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Abstract

Industrial sites are key factors in urban and regional land use planning. Therefore, determining the location of industrial areas is a critical and complex process for development and success. Industrial site selection aims in identifying the most suitable sites for industry creation, considering a set of influential criteria. Therefore, site selection generally and industrial site selection specifically can be categorised as a multi-criteria decision making (MCDM) problem that requires detailed evaluation of various dimensions. This study developed a set of clusters containing 10 selection criteria for industrial site selection in Isfahan metropolitan area, Iran. The relationships between the criteria and clusters were modelled and analysed using Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP). AHP and ANP agree in finding distance to water bodies and distance to other industries as the most and least important selection criteria. Four patches have been identified as suitable alternatives for industrial construction. While AHP found Borkhar Patch 1 as the most appropriate alternative, ANP demonstrated the superiority of Ardestan Patch over others. Conducting a sensitivity analysis for the models confirmed both models robustness in industrial site selection decisions.

Key words: AHP, ANP, Site selection, Industrial site, MCDM, Isfahan

1. Introduction

Industry is an economic activity for producing goods and services (Ohri et al. 2010). Therefore, industrial sites play key roles in economy and are important parts of urban planning and design (Fernández and Ruiz 2009; Ruiz Puente et al. 2007). Moreover, industries are one of the land uses creating considerable negative impacts on the environment (CPCB 1997). Developing countries have major challenges in achieving socio-economic development along protecting the environment in industrial establishment process (Ohri et al. 2010). Finding the best location for industrial establishment is a selection of potential sites satisfying a set of selection requirements, which are mostly spatial in nature (Rikalovic et al. 2014; Worral 1991). In the past, selection requirements were mostly restricted to economic and technical criteria. However, currently site selection should also satisfy environment protection requirements (Rikalovic et al. 2015). Various range of criteria were considered as selection requirements for industrial establishment in the literature including transport infrastructure, telecommunication infrastructure, water supply, wastewater network, availability of land, cost of construction, availability of trained workforce, labour cost, unemployment rate, rivers and water bodies, soil, slope, environmental pollution concentration, noise, and land use (Ohri et al. 2010; Rikalovic et al. 2015; Ruiz Puente et al. 2012). Therefore, it could be concluded that industrial site selection can be categorised as a multi-criteria decision analysis (MCDA) (Keeney 2013; Williams and Massa 1983). MCDA helps decision makers to evaluate different alternatives considering various criteria in order to find the most suitable locations (Arabsheibani et al. 2016; Dodgson et al. 2009).

Site selection has been extensively conducted in the literature for different land uses including landfills (Afzali et al. 2014; Banar et al. 2007; Isalou et al. 2013), wind farms (Yeh and Huang 2014), hospitals (Vahidnia et al. 2009; Zhou and Wu 2012), and waste incinerators (Aragon'es-Beltr'an et al. 2010; Norese 2006). Compared to other areas, site selection for industrial areas has received less attention. Most of the research in this area were conducted by Ruiz Puente, Rikalovic and the colleagues (Rikalovic et al. 2015; Rikalovic et al. 2014; Ruiz Puente et al. 2007; Ruiz Puente et al. 2012). Ruiz Puente et al. (2007) developed a site selection model based on fuzzy logic considering planning, infrastructure, social, economic, and environmental factors (Ruiz Puente et al. 2007). Fernández and Ruiz (2009) in developing an Analytical Hierarchy Process (AHP) model for industrial site selection claimed that environmental and economic factors are the most important factors, with 50% and 35% of the importance, respectively (Fernández and Ruiz 2009). Rikalovic et al. (2015) proposed a method integrating different decision support systems including geographic information system (GIS), fuzzy inference systems (FIS), and weighted linear combination (WLC). Criteria were normalized using fuzzy systems and integrated by WLC method to generate a final suitability map. In Iran, Arbabsheibani et al. (2016) integrated fuzzy Decision-Making Trial and Evaluation Laboratory (fuzzy DEMATEL), and Analytical Network Process (ANP) to study land suitability for industrial parks establishment in Hamedan province and they found accessibility and economic indicators essential.

According to the literature reviewed, there are some knowledge gaps associated with industrial site selection. First, compared to extensive site selection studies considering various land uses, site selection for industrial establishment is not extensively well researched. On the other hand, different techniques including WLC, Fuzzy, ANP, AHP, and fuzzy DEMATEL have been applied for site selection problems. However, no attempt was undertaken on comparing AHP and ANP capabilities and suitabilities for industrial site selections. With focus on industrial site selection from environmental perspective, this study aims to compare ANP and AHP which are the most frequently applied methods in MCDA and site selection context (Huang et al. 2011). The results of the study could be used for evaluating strengths and limitations of each method. Before presenting the methods applied to the study area, some fundamentals on AHP and ANP are presented.

