civil aviation authorities and the environment ministry. New criteria are produced in a different way to weight them. Fiedorowicz et al. Fiedorowicz, K., Fiedorowicz (2004) applied the multi-criteria analysis (MCA) method to seven selected locations to select the best location close to Warsaw. The location had the possibility of accessibility by railway and motorway, good meteorological conditions, a good air traffic network, appropriate environmental conditions, revenue of airport investment and safety and security. Kassomenos et al. (2005) also studied the optimum site of an airport on an island in the Aegean Sea in Greece using meteorological data. The methodology of three stages to investigate the issue at three scales of motion, studying the synoptic weather regimes was based on meteorological records using the computational fluid dynamics (CFD) model PHOENICS to examine the mesoscale circulations for each of the synoptic schemes. Lastly, microscale circulations were investigated via questionnaires and in-situ tests. Augusto & Togatlian (2007) considered different types of criteria in their AHP model, infrastructure criteria (runway length, apron area, accessibility, receiving/flow off), which are the most critical in the choice. WANG et al. (2008) established the index system of the model and used the expert knowledge system, followed by applying the model of single objective optimization and the theory of interval numbers. The airport site location issue which belongs to uncertain multi-attribute decision making will be solved. Ssamula (2010) applied the method of multi-criteria decision analysis (MCDA) to select a hub airport in Africa that has minimum cost of transport in an effective hub and spoke network. The author found that the selection of a hub airport alternative was based significantly on the value of routing travelers via that airport. The new approach consisted of multi methods, including the Delphi method, AHP rule, Gray correlation and the Fuzzy assessment (DAGF) model. The Delphi method was used for evaluation of the system, followed by AHP for weighting the matrix, Gray correlation for analyzing the scores of experts, and finally, the Fuzzy method for assessment of the outcomes. The author considered this approach as a comprehensive evaluation for selecting the location of airport, which was scientifically, rationally and more compatible in use (Ding et al. 2011). Postorino & Praticò (2012) again used the MCDM method to determine the role/position of airports inside a multi-airport system. Sur & Majumder (2012) used the mathematical entropy model and construction cost per person as criteria to assist the alternatives for determination of airport site location in developing countries. Zhao & Sun (2013) made scheme comparisons of new airport site selections by presenting the multi-objective Lattice Order Decision Making and building Lattice Order Decision evaluation index systems. They then computed the evaluation index relative weights and determined the overall differences in magnitudes of the schemes. To remove the ambiguity of linguistic factors arising from uncertainty and affecting the decision making process, two rules of ranking methods included fuzzy TOPSIS and fuzzy ELECTRE I, which were applied to determine the proposed airport location using the criteria of costs, environmental, climatic, geographical condition, infrastructure, potential demand, social effects, the possibility of extension, and legal restrictions and regulations (Belbag et al. 2013). Carmona-benítez et al. (2013) looked to the problem of airport location from the view of maximizing the sum of expected air passenger demand as the essential factor by using the index of wealth to determine air passengers' demand at every point of demand, including