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A MIXED INTERVAL TYPE-2 FUZZY BEST-WORST MACBETH APPROACH TO CHOOSE HUB AIRPORT IN DEVELOPING COUNTRIES: CASE OF IRANIAN PASSENGER AIRPORTS

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Abstract. Hub airports are the ones that model networks in which most journeys go via a few central points. Famous hub airports deliver positive social and environmental impact to the communities along with economic effects. This paper is about to investigate indicators related to hub performance excellence from various angles, considering leading hub airports performance while determining the priorities in order to help airports especially in developing countries to find the way of progress. A list of Key Performance Indicators (KPIs) is prepared from the literature, which is prioritized using Best-Worst Method (BWM). The weights of these criteria are specified via application of interval type-2 fuzzy BWM. Then using five most important criteria, MACBETH (Measuring Attractiveness by a Categorical Based Evaluation TecHnique) ranking approach is used to analyse 19 Iranian international airports and find the most appropriate one for being hub airport. The results show Kish airport with the International Civil Aviation Organization (ICAO) code "OIBK" is prior to other airports and can be chosen as the hub airport that means Iran airports holding company is suggested to focus more investments in this airport to gain fastest possible benefits of an international hub airport.

Keywords: hub airport, international airport, KPI, BWM, MACBETH, fuzzy type-2, MCDM.

Notations

AHP – analytic hierarchy process;
ANP – analytic network process;
BWM – best-worst method;
CI – compatibility index;
CR – compatibility rate;
DEA – data envelopment analysis;
DEA-AR – assurance region DEA;
DSS – decision support system;
EBITDA – earnings before interest, taxes, depreciation and amortization;
EMAS – eco-management and audit scheme;
FARE – factor relationship;
ICAO – International Civil Aviation Organization;
KPA – key performance area;
KPI – key performance indicator;
MACBETH – measuring attractiveness by a categorical based evaluation technique;
MADM – multiple attribute decision-making;
MCDM – multi-criteria decision-making;
PMS – performance measurement system;
SERVQUAL – service quality;
SMART – simple multi-attribute rating technique;
WLU – work load unit.

Introduction

Nowadays, airport traffic is much more uncertain and every government has become aware of the importance of hub airport presence in their country because of its various benefits for airlines, passengers, local people and the whole country (Shojaei *et al.* 2018; Scholz, Von Cossel 2011). Hub airports are the ones that model networks in which most journeys go via a few central points. Airlines can run more frequent planes if the network is efficient. The excellence of the international airport to become the passenger hub and make connections to other regions in the world is the most important criteria to decrease operating costs for the aviation business (Jantachalobon, Suthikarnnarunai 2015). Besides, it should be noted that economic effects of successful hub airports have incredible role in financial gaining of the countries (Jahango-

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shai Rezaee, Yousefi 2018; Homsombat *et al.* 2011). Based on "Airport Economics 2018 Report…" presented by Airports Council International (ACI), global aviation revenue is about 161.3 $ billion, 56% of which is gained by aeronautical services while the other share belongs to non-aeronautical and non-operating services. Revenue of Hartsfield-Jackson Atlanta International Airport as the busiest airport by passenger traffic in the whole world is about 723678 $ for 2017 while Frankfurt hub airport for instance as the 14th global busiest airport by passenger traffic is about 2934.8 € million for 2017, which is still enormous (ACI 2018).

Global trend in air passenger movements is changing and competition between airports and airlines is getting fiercer in a way that they themselves challenge the quality of their non-financial performance too (Mirković, Tošić 2017). Because of growing air travels, modern airports are more and more looking like cities considering infrastructure, interior and exterior design and the overall resources are required to help travellers to have pleasure time (Milbredt *et al.* 2017; Thomas-Emberson 2007). Airport terminals today even include welfare facilities such as movie theatres, hotels and yoga classes. People can shop, have fun or organize their work meetings at the conference halls while waiting to get on the next flight. However, Services like these make the ecological footprint of the aviation industry to go higher too. That is why if airports want to survive and gain brand image or enhance their networks with other airports, they should be brought in with the current process of becoming sustainable (Mirković, Tošić 2017).

Famous hub airports deliver positive social and environmental impact to the communities along with economic effects. Airports know that investing in renewable energy sources has a positive impact on their financial status (Peneda *et al.* 2011). For instance, Middle Eastern airports are now capable of running a large amount of potential flight connections between other origins with optimum travel times and least interruptions. Emirates, Doha, Abu Dhabi and Qatar Airways have entered the air travel market and challenges have leaked in the way of European and American airports such as Frankfurt Airport, although Frankfurt strengthens its position as super-hubs (Piltz *et al.* 2018). Frankfurt Airport is one of the world's busiest international gateways, known as the 360-degree hub. It has a strongly integrated network spanning all continents, outmanoeuvring many European competitors, which focus only on particular regions. Its terminal 2 offers direct road links to the airport, the autobahn system and even rail networks while the baggage sorting and conveyor system enables the airport to offer transfer times of less than 45 min. Service companies, hotels, meeting and conference facilities, catering, retail, and entertainment facilities are all available. Frankfurt Airport has made substantial headway in developing its environmental leadership in the aviation business too. European EMAS is under attention of this airport allowing companies to evaluate and improve their environmental performance (Schulte 2009). Similar characteristics have made Singapore Airport one of the bests too. Luggage carts are widely and freely available while passengers can gain their needed information from special kiosks in every terminal section. Staffs are well trained and truly guide passengers. However, printed map can be used too. Wi-Fi is free throughout the airport. There are also some cinemas, fitness and massage centres, children's playgrounds, many shops and food and beverage outlets (CAG 2018).