1.1. AHP

AHP is a technique for multi-criteria decision making, which is proposed by Saaty (1977). In this method, a complex problem is divided into a hierarchical structure composing main goal of the decision problem, criteria, and alternatives, which demonstrates unidirectional hierarchical relationships between levels. In the next step, pairwise comparisons are conducted in each level of the hierarchy to drive the relative importance of criteria and finally the alternatives. Pairwise comparisons are proposed to rate decision makers' preferences using a 1 to 9 scale. While 9 shows extreme importance, 1 is applied for showing equal importance of one criterion over another. The pairwise comparisons of various criteria are then organised into a matrix and the relative importance of criteria are calculated using the matrix. The quality of AHP method depends on the consistency of pairwise comparisons. In other words, a consistency ratio (CR) is calculated to check judgments inconsistencies. Acceptable CR must be 0.1 or less. A CR greater than 0.1 demonstrates disagreements among decision makers on criteria importance, which results from randomly generated ratings instead of an objective, shared view of criteria among decision makers. In these circumstances, pairwise comparisons should be reconsidered. Detailed description of weights and CR calculation using AHP could be find in related literature (Albayrak and Erensal 2004; Borajee and Yakchali 2011; Görener 2012; Rao 2013; Saaty 1987; Saaty 1977; Saaty and Vargas 2006; Semih and Seyhan 2011; Sharma et al. 2008).

1.2. ANP

ANP is also proposed by Saaty (1996) with slight differences compared to AHP, resulting in different outputs. While AHP considers independency among criteria, correlations among criteria play a key role in ANP. In other words, while AHP could not address the complexity of real world situation on its hierarchical structure, ANP presents a problem in a network of criteria and alternatives which are strongly intercorrelated. In ANP, the problem is modelled as a network of criteria and alternatives (all called elements), grouped into clusters. In the next step, the feedback and interrelationships between and within clustered are specified. Then, the interdependencies among elements go under pairwise comparisons using Saaty's 1-9 scale. Using the pairwise comparisons, alternatives priorities are recognized. The priorities derived from pairwise comparison matrices are applied to form an unweighted super-matrix. The unweighted super-matrix comprises the influence priority of an element on the left of the matrix on an element at the top of the matrix with respect to a particular control criterion. The weighted super-matrix is then formed by multiplying the unweighted super-matrix to the weights of criteria comparisons. If there is no cluster comparison, the weights are calculated assuming equal importance for all criteria. In the next step, the weighted super-matrix is raised to a sufficiently large power until it has converged. The priorities of any set of elements in a component are obtained by normalizing the corresponding values in the appropriate columns of the limit matrix. Detailed foundation and mathematical calculations related to ANP and the matrices could be found in related research (Afzali et al. 2014; Huang and Yoon 2011; Saaty 1996; Saaty 2008; Saaty and Ozdemir 2005; Yang et al. 2008; Yüksel and Dagdeviren 2007).

2. Materials and methods

2.1. Study area

Isfahan metropolitan, as the second largest industrial centre in Iran after the capital, is selected for this research. The region is located at 51° 03′ 07″, 52° 20′ 07″ E longitude and 32° 08′ 06″, 33° 12′ 21″ N latitude, with an area of 785,000 hectares, and a total population of 3,117,341. Currently, Isfahan faces critical environmental conditions due to large industrial developments. To reduce industrial pollution, Department of Environment has decreed that industrial establishment should be banned in a radius of 50 km around Isfahan metropolitan (Taebi and Eshaghy 2001). Therefore, this study was designed to evaluate the legislation in 50 km radius around Isfahan metropolitan as the study area (Figure 1).

Fig 1 Study area

2.2. Methods

Site selection problem involves two distinct phases. In the first phase, screening is conducted to select a limited number of suitable locations (alternatives) in a large geographic area, considering selection criteria. In the second phase (site evaluation) alternatives identified by the screening are evaluated in details which results in finding the most suitable site among alternatives (Findikaki 1990; Mak 1999; Ruiz Puente et al. 2012). As the first step in the screening phase, criteria are defined for industrial site selection. Industrial site selection as a multi-criteria decision cannot be made based on one single criterion and to achieve the main goal, various criteria must be taken into account (Arabsheibani et al. 2016). Generally, selection criteria are divided into two groups including factors and constraints. While a factor increases or decreases the suitability of a considered alternative, a constraint limits alternatives under consideration. In other words, constraints are applied to identify which areas are not permitted for a specific activity (Estoque 2011). In this study, criteria identification was based on available literature in the field and essential criteria enforced by government legislation. Selected criteria were classified in two categories: Physical-environmental and infrastructure-urban development. The physical–environmental criteria consider the ability of natural environment to mitigate the impact of new industrial activities. On the other hand, the infrastructures-urban development category considers facilities needed for successful industrial establishment. According to the literature and legislations (Dudukovic et al. 2005; Eldrandaly et al. 2003; Iran parliament 1996; Nouri 1993; Reisi et al. 2011), industrial site should meet the following specification:

1- *Distance to water bodies (Factor)*: To avoid industrial pollution in waters, industrial establishment must be at least 1600 m away from water bodies.

2- *Slope (Factor)*: From both construction and environmental perspectives, suitable slope for industry construction is 0-10% to facilitate infrastructure provision and reduce environmental degradation.

3- *Distance to urban area (Factor)*: Due to harmful effects of industries on urban areas, industries should be established at least 5000 m away from cities.

4- *Distance to roads and railways (Factor)*: The importance of this criterion is due to its role in transferring raw materials and final products. Minimum and maximum distance of industries from major roads and railways should be 1500 and 5000 m, respectively.

5- *Protected areas (Constraint)*: Industrial construction is forbidden in protected areas and 1000 m buffers around them from the conservation point of view.

6- *Distance to other industries (Factor)*: Industrial areas must be at least 250 m away from food industries to reduce their negative effects.

7- *Groundwater depth (Factor)*: High-level groundwater in industrial lands may cause water pollution. Minimum depth of ground water should be 53 m in industrial areas.

