Logical Selection of Potential Hub Nodes in Location of Strategic Facilities by a Hybrid Methodology of Data Envelopment Analysis and Analytic Hierarchical Process: Iran Aviation Case Study

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Received: 21. 05. 2018 Accepted: 09. 10. 2018

Abstract

Hub facility location problem looks to find the most appropriate location for deploying such facilities. An important factor in such a problem is the pool of potential locations from which the optimal locations must be selected; i.e., which locations may actually be selected for a potential hub. The present research was performed to address two key objectives: (1) identifying the factors contributing to the selection locations for hub establishment, and (2) presenting an efficient methodology for assessing the efficiency and effectiveness of each node, followed by selecting optimal nodes for establishing potential hubs. The paper begins with a review on related literature, leading to identification and classification of the most important factors and criteria for a hub based on the required features in transportation systems. Subsequently, in order to assess all nodes, the identified factors were grouped into input and output criteria, with the extended Data Envelopment Analysis used to assess the efficiency of the nodes. Moreover, the assessment accuracy was enhanced by weighting the input and output criteria using Analytic Hierarchy Process. A significant achievement of this research was the innovative combination of Analytic Hierarchical Process and Data Envelopment Analysis by presenting a scientific model in the form of a heuristic pair-wise comparison matrix followed by adopting power eigenvector methodology. The result of this hybrid approach highlighted the nodes upon which unavailability the efficiency of other nodes was significantly affected, and new rankings of the nodes upon such unavailability. As findings, the present research identified the input and output criteria and their weights and developed a hybrid Analytic Hierarchy Process and Data Envelopment Analysis method for potential hub location. In order to validate the findings, Iranian Airport Dataset (IAD) was used.

Keywords: Hub location, data envelopment analysis, most efficient, analytic hierarchical process.

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1. Introduction

A hub location problem looks to find optimal location(s) for service-providing hub facility(ies) and to further allocate demand center(s) to the facility(ies). Primary concepts and principles of the hub location problem were proposed by [Hakimi, 1964]. Assessing and modeling several aviation networks, [O'Kelly, 1986] developed the hub location problem into P-hub location problem – a mathematical model. [Ernst and Krishna Moorthy, 1996] studied Australian post system; based on their results, they contributed a new concept into the hub location literature: Different values of α- discount for collection and distribution networks. In the hub location literature, several efforts have been made to compute efficiency of facilities.

Reliability is an important criterion in hub location problem. [Aziz, 2017] presented a mathematical model for designing hub network under hub failure, featuring fast and low-cost recovery of the network following a potential hub failure with the help of backup hubs. Following the same line of research, [Kim and Ryerson, 2017] designed multi-modal transportation networks wherein an alternative hub was used whenever a particular transportation mode was unavailable or poor along the path connecting particular nodes. The methodology was based on adopting critical infrastructures for general purposes.

Such factors as strikes, disasters or traffic breakdown also impose significant impacts on decision-makings related to hub location problems, and tend to highly increase uncertainty for a short period of time. [Correia et al.2018] considered the three factors when designing their model and proposed a two-stage formulation for the single allocation hub location problem which included the reallocation of sources to a backup hub in case the hub breaks down. Benders decomposition algorithm was further developed to solve the model. Hub location problems have found particular applications in telecommunication industry. [Xu et al. 2017] focused on uncapacitated k-median facility location problem and undertook modeling to minimize total routing time and improve the server-client connection speed.

Alongside the applied aspects, development of a model for real conditions represents a major concern. [Essaadi et al. 2017] succeeded to present a model for hub location problem wherein hierarchical logistic structure, postponement strategy, multi-commodity, multi-packaging of goods (raw materials or components vs. final products), and multi-period planning were simultaneously taken into account when designing the network.

The approach to solving a hub location problem (rather than the problem itself) represents a challenge to researchers. Developing Banders decomposition algorithm, [De Camargo et al.2017] obtained good results in the incomplete hub location problem with and without hop-constraints and could solve the problem in very large dimensions.

In addition to the mathematical methodologies, novel techniques have been developed for solving a hub location problem. As an instance of such novel techniques, cellular learning automata (CLA) is based on machine learning, as proposed by [Saghiri and Meybodi, 2018].

Most of the parameters contributing to a hub location problem are associated with uncertainty, so that their values exhibit a probabilistic behavior under different sets of conditions. [Rostami et al.2018] designed a model for multi-period stochastic capacitated multiple allocation hub location problems under uncertain demand.

[Zhalechian et al. 2018] considered the uncertainty in terms of operational and disruption risks. They introduced a novel decision-making framework to design a resilient hub network. The decision-making framework considered three dimensions at the same time: reactive capability, proactive capability, and design quality.

Classified as a location-allocation problem, the present research problem covers a wide scope of applications, including location-routing problems wherein the capacity and demand delivery time are two key parameters contributing to the decision-making process on hub facility location [Nadizadeh and Hosseini Nasab, 2019]. Moreover, uncertainty imposes significant impacts on the choice of facilities in location-routing problems. For example, [Ghatreh Samani and Hosseini-Motlagh, 2017] tried to design an uncertainty-appropriated model for demand.

On the other hand, [Shroff et al. 1998] described location benchmarking system and used Data Envelopment Analysis (DEA) technique to measure the efficiency at potential locations for long-term guarding facilities. [Thomas et al. 2002] employed DEA to address hazardous facilities location-allocation problems, integrating the DEA and location problem in terms of goal. Using a DEA- based decision making model, [Ertay et al.2006] examined quantitative and qualitative criteria for evaluation of topological design of facilities. [Bunyaratavej et al. 2008] developed a model to undertake a country-based assessment of hub facilities by means of DEA for the purpose of facilitating the process of decision-making on in-sourcing or out-sourcing in such a way to keep their constant trend of activity. [Ertay et al. 2011] suggested an integrated fuzzy Multiple-Criteria Decision-Making (MCDM) methodology for addressing material handling equipment selection problem in production companies, wherein the efficiency of facilities at different locations was assessed.

Solid waste location problem is a complex instance of the family of location problems, in which appropriate selection of potential locations depends on important parameters. [Khadivi and Ghomi, 2012] proposed a technique that could efficiently consider managerial adjustments and subjective data along with quantitative factors. They proposed a procedure for locating double-stage facilities. According to this technique, important factors were assessed by Analytic Network Process (ANP) and the results (i.e., the level of importance) were then used to select optimal locations for the facilities among the pool of potential locations identified by DEA.