Developing countries are seeking to get a position in this industry too. Tehran's International Airport is in the early phases of a gradual improvement, a long-term plan to boost trade and turn Iran into a regional hub, hoping to compete with successful airports in special zones of the area such as airports in the United Arab Emirates and Turkey. New terminals and a vast airport free-trade area that includes sections for industry, logistics, hotels and conference centres are somehow in the centre of such a hope to convince foreign companies and international carriers to start choosing Tehran over other regional hubs. However, it is questionable, which criteria could lead to full-scale efficiency of hub airports especially in developing countries such as Iran that have not yet used this opportunity. Previous studies show this efficiency is largely based on competitive cost structure, a strong brand image, sustainable performance and efficient operation (Piltz *et al.* 2018; O'Connell 2011; Fitch 2016). The number of quantitative studies about hub excellence focusing from comprehensive perspective is not high. That is why this paper is about to investigate indicators related to hub performance excellence from various angles, considering leading hub airports performance while determining the priorities in order to help airports especially in developing countries to find the way of progress. A list of KPIs is prepared from the literature, which is prioritized using BWM, then using five most important criteria, MACBETH ranking approach is applied to analyse 19 Iranian international airports and find the most appropriate one for being hub airport.

In the Section 1, the literature of airport KPIs, BWM MCDM, interval type-2 fuzzy numbers and MACBETH methods are reviewed. The research methodology is explained in Section 2, and discussion and managerial implications are presented in Section 3. Finally, the last section concludes the paper, including suggestions for further research.

1. Literature review

1.1. Airport KPIs

Since about 70s, performance management has gained much more attention changing the view angle from financial point to multidimensional perspective, leading to new system of performance evaluation. Today each organization in each industry is ever more willing to improve its PMS (Halpern, Pagliari 2008; Bezerra, Gomes 2016a). It is noticeable that airports management have mostly transformed from governmental to private sector. Benchmarking and performance improvement has become a burgeoning area as a result (Baltazar *et al.* 2018).

For covering the purpose of this study, the literature has emphasized the design and implementation of PMS of airports. It is clear that contrary to initial studies, recent studies have set performance analysis system from much more holistic approach considering financial and non-financial factors simultaneously.

Various scholars have focused on airport performance appraisal form different aspects. Enoma and Allen (2007) developed and tested a set of key performance factors for airport management, with the focus on safety and security. Data was collected from ways such as interviews, workshops and the internet by use of case study methodology.

Schmidberger *et al.* (2009) put their main attention on ground handling services at European hub airports and developed a PMS for benchmarking by use of action research method for one year. The result is a PMS containing a process-based perspective with the focus on the supply chain of airport logistics.

Lozano *et al.* (2013) put their main attention on developing DEA model and its application to airports' performance comparison. They considered two process ("aircraft movement" and "aircraft loading") with two final outputs ("annual passenger movement" and "annual cargo handled"), one intermediate product ("aircraft traffic movements") and two undesirable outputs ("number of delayed flights" and "accumulated flight delays") to evaluate Spanish airports performances for year 2008.

However, Lai *et al.* (2015) compared efficiency between different samples of airports. This study has applied AHP, DEA and DEA-AR models, with number of employees, number of gates, number of runways, size of terminal area, length of runways and operational expenditures as outputs of DEA-AR model, while number of passengers, amount of freight and mail, aircraft movements and total revenue as inputs. Performances of 24 major international airports are compared in this empirical analysis. Of course, other scholars have also addressed this issue with different indicators and use of DEA modelling (Wanke 2012; Olfat *et al.* 2016; Olfat, Pishdar 2017; Wanke *et al.* 2016; Lo Storto 2018; Ennen, Batool 2018).

Bezerra and Gomes (2016a) fit a measurement model for perceived airport service quality by a multidimensional approach in order to become able to face the complexity of the airport service environment. Conformity factor analysis showed that check-in, security, convenience, ambience, basic facilities and mobility constitute the elements that should be measured to evaluate airport's service quality. The model is validated for international and domestic departing passengers. Of course, there are other studies that have focused on the quality of the airport's services delicately. Lee and Yu (2018) showed that user-generated online contents can be used as a data-source for assessing airport service quality. Pantouvakis and Renzi (2016) also pointed to this point that different nationalities perceive airport service qualities differently and that is why airports management should try to upgrade services according to passenger tastes with different cultures.

Eshtaiwi *et al.* (2017) evaluated the performance of three international Libya airports of Mitiga, Misurata and Al-Abraq by considering grey theory and five aspects of service quality, airport operations, airport economy, safety and security and environmental impact. In this way, it becomes possible to do benchmarking correctively and set the path to performance improvement.

Mirković and Tošić (2017) paid attention to differences between hub and non-hub airports only based on airside capacity under different traffic characteristics. The main finding is that functional relationship between the runway system and aprons is much stronger in the case of hub airports, and should be carefully considered when analysing airside capacity.

Meanwhile, Cahill *et al.* (2017) considered the case of Ireland's Dublin Airport authority for making investigations about the effects of commercialization on airport labour productivity and total factor productivity. Results do not show continuous upward trend in total factor productivity by continued commercialization over the 1994–2014 period. However, it is notable that long-term benefits of investment in physical capacity will not be immediately revealed in any productivity analysis. There are other studies that have considered the airport commercialization too (e.g. Freathy, O'Connell 1999; Yang *et al.* 2008; Castro, Lohmann 2014; Chung *et al.* 2017; Puls, Lentz 2018).

Keshavarz Ghorabaee *et al.* (2017) evaluated five airlines based on 28 service quality criteria. Several different MCDM methods are applied for evaluating the alternatives.

Bezerra and Gomes (2018) investigated key aspects of airport performance measurement practices by systematic literature review. The results revealed that safety, economic-financial, and service quality are in the main of concern. In contrast, competition, long-term economic results, and the environmental and social outcomes of the airport activities are not yet totally considered. Therefore, PMS of this industry should be broadened to present airports as business systems.

However, Baltazar *et al.* (2018) used MACBETH approach to set a hierarchical additive value model by use of expert's judgments. Safety and security, core, productivity/cost effectiveness, service quality, financial/commercial and environmental factors are the main elements constituted the performance evaluation model.

Eshtaiwi *et al.* (2018) determined a list of essential airport KPIs to provide a practical framework to measure and put under control the performance of Libyan airports over time. They also used AHP technique to set the weights of the KPIs and to compare airports in Libya according to the judgments of experts.