the economic factors that form the marginalization index (MI), the total population and distances to every potential airport location. Carmona also commentated on de Neufville and Keeney (1972) because the researcher did not use the wealth index per demand point. He also commentated on each of Paelinck (1977), Saatcioglu (1982), Neufville (1990), Min & Wu (1997), and Zhao & Sun (2013) as they did not consider the maximization of the expected passenger demand as a main objective in their studies of the airport location issue. Huang B. et al. (2013) used the GIS technique to select airport location under complex airspace by gathering the geographic data of the complex airspace region and utilizing Supermap programming to construct the geographic spatial database. The airspace structure of complex airspace zones was analyzed, and the air space structure was determined according to the geographic spatial database. Then the airport location was selected. Liao & Bao (2014) considered the problem of airport location as a multi-attribute decision making issue and the decision matrix entries (crisp numbers) which express the opinion of experts would affect the accuracy of the result. They introduced a method of the triangular fuzzy number, which provided an extremely compelling approach to clarify priorities in relation to the experts and constructed a mathematical model to rank the triangular fuzzy number and solved it. Yang et al. (2014) used two ranking methods, namely the Weighted Least-Square Method (WLSM) integrated with the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method to evaluate airport location selection. The first method, WLSM, was adopted by the experts to compute the index weight and transform the linguistic variables into numerical values. The second method used was the TOPSIS method to pool those values and examine the level of closeness to determine the ranking of alternatives. Bo et al. (2014) took the benefit of the multilayer fuzzy reasoning model that can keep away from assessment disappointment caused by nonsensicalness in the human mind when indicators change to multi directions. Merkisz-guranowska (2016) introduced a multi stage approach to solve the airport location problem which included three approaches which could permit more development than the existing applied method. The first approach expands the problem of location by adding criteria such as the environmental criterion and developing the genetic algorithm. The second approach uses fuzzy set theory and the third develops the suggested Min and Melachrinoudis (1997) method. Yang et al. (2016) expanded a quantitative technique to determine optimal airport locations taking into consideration the accessibility to airports by airside and surface transportation. A structural equation model (SEM) was used to investigate the connection between the size of an airport catchment territory and its flight network scale. Fu et al. (2016) studied the case of relocating Jinzhou Bay airport in China and the expansion of the existing Zhoushuizi airport from the viewpoint of bird strike risk (intersection between the bird's flight routes and aircraft routes). Using the Markov chain for analyzing the flying process of birds and building a model to evaluate bird strikes, it was found that planned relocation of an airport is better than the development of a current airport because airport relocation has less value of bird strike risk than an existing airport in addition to more safety. Hammad et al. (2017) developed an optimization model of a multi-objective (minimizing noise and pollution, minimizing access time, maximizing the coverage of the airport. Mixed integer linear programming (MILP) model that was used to solve the problem which was formulated as a bilevel program.