Seller selection problem in online trading platforms is an emerging topic. In this respect, [Aji and Hariga, 2013] used an Analytical Hierarchy Process (AHP)-DEA hybrid method on a restricted list of sellers. In another work, [Mitropoulos et al.2013] identified the factors contributing to the location of a medical center and then located such centers by the aid of DEA technique. Wind energy facility location problem is a quickly growing topic. [Azadeh et al.2014] used fuzzy DEA to locate such facilities. Given the growing demand for food products, location of agricultural service centers largely contributes to the availability of such centers to farmers. Combining DEA, Sample Additive Weighting (SAW), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), [Zangeneh et al. 2015] evaluated the factors affecting the selection of such centers and identified the most significant factors. Brazil is a leading producer of sugar and ethanol. Accordingly, locations of sugar and ethanol mills are important for appropriate management of the transportation of raw materials to the mills and then the processed products to export terminals. Thus, in a survey, [Bargos et al. 2016] studied major production centers of sugar and ethanol across Sao Paulo using zero-planning model and DEA to realize the goals followed in optimal location of sugar and ethanol production mills. [Sun and Zheng, 2016] developed a model for locating potential hub facilities along shipping lines. The model sought to identify locations for potential hub facilities in unknown regions of no port. They set the model to avoid the selection of existing ports. The present study is intended to assess efficiency in discrete space, so to improve facility location in discrete space in terms of efficiency; i.e., maximum efficiency at minimum possible cost. Although facility efficiency has been considered in a number of research works on facility location problem, but this important factor has been widely overlooked. Accordingly, there is a need for studying facility establishment location in terms of efficiency parameters before proceeding to compute efficiency.

In some other research works, in order to avoid non-analyzed selection, each and every node was considered as a potential location for hub establishment. Since [O'Kelly, 1986], this approach has been adopted in many works. However, given the development of modern mathematical models and increased number of nodes to be studied in a single problem, researchers are likely to solve such problems via complex and time-intensive techniques such as heuristic and metaheuristic algorithms. In the meantime, efficient node identification (for the purpose of hub establishment) can bring about two fundamental advantages: (1) eliminating the need for designing particular algorithms and solving methods for problems of increasingly larger dimensions, and (2) avoiding improper selection of inefficient nodes and/or arbitrary deletion of efficient nodes from the pool of potential hubs.

In the present research, MCDM was utilized to identify efficient nodes for hub establishment. The rest of this contribution is organized as follows. The research problem is described in Section 2. Section 3 present the model input and output variables and the criteria used to weight the variables based on related literature. The weighting process is discussed in Section 4. Section 5 explains different steps taken to develop DEA model, followed by developing the respective heuristic model in Section 6, with a further elaboration on the estimation of the network efficiency in cases where particular node(s) is infeasible to select. A computational approach is followed to identify a group of potential hub nodes for Iranian Airport Dataset (IAD), as a standard dataset hub location literature, in Section 7. Conclusions and future suggestions are incorporated into a final section.

2. Problem Description

Hub location problems involve the selection of locations for hub establishment. In general, a hub delivers three functionalities: (1) switching, (2) transshipment, and (3) sorting [Farahani et al.2013]. As such, a wide range of applications may be addressed by hub facility location models, among which one may refer to production planning, retail management, wholesale management, and health and medical care [Teo and Shu, 2004; Jia et al.2007; Revelle et al.2008; Melo et al. 2009; Gelareh and Nickel, 2011; Yaman and Elloumi, 2012; Korani and Sahraeian, 2013; Alumur et al. 2012; Yu An et al.2014].

In hub location problems, a number of locations (nodes) are selected for establishing hubs. In this approach, the model performs much complicated analysis to identify optimal locations for hub establishment. Despite the performance of such complicated analysis, since not every single factor contributing to hub location is considered in such analysis, it is much likely that the finally selected nodes are practically infeasible. That is, there is no guarantee that such a long and complicated process ends up with an actually feasible location for establishing a hub as the optimal location has been identified solely based on a set of model parameters. For a hub location problem, the traditional approach considers such factors as distance and traffic volume as decision variables, while many other parameters tend to affect the choice of optimal location for establishing a hub (e.g., population, traffic volume, distance, reliability, capacity, etc.). As such, a workaround seems to be a preprocessing step wherein the most appropriate nodes are selected to form a set of potential hub establishment nodes, before proceeding to solve the main problem.

Therefore, the present research looks to assess all nodes and identify the optimal ones as potential hub facility establishment nodes. Outcome of such an approach is a set of nodes defined as potential nodes for hub establishment. On this basis, one may raise three secondary questions: (1) what are the criteria and factors contributing to the node selection process? (2) what are the weight (significance) of each of the criteria in the decision-making process? and (3) which method is capable of performing the selection process efficiently in such a way that no pair of nodes end up with the same rank, so as to achieve a non-repeated ranking? Since we are dealing with a discrete space of nodes, a review on the literature revealed “the most efficient decision-making unit (DMU) DEA” methodologies were found to be the best approaches to non-repeated ranking selection in discrete space [Amin and Toloo, 2007].

A step-by-step demonstration of the methodology adopted in this research to address the three secondary research questions is depicted in Figure 1. The process begins with identifying the effective criteria and then proceeds to their significance and rank. Finally, based on the obtained value of significance for each criterion, node selection process is performed based on node efficiency. AHP and DEA were used in the second and final spaces, respectively.

3. Input and Output Criteria for Efficiency of Hub Facilities

Given a system (decision making unit) converts some of inputs into some outputs in DEA analysis, efficiency is assumed as a ratio of weighted sum of output to weighted sum of inputs [Porembski et al.2005].

There are four properties as characteristics in location problems where these characteristics include 1) customers for whom it is imagined they are present at the points and or settled in the paths; 2) facilities based on which some locations are established; 3) a space or limit in which customers and facilities are placed; and 4) a metric that indicates distance or time interval between customers and facilities [Bhatnagar and Sohal, 2005]. Pyramidal structure and coverage of the identified criteria and sub-criteria are given for hub facilities at two levels that included by study on literature and adjustment of them with the existing data in groups of used data for validation of mathematical models. The main criteria placed at first levels are as follows:

Cost of establishment of facilities (input): The land is considered as main infrastructure for construction of units in any facility. Thus, facilities establishment cost is selected as input parameter for level-1 at any node and location.

Mean distance of any location from other locations (input): As it mentioned before, in order to create a facility, the more populated regions are preferred. Thus according to the same deduction it should mentioned that if this great population is averagely placed at the least distance from other locations, transportation cost will be extremely reduced.

Mean size of tradeoffs and population (output): Accumulation and density of demographic texture is one of the efficient parameters in position of location for facilities. It should be noticed that as quantity of demand is higher, the necessity and justification is increased for establishment of facilities.

Potential and capacity (output): Infrastructures always an important role at all three processes of design, execution, and maintenance in implementation of a civil project because probability of non-responsiveness will be extremely low. Thus, despite of public welcoming, the financial sources and liquidity flow will be constantly continued and continuous trend of service-giving process will be promoted noticeably.

Rate of reliability and confidence (output): Any location is always subject to occurrence of natural and unnatural disasters therefore one of the effective elements in determination of efficiency of locations is the rate and intensity of level of exposure to disasters in a specific location that may highly impact on selection of establishment location of a facility.