Considering previous related studies, initial KPIs for airports are set and finalized via experts' opinions that their characteristics are described in research methodology section (Table 1).

Table 1. Initial KPIs for airports

KPA	KPI	References
Strategic management	– mission and vision statement of sustainable development; – value chain coordination; – development of trade policies related to sustainable development; – consideration of sustainability standards – human resource management; – research and development; – design and construction of the airport environment based on sustainability principles; – governmental legislations	Berry *et al.* (2018); CDA (2013); ICAO (2012); OECD (2001); SAGA (2018)
Airport branding	– public image; – airport reputation; – brand value	Bond (2013); Castro, Lohmann (2014); Lee, Park (2016)
Airport connectivity	– direct connectivity; – indirect connectivity; – hub connectivity	ACI (2017); Burghouwt *et al.* (2009); O'Connell, Bueno (2018); Tłoczyński (2017)
Productivity	– expenditure per passenger measured per year; – income per passenger measured per year; – non-aeronautical income per passenger measured per year; – revenue per m^2 of floor space measured per year; – total cost per WLU measured per year	Eshtaiwi *et al.* (2018); Schmidberger *et al.* (2009)
Financial	– aeronautical revenue per passenger; – aeronautical revenue per movement; – non-aeronautical operating revenue as percent of total operating revenue; – non-aeronautical operating revenue per passenger; – debt service as percentage of operating revenue; – long-term debt per passenger; – debt to EBITDA ratio; – EBITDA per passenger	BAC (2014); Bezerra, Gomes (2018); CDA (2013); Eshtaiwi *et al.* (2018); ICAO (2013); Rodgers (2015); Schmidberger *et al.* (2009)
Safety and security	– runway accidents; – runway incursions; – bird strikes; – public injuries; – occupational injuries; – lost work time from employee accidents and injuries; – hygiene monitoring	ACI (2012); Bezerra, Gomes (2018); Enoma, Allen (2007)
Social responsibility	– community involvement; – human rights; – social programs; – number of jobs created per percent by women, minorities, disabled people of the total workforce; – sporting/social/cultural sponsorship; – number of activities focused on community; – media contacts	Bezerra, Gomes (2016b, 2018); CDA (2013); ICAO (2012); SAGA (2018)
Environmental protection	– carbon footprint; – waste recycling; – waste reduction percentage; – renewable energy purchased by the airport [%]; – utilities/energy usage per square meter of terminal; – water consumption per passenger; – noise reduction	BAC (2014); Berry *et al.* (2018); Bezerra, Gomes (2018); ICAO (2012); Monsalud *et al.* (2015)
Service quality	– SERVQUAL elements (tangibility, reliability, responsiveness, assurance, empathy); – enjoyment and refinement of the environment; – consideration of passengers' nationality in servicing; – turn-around process time; – number of runways; – number of delayed flights measured per day; – length of runway taxi departure delay measured per day; – number of boarding; – number of baggage collection belts; – check-in waiting times; – baggage delivery time waiting time at security control; – customer satisfaction monitoring	ACI (2012); Bezerra, Gomes (2016a); Eshtaiwi *et al.* (2018); Lee, Yu (2018); Pantouvakis, Renzi (2016); SAGA (2018)
Competitiveness	– market share for airports; – airline competition at the airport; – number of destinations (non-stop); – airline operating expenses per passenger at the airport	Bezerra, Gomes (2016b)

1.2. BWM – MCDM method

BWM is one of the new MCDM techniques presented by Rezaei (2015). In this method, the best and worst indicator is determined by the decision maker, and a pair comparison between each these two (best and worst) indicators and other indicators are then formulated and resolved; a minimization model is designed to calculate the weight of the various indicators. In addition, in this method, a formula for calculating the in CR to test the validity of the comparisons in mind is taken. Among the prominent features of this method, several factors of decision-making are that it needs less comparative data and this method leads to comparisons that are more robust; that is, it provides more reliable answers (Brunelli, Rezaei 2019).

After determination of criteria, the most important and least important criterion is to be found among all the indicators that are called best and worst, and then the comparison of all other criteria is done pairwise with the best criteria and other criteria with the worst criteria in the form of two matrices. In the next step, a linear model should be constituted as is depicted in Equation (1). The weights are determined by solving the linear model (Brunelli, Rezaei 2019).

$$\begin{aligned}
&\min \varepsilon \\
&\text{subject to:} \\
&\left| w_b - a_{Bj}.w_j \right| \le \varepsilon; \\
&\left| w_j - a_{jw}.w_w \right| \le \varepsilon; \\
&\sum_j w_j = 1; \\
&w_j \ge j, \text{ for all } j.
\end{aligned} \tag{1}$$

By consideration of the ε value and the related value in Table 2, CR can be determined. The closer to 0, the more compatibility of the comparisons has been created, and the closer to one, the comparisons have less compatibility and less stability. CI, which is used to determine CR can be reached via Table 2. The CR is specified by use of Equation (2):

$$CR = \frac{\varepsilon}{CI}. \tag{2}$$

Table 2. Values of CI

Number	1	2	3	4	5	6	7	8	9
CI	0	0.44	1	1.63	2.3	3	3.73	4.47	5.23

1.3. Interval type-2 fuzzy numbers

Fuzzy sets are considered while analysis of the experts' opinions. However, membership function in type-1 fuzzy sets does not show any ambiguity although the fuzzy concept contains lots of uncertainty; this caused the introduction of type-2 fuzzy sets by Zadeh (1975) by extending the concept of type-1 fuzzy set (Wu, Mendel 2007, 2008). In type-2 fuzzy sets, membership function is itself a type-1 fuzzy number. Since, using type-2 fuzzy sets are somewhat sophisticated; interval type-2 fuzzy sets are used in many aspects. In interval type-2 fuzzy numbers, uncertainty of membership function is shown by interval value – see Equation (3) – (Hu *et al.* 2013). An interval type-2 fuzzy illustration of a crisp number like C, is defined as $(c, c, c, c; 1, 1)$ (Abdullah, Zulkifli 2015).