8- *Distance to water supplies (Factor)*: Water supplies as one of the major infrastructure for industries should be in vicinity (less than 8000 m).

9- *Land use (Factor)*: Urban areas, agriculture lands, forests, gardens, and water bodies must be avoided for industrial construction. On the other hand, uncultivated areas and pastures with low vegetation density are suitable land uses for industrial construction.

10- *Distance to Faults (Constraint)*: Faults would harm industrial construction and industrial structures should be at least 2000 m away from this geological phenomenon.

To eliminate unsuitable locations and find suitable alternatives in the screening phase, criteria were standardised in ArcGIS, with 0 showing sites totally unsuitable for industries and 1 representing suitable sites. Factors were also standardised using Sigmoid and user-defined Fuzzy membership functions. While in Boolean an alternative is considered as suitable (1) or not suitable (0), with no other class between, Fuzzy functions let alternatives to have partial suitability between 0 and 1 (Hall et al. 1992). Standardized constraints and factors are presented in Figure 2, 3, and 4. Criteria standardized using Boolean were then overlaid in ArcGIS environment to find the suitable locations for the industrial establishment (Figure 5). As illustrated, there are some scattered patches over the study area, which might not be suitable for industrial establishment due to small size. Therefore, the rest of the investigation focuses on four large patches in Isfahan, Ardestan, and Borkhar. To distinguish the alternatives located in Borkhar area, the alternatives were named as Bokhar Patch 1 for the larger patch and Borkhar Patch 2 for the smaller patch.

In the site evaluation phase, the selection criteria should be weighted based on their relative importance to find the most suitable alternative (Ruiz Puente et al. 2012). For this purpose, one hierarchical model and one network-based model were developed. It is worth noting that protected area and distance to faults are not considered in this phase, as they are constraints and are only useful for eliminating unsuitable sites. In other words, industrial development is not permitted in protected areas and faults.

Fig 2 Standardized constraints using Boolean logic

Fig 3 Standardized physical-environmental factors using Fuzzy method

Fig 4 Standardized infrastructure-urban development factors using fuzzy method

Fig 5 Suitable alternatives for industrial construction identified at the screening phase

2.2.1. Hierarchical model

In the hierarchical model, the main goal (industrial site selection) is positioned at the top of the hierarchy. Selected criteria and potential alternatives were places on the second and third level of the hierarchy, respectively (Table 1). After establishing the hierarchy, weights should be assigned to each level through pairwise comparisons. Fifteen decision makers including six environmental engineers, seven members of Industrial Parks Organization, and two industrial engineers were asked to evaluate the importance of criteria for industrial construction using 1-9 Saaty's scale. The results of the pairwise comparisons were entered to 'Expert Choice' software to calculate criteria weights and finding the most suitable alternative. In all judgments, it was verified that the consistency ratio is less than 0.1. Therefore, the obtained weights are consistent. Pairwise comparisons matrices created for physical-environmental and infrastructures-urban development criteria are presented in Table 2 and 3.

Table 1. Structure of the hierarchical model

Goal	Categories	Criteria	Alternatives
Industrial site selection	Physical-Environmental	Distance to water bodies Slope Ground water depth	Isfahan Patch Ardestan Patch Borkhar Patch 1 Borkhar Patch 2
	Infrastructure-Urban development	Distance to urban area Distance to roads and railways Distance to water supplies Land use Distance to other industries	

Table 2. AHP pairwise comparisons for physical-environmental criteria in Expert Choice

	Distance to water bodies	Slope	Ground water depth
Distance to water bodies	1	4.00	1.78
Slope		1	0.25
Ground water depth			1

Table 3. AHP pairwise comparisons for infrastructures-urban development criteria in Expert Choice

	Distance to roads and railways	Distance to water supplies	Distance to other industries	Land use	Distance to urban area
Distance to roads and railways	1	1.18	2.03	1	0.83
Distance to water supplies		1	2	1.04	1
Distance to other industries			1	0.5	0.26
Land use				1	0.73
Distance to urban area					1

2.2.2. Network-based model

Developed network consists of three clusters. Clusters of Alternative, Infrastructure-Urban development, and Physical-Environmental have 4, 5, and 3 elements, respectively (Figure 6). In the next stage, the influence of each element on other elements was analysed using pairwise comparison matrices. The relative importance weights of elements calculated from pairwise comparisons were applied to build an unweighted, weighted and limit super-matrices, as described in Section 1.2. To facilitate decision making, the network and related calculations were developed using ‘Super Decisions’ software. In ANP, like AHP, all the judgments were consistent (i.e. consistency ratio <0.1). The limit super-matrix developed for this study is presented in Table 4.