Accordingly, we should consider four important natural and unnatural accidents with high probability for their occurrence and rate of their occurrence should be determined and combination of them should be assumed as one of the needed indices. These four events are terroristic operations, probability of war outbreak, earthquake, and torrent (a fast flowing stream) where two first cases are unnatural and the two latter ones are of natural disasters. In order to compare the contribution of the present research compared to previous works, Table 1 reports several criteria contributing to the choice of location for establishing potential hubs (facility establishment cost (I_1), average distance from other locations (I_2), average traffic volume (O_1), capacity (O_2), reliability (O_3), effect of weight in decision-making (M_1), professional assessment of potential hub nodes (M_2), and estimated efficiency of hub establishment nodes (M_3)) to compare different research works and highlight the great contribution of the present research. A review on Table 1 shows that, most of such works have been based on the distance as the key criterion, and none of them have undertaken efficient node assessment. Moreover, the works have generally failed to consider the impact of the weight of each criterion in the professional process of potential hub location selection. Therefore, the contribution of the this research includes (1) considering 8 different criteria in the potential hub location selection, and (2) presenting an effective methodology to maximally take advantages of the resultant data for selecting potential hub locations.

Figure 1. Step-by-step demonstration of the methodology adopted in this research

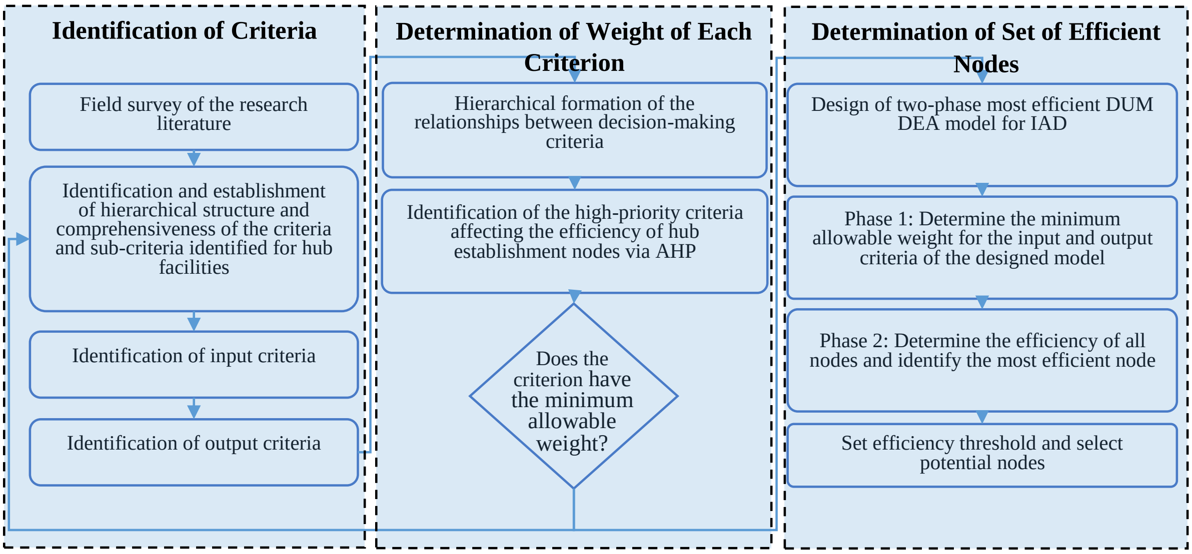

Table 1. Comparison of the present work to the related literature.

Authors and publication year	I_1	I_2	O_1	O_2	O_3	M_1	M_2	M_3
Cunha and Silva (2007)	✓	✓						
Yaman (2009)		✓	✓					
Limbourg and Jourquin (2009)	✓	✓	✓					
Kim and O'kelly (2009)		✓	✓		✓	✓		
Campbell (2009)	✓	✓	✓	✓				
Costa, Lohmann, and Oliveira (2010)	✓	✓						
Lin (2010)	✓		✓	✓				
Wang and Cheng (2010)		✓	✓	✓				
Ishfaq and Sox (2010)		✓	✓	✓				
Gelareh et al. (2010)	✓	✓	✓				✓	
Lin and Lee (2010)		✓		✓				
Vidović et al. (2011)	✓	✓	✓	✓				
Gelareh et al. (2010)		✓						
Vasconcelos et al. (2011)		✓		✓				
Karimi and Bashiri (2011)		✓	✓			✓		
Lin et al. (2012)		✓	✓	✓				
Korani and Sahraeian (2013)	✓	✓	✓			✓		
An et al (2015)	✓	✓		✓	✓			
Azizi (2017)	✓	✓	✓					
Kim and Ryerson (2017)	✓		✓		✓			
Correia et al. (2018)	✓	✓	✓	✓				
Rostami et al. (2018)	✓		✓		✓			
Zhalechian et al. (2018)		✓	✓		✓			
Our work	✓	✓	✓	✓	✓	✓	✓	✓

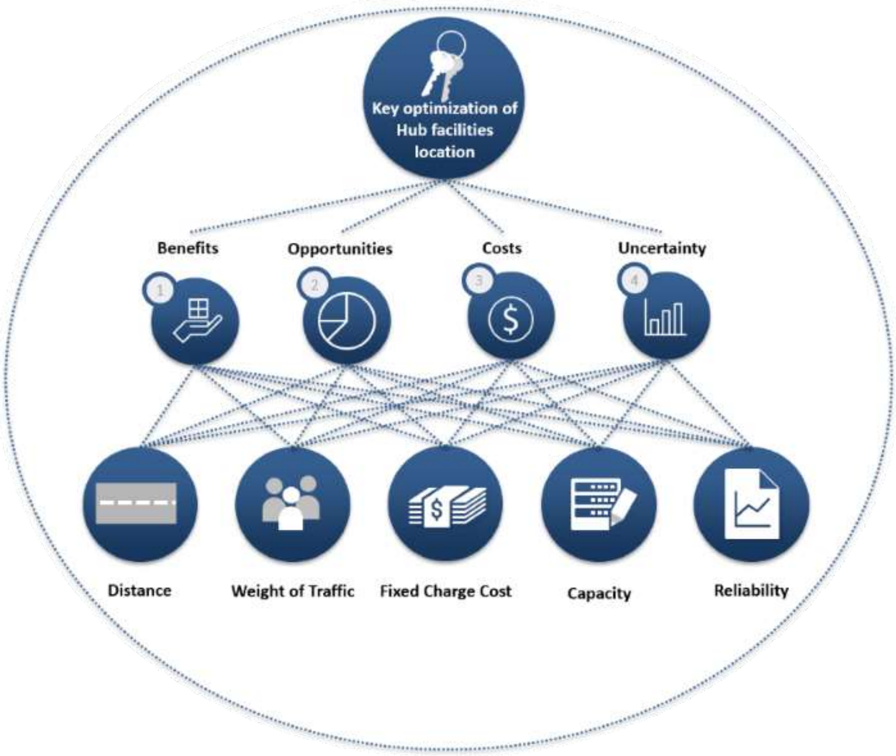

Figure 2. Hierarchical structure of the criteria and sub-criteria identified for hub facilities

Moreover, the hierarchical relationships among different criteria are illustrated in Figure 2, where optimal hub facility location has been recognized as being based on four significant dimensions: benefits, opportunities, costs, and uncertainty. At practical level, these dimensions include such parameters as distance to other nodes, volume of traffic, fixed cost of hub facility establishment, available capacity, and rate of reliability.