2. METHODOLOGY

In this paper, searches were performed in English language scientific journals for the period between 1969 to 2017 using the Web Science search engine for all databases and the Science Technology search engine and we searched only for titles pertaining to airport site selection and we ignored all papers containing other facilities. All collected papers were classified according to the year of publication, as shown in Figure 1.

All papers are categorized according to the rule of determining airport location giving 42% using the mathematical approach and 58% using the ranking approach, as indicated in Figure 2.

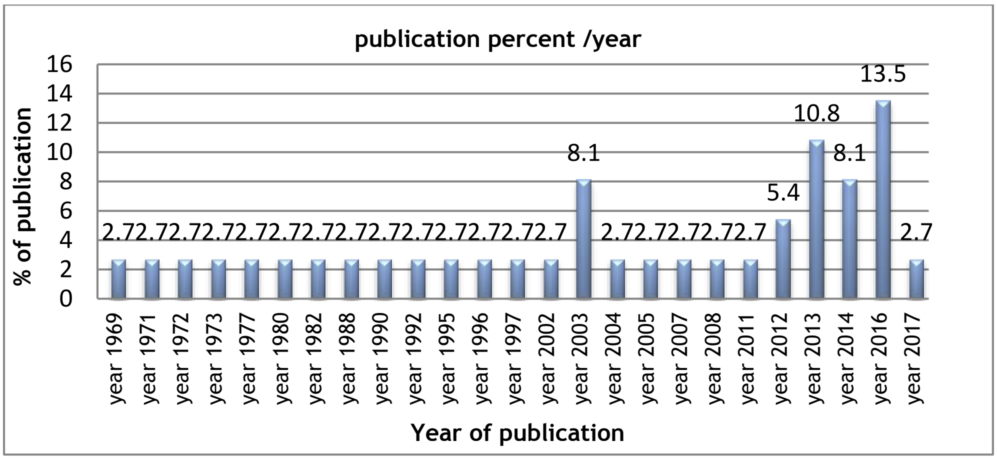

Fig. 1: Percentage of publication of papers according to the year of publication

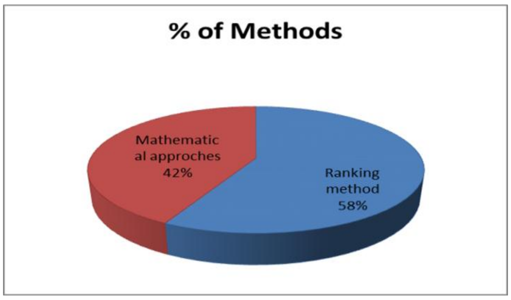

Fig. 2: Percentage of each method used

Determining the used criteria in all collected papers and categorizing them to obtain the most recurrence gives us an indicator about the most important criteria (Figure 3).

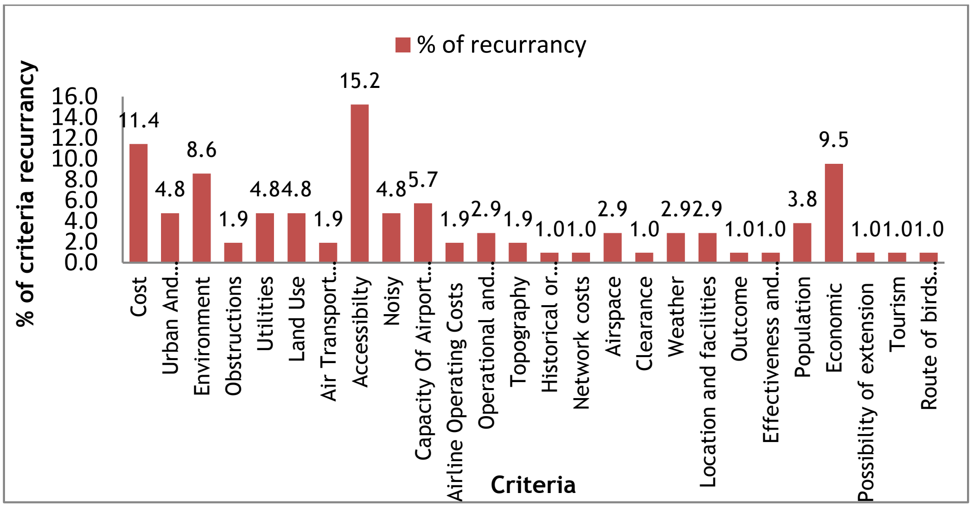

Fig. 3: Recurrence percentage of each criterion

3. DISCUSSION

From the literature review above, the aim is to determine the optimal site of an airport in a given region by evaluating selected potential locations. This evaluation includes the consideration of multiple criteria including the specific characteristics of the region that will accommodate the airport facility. Some of these criteria become higher in weight in relation to other criteria (Ballis 2003). Some authors used a single criterion, such as meteorological factors (Kassomenos et al. 2005), risk of bird strikes (Fu et al. 2016), airport construction cost per person (Sur & Majumder 2012) or a bi-criterion such as the cost of the airport per person and the cost of buses between cities (Saatcioglu 1982), landside and airside accessibilities (Yang et al. 2016) as well as multiple criteria, such as cost, noise, economic and accessibility time from communities centers to the airport (Min & Wu 1997). Despite several authors using single criteria in solving the airport location problem, they admit that they should not be the only criteria taken into consideration to make decisions and there should also be other criteria (Kassomenos et al. 2005; Kleij & Hulscher 2003).