Considering A, B as two trapezoidal interval type-2 fuzzy numbers, laws of calculations are as follow:

$$\begin{aligned}
&A = \left(A^U, A^L\right) = \\
&\left(\left(a_1^U, a_2^U, a_3^U, a_4^U; H_1\left(A^U\right), H_2\left(A^U\right)\right),\right. \\
&\left.\left(a_1^L, a_2^L, a_3^L, a_4^L; H_1\left(A^L\right), H_2\left(A^L\right)\right)\right);
\end{aligned} \tag{3}$$

$$\begin{aligned}
&B = \left(B^U, B^L\right) = \\
&\left(\left(b_1^U, b_2^U, b_3^U, b_4^U; H_1\left(B^U\right), H_2\left(B^U\right)\right),\right. \\
&\left.\left(b_1^L, b_2^L, b_3^L, b_4^L; H_1\left(B^L\right), H_2\left(B^L\right)\right)\right);
\end{aligned} \tag{4}$$

$$\begin{aligned}
&A + B = \left(A^U, A^L\right) + \left(B^U, B^L\right) = \\
&\left(\left(a_1^U + b_1^U, a_2^U + b_2^U, a_3^U + b_3^U, a_4^U + b_4^U;\right.\right. \\
&\left.\min\left(H_1\left(A^U\right), H_1\left(B^U\right)\right), \min\left(H_2\left(A^U\right), H_2\left(B^U\right)\right)\right), \\
&\left(a_1^L + b_1^L, a_2^L + b_2^L, a_3^L + b_3^L, a_4^L + b_4^L;\right. \\
&\left.\left.\min\left(H_1\left(A^L\right), H_1\left(B^L\right)\right), \min\left(H_2\left(A^L\right), H_2\left(B^L\right)\right)\right)\right);
\end{aligned} \tag{5}$$

$$\begin{aligned}
&A - B = \left(A^U, A^L\right) - \left(B^U, B^L\right) = \\
&\left(\left(a_1^U - b_4^U, a_2^U - b_3^U, a_3^U - b_2^U, a_4^U - b_1^U;\right.\right. \\
&\left.\min\left(H_1\left(A^U\right), H_1\left(B^U\right)\right), \min\left(H_2\left(A^U\right), H_2\left(B^U\right)\right)\right), \\
&\left(a_1^L + b_4^L, a_2^L - b_3^L, a_3^L - b_2^L, a_4^L - b_1^L;\right. \\
&\left.\left.\min\left(H_1\left(A^L\right), H_1\left(B^L\right)\right), \min\left(H_2\left(A^L\right), H_2\left(B^L\right)\right)\right)\right);
\end{aligned} \tag{6}$$

$$\begin{aligned}
&\frac{1}{k}(A) = \left(\left(\frac{1}{k}\cdot a_1^U, \frac{1}{k}\cdot a_2^U, \frac{1}{k}\cdot a_3^U, \frac{1}{k}\cdot a_4^U; H_1\left(A^U\right), H_2\left(A^U\right)\right),\right. \\
&\left.\left(\frac{1}{k}\cdot a_1^L, \frac{1}{k}\cdot a_2^L, \frac{1}{k}\cdot a_3^L, \frac{1}{k}\cdot a_4^L; H_1\left(A^L\right), H_2\left(A^L\right)\right)\right);
\end{aligned} \tag{7}$$

$$\begin{aligned}
&A \otimes B = \left(A^U, A^L\right) \cdot \left(B^U, B^L\right) = \\
&\left(\left(a_1^U \cdot b_1^U, a_2^U \cdot b_2^U, a_3^U \cdot b_3^U, a_4^U \cdot b_4^U;\right.\right. \\
&\left.\min\left(H_1\left(A^U\right), H_1\left(B^U\right)\right), \min\left(H_2\left(A^U\right), H_2\left(B^U\right)\right)\right), \\
&\left(a_1^L \cdot b_1^L, a_2^L \cdot b_2^L, a_3^L \cdot b_3^L, a_4^L \cdot b_4^L;\right. \\
&\left.\left.\min\left(H_1\left(A^L\right), H_1\left(B^L\right)\right), \min\left(H_2\left(A^L\right), H_2\left(B^L\right)\right)\right)\right).
\end{aligned} \tag{8}$$

Scale that is shown in Table 3 can be applied to gather experts' opinions. Then, opinions of all experts are determined and the mean of them is specified by use of Equation (7).

Table 3. The scale used in data gathering

Linguistic variables	The equivalent interval type-2 fuzzy number in the format of: $\left(\left(a_1^U, a_2^U, a_3^U, a_4^U; H_1\left(A^U\right), H_2\left(A^U\right)\right), \left(a_1^L, a_2^L, a_3^L, a_4^L; H_1\left(A^L\right), H_2\left(A^L\right)\right)\right)$
Strongly agree	((0.8, 0.9, 0.9, 1; 1, 1), (0.85, 0.9, 0.9, 0.95; 0.9, 0.9))
Agree	((0.6, 0.7, 0.7, 0.8; 1, 1), (0.65, 0.7, 0.7, 0.75; 0.9, 0.9))
Undecided	((0.4, 0.5, 0.5, 0.6; 1, 1), (0.45, 0.5, 0.5, 0.55; 0.9, 0.9))
Disagree	((0.2, 0.3, 0.3, 0.4; 1, 1), (0.25, 0.3, 0.3, 0.35; 0.9, 0.9))
Strongly disagree	((0, 0.1, 0.1, 0.1; 1, 1), (0, 0.1, 0.1, 0.05; 0.9, 0.9))

In this regard, value of each variable is determined and the upper and lower limits of values are specified considering Equations (9) and (10):

$$M_*\left(A\right)=\frac{1}{6}\cdot\left(a_1^U+2a_2^U\right)\cdot h_1^U+\frac{1}{6}\cdot\left(a_1^L+2a_2^L\right)\cdot h_1^L; \quad (9)$$

$$M^*\left(A\right)=\frac{1}{6}\cdot\left(a_4^U+2a_3^U\right)\cdot h_2^U+\frac{1}{6}\cdot\left(a_4^L+2a_3^L\right)\cdot h_2^L. \quad (10)$$

1.4. MACBETH model

MACBETH is an approach that uses pair judgments about the attractiveness differences of alternatives to quantify the amount of attractiveness of each (Bana e Costa, Vansnick 1999). What makes it friendlier is that via questioning about each two of alternatives, which are called "option" in this method and also in the M-MACBETH software, by giving qualitative judgment, the user can transfer whole comparative answers.