Five above indices have been considered for optimization of efficiency and effectiveness of location of establishment of hub facilities. These indices were presented with respect to Iranian Airport Dataset (IAD) by [Karimi and Bashiri, 2011] and there were defined and suggested by [Azadeh et al. 2011].

mean distance of any location from other locations have been indicated by I_1 and I_2 and mean outputs of size of tradeoffs (transactions), capacity, and reliability are characterized by O_1, O_2, and O_3, respectively.

According to an approach considered in selection of inputs and outputs and with respect to frequency of parameters in process of decision making, mathematical models have been more addressed in literature locations.

Second- order parameters and sub- criteria that are considered from [Khadivi and Ghomi, 2012] are consistent with requirements of Iranian data. The second- order criteria include financial and intellectual advantages and benefits, costs, opportunities, and uncertainties. Importance of AHP technique has been highly noticed for decision making process in research literature; for example, [Ren and Xiong, 2010] expressed that use of AHP method reduces subject and objective in determination of error weights for assessment based on purposeful focus.

According to attitude of [Jenab et al. 2012], AHP method is a type equalizer for uncertainty in general process of decision-making. Accordingly, before entry into process of assessment of efficiency at centers of hub facilities establishment in this study we also evaluate weights of inputs and outputs and make them involved according to ratio of their effect in process of assessment of performance of their potential nodes. Thus based on research literature, AHP contributes to decision-makers to adjust preferences based on their own goals, knowledge, and experience so that to take their emotions and judgments totally into consideration. The problem should be accurately defined and interpreted with all details to solve decision making problems via AHP and their details should be drawn in form of hierarchical structure [Saaty, 1996].

After determination of type of relations, polling is executed for experts and this polling is typically based on multiplicity of benefitting from each of parameters in research literature. For this purpose, the cases study was used that it was done by [Farahani et al. 2013] dealt with subject of hub location problems. Symbol of I denotes n-5 member set that shows 5 inputs and outputs which have been evaluated by the aid of Eigen-vector in the following steps. Thus, sets of I and J include n members and pairwise comparison matrix- A is also symmetric with n dimensions in which a_{ij} arrays comprise of preference of i^{th} element to j^{th} element and W_i is the weight of i^{th} and λ is a fixed number. The weight of i^{th} where $i \in I$ can be defined as $W_i = (1/\lambda)\sum_{j=1}^{n} a_{ij} W_j$.

Given that the set I includes n members therefore problems has n equations of $W_i = (1/\lambda)\sum_{j=1}^{n} a_{ij} W_j$ that will form n- equation coordinates. Therefore, the coordinates of above equations may be written as $A \times W = \lambda . W$ in which matrix-A is the same as pairwise comparison matrix $(A=[a_{ij}])$ and W weighted vector, and λ is a scalar value. As it mentioned, Matrix- A was formed by benefitting from attitude of experts and it calculated determinant of matrix $(A - \lambda . I)$ and solving of its zero-equation presented values of λ. Then values of W_i were computed by the aid of λ_{MAX} and formula $(A.I- \lambda_{MAX}) \times W = 0$ in which input criteria of *Fixed Charge Cost* and *Distance* acquired weights 0.23 and 0.10 respectively and also output criteria of Weight if Traffic, Reliability, and Capacity obtained weights 0.29, 0.21, and 0.17 correspondingly.

4. Mathematical Two-Phase Model of DEA

DEA technique is a method based on linear planning that can measure relative efficiency of units with multiple similar inputs and outputs. The origin of this technique is a model that was proposed by [Farrell, 1957]. The model suggested by Farrell was developed by [Charnes et al. 1978] and proposed under title of DEA. The first suggested model for DEA was proposed by Charnes, Cooper and Rhodes and it became well-known as CCR model because it included first letters of names of these experts. Following to study of, these three experts many investigations have been carried out but it can be found by analysis of this literature that the former models are exposed to three problems which can be classified into three items:

Table 2. Classification of inputs and outputs based on research literature

scope	Authors and publication year	Case study in the real world	Location implement	I_1	I_2	O_1	O_2	O_3
Airlines and airport industry	Kim and O'kelly (2009)	Airlines	United States of America		✓	✓		✓
	Costa, Lohmann, and Oliveira (2010)	Airport hubs - Tourism	Brazil	✓	✓			
	Lin (2010)	Dual quick service (air and ground)	Taiwan	✓		✓	✓	
	Karimi and Bashiri (2011)	Airport hubs - Tourism and Industry	37 cities of Iran		✓	✓		
Supply chain - logistics	Lin et al. (2012)	Air cargo network	China		✓	✓	✓	
	Wang and Cheng (2010)	cargo transportation	Hong Kong		✓	✓	✓	
	Ishfaq and Sox (2010)	Load flow	25 cities of the United States of America		✓	✓	✓	
Transportation systems	Cunha and Silva (2007)	Transportation companies	Brazil	✓	✓			
	Gelareh and Nickel (2011)	Public transportation	Germany	✓	✓	✓		
	Campbell (2009)	cargo transportation	North America	✓	✓	✓	✓	
	Limbourg and Jourquin (2009)	Multimodal transportation	Europe Transportation terminals	✓	✓	✓		
	Lin and Lee (2010)	Cargo Freight	Taiwan		✓		✓	
	Vidović et al. (2011)	Cargo transportation	Serbia	✓	✓	✓	✓	
	Gelareh and Nickel (2011)	Navy Establishment	Network ports of Europe and North America		✓			
	Vasconcelos et al. (2011)	Multimodal transportation	Brazil		✓		✓	
	Korani and Sahraeian (2013)	Airport hubs - Tourism and Industry	Iran	✓	✓	✓		
	Yaman (2009)	Multilevel Hub	Turkey		✓	✓		
	An et al (2015)	Hub Reliability	United States of America	✓	✓		✓	✓

(1) The first one is that number of outputs should be more than number of inputs of model. (2) There is possibility in many cases a great number of DMUs are known as efficient. (3) The model should be executed once for calculation of each of DMUs [Amin and Toloo, 2007].

However regarding new field that has occurred in recent years, some DEA models were introduced that presented most efficient DMU individually so that only one of them possessed efficiency level 1 while the other units acquired the lower rank.

