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# Assessment of Residential Blocks with an Emphasis on Sustainability and Use of Renewable Energies

**Neda Shahkaramipour**, **Mohsen shamsi Goushki**

Msc Student, Department of Architecture, University of Payam Noor, Branch of Bandar Abbas

**ABSTRACT**

In addition to improvement of indoor thermal convenience, layout and design of residential blocks in harmony with principles of stability and renewable energy sources also saves more energy and improves environmental condition. This issue is a great matter for urban areas such as Tehran where air pollution is high and dwelling congestion is considerable. The present study analyzes and assesses conditions in residential blocks in the 2 region of Tehran while emphasizing observation of principles of stability and use of renewable energies. Delphi method, information layers and fuzzy AHP methods were used for conducting the analyses and assessments on the condition. Afterward, all the criteria and sub-criteria were weighted in MATLAB. The weights obtained through fuzzy AHP were loaded on the input layers. Then, the weights were multiplied by the layers in GIS, which also included combining the layers. As the next step, final raster map of residential blocks analysis in the region were obtained at three zones of A, B, and C. The results showed that zone B, based on the parameters and the criteria enjoy better condition regarding use of renewable energy sources in comparison with other two zones.
**KEYWORDS:** Renewable Energies, Sustainability Energies, Residential Blocks

## 1. INTRODUCTION

Man's quest to find settlement safe from harsh weather condition is old as the history. This makes man to always take care of the environment, climate, and the materials accessible for construction.

When they are consistent with principles of stability and renewable energy, layout and design of residential blocks both support indoor thermal convenience and saving energy, which results in better environment (Chua and Chou, 2010). This is of great importance for urban areas such as Tehran with high air pollution and population congestion. Results obtained by other works in the field showed that failing to observe such principles in lying out and designing residential blocks and use of renewable resources as well, puts more loads on air conditioning facilities throughout the year. Add to that, mere utilization of mechanical systems and spending more money does not guarantee satisfactory and acceptable condition for the residents. This calls for utilization of modern architectural methods and proper layout of the blocks based on principles of stability and renewable energies to achieve satisfactory results in construction development in different regions (Ghisi and Ferreira, 2007). In other words, residential blocks designed in harmony with climate ensure thermal convenience for the residents throughout the year by preventing wind blow inside the building and using humidity of the region as required. Moreover, it is essential to devise specific layout of the building blocks to provide direct sunshine in cold seasons and avoid it during hot seasons (Chan, 2012).

Having in mind the importance and role of layout design in residential blocks, the work analyzes and assesses status of residential blocks in the 2 region of Tehran regarding observation of principles of stability and harmony in utilization of renewable energies.

## 2. Necessity and reasons for employing principles of stability and use of renewable energy source in residential blocks

Buildings Layout and design in harmony with the regions has intrigued the architectures long since. When a building is designed in observance of such principles an optimum utilization of the local facilities is ensured. Use of natural energies in buildings may play a significant role in saving energy, improving health status in the buildings, and preservation of environment (Menegaki, 2012; Asami and Niwa, 2008).

Considerable costs of fuel make utilization of sun energy as a promising candidate for supplying thermal energy to buildings under modern architecture. Utilization of sun energy may not be a success unless layout of the building ensures sun shields during hot seasons, though there are drawbacks in such design as well (Peidong et al., 2009).

*Corresponding author: Neda Shahkaramipour, Msc Student, Department of Architecture, University of Payam Noor, Branch of Bandar Abbas Shahkarami_arch@yahoo.com

However, proper positioning of the building may make it unnecessary to use sun shield, so that increase of temperature in the space between the buildings is avoided and considerable costs of air conditioning facilities is no longer a matter (Yuan et al., 2013). It is essential, therefore, to taking into account the climate of the region and layout of the building before designing the construction (Hwang, 2010).

**3.Case study**

The 2 region of Tehran is one of the developed regions located in mid and north part of the city. The region with an area of 64 $km^2$ was home to 650000 in 2011; this is about 10% of total area and 5% of total population of the city. In the region also live 183303 families and average family population of 3.31 individuals.

The main portion of the region has been developed during the last 15 decades and population has been grown at 2.36% rate between 1996 and 2011 (Tehran Municipality, 2012).

The region is divided into 9 zones and 14 neighborhoods (as the statistics show). From north it reaches to southern skirts of Alborz, to region 5 from the west, and from south to region 9 and 10, and from east to region 1, 3, and 6 (Figure 1).