As the comparative values are introduced into the M-MACBETH software, which is designed as a DSS, it starts verifying their consistency then makes a numerical scale according to the decision maker's judgments. Same process happens to calculate criteria's weights. Furthermore, it provides tools to facilitate several types of sensitivity analyses.

A decision tree is then created in the M-MACBETH, listing the criteria. The options, which are airports in this research, then will be introduced into the model.

Next, qualitative judgments regarding the difference of attractiveness between options are elicited from the decision maker, who then chooses among 6 predefined answers such as "very weak", "weak", "moderate", "strong", "very strong" and "extreme". If unsure about the difference of attractiveness he can choose more than one qualitative rating also.

When each judgement is given, the software automatically verifies the matrix's consistency, and suggests judgement modification(s) that could be made to fix any possible detected inconsistency, which helps decision maker correct his mindset.

Although M-MACBETH works as a DSS, here the mathematics of this method is summarized. If decision maker ranks option X_i higher than X_j for the criterion k, it will be:

$$X_i \succ X_j. \quad (11)$$

As explained above, the decision maker chooses one of the six answers to define his preference that is quantified as $h=\left\{0,1,2,3,4,5,6\right\}$ so it will be:

$$X_i \overset{h}{\succ} X_j. \quad (12)$$

This means:

$$X_i - X_j = h \cdot a. \quad (13)$$

In MACBETH each alternative will have a score in [0, 100] interval so a is a coefficient for score differences. The score assigned to the most preferred alternative is 100 and to the less preferred one is 0, it's shown as by $\nu_j\left(X_i\right)$ According to the pairwise matrix of criteria, filled by the decision maker, these scores can be calculated. Then from Equation (13), the overall value of alternatives can be found:

$$V\left(X_i\right)=\sum_{j=1}^{n} w_j\left(\nu_j\left(X_i\right)\right); \quad (14)$$

$$\sum_{j=1}^{n} w_j,\ w_j \succ 0. \quad (15)$$

Alternative with highest $V\left(X_i\right)$ is the most preferred one and others will be ranked accordingly.

There are several examples of MACBETH application in different industries in the literature; Santa Catarina textile industry strategic planning (Bana e Costa *et al.* 1999), analysis of investment in the new inter-municipal road-links (Bana e Costa 2001), railway construction problem (Bana e Costa *et al.* 2001), preventive maintenance management in a municipal housing stock (Bana e Costa, Oliveira 2002), strategic metropolitan decisions (Bana e Costa *et al.* 2002b), credit assignment algorithms in banking systems (Bana e Costa *et al.* 2002c), bid evaluation systems (Bana e Costa *et al.* 2002a), career selection (Bana e Costa, Chagas 2004), stable government coalition structure (Roubens *et al.* 2006), industrial performance assessment system (Clivillé *et al.* 2007), bridges and tunnels prioritization in earthquake risk mitigation (Bana e Costa *et al.* 2008), hydrogen storage technologies performance evaluation (Montignac *et al.* 2009), customer satisfaction assessment (Fakhfakh *et al.* 2011), supplier selection (Karande, Chakraborty 2013), healthcare performance indicators (Rodrigues 2014), facility location selection (Karande, Chakraborty 2014), performance satisfaction level (Pourhejazy *et al.* 2019).

2. Research methodology

Many scholars and experts have come to notice set of indicator effective in making airports the hub ones. This can be more useful about airports in developing countries with less experience in comparison to airports in developed countries.

For gaining this aim, the components are determined by literature review and concluded by professionals of Iran airports holding company and writers of the related papers in other countries. These experts know the concept of making airports hub and the situation of airports in developing countries as a whole. They also have experiences of airports' visions determination. As a result, their opinions can be trustful.

The weights of these criteria are specified using interval type-2 fuzzy BWM. As BWM is one of the latest MADM methods, it was chosen to efficiently tackle the inconsistency derived from pairwise comparisons. This method is more consistent compared to many famous methods such as AHP, ANP, FARE and SMART methods (Hashemkhani Zolfani, Chatterjee 2019). Indicators are ranked through their obtained weights to evaluate the most suitable Iranian passenger airports with Macbeth technique in order to see which one of these airports is more ready to become hub at the moment. The MACBETH method is selected for this step because of its simplicity, as well as its user-friendly manner, which helps respondents feel relax as they can transfer whole comparative answers by giving qualitative judgment in the M-MACBETH software. Initial screening is done via investigation of official documents keeping in Iran airports holding company office.

The total number of 54 airports is there in Iran, 19 of which are counted as international ones based on statistics of Iran airports holding company. Many of them are not profitable at the moment and the non-aviation income is far less than the average global rate. Another matter is that these airports may not be experienced in communicating with local shareholders or may encounter natural disasters. Some of them also have difficulties in preserving local species. Gaining such characteristics makes the airport more sustainable and this is while previous studies show that hub airports usually have more effective sustainability performance (Carlucci *et al.* 2018; Scholz, Von Cossel 2011). Therefore, determination of the readiest Iranian airports in regards to becoming a hub, can bring various values for government and people at the same time. The main steps of this study are depicted in Figure 1.