Fig 6 Network-based model

Table 4. Limit super-matrix

	Ardestan	Borkahr1	Borkhar2	Isfahan	Land use	Other industries	Road and railways	Urban areas	Water supplies	Groundwater depth	Slope	Water bodies
Ardestan	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955	0.12955
Borkhar 1	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560	0.12560
Borkhar 2	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695	0.11695
Isfahan	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777	0.11777
Land use	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038	0.03038
Other industries	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070	0.07070
Road and railways	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108	0.07108
Urban areas	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605	0.01605
Water supplies	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686	0.06686
Groundwater depth	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829	0.09829
Slope	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753	0.05753
Water bodies	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924	0.09924

3. Results and discussion

3.1. AHP and ANP comparison

A 50 km radius around Isfahan metropolitan was assessed in terms of suitability for industrial establishment, considering the 10 criteria presented in Section 2.2. Four patches were determined as suitable in the initial screening phase. In the next phase, AHP and ANP methods were undertaken to weight selection criteria to find the degree of suitability in each alternative. Figure 7 illustrates the weights obtained for site selection criteria in each model. Both AHP and ANP models found 'distance to water bodies' and 'ground water depth' as the first and second important criteria for indusial site selection. However, despite ranking similarity in the AHP and ANP models with regards to 'distance to water bodies' and 'ground water depth', the calculated weights are 0.530, 0.361 and 0.389, 0.385 in the AHP model and ANP methods, respectively. On the other hand, priorities of the remaining criteria do not match between the models. For instance, while 'distance to other industries' has the lowest priority based on the AHP model, 'distance to urban areas' is the least important criteria based on the ANP model. This is due to information handling differences in AHP and ANP. In AHP, weights are calculated based on the importance given to each criterion by decision makers. Moreover, the priorities are independent of the analysed alternatives and influences among criteria are not considered in the AHP model. However, in the ANP model, relationships between criteria influence priorities. Moreover, considering certain alternatives might change the importance of criteria compared to the hierarchical model.

Fig 7 Comparison of criteria weights in AHP and ANP

The outcome of site evaluation phase is alternatives ranked based on their suitability. Table 5 demonstrates ranking of the alternatives obtained in both models. According to the results, priority of alternatives is completely different in the ANP and AHP models. In the AHP model, Borkhar Patch 1 and Isfahan Patch are the best and worst alternatives, respectively. However, the ANP model found Ardestan Patch and Borkhar Patch 2 as the best and worst cases. In other words, Borkhar Patch 1 and 2 swap their positions in the AHP model with Ardestan Patch and Isfahan Patch in ANP, respectively. Overall, the results show differences between AHP and ANP outcomes, which is due to interdependencies, outer-dependencies and feedback considered in ANP method.

Table 5. Priorities of the alternatives in AHP and ANP

Ranking	AHP priority	Alternatives	ANP priority	Alternatives
1	0.285	Borkhar Patch 1	0.264	Ardestan Patch
2	0.244	Ardestan Patch	0.256	Borkhar Patch 1
3	0.240	Borkhar Patch 2	0.240	Isfahan Patch
4	0.231	Isfahan Patch	0.238	Borkhar Patch 2

3.2. Sensitivity analysis in AHP method

A sensitivity analysis was conducted to test the accuracy and robustness of multi-criteria decisions through criteria variation. Criterion values and weights could be evaluated in sensitivity analysis. However, criterion weights due to subjectivity are more important in sensitivity analysis compared to the values. If ranking of alternatives remains unchanged after sensitivity analysis, it could be concluded that the results of multi-criteria decision analysis are sufficiently accurate and robust. Otherwise, criteria weights should be redefined (Rikalovic et al. 2015).

To test the sensitivity of the AHP model developed in this study, criteria weights were varied by ±20%. The results showed that the priorities of Ardestan Patch and Borkhar Patch 2 were changed as a result of 15% increase in the weight of 'land use', 20% increase in the weight of 'ground water depth' and 10% reduction in the weight of 'distance to water bodies' (Figure 8). Changes in other criteria weights did not have any effects on the final ranking of the patches. Non-presented criteria resulted in a high level of robustness of alternatives' ranks over a wide range of criteria weights.

Fig 8 Sensitivity analysis for -10% changes in 'distance to water bodies' weight, +15% change in 'land use' weight, +20% changes in 'ground water depth' weight

3.3. Sensitivity analysis in ANP method

For the ANP model sensitivity to be equivalent to the AHP model sensitivity calculation, a new approach on sensitivity analysis was proposed by Adams and Saaty (2013a). In the new approach, a node of a network is selected and its weight is adjusted globally and prior to matrix calculation. This is accomplished by modifying, not just the weight of the node with respect to a single node, but with respect to all nodes connecting to it. Moreover, various influence analysis could be conducted based on sensitivity calculation to find the most influential nodes within the model (Adams and Saaty 2013a). Rank influence analysis was conducted in this study (Table 6) to check how much the importance of a given node must change to cause a change in the rankings of the alternatives. The smaller the change needed, the more rank influence that node has. Sensitivity analysis was conducted by having a single parameter (p) representing the importance of a given node, which is between 0 and 1. Original parameter value returns the nodes values to the original weights. For parameter values larger than the original value, the importance of the nodes goes up, and for parameter values less than the original the importance of the node goes down. In other words, the system searches for the first value higher than the original value where a rank change occurs and the first value below the original value where rank change happens. The rank influence score represents how quickly rank changes occur. The larger the score, the more rank influence the node has. Adams and Saaty (2013b) provided more detailed discussion on ANP sensitivity analysis. According to Table 5, the most influential criteria are slope, land use, distance to water bodies, and distance to road and railways, respectively. 2.2%, 3%, 5%, and 12% changes in the value of these criteria made Borkhar Patch 2 superior compared to Isfahan Patch.