Similarly, this model presents efficiency of all DMUs at the same time and at last the ratio of inputs to outputs is not important. One of the best proposed essays that provide these three items includes a model that was posited by [Amin and Toloo, 2007] where they introduced an integrated DEA model of efficient DMUs without constraint in terms of number of inputs and outputs. Following to this study, [Amin, 2009] presented another model to improve this process that only knew only one DMU as efficient and introduced others compared to this unit. Mathematical DEA model used in study of [Toloo and Tichý, 2015] is introduced along with constraints. This model is formed at two phases in which first phase is initially maximized the minimum value for weights of inputs and outputs that will occur within Formula (1) to (5). The first phase is utilized to compute the minimum values for weights of inputs and outputs called ε^*. The reason for execution of this phase takes place before phase of calculation of efficiency rate to confirm AHP step because weight of any input and output should not be smaller than one at least since if it was not important surely weight value was not computed for it at AHP weighting step. Therefore, assuming that number of assessed units is *n*, number of output of units is *J* and number of input of units is *I*, O_{jr} shows j^{th} output of unit-r and I_{ir} indicates i^{th} input of unit-*r*. Variables of problem are u_j and v_i that respectively indicate weight of j^{th} and weight of i^{th} input and target function tries to maximize ε^* [Refer to Amin and Toloo (2007)] to study the details of notations, terminologies and assumptions]. But, the following is a summary of the assumptions considered in this model;

1. Input values are quantitative, fixed, and certain.
2. Output values are quantitative and fixed.
3. Lower bounds of the input and output weights is a scalar value obtained by running the first phase of the model.
4. All of the decision variables are non-negative with fixed certain lower bounds.
5. Each node (city) is herein considered as a DMU.

$$Max = \varepsilon \tag{1}$$

Such that:

$$\sum_{i=1}^{I} v_i I_{ik} \le 1 \ \forall \mathrm{k} \in \mathrm{n} \tag{2}$$

$$\sum_{j=1}^{J} u_j O_{jk} - \sum_{i=1}^{I} v_i I_{ik} \le 0 \quad ,\forall \mathrm{k} \in \mathrm{N} \tag{3}$$

$$u_{\mathrm{j}} \ge \varepsilon \quad ,\forall ,\mathrm{i} \in \mathrm{J} \tag{4}$$

$$v_i \ge \varepsilon \quad ,\forall \mathrm{i} \in I \tag{5}$$

The output of this model i.e. minimum value of weight of inputs and outputs is called ε^* and this value will be used as the lower boundary of constraint for variables of weight of inputs and outputs in Phase-II model given by formulae (6) to (14) in the second model. The important point about value of ε^* is a determinant role for prevention from neutralization of some inputs or outputs and solving this problem will be led to selection of only one efficient unit and the existing difference among efficiency rate of each of the studied units (See also [Amin, 2009; Toloo and Tichý, 2015]).

$$\mathrm{Min} = \mathrm{M} \tag{6}$$

Such that: (7)

$$M - d_j \ge 0 \ \forall \mathrm{r} \in \mathrm{n} \tag{8}$$

$$\sum_{i=1}^{I} v_i I_{ir} \le 1 \ \forall r \in n \tag{9}$$

$$\sum_{j=1}^{J} u_j O_{jk} - \sum_{i=1}^{I} v_i I_{ik} + d_j = 0 \quad ,\forall k \in N \tag{10}$$

$$\sum_{j=1}^{J} \theta_j = n - 1 \tag{11}$$

$$\theta_j - d_j \beta_j = 0 \ \forall j \in J \tag{12}$$

$$\theta_j \in \{0,1\}, \quad \beta_j \ge 1, \ \forall j \in J \tag{13}$$

$$d_j, u_j, v_i \ge \varepsilon^* \quad ,\forall i \in I, i \in J \tag{14}$$

Using IAD data at next section and model posited by [Toloo and Tichý, 2015], we evaluate efficiency of potential locations and determine their efficiency and inefficiency. Similarly, numbers of reference units will be identified for inefficient units.

5. Ranking and Analytic Hierarchy of Efficiencies

The other fascinating subject proposed in this paper is to present a model that can compute new efficiency and basis for ranking of locations if it is not possible to select each of nodes. This operation will take place with formation of heuristic pairwise comparison matrix and integration of this matrix in AHP technique. Thus, with respect to deletion of each of units, assessment of efficiency of nodes is addressed in this section in order to examine level of effect of any node on efficiency of other nodes within framework of AHP technique so that to be able to have alternative choices if there is no possibility for selection of efficient node under special conditions. This measure excerpted from [Ray, 2004] who suggested AHP theory and technique for economic data. To this end, we call e_k^i as efficiency of node-I under the conditions the k^{th} node has been omitted from assessment process. Accordingly, if the studied set of nodes is $I \in \{1,2,...,n\}$, Table 3 will be formed.

Table 3. Values of efficiency of nodes after deletion of ($k \in I$)th unit

Node	*1*	*2*	*3*	*…*	*n-1*	*N*
1	e_1^1	e_1^2	e_1^3	$\cdots$	e_1^{n-1}	e_1^n
2	e_2^1	e_2^2	e_2^3	$\cdots$	e_2^{n-1}	e_2^n
3	e_3^1	e_3^2	e_3^3	$\cdots$	e_3^{n-1}	e_3^n
…				…		
n-1	e_{n-1}^1	e_{n-1}^2	e_{n-1}^3	$\cdots$	e_{n-1}^{n-1}	e_{n-1}^n
n	e_n^1	e_n^2	e_n^3	$\cdots$	e_n^{n-1}	e_n^n

Now, to distinguish degree of preference of i^{th} node to j^{th} node, we will form pairwise comparisons matrix out of Equations (15) – (17). It should be noticed that d_j was rate of inefficiency of j^{th} unit that was acquired from sum of Equations (6) to (14). Thus, $\tilde{d}_j = 1 - d_j$ is efficiency of j^{th} node, all nodes are considered.

$$\alpha_{ij} = \frac{\tilde{d}_i + (e_i^j - \tilde{d}_j)}{\tilde{d}_j + (e_j^i - \tilde{d}_i)} \ ; \qquad \forall i \in I, j \in I \tag{15}$$

$$\alpha_{ij} = \frac{1}{\alpha_{ji}} \ ; \qquad \forall i \in I, j \in I \tag{16}$$

$$\alpha_{ii} = 1 \ ; \qquad \forall i \in I, j \in I \tag{17}$$

Phrase $(e_i^j - \tilde{d}_j)$ indicates rate of effect of i^{th} node on j^{th} node in Eq. (15). In other words, to what extent efficiency of j^{th} node will be improved in the absence of *i* node in calculations of efficiency. Therefore, the rate of preference will result in based on ratio of sum of efficiency and rate effect of *i* and *j* pair-node. Formulae (16) and (17) have been assumed according to the proposed logic in AHP method [Saaty, 1996].

We will rank the nodes after formation of pairwise comparisons matrix by the aid of single-stage AHP technique or i.e. Eigenvector method. The final ranking will result in important outcomes in final ranking approach that has been derived from some corollaries as described as follows.

Corollary 1: If $j \in I$ is inefficient, then it will be $e_j^i = \tilde{d}_i$ for any arbitrary node $i \in I$ so that $i \neq j$ [Chandran et al.2005].

Proof 1: Two-phase DEA model introduces only one node as the most efficient node and based on which it measures efficiency of other nodes [Amin, 2009]. Therefore, if node *j* is inefficient then the fixed efficient boundary and result will remain unchanged therefore we will have $e_j^i = \tilde{d}_i$.