From the literature above, two different approaches of solutions relating the problem of airport location were found, namely a ranking approach (factor assessment) and an optimization approach (mathematical approaches). The former includes selection of the best site among several preselected sites and the latter approach entails finding the best site in a particular region where no preselected sites have been determined (Merkisz-guranowska 2016; Yang et al. 2016). For the ranking approach, the methods of MDA and AHP are often used to select the location of a facility, and sometimes a combination of two or more techniques are applied, such as the AHP and Monte Carlo approaches (Kleij & Hulscher 2003), AHP, SAW and TOPSIS (Janic & Reggiani 2002), the Delphi method and AHP (Ding et al. 2011), fuzzy TOPSIS and fuzzy ELECTRE I (Belbag et al. 2013) and WLSM and the TOPSIS Method (Yang et al. 2014). For the mathematical approach, it is often for maximization of profit or minimization of cost (Yang et al. 2016). Mathematical approaches include defining several functions of the objective with several frequently conflicting criteria, the vast majority of which are to be done by PC programming. For instance, airports are considered to be semi-undesirable and semi-desirable facilities (Zanjirani et al. 2010; Merkisz-guranowska 2016). For further explanation, the cost objective obviously conflicts with the objective of access time and the objective of noise exposure, which conflicts with the economic impact objective (Min & Wu 1997). In the literature, similarly to the ranking approaches, several mathematical approaches to modeling were used to solve the airport location problem, including the simple gravity model (HUDSON, Jr. 1971), the location-allocation algorithm (Horner 1980), mathematical programming models (Saatcioglu 1982), dynamic, multi-objective and mixed integer programming model (Min & Wu 1997), the mathematical entropy model and entropy optimization method (Sur & Majumder 2012), the maximum coverage location model (Carmona-benítez et al. 2013), and a mixed-integer linear programming (MILP) model (Hammad et al. 2017).

4. DRAWBACKS

From the literature above, some drawbacks were found in both approaches, as summarized as follows:

- In ranking problems, it is mainly to predefine the potential locations of airport which are to be subsequently evaluated, despite it being possible to unintentionally overlook some potentially better locations (Merkisz-guranowska 2016).
- In the optimizing problem, the criteria being used seem to be too narrow. The only criteria considered are the population size and the distance to the airport (Merkisz-guranowska 2016).

- Objective analysis and subjective judgment are the main components of the methods which requires weighted computation. The defect of subjective judgment is that it is too dependent on the experience of experts. On the other hand, the disadvantage of objective analysis is that the experts' experience and knowledge is disregarded and the results which are obtained via computing devices may deviate from the actual (Zhao & Sun 2013).
- The crisp number of the decision matrix does not express the decision of experts: therefore, the accuracy of the decision will be poor (Liao & Bao 2014).
- Using the AHP approach necessitates checking the consistency index (CI), which is affected by expert subjective judgment in order to check the degree of consistency (Yang et al. 2014).
- In models using grids, the defect is that it cannot disregard grids which are unsuitable for the location of an airport because of geographical factors such buildings and mountains, etc., or considerations of urban density such as proximity to very densely populated regions (Yang et al. 2016).
- GIS has some weakness when used in decision- making problems involving spatial data because of its restricted capabilities for coordinating geographical information with subjective weights and preferences enjoined by decision makers.

5. CONCLUSION

Finding the location of a facility is a vital decision for a decision maker. Such a decision represents the success of association. Several techniques have been evolved in this field, resulting in a number of methods to find the most efficient location. To overcome the disadvantages of the approaches mentioned above and to improve the quality of solving the problem of airport location, a geographic information systems (GIS) with fuzzy logic is proposed since GIS can facilitate data input and improve the presentation of results. Moreover, GIS is widely used as a major role for spatial analysis, planning and management because it is a powerful tool in integrating software and data in the analysis and planning process and using multiple criteria in decision making, in addition to GIS being a useful technique in cases of scarcity of resources and insufficiency or inaccuracy of necessary data (Malczewski 1996; Eastman, J., W. Jin, P. Kyem 1995). Using the GIS technique, the defect of not eliminating the grids which are unsuitable for an airport location due to geographical factors or urban density considerations will be controlled (Yang et al. 2016). In addition, fuzzy logic can avoid the failure of an appraisal caused by unreasonableness in the human brain when indicators change to multi direction (LI Mingjie 2011), (Bo et al. 2014). The fuzzy set has a suitable ranking power when various criteria are considered for site selection. Moreover, the ability of representing ambiguous qualitative data and presenting all potential results with several degrees of membership. The requirement for combination the strengths of GIS technique and fuzzy logic become necessary to avoid shortcomings and providing accurate solution in short time.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