Table 6. Rank influence analysis for ANP method

Top level network	Parameter value	Raw score[c]	Ardestan	Borkhar 1	Borkhare 2	Isfahan
Original value	0.500	0.000	0.264449	0.256401	0.238737	0.240414
Land use: upper[a]	0.515	0.969	0.263083	0.25809	0.239414	0.239412
Other industries: upper	0.551	0.896	0.270135	0.244884	0.240082	0.244899
Road and railways: upper	0.525	0.950	0.263378	0.255399	0.240612	0.240611
Urban areas: upper	0.535	0.929	0.261478	0.261484	0.237891	0.239147
Water supply: upper	0.586	0.824	0.252804	0.251558	0.244075	0.251563
Ground water: upper	0.990	0.000	0.250288	0.250128	0.249775	0.249809
Slope: upper	0.511	0.977	0.266113	0.256322	0.238783	0.238781
Water bodies: upper	0.560	0.877	0.267428	0.267435	0.228282	0.236855
Land use: lower[b]	0.000	0.000	0.267458	0.25272	0.237238	0.242583
Other industries: lower	0.350	0.700	0.261784	0.261786	0.238114	0.238316
Road and railways: lower	0.000	0.000	0.267837	0.259737	0.232697	0.239729
Urban areas: lower	0.000	0.000	0.265704	0.254227	0.239171	0.240898
Water supply: lower	0.341	0.683	0.267833	0.257789	0.237189	0.237189
Groundwater: lower	0.000	0.000	0.268061	0.25801	0.235908	0.238021
Slope: lower	0.104	0.207	0.256757	0.256757	0.238538	0.247948
Water bodies: lower	0.443	0.887	0.263674	0.254015	0.241156	0.241155

[a]Upper: looking at upper rank change information for that node; [b]Lower: looking at lower rank change information for that node; [c]Raw influence score

3.4. Comparison of the current study with published literature in the field

Decision making related to industrial establishment has been investigated in a limited number of research across the world. Fernando et al. (2015) found land use, water, soil type, wildlife, archeological sites, roads and power lines as important criteria for industrial establishment in Sri Lanka. However, standardizing and weighting criteria before aggregation does not follow particular transparent methods and seems completely arbitrary, without any attempts in evaluating sensitivity of decision to assigned weights. Ohri et al. (2010) considered 12 criteria for industrial establishment using MCDA and AHP methods in India. Their results confirmed slope as the least important criteria which is aligned with this study finding slope as one of the least using both AHP and ANP methods. The Ohri et al. (2010) study lacks sensitivity analysis to ensure decision makers on robustness of selected sites. In another study, Alzamili et al. (2015) explored and ranked industrial site selection criteria using AHP, including urban areas, landfill site, heritage site, airport site, rivers, road network, slope, natural resources, railways, land use oil pipe and highways. Similar to the current study, Alzamili et al. (2015) found urban areas and rivers with high, road and railways with moderate, and slope with low importance for industrial establishment. Aragon'es-Beltr'an et al. (2010) also conducted a very similar study with the current study methodologically. They compared AHP and ANP capabilities in making decision regarding siting a municipal solid waste plant in Spain. While the current study found more similarities between AHP and ANP in assigning criteria weights, Aragon'es-Beltr'an el al. (2010) research found dissimilar criteria weights using AHP and ANP methods. This difference might be due to considering more criteria and consequently more interdependencies, outer-dependencies and feedback among elements and clusters in Aragon'es-Beltr'an et al. study compared to the current research.

4. Conclusions

The problem of industrial site selection was investigated in this study as a strategic decision in urban areas. Isfahan metropolitan, located in the central Iran, was selected as the study area. As one of the major industrial centre of the country, industrial establishment is a matter of concern in Isfahan metropolitan. Moreover, according to Iranian legislation, industries could only be built outside 50 km radius around the metropolitan to reduce environmental adverse effects to the metropolitan areas. This study was designed to evaluate the legislation and find the most suitable sites for industrial establishment in Isfahan metropolitan. Considering available literature, related legislation, regulations, and available data for the study area, 10 criteria in two categories were selected for industrial site selection. Considering selected criteria, suitable alternatives for industrial allocation were determined on the screening phase. Four determined alternatives from the screening phase were then prioritised in site evaluation phase using the weights extracted by hierarchical and network-based model.

The experience gained in developing hierarchical model in this study confirmed that the AHP model is easy to develop and use. However, it cannot handle the complexity of real world situations, as emphasised by other studies (Aragonés-Beltrán et al. 2014). As a solution, the ANP model was also developed in this study. In developing a network-based model, all possible dependencies among criteria and between criteria and the alternatives were modelled. Although the network-based model is more complex and harder to develop compared to the AHP model, it provides better understanding of the problem for decision makers and helps them to make a more reliable final decision. Moreover, comparisons between the two models could be informative for decision makers. Analysing the results of the AHP model allows decision makers to find out most significant criteria for industrial site selection, independent of specific alternatives. On the other hand, results obtained by the ANP model help decision makers to understand initially significant criteria might not have such a great influence on the real-world site selection problem.

Considering the results obtained in this study, it could be concluded that along differences in alternatives priorities using ANP and AHP, sensitivity analyses found robustness difference between the two. Modelled AHP for industrial site selection is more robust compared to ANP. In other words, changes in weights that cause changes in original alternative priorities are higher in AHP compared to ANP. Overall, it could be concluded that due to higher complexity and lower robustness, ANP is more complex to develop and needs extensive expertise in the field.