***Result of Theorem 1*:** Based on this theorem, it does not need to deletion of each of nodes for ranking of units but the results of preference can be distinguished in selection of units in a descending deletion trend from efficient units at any step and formation of lower triangular matrix derived from results of preference [adopted from Ray (2004)].

Corollary 2: If there are arbitrary node $k \in I$, efficient node $i \in I$, and inefficient node $j \in I$ so that it is $k \neq j$ and the weights resulting from pairwise comparisons matrix for nodes *i* and *j* include W_i and W_j, then it satisfies in $W_i < W_j$ [Chandran et al.2005].

Proof 2: According this theorem, it is $e_j^k = \tilde{d}_k$ and on the other hand *i* is efficient and *j* is inefficient, therefore it will be $\tilde{d}_i \succ \tilde{d}_j$. Thus, we will have Eq. (18):

$$\tilde{d}_i + (e_i^k - \tilde{d}_k) \succ \tilde{d}_j + (e_j^k - \tilde{d}_k) \quad (18)$$

On the other hand, since there is only one efficient node and according to theorem node *i* is efficient thus nodes *j* and *k* are inefficient and deletion of inefficient unit has no effect on efficiency of an efficient unit then $(e_k^i - \tilde{d}_i) = 0$ and $(e_k^j - \tilde{d}_j) \geq 0$. Whereas it is $(e_k^j - \tilde{d}_j) \geq (e_k^i - \tilde{d}_i)$ and on the other hand $(e_k^j - \tilde{d}_j) \geq 0$ and efficiency has non-negative efficiency for any node or $\tilde{d}_k \geq 0$ therefore it is $\tilde{d}_k + (e_k^j - \tilde{d}_j) \geq 0$ and also $(e_k^i - \tilde{d}_i) = 0$ and $\tilde{d}_k \geq 0$ so we will have Eq. (19):

$$\tilde{d}_k + (e_k^j - \tilde{d}_j) \geq \tilde{d}_k + (e_k^i - \tilde{d}_i) \quad (19)$$

With respect to non-negative sign of both sides of inequality (19), the Inequality (20) is significant:

$$\frac{1}{\tilde{d}_k + (e_k^j - \tilde{d}_j)} \leq \frac{1}{\tilde{d}_k + (e_k^i - \tilde{d}_i)} \quad (20)$$

Therefore according to formulae (15), (18), and (20), we have Formula (21):

$$\frac{\tilde{d}_j + (e_j^k - \tilde{d}_k)}{\tilde{d}_k + (e_k^j - \tilde{d}_j)} < \frac{\tilde{d}_i + (e_i^k - \tilde{d}_k)}{\tilde{d}_k + (e_k^i - \tilde{d}_i)} \quad (21)$$

Thus, it was shown according to Formulae (15) and (21) that it satisfies $\alpha_{jk} < \alpha_{ik}$ in pairwise comparisons matrix; accordingly, based on Eigenvector method, it satisfies in inequality $W_j < W_i$ [All equalities adapted from Ray (2004) and Chandran et al. (2005)].

Result of Theorem 2: The current theorem shows that at any phase of execution in deletion process, efficient unit is placed at higher rank and level than inefficient units. Therefore, there will be full coordination in ranking process of both of DEA and AHP techniques. Hence, the problem of non-coordination will not take place among DEA ranking process and integrated AHP- DEA approach [adopted from Ray (2004)].

6. Experiments: The Case Studies

The approach of optimization of hub facilities establishment location will be validated and analyzed by logical selection of sum of potential locations that are efficient in hub establishment by the aid of the relevant data to well-known system of IAD. These data were introduced by [Karimi and Bashiri, 2011] and they include information of industrial and touristic aviation transport from 37 cities in Iran. This dataset comprises of distance matrices, freight cost, and size of tradeoff (transaction) between any pair of cities and also the other data are related to cost of hub establishment in any city.

6.1 Studied Data

Whereas this study is intended to assess efficiency of units the average of data for any city has been considered for optimization of efficiency and effectiveness of location of hub facilities establishment in distance matrices, cost, and size of tradeoffs between *IAD* data and it has been inspired from studies done by [Kim and O'Kelly, 2009] and [An et al.2015] to determine reliability. Likewise, for weighting of data, weight of effect was used for each of five indices in pair-to-pair values of data from 37 cities.

6.2 Analytic Results of DEA Model

With respect to data resulting from efficiency of all 37 cities in the previous section and based on efficiency boundary and input and output weights in this section, the reason for selection and/ or non- selection of efficient units is described by the model. However before doing it, firstly the lower boundary of output and input weights should be extracted at first phase in two-phase DEA model. Based on the result of first phase, model ε^* has been derived for weighted *IAD* data by the weights resulting from AHP technique as 0.001517508. Given rate resulting from the first phase, the second phase was executed for ε^* where the given results are shown in three datasets including rate of inefficiency, total efficiency, and rank at any city in Table 4.

With respect to results of Table 4, Mashhad city (Node 19) was selected as the best city that possessed adequate capacities and potentials for hub establishment. The origin for such a selection may be found in high capacity of this city as a pilgrimage center that receives millions of people every year as pilgrims. Similarly, its appropriate reliability of this city has been distinguished from other cities with respect to strategic ideological center of Iran among others. In contrast to this selection, Khorramabad city (node 18) was introduced as the worst cities where there are suitable characteristics for establishment of hub facilities at the possible minimum level. The reason for such inefficiency and inadequacy is related to deprivation and lack of suitable infrastructure in this city however despites of all these conditions, fifteen superior cities were known with potential for execution of project as capable centers for hub establishment respectively as follows:

Mashhad, Noshahr, Tabriz, Arak, Birjand, Kerman, Zahedan, Uremia, Ardebil, Sanandaj, Ahwaz, Kermanshah, Gorgan, Booshehr, Isfahan, Rasht, and Sari. The most interesting point in this report is geographic establishment of each of cities on map of Iran so that the cities are selected at Iranian borders and/ or at central Iran while there was no data for route finding on it in two-phase DEA model and this is an evidence for their suitable performance.