REFERENCES

[1] Augusto, M. & Togatlian, P., 2007. a Modeling Tool to Assist on the Decision Process of Determining the Optimal Location of an Industrial Airport in Brazil. The Brazilian Air Transportation Research Society, 3(1), pp.67–81.

[2] Ballis, A., 2003. Airport Site Selection Based on Multicriteria Analysis : the Case Study of the Island of Samothraki. An International Journal, 3(3), pp.261–279.

[3] Belbag, S., Deveci, M. & Uludag, A.S., 2013. Comparison of Two Fuzzy Multi Criteria Decision Methods for Potential Airport Location Selection. International Conference on Operations Research and Enterprise Systems, pp.122–128.

[4] Bo, J. et al., 2014. The Evaluation of Airport Site Selection Based on the Multilayer Fuzzy Reasoning Model. International Conference of Logistics Engineering and Management | Shanghai, China, pp.836–841.

[5] Carmona-benítez, R.B., Fernandez, O. & Segura, E., 2013. Site Selection of the New Mexico City Airport from the Perspective of Maximizing the Sum of Expected Air Pax Demand. Computational Logistics, 8197, pp.586–601.

[6] Ding, D. et al., 2011. Application of Comprehensive Evaluation of the Airport Site Selection. Applied Mechanics and Materials, 98, pp.311–315.

[7] Eastman, J., W. Jin, P. Kyem, and J.T., 1995. Raster Procedures for Multi-Criteria/Multi-0bjective Decisions. Photogrammetric Eng Remote Sens, 61(5), pp.539–547.

[8] Fiedorowicz, K., Fiedorowicz, J., 2004. Airports Location Problems for Warsaw Metropolis. 40th ISoCaRP Congress, Geneva, Switzerland, (September), pp.18–22.

[9] Fu, Q. et al., 2016. A Study of The Site Selection of a Civil Airport Based on The Risk of Bird Strikes : The case of Dalian , China. Journal of Air Transport Management, 54, pp.17–30.

[10] Hammad, A.W.A., Akbarnezhad, A. & Rey, D., 2017. Bilevel Mixed-Integer Linear Programming Model for Solving the Single Airport Location Problem. Journal of Computing in Civil Engineering, 31(5), pp.3–7.

[11] Horner, B.A.A., 1980. Population Distribution and the Location of Airports in Ireland. Royal Irish Academy,

80, pp.159–185.

[12] Huang Bangju, Lin Junsong, Z.X. and F.X., 2013. Airport Site Selection Under Complex Airspace Based on GIS. ASCE, pp.202–209.

[13] Hudson, Jr., J.F., 1971. An Investigation of Possible Locations for the Proposed South Florida Regional Airport. Dessertation, Florida Atlantic University.

[14] I.K. Panagopoulos, A.N. Karagiannis, P. A. Kassomenos, N. Pavlopoulos, and E.X., 2003. Selection of An Optimum Site to Construct and Develop an Airport in the North Aegean Using Multi Criteria Analysis. International Conference on Environmental Science and Technology, (September), pp.8–10

[15] Janic, M. & Reggiani, A., 2002. An Application of the Multiple Criteria Decision Making (MCDM) Analysis to the Selection of a New Hub Airport. European Journal of Transport and Infrastructure Research (EJTIR), 2(2), pp.113–141.

[16] Kassomenos, P.A., Panagopoulos, I.K. & Karagiannis, A., 2005. An Integrated Methodology to Select the Optimum Site of an Airport on an Island Using Limited Meteorological Information. Meteorol. Appl., pp.231–240.