3. Discussion and managerial implications

Finalized set of indicators depicted in Table 1 is weighted via experts' opinions, who are 16 anonymous experts of Iran airports holding company chosen by top manager of the company to cooperate in the research. However, they have been asked to choose the most important one and the least important item at the beginning. These are named as best and worst indicators in BWM technique. First, each expert identifies the preference of the first criteria as compared to other indicators. After that, the priority of other indicator is determined in comparison with the worst indicator. Each expert has announced his opinion considering the scale in Table 2. Then, the averages of opinions about each indicator are specified via consideration of Equations (5) and (6). In this step, values of a_{Bj} and a_{jw} are obtained. Two linear models are solved to gain the upper limit and lower limit of interval type-2 fuzzy weights – see Equation (1). These values are observable in Table 4.

Since epsilon value while determination of upper limit value of weight and lower limit value of weight is respectively equal to 0.066 and 0.064, the CRs will be equal to 0.0126 and 0.0121. These rates are so close to 0 and one can claim that comparisons have a good compatibility.

Hereafter, by substituting the upper $\overline{E}$ and lower $\underline{E}$ limits values in Equation (16); the possibility degrees of preferences about indicator can be calculated. Same way, the matrix of possibility degrees of preferences about indicator is obtained – Equation (17). Each row of this reflects possibility degrees of preferences of an indicator against other ones. This matrix surely contains a row with degrees of equal or more than 0.5 value. The related indicator gets the first rank in this way. Other indicators are ranked after elimination of row and column of the mentioned indicator as such (Hashemi *et al.* 2014).

$$P\left(E_2 \succ E_1\right) = \frac{b_1}{b_2}, \quad (16)$$

where:

$$b_1 = \max\left(0, \left(\overline{E}_2 - \underline{E}_2\right) + \left(\overline{E}_1 - \underline{E}_1\right)\right) - \max\left(0, \left(\overline{E}_1 - \underline{E}_2\right)\right);$$

$$b_2 = \left(\overline{E}_2 - \underline{E}_2\right) + \left(\overline{E}_1 - \underline{E}_1\right).$$

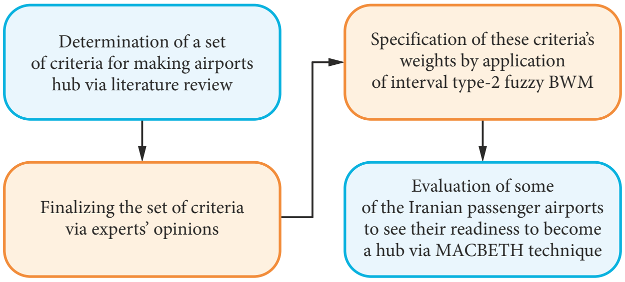


Figure 1. Main steps of this study

Table 4. The weights of indicators via application of BWM plus their ranks

Indicator	Lower limit value	Upper limit value	Ranks
Strategic management	0.1133	0.1135	1
Airport branding	0.1114	0.1116	2
Airport connectivity	0.1095	0.1097	3
Productivity	0.1076	0.1078	4
Financial	0.0697	0.0706	9
Safety and security	0.10567	0.10593	6
Social responsibility	0.1037	0.1040	7
Environmental protection	0.1018	0.1021	8
Service quality	0.0697	0.0706	9
Competiveness	0.10420	0.10510	5

$$P = \begin{array}{c} \\ \text{Indicator 1} \\ \\ \vdots \\ \text{Indicator 10} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Indicator 1} & \dots & \text{Indicator 10} \end{array} \\ \begin{pmatrix} P(E_1 \succ E_1) & P(E_1 \succ E_2) & \dots & P(E_1 \succ E_{10}) \\ P(E_2 \succ E_1) & P(E_2 \succ E_2) & \dots & P(E_2 \succ E_{10}) \\ \vdots & \vdots & \dots & \vdots \\ P(E_{10} \succ E_1) & P(E_{10} \succ E_2) & \dots & P(E_{10} \succ E_{10}) \end{pmatrix} \end{array}. \quad (17)$$

Ranks of indicators are specified via use of Equations (16) and (17) and are depicted in Table 4. Such result is transferred to experts again for gaining a realistic interpretation. As is obvious, service quality is the most tangible indicator of the airport's performance and always has been under control by taking comments from passengers or use of famous models such as SERVQUAL. It is actually among the first indicators to be investigated and always considered while policy making. Now, airport managers in developing countries are familiar enough with its related principles and benchmarking system. However, "system and security" is still a threat in such countries although its importance is obvious. In the history of aviation in Iran for instance, the death toll of 1694 people has been recorded for aircraft owned or leased by Iranian air companies or Iran airports holding company. This is because of the weakness in operation of aircraft safety standards or any other reason; it shows that this indicator should receive more attention. Another important indicator, which was not under consideration until recently is about airport branding. Governments are taking the pass through privatization of airports in recent decades and that is why airport managers are forced to place greater emphasis on airport marketing and branding (Castro, Lohmann 2014). Brand management helps airports to differentiate themselves from competitors and be chosen by passengers as final destination or a hub. Such branding helps airports to increase their connectivity as hubs. Besides, studies show that airport brand management enhances performance transparency, and social-environmental responsibility, resulting to sustainability (Lee, Park 2016; Figueiredo, Castro 2019). However, airport managers in developing countries are still inexperienced in this domain. It is advised to take use of leader airports such as Heathrow Airport near London or Singapore Changi Airport to symbolizing brands and create lovable brand. In this way, it becomes possible to shape a unique image in passengers' minds and also show the importance of local species and culture preservation at the same time. It also creates a pleasant atmosphere, which makes waiting to continue air travel as hubs easier. All of these activities, which seeks to distinct airport from competitors and enhance its productivity of performance should be considered in airport vision when policy-making. Then, airport will become a commercial business and not just a way for transportation. Now, it can be seen that financial concept and revenue value has not a considerable importance by itself and the way it will be used gains more importance; a matter that should be investigated while policy-making.