Table 4. Output of second phase in two-phase DEA model for different cities with IAD data

City	Inefficiency	Efficiency	Rank	City	Inefficiency	Efficiency	Rank
Abadan	0.208227	0.79177	33	Nowshahr	7.19E-08	1	2
Ahvaz	0.140895	0.8591	11	Ramsar	0.180855	0.81915	25
Arak	1.15E-02	0.98846	4	Rasht	0.153452	0.84655	16
Ardabil	0.139334	0.86067	9	Sabzevar	0.217237	0.78276	34
Bandar Abbas	0.183627	0.81637	26	Sanandaj	0.140474	0.85953	10
Birjand	7.83E-02	0.92167	5	Sari	0.154645	0.84535	17
Bojnurd	0.188758	0.81124	29	Shahrekord	0.155991	0.84401	18
Bushehr	0.147568	0.85243	14	Shahrud	0.239971	0.76003	35
Chabahar	0.195874	0.80413	30	Shiraz	0.196557	0.80344	31
Esfahan	0.148165	0.85184	15	Sirjan	0.163291	0.83671	23
Gorgan	0.143702	0.8563	13	Tabriz	1.23E-05	0.99999	3
Hamedan	0.162262	0.83774	22	Tehran	0.161239	0.83876	21
Ilam	0.186111	0.81389	27	Urmia	0.135874	0.86413	8
Iranshahr	0.166639	0.83336	24	Yasooj	0.197395	0.80261	32
Kerman	8.67E-02	0.91325	6	Yazd	0.1598	0.8402	20
Kermanshah	0.142995	0.85701	12	Zabol	0.240598	0.7594	36
Khark	0.156059	0.84394	19	Zahedan	0.132634	0.86737	7
Khoramabad	0.240598	0.7594	37	Zanjan	0.187196	0.8128	28
Mashhad	0	1	1				

Similarly, the other important point is the selection of cities at northern Iran where there is density of population and it is another emphasis for precision of model output. In Figure 3, five, ten, and fifteen first cities are given respectively from right to left in terms of efficiency in this image. Selection of five first cities may be verified from this perspective where Mashhad is a pilgrimage city with much potential for receiving passenger and commercial goods since with respect to dense and extreme presence of pilgrims at specific time periods, its infrastructure has made this city as susceptible for being as hub. Regarding Noshahr city, one can imply place of this city at the center of northern Iran that is a touristic center with respect to pleasant and green space of northern Iran and at the same time it experiences commercial dimensions in terms of marine ports in Free Economic Zone with major transactions as importation and exportation and it is deemed as the paramount city locating at Mazandaran Province in northern Iran. Also each of Tabriz and Arak cities is known in the world in terms of great and huge industries therefore their selection is assumed as evident under title of potential center for hub establishment. However concerning selection of Birjand city that is located at east of Iran, one can refer to equalization of southeastern traffic load as the reason for this choice because it can facilitate access to the adjacent centers and on the other hand it is located significantly adjacent to great trade centers such as Mashhad and Isfahan as well. The first step toward validating the proposed solving method was to refer to the related literature and previously proposed methodology (e.g., [Amin and Toloo, 2007; Amin, 2009; Toloo and Tichý, 2015]). In another attempt to further validate the model, results of the model were investigated under current conditions in Iran. For instance, on Figure 4, the model output is evaluated and analyzed from scrap, with specific city names and geographical locations further considered. Accordingly, the facilities and conditions in the cities were recognized as reasons confirming the validity of the model outputs.

6.3 Computational Results from Analytic Hierarchical of Efficiencies

The results derived from two-phase DEA model in the current essay were presented in previous section. Now based on theorems and approach of hierarchical evaluation of efficiencies offered in Section 5, fifteen superior cities resulted from analytical outcomes of DEA model in this section and they were drawn in Figure 3 so they are evaluated in this section.

To do it, primarily calculation matrix for efficiencies is computed after deletion of efficient units where this has been done according to approach mentioned in section 5 of current essay and set of studied node is as follows: $I \in \{2,3,4,6,8,10,11,15,16,19,20,24,30,32,36\}$. Therefore, efficiency of node $i \in I$ is given in Pairwise efficiency matrix while $(k \in I)^{th}$ node has been deleted from assessment process. Likewise, to perceive threshold of decision making in Pairwise efficiency matrix, rate of ε^* is given in the last row where by observation of trend of its changes, Mashhad, Tabriz, and Noshahr cities had major effect on threshold ε^* and they exerted noticeable change on it. However in order to distinguish rate of preference of $(i \in I)^{th}$ on $(k \in I)^{th}$, we formed pairwise comparisons matrix from Equations (15) to (17) in which results of calculations are given in Rate preference of $(i \in I)^{th}$ node to $(k \in I)^{th}$ node within pairwise comparisons matrix but it is necessary before this measure to calculate d_i as rate of inefficiency of $(i \in I)^{th}$ unit based on sum of Equations (6) – (14) and $\tilde{d}_j = 1 - d_j$ as rate of efficiency of $(i \in I)^{th}$ node when considering all nodes in these calculations. Rate of inefficiency, efficiency, main number of any city, and rank among 15 nodes are given in Table 5.

Table 5 presents operational information of the top 15 Iranian cities evaluated in this research. A review on the table shows the top-ranked cities and the cities that may be selected as the more efficient nodes for hub establishment in cases of limitations in the number of hubs. In this table, different cities are raked by efficiency. However, one should notice that, the inefficiency is also an important criterion, and a possible ranking by inefficiency ends up with the same results. After formation of pairwise comparisons matrix and due to multiple dimensions of matrix [Amiri et al. 2010], Eigenvectors were collected by the aid of power method titled $A_{n\times n}$ and whereas they form a base stack for R^n therefore an iterative algorithm was designed. At first phase, vector $i \in I$ was determined in such a way that it satisfies in $\|u_0\|_\infty = \max_{1\le i\le n}\{|u_i|\} = 1$. At next step, vector $u_1 = Au_0 / \|Au_0\|_\infty$ is calculated and then iterative cycle $u_1 = Au_{k-1} / \|Au_{k-1}\|_\infty$ is computed up to phase $\lambda_1 = u_k^T Au_k / u_k^T u_k$ as the greatest eigenvalue in terms of absolute.

Figure 3. Selected locations by two-phase DEA model; as efficient centers for hub facilities establishment

value and correspondent Eigenvalue $v_1=u_k$ to it. The condition for stop and time of termination of algorithm was determined based on ε^* and relation $\left|(\lambda^{(i+1)}-\lambda^{(i)})/\lambda^{(i+1)}\right|\le\varepsilon^*$.

With respect to results of iterative algorithm for 15 superior nodes, their final ranking was specified and it was formed as it described in Table 6. Table 6 provides a final report of the methodology proposed in this research, which has been obtained upon applying the iterative AHP-based Eigenvector method. This table actually improves the rankings reported in Table 5, and proposes Eigenvalues (a obtained from iterative Eigenvector method) for different cities, indicating the significance of each city should the related data is not considered in the calculations. The report given in Table 6 has been affected by the hierarchical structure of the relationships among all cities in the decision-making process. On this basis, mutual effects of the cities have been considered in the ranking process. As a result, it was seen in that process Noshahr city (weight=0.2027) acquired the highest rank so that Kermanshah was the second best city (W=0.1029) where noticeable 10% reduction is visible compared to the first rank. The important point was small weight difference between third to seventh ranks all of them had weight within range (0.07303-0.7394). This indicates special importance of two cities of Noshahr and Kermanshah compared to other ones and the reason of this issue may be assumed due to proportional distance between these cities from their neighbor towns and the other reason can be deemed as placement of these cities among other noticeable cities all of them have high rate of demand with great size of population. Furthermore, in terms of reliability rate, these two cities have relatively favorable rate. If the map is seen, Noshahr city is located at central north of Iran while Kermanshah is situated at the west while the majority of Iranian population is focused at north-northwestern to southwestern line.