Identification of four suitable alternatives for industrial establishment in the current study raises a new concern in re-evaluating local government legislation prohibiting industrial construction inside 50 km radius around Isfahan metropolitan area. Detailed consideration of land uses in Isfahan metropolitan area along with the results obtained in this study revealed that most agriculture lands, gardens and industries are located in the West and there is no suitable site for industrial establishment. Therefore, it is recommended to extend the limitation beyond 50 km in the West. On the other hand, uncultivated lands, pastures, deserts, sandy hills, and high soil salinity lands are concentrated in the East and are suitable for industrial construction in the identified alternatives (Ardestan, Isfahan, Borkhar). However, it is better to adhere to 50 km radius limitation in the East to prevent environmental hazards. Moreover, it should be noted that selected criteria and thresholds are minimum requirements for industries regardless of their types. After finding potential industrial sites, the process could be iterated using a new set of criteria customised by industry types to narrow suitable locations for specific industries. It is also worth noting that previous research in the field have evaluated industrial site selection as a major decision problem for urban areas independent of industry types (Boutkhoum et al. 2015; Fernando et al. 2015; Taibi and Atmani 2017; Ziaei et al. 2012).

5. References

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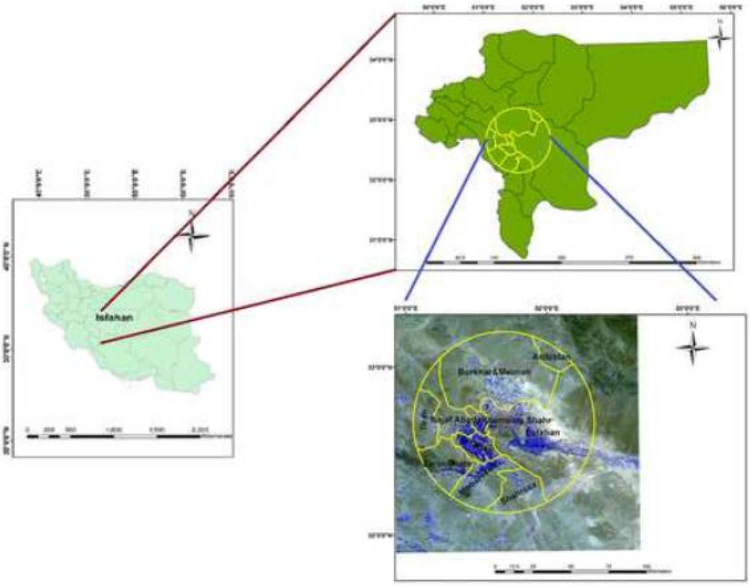
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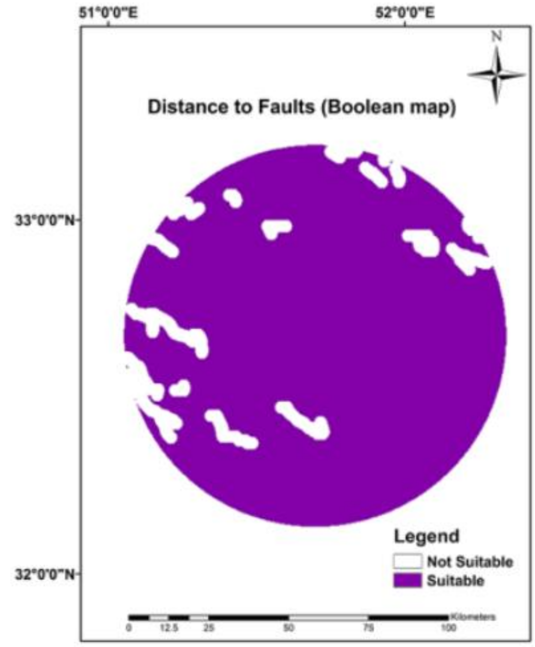
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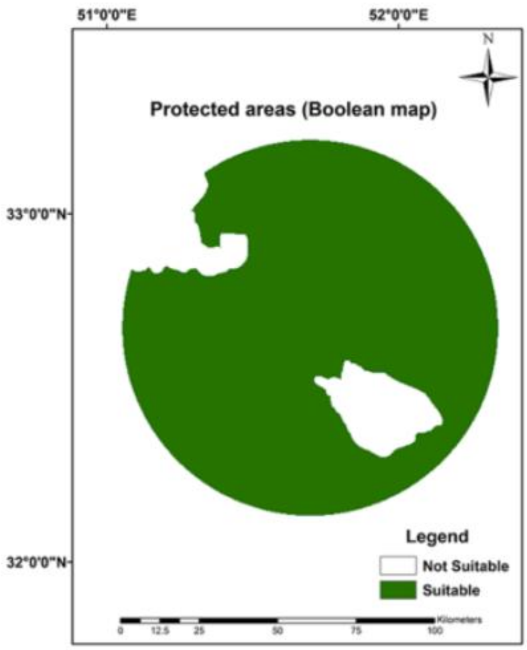
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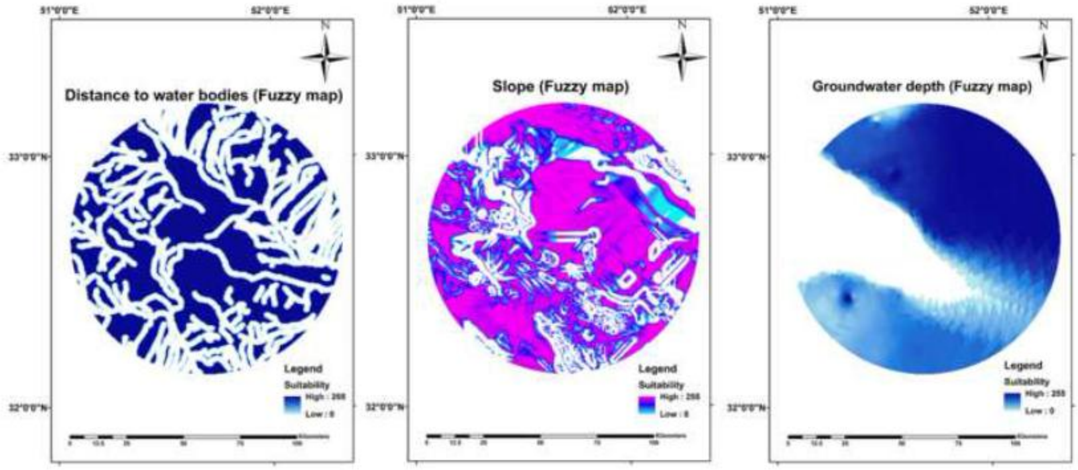