[17] Kleij, C.S. Van Der & Hulscher, S.J.M.H., 2003. Comparing Uncertain Alternatives for a Possible Airport Island Location in the North Sea. Ocean & Coastal Management, 46, pp.1031–1047.

[18] LI Mingjie, S.R., 2011. Site Selection Assessment Model for Civil Aerodrome Based on Catastrophe Assessment Method. Journal of Civil Aviation University of China, 29(6), pp.35–38.

[19] Liangcai Cai, X.Z.A., 1996. Comprehensive Evaluation Intelligent Assistant Decision-Making System of Airport Site Selection Alternative. Aeronautical Computing Technique, 3, pp.42–46.

[20] Liao, Y. & Bao, F., 2014. Research on Airport Site Selection Based on Triangular Fuzzy Number. Applied Mechanics and Materials, 505–506, pp.507–511.

[21] Malczewski, J., 1996. A GIS-Based Approach to Multiple Criteria Group Decision Making. International J Geographic Information Sysyem, 10(8), pp.955–971.

[22] Martel, J., 1992. Multi Criteria Method for Site Selection - Example of An Airport for New Quebec. INFOR, 30(2), pp.97–117.

[23] Merkisz-guranowska, A., 2016. Location of Airports - Selected Quantitative Methods. Scientific Journal of Logistics, 12(3), pp.283–295.

[24] Min, H., 1994. Location Planning o Airport Facilities Using the Analytic Hierarchy Process. Logistics and Transportation, Review(30), pp.79–94.

[25] Min, H. & Wu, X., 1997. Dynamic Expansion and Location of an Airport : A Multiple Objective Approach. Transportation Research, 31(5), pp.403–417.

[26] Neufville, B.R. De, 1990. Successful Siting of Airports: Sydney Example. ASCE, 116(1), pp.37–48.

[27] Paelinck, J., 1977. Qualitative Multicriteria Analysis : An Application to Airport Location. Environment and Planning, 9(May), pp.883–895.

[28] Postorino, M.N. & Praticò, F.G., 2012. An Application of The Multi-Criteria Decision - Making Analysis to A Regional Multi-Airport System. Research in Transportation Business & Management (RTBM), 4, pp.44–52.

[29] Saatcioglu, O., 1982. Mathematical Programming Models for Airport Site Selection. Transportation Research Part B: Methodological, 16(6), pp.435–447.

[30] Ssamula, B., 2010. Exploring Multi-Criteria Decision Analysis Method as a Tool to Choose Regional Airport Hubs within Africa. International Journal of Sustainable Development and Planning, 5(2), pp.83–97.

[31] Sur, K.K. & Majumder, S.K., 2012. Construction of a New Airport in a Developing Country , Using Entropy Optimization Method to the Model. ICSRS Publication, 8(1), pp.29–34.

[32] Wang Zhang, CAI Liangcai, Chong Xiaolei, Z.L., 2008. Airport Site Selection Based on Uncertain Multiattribute Decision Making. ASCE, 7, pp.647–654.

[33] Yang, C., Wu, T. & Liao, Y., 2014. Evaluation for the Location Selection of Airport Based on WLSM-TOPSIS Method. Applied Mechanics and Materials, pp.1823–1827.

[34] Yang, Z., Yu, S. & Notteboom, T., 2016. Airport Location in Multiple Airport Regions (MARs): The Role of Land and Airside Accessibility. Journal of Transport Geography JTRG, 52, pp.98–110.

[35] Zanjirani, R., Steadieseifi, M. & Asgari, N., 2010. Multiple Criteria Facility Location Problems : A survey. Applied Mathematical Modelling, 34(7), pp.1689–1709.

[36] Zhao, S. & Sun, P., 2013. Scheme Comparison of New Airport Site Selection Based on Lattice Order Decision Making Method in The Integrated Transportation System. International Journal of online Engineering, 9(SPL.Issue4), pp.95–99.