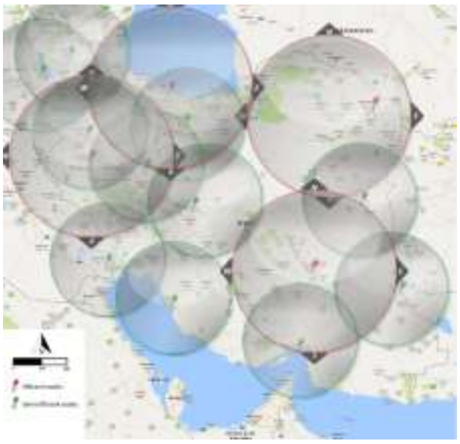

Figure 4. Potential for suggested establishment of Iranian aviation hub facilities by means of

Therefore, selection of these two cities is also deemed proper and logical in terms of geographic analytic logic however the other much interesting point is the selection of Kerman city (W=0.07394) at the center part with tendency to southeastern direction that typically can provide the need for other part of country. Of course, Mashhad city

(W=0.07339) is placed at subsequent choices that may also meet the requirement at northeast of Iran if necessary. Thus, it can be found that systematic analysis of points is also relatively better than one-dimensional selection of them because reduction in quantity of computations is one its outcome in addition to selection of potentially suitable points and avoidance from improper selection.

The results came from final phase of ranking and AHP analysis of efficiencies in current essay can be observed synchronously with location for placement of efficient hubs shown in red color and thick circles and semi-efficient hubs with enveloped circle in green color on map of Iran in Figure 4. At present, cities of Mashhad, Tehran, Isfahan, Tabriz, Sari, Ahwaz, Bandar Abbas, Arak, Kermanshah, Yazd, Kerman, Hamedan, Gorgan, Booshehr, and Uremia are considered as Iranian aviation hub centers where their airports have noticeable aviation traffics and output of Figure 4 is significantly near to the existing status and such results will be certainly capable for more convergences with change in primary values derived from attitude of experts. Despite of many constraints in terms of available data for analysis, analytical model of present essay has included very accurate and close choices compared to real conditions so it is assumed as specific advantage for it. Figure 4 has introduced image of site suggested for establishment of hubs in this study in Iran where red circles indicate hub at first to fifth ranks and circles in green color are subsequent premium ranks.

The choice of hub facility location is a strategic decision. Therefore, identification of the most important criteria contributing the decision largely helps in making an appropriate decision in this respect. Accordingly, single-stage AHP technique (i.e. Eigenvector method) may provide a method for enhancing the accuracy of decision-making by determining the effect of each location on the efficiency structure of other locations. The significance of each criterion, however, may be obtained by determining minimum allowable weight and significance of that criterion, and this contributes to appropriate selection of the locations based on the ranking and significance of the criteria. We always look for a method which results may facilitate the decision-making process for the manager, rather than making the process even more complicated. Traditional DEA methods, for example, introduced several efficient DMUs, while the methodology presented in this research ends up with a single most efficient DMU, with the other DMUs ranked with reference to this most-efficient DMU. Therefore, it is of paramount importance to present an effective method for determining the efficiency of each candidate location for establishing potential hub facilities, so as to provide a basis for selecting optimal location based on an accurate ranking, because the location selection and actual hub establishment incur large costs and are usually irreversible actions. Accordingly, such a decision shall be made based on ranking of every single node by efficiency, with no two nodes overlapping in terms of efficiency (ranking). Development of hierarchical networks is related to the establishment of service centers providing facilities at different levels. Therefore, a knowledge of the locations of superior efficiency may facilitate the selection process.

7. Conclusion and Future Suggestions

Presentation of a new and facilitating method to solve hub location models is the remarkable result of current research. As a result in this approach, initially it evaluates the studies nodes and locations in terms of efficiency for location of placement of hub facilities and introduces a limited number of them among group of locations as the choices close to efficient boundary. Thus it is not necessary to consider all nodes as potential hub location in the process of solving of model and thereby it extremely reduces process of solving given models and it will permitted the researchers to design models stress-free and remove the concerns mainly for the pre-existing problems in solving this model and it will help them to design model freely with more comfort. Numerous uses of hub facilities have encouraged many researchers in conducting study on structures of formation of networks and models for allocation and establishment of these facilities. Thus, it has been tried in current essay to mitigate this destructive effect i.e. perfect analysis of all choices and existing locations and deductive method and framework for selection of the best possible choices under title of potential centers for establishment of hub facilities.

Hence, initially the efficient locations can be separated from inefficient places by the aid of this method and to put them as input for decision making model. This measure may extremely impact on time for solving of complex problems. IAD data were employed for confirmation of suggested technique in this essay and results of model were compared with results existing in real world where output of comparisons verified performance of suggested method. Therefore, the significant

Table 5. Full information of 15 superior cities as general

City	No	rank	$\tilde{d}$	d	City	No	rank	$\tilde{d}$	d
Ahvaz	2	6	0.840665000	0.159335	Kermanshah	16	14	0.003642638	0.996357
Arak	3	7	0.808370800	0.191629	Mashhad	19	4	0.887815400	0.112185
Ardabil	4	13	0.223626700	0.776373	Nowshahr	20	3	0.935106000	0.064894
Birjand	6	9	0.702514300	0.297486	Sanandaj	24	12	0.235267000	0.764733
Bushehr	8	5	0.883881300	0.116119	Tabriz	30	1	0.999736500	0.000263
Esfahan	10	11	0.517917900	0.482082	Urmia	32	8	0.798416300	0.201584
Gorgan	11	10	0.700421200	0.299579	Zahedan	36	15	0.000000000	1
Kerman	15	2	0.987873500	0.012127					

Table 6. Results of iterative algorithm for 15 superior nodes and final ranking

City	Eigenvalues	Standard values	Final weight	Final ranking
Ahvaz	-0.01819	0.98180651	0.071968763	11
Arak	0.004084	1.00408363	0.073601729	5
Ardabil	-0.07243	0.92757401	0.067993391	14
Birjand	-0.00366	0.99633681	0.073033869	7
Bushehr	-0.00436	0.99563629	0.072982519	8
Esfahan	-0.01977	0.98023163	0.071853321	12
Gorgan	-0.01287	0.98713046	0.072359021	10
Kerman	0.008753	1.00875334	0.07394403	3
Kermanshah	-0.20181	0.79818856	0.102906412	2
Mashhad	0.001309	1.0013095	0.073398379	6
Nowshahr	0.005875	1.00587528	0.202700218	1
Sanandaj	-0.04441	0.95559394	0.070047319	13
Tabriz	0.00521	1.00520977	0.073684278	4
Urmia	-0.00561	0.99439037	0.07289119	9
Zahedan	-1	0	0	15

contribution of this research is the development of a DEA-AHP hybrid method for selecting the most efficient locations for establishing hub facilities, by which one can identify the parameters affecting the decision-making and evaluate their weights.

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