Table 5. The list of Iranian international airports

Airport's name	ICAO code
Abadan	OIAA
Ahvaz	OIAW
Ardabil	OITL
Bandar Abbas	OIKB
Shahid Beheshti of Isfahan	OIFM
Payam	OIIP
Hashemi Rafsanjani of Kerman	OIKK
Ashrafi Isfahani of Kermanshah	OICC
Kish	OIBK
Larestan	OISL
Hasheminejad of Mashad	OIMM
Pars Abad of Moghan	OITP
Dashte Naz of Sari	OINZ
Dastgheib of Shiraz	OISS
Madani of Tabriz	OITT
Imam Khomeini	OIIE
Mehrabad	OIII
Oroumieh	OITR
Zahedan	OIZH

Now using the first 5 criteria, the most appropriate Iranian international airport to be hub airport is found. The list of all 19 Iranian international airports is presented in Table 5 and their ICAO code is used to mention them now onwards.

The criteria are introduced in M-MACBETH and the value tree is as presented on Figure 2.

Then all the alternatives/options are compared pairwise to fill the judgement matrix for each criterion.

The results for each criterion are as shown in Figure 3; the ranking of airports according to each criterion is different from the overall result. In addition, the scores and differences between scores are completely different, for example it can be seen that "Airport branding" in Payam Airport with the ICAO code "OIIP" is better than other airports but in no other criterion this airport got the first level. The results are better reported in Figure 4.

Finally, the software calculates the overall ranking of alternatives considering all the criteria, which is shown in Figure 5.

As the results show, Kish Airport with the ICAO code "OIBK" is prior to other airports and can be chosen as the hub airport.

Figure 2. Value tree of the model

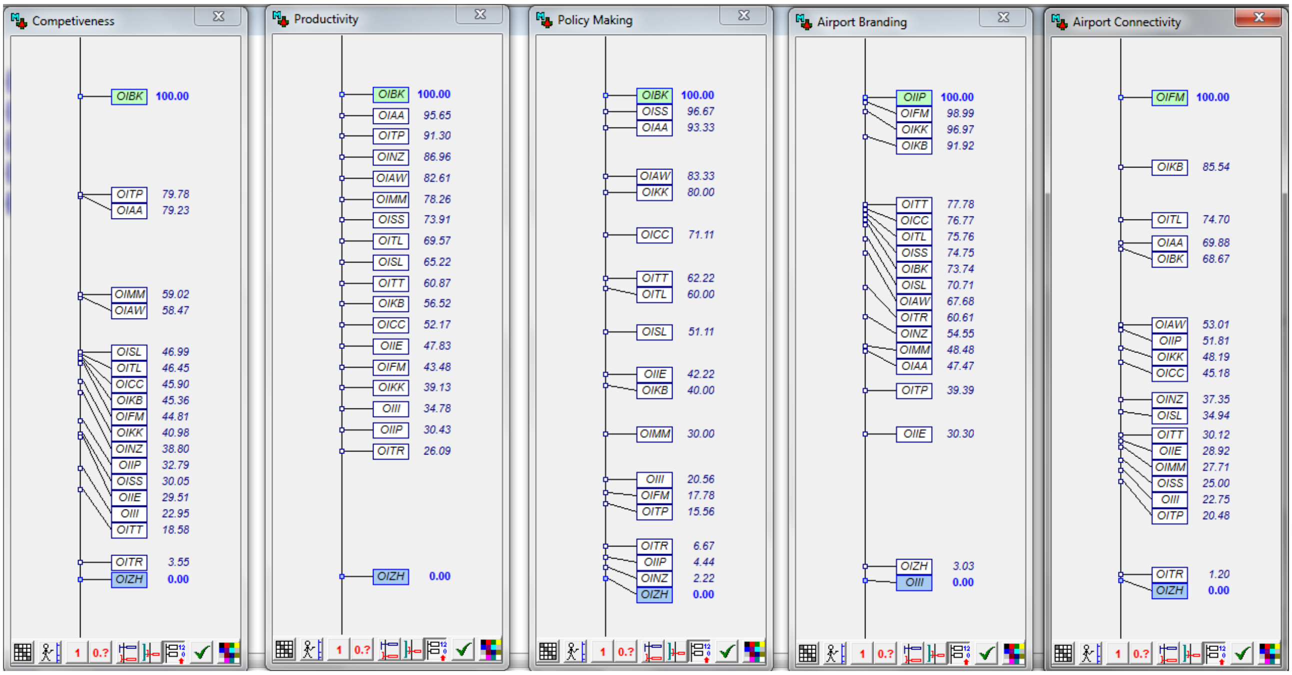
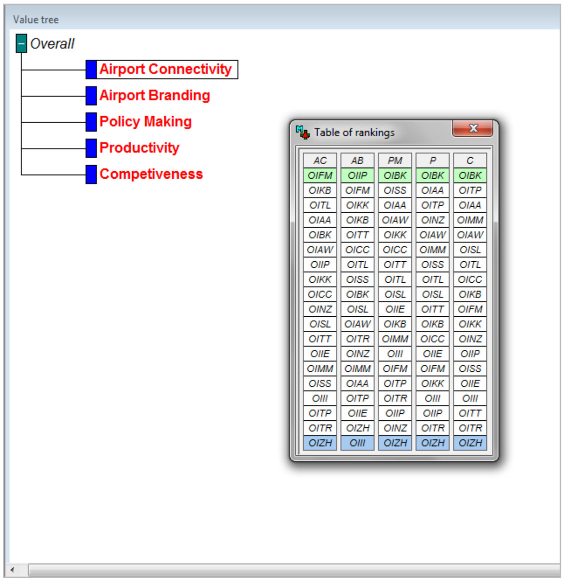
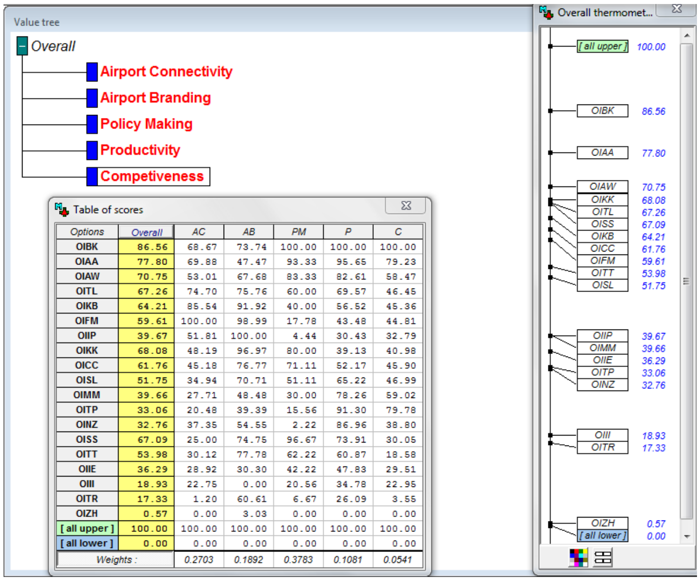