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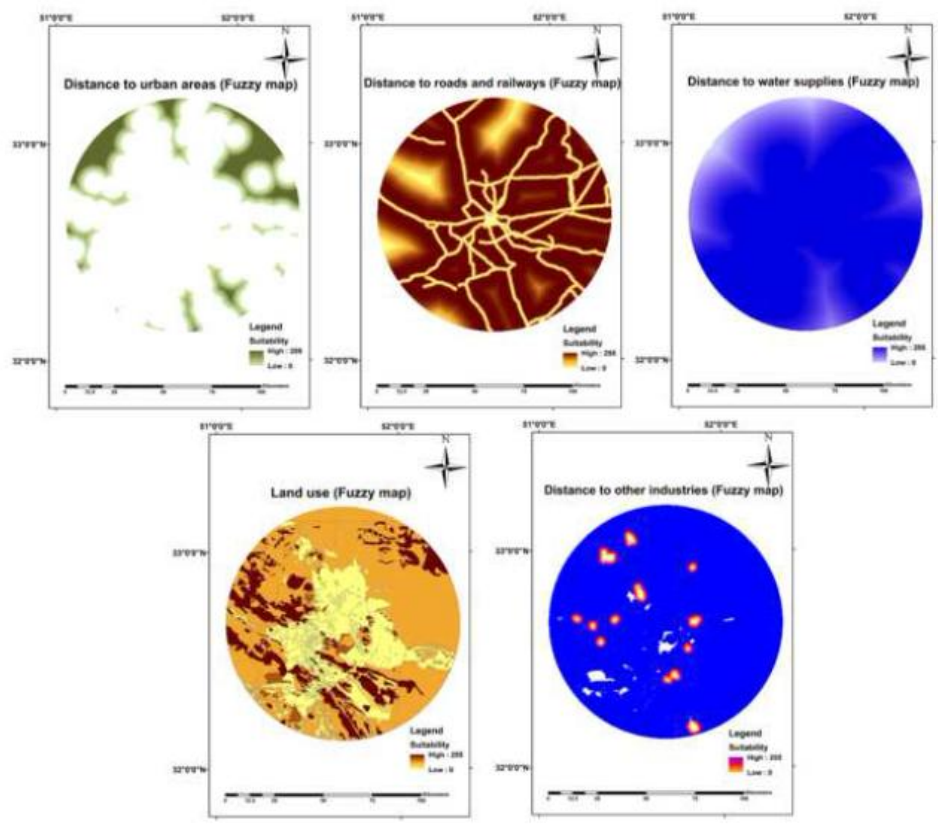

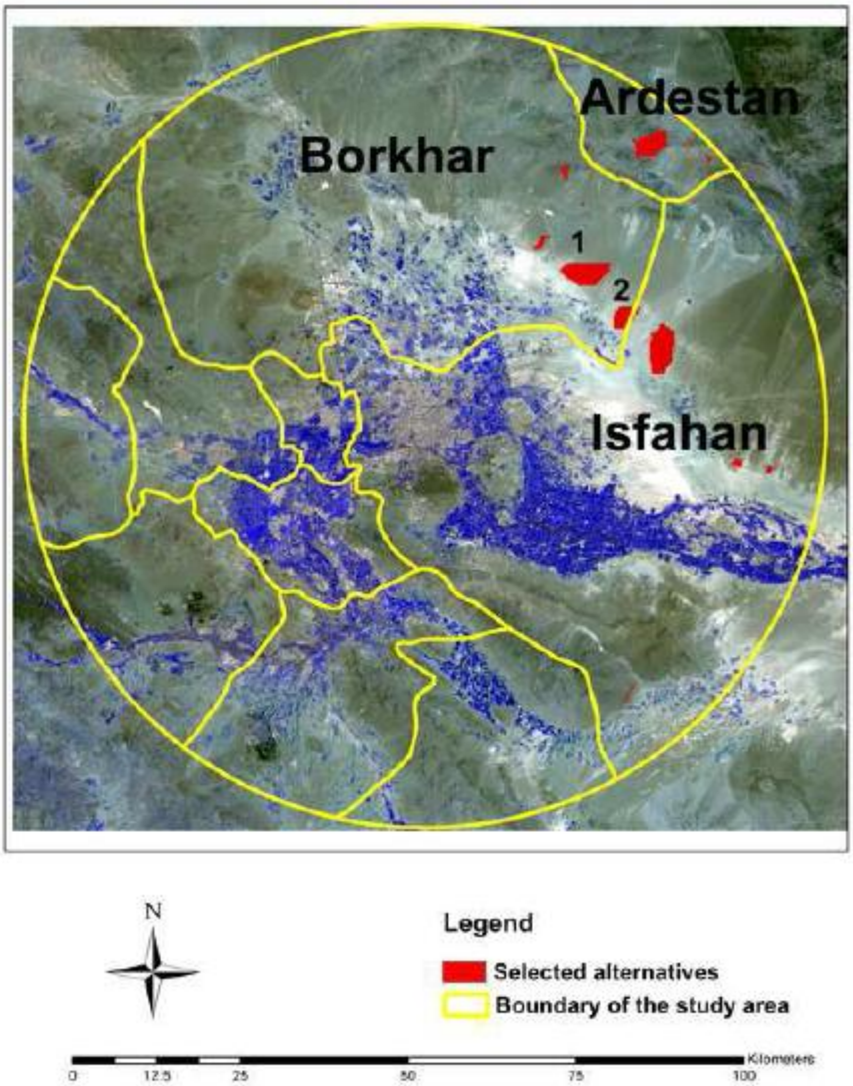
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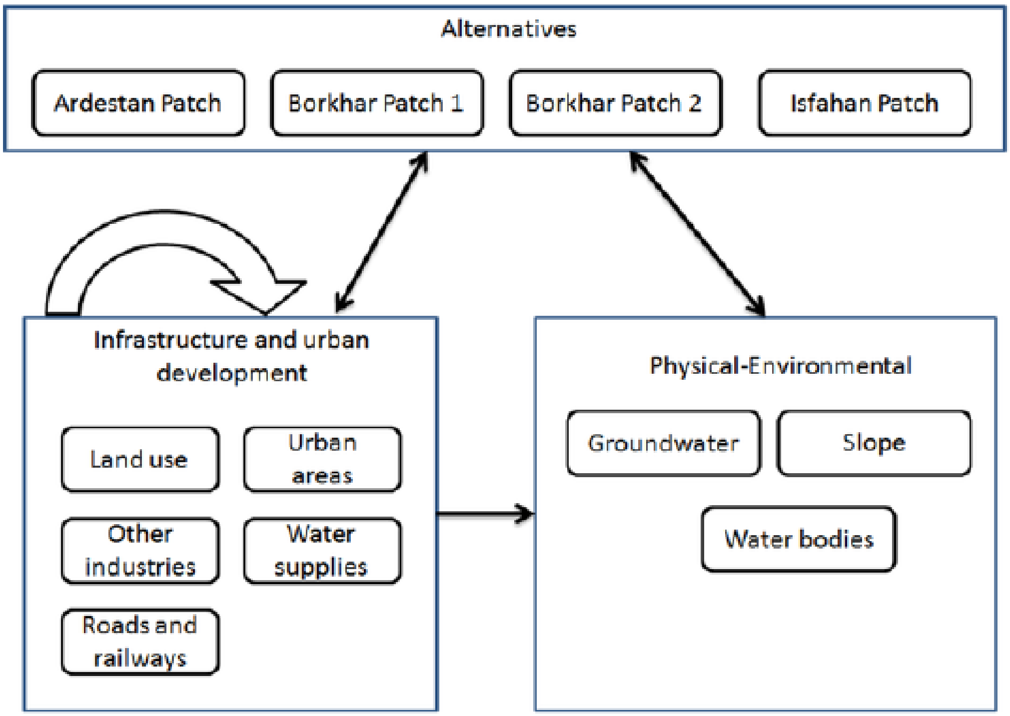

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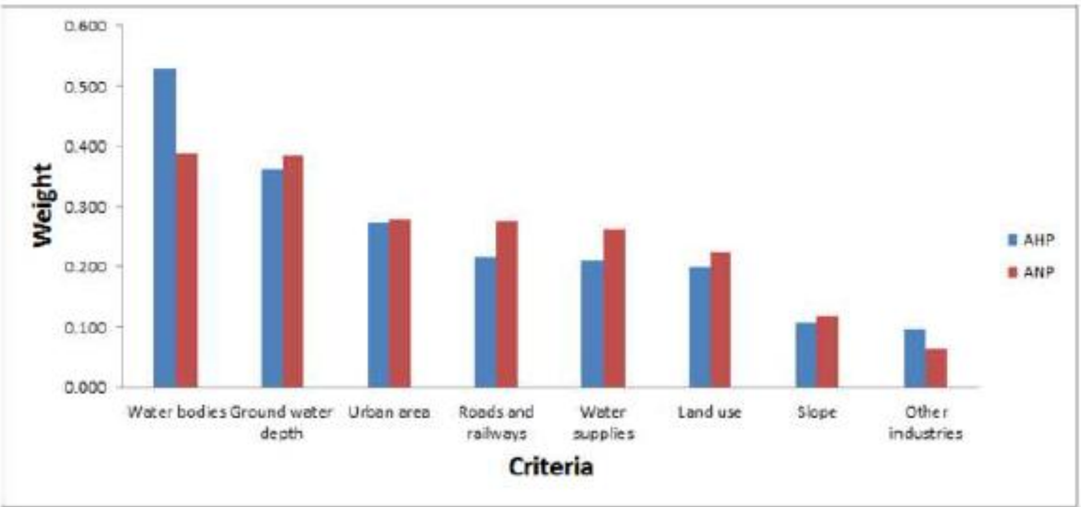

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