Figure 3. Alternatives' position according to each criterion



AC	AB	PM	P	C
OIFM	OIIP	OIBK	OIBK	OIBK
OIKB	OIFM	OISS	OIAA	OITP
OITL	OIKK	OIAA	OITP	OIAA
OIAA	OIKB	OIAW	OINZ	OIMM
OIBK	OITT	OIKK	OIAW	OIAW
OIAW	OICC	OICC	OIMM	OISL
OIIP	OITL	OITT	OISS	OITL
OIKK	OISS	OITL	OITL	OICC
OICC	OIBK	OISL	OISL	OIKB
OINZ	OISL	OIIE	OITT	OIFM
OISL	OIAW	OIKB	OIKB	OIKK
OITT	OITR	OIMM	OICC	OINZ
OIIE	OINZ	OIII	OIIE	OIIP
OIMM	OIMM	OIFM	OIFM	OISS
OISS	OIAA	OITP	OIKK	OIIE
OIII	OITP	OITR	OIII	OIII
OITP	OIIE	OIIP	OIIP	OITT
OITR	OIZH	OINZ	OITR	OITR
OIZH	OIII	OIZH	OIZH	OIZH

Figure 4. Table of alternatives' ranking according to each criterion



Options	Overall	AC	AB	PM	P	C
OIBK	86.56	68.67	73.74	100.00	100.00	100.00
OIAA	77.80	69.88	47.47	93.33	95.65	79.23
OIAW	70.75	53.01	67.68	83.33	82.61	58.47
OITL	67.26	74.70	75.76	60.00	69.57	46.45
OIKB	64.21	85.54	91.92	40.00	56.52	45.36
OIFM	59.61	100.00	98.99	17.78	43.48	44.81
OIIP	39.67	51.81	100.00	4.44	30.43	32.79
OIKK	68.08	48.19	96.97	80.00	39.13	40.98
OICC	61.76	45.18	76.77	71.11	52.17	45.90
OISL	51.75	34.94	70.71	51.11	65.22	46.99
OIMM	39.66	27.71	48.48	30.00	78.26	59.02
OITP	33.06	20.48	39.39	15.56	91.30	79.78
OINZ	32.76	37.35	54.55	2.22	86.96	38.80
OISS	67.09	25.00	74.75	96.67	73.91	30.05
OITT	53.98	30.12	77.78	62.22	60.87	18.58
OIIE	36.29	28.92	30.30	42.22	47.83	29.51
OIII	18.93	22.75	0.00	20.56	34.78	22.95
OITR	17.33	1.20	60.61	6.67	26.09	3.55
OIZH	0.57	0.00	3.03	0.00	0.00	0.00
[all upper]	100.00	100.00	100.00	100.00	100.00	100.00
[all lower]	0.00	0.00	0.00	0.00	0.00	0.00
Weights :		0.2703	0.1892	0.3783	0.1081	0.0541

Figure 5. Overall calculations of alternatives' ranking

Conclusions

BWM is a new decision making method, which accurately can be used to rank different alternatives. In this paper, this method is used for criteria ranking in a situation that applying all found criteria in the chosen DSS isn't possible because the number of alternatives is too large and it increases the number of judgements very dramatically and consequently makes it difficult for experts to fill the matrix. As the criteria mentioned here are listed from previous studies in air transportation researches, comparing them with quantitative scores isn't simple for experts, so interval type-2 fuzzy numbers are generated to simplify assessment process. Then by the use of M-MACBETH software, alternatives are compared considering each high-rank criterion specified in previous step, alternatives in this study are Iranian international airports. Up to our knowledge, its first time that this combined method is used to rank alternatives or make decisions especially using interval type-2 fuzzy numbers.

Air traffic is attracting more attention among other transportation systems because of its potential of financial gaining in different ways other than just transportation mode. This makes it critical for managers to decide about investments in each development project. This can be more critical in shadow of budget restrictions, that's why in developing countries like Iran although the intention for having a good position in international air transportation system is very high, but the process of development is slow mostly because of low investment and uncertainties in best place for investment.

As expressed before among 54 airports in Iran, 19 of them are known as international ones. Many of them are not beneficial recently and the non-aviation earning is far less than the average global rate. Another problem is that these airports may not be experienced in communicating with local shareholders or may encounter natural disasters. Some of them also have difficulties in preserving local species. Gaining such characteristics makes the airport more sustainable and this is while previous studies show that hub airports usually have more effective sustainability performance. The results show that Kish airport with the ICAO code "OIBK" is prior to other airports and can be chosen as the hub airport, although it's not located in capital of the country and in fact is far away from that, but as is located in a free zone island, it can be a logically acceptable choice for managers and experts.

Besides the main goal of this research to find the most appropriate airport to be the hub airport in Iran, the results can be used for airport managers to find their weak points in each airport. Rankings according to each criterion in Figure 3 show this, that was attractive for respondents also.

The proposed approach to decision making is suggested for other industries as well, the most important advantage of this method is the combination of fuzzy judgements and qualitative comparisons, which is main challenge for experts of different aspects.

Author contributions

Mahsa Pishdar and Fatemeh Ghasemzadeh conceived the study, designed and developed the methodology, made data collection and analysis, wrote the first draft of the article.

Jurgita Antuchevičienė provided extensive advice throughout the study, assisted with the research design and revised the manuscript. All of the authors have read and approved the final manuscript.

Disclosure statement

Authors declare that they have no any competing financial, professional, or personal interests from other parties.

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