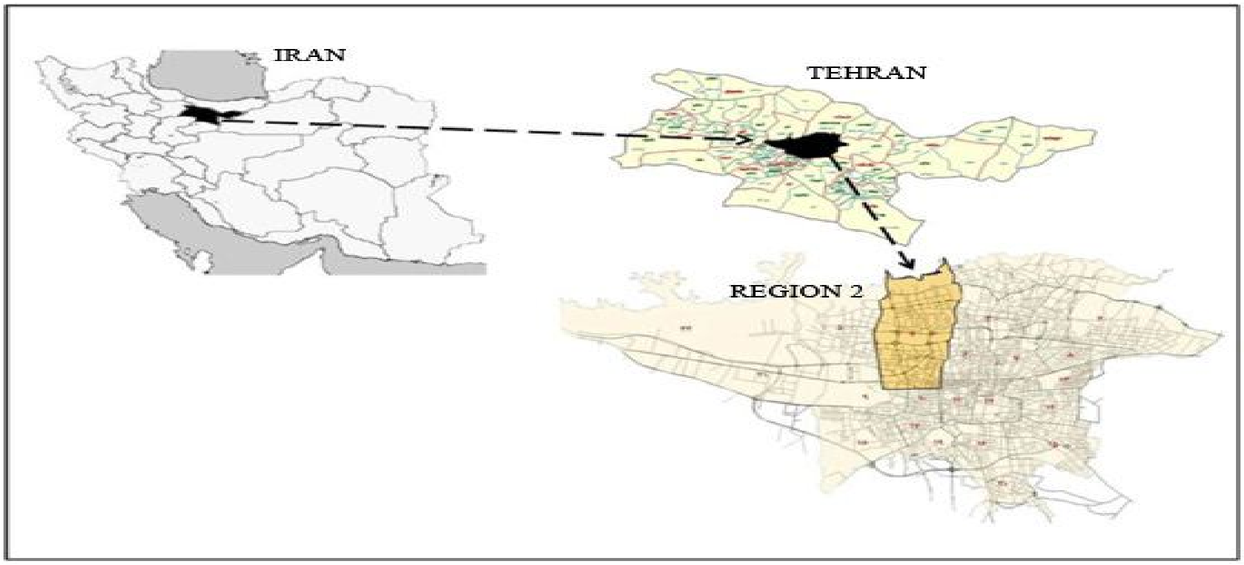



**Fig. 1.** The2 region of Tehran

The region is classified as vulnerable regions as the main north fault of Tehran, and secondary faults of Niavaran, Davoudieh, and Bagh Feigz. Moreover, there are other phenomena such as fault and land slide that add to hazard status of the region.

The region is home to private and complex residential classified into 1 – 2 floors, 3-5 floors, and more than 6 floors. In addition, there are residential gardens in Tarasht, Darakeh, Evin, and Farahzad zones.

Regarding the potentials of the regions, we may mention city highways and other important streets of the city. This brings in economic advantage to the region as transportation costs are less than other regions. Moreover, the region enjoys easy access to other parts of the city through east – west and north – south highways.

Wide area of unused land adjacent to the highways and streets is another potential of the regions, which may be used for commercial, public, and services purposes.

The region also enjoys large green areas for spending leisure time. Darake and Farahzad are two main destinations for the citizen to spend their leisure time. Commercial centers, thanks to good infrastructural facilities, attract many throughout the city to the region as well.

## 4. MATERIALS AND METHOD

The study is aimed to assess and analyze condition of residential blocks with an emphasis on observation the principles of stability and renewable energy. The study was conducted through physical-spatial studies using an analytical model in two steps. First, identification and analysis of status quo of the region regarding environmental, natural, infrastructural, economic-social conditions was surveyed. To draw logical results, gleaning and classifying data regarding the region, a set of criteria to achieve stability and utilization of the potentials of the region to use renewable energies were used after consulting the experts and scholars in the field (Table 1). Then, an assessment model was defined based on fuzzy AHP and all the criteria and sub-criteria were weighted and inputted to MATLAB. The weight obtained from fuzzy AHP was assigned to physical layers of the region. Then, the weights were multiplied by corresponding layers of the criteria in GIS before combining them. Afterward, the final raster map was obtained by GIS (Figure 2).

The obtain criteria from Delphi method used in analyzing conditions of residential blocks in the 2 region of Tehran with emphasis on stability principle and utilization of renewable energies are as follows:

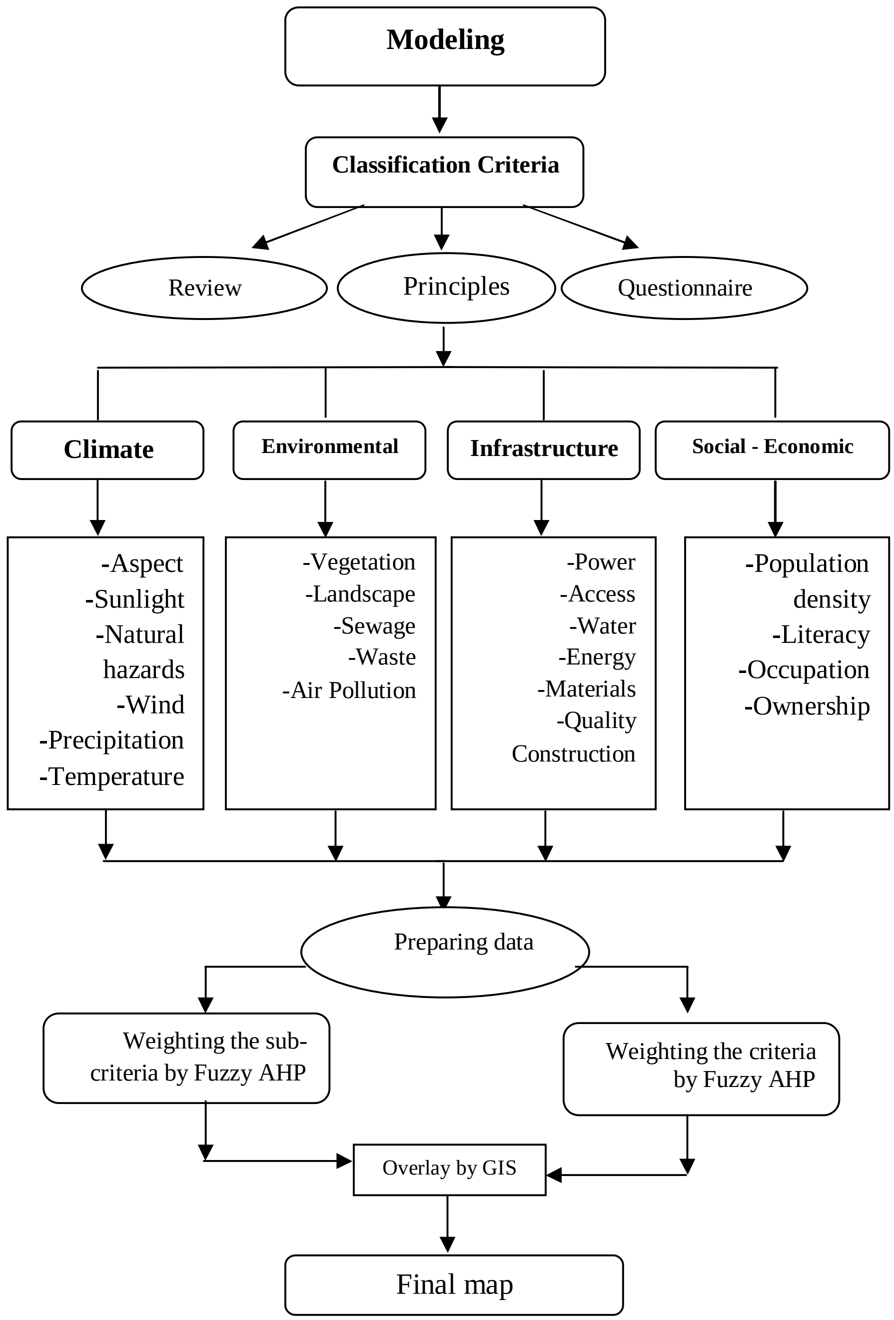



**Fig. 2.** Research process

**Table 1.** criteria and sub-criteria by Delphi

| Criteria | Sub criteria |
|---|---|
| | Aspect (C 11) |
| | Sunlight (C 12) |
| Climate (C1) | Natural hazards (C 13) |
| | Wind (C 14) |
| | Precipitation (C 15) |
| | Temperature (C 16) |
| | Vegetation (C 21) |
| | Landscape (C 22) |
| Environmental (C2) | Sewage ( C23) |
| | Waste (C 24) |
| | Air Pollution (C 25) |
| | Power (C 31) |
| | Access (C 32) |
| Infrastructure (C3) | Water (C 33) |
| | Energy (C 34) |
| | Materials (C 35) |
| | Quality Construction (C 36) |
| | Population Density (C 41) |
| Social – Economic (C4) | Literacy (C 42) |
| | Occupation (C 43) |
| | Ownership (C 44) |

## 5.Fuzzy AHP

AHP has been widely used to address multi-criteria decision-making (MCDM) problems in political, social, economic, and management sciences. MCDM essentially chooses the best alternative from a set of competing alternatives that are evaluated with a set of criteria. The relative importance of different criteria in decision- making problems involves a high degree of subjective judgment and individual preference (Liao, 2011; Ansari and Naghibi, 2013).

Fuzzy sets were introduced by Zadeh (1965) to represent/ manipulate data and information possessing non-statistical uncertainties. It was specifically designed to mathematically represent uncertainty and vagueness and to provide formalized tools for dealing with the imprecision intrinsic to many problems. Fuzzy logic provides an inference morphology that enables approximate human reasoning capabilities to be applied to knowledge-based systems (Rostamzadeh and Sofian; Anagnostopoulos and Petalas, 2011).

fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems and many fuzzy AHP methods by various authors are proposed (Büyüközkan and Çifçi, 2012). This tool which is first introduced by Saaty (1980, 1996) works on eigenvalue approach to the pairwise comparison (Das et al., 2012).

The fuzzy scale used for pairwise comparisons of one attribute over another is shown in Table 2. We used the fuzzy scale when decision makers conduct pairwise comparison judgments with regards to criteria and alternatives. Let

A = (aij)nxm be a fuzzy pairwise comparison judgment matrix.

Let Mij = (lij, mij, uij) be a triangular fuzzy number (TFN).

The steps used for the fuzzy AHP are as follows:

The steps used for the fuzzy AHP are as follows:

Step 1: Pairwise comparison judgments of attributes are made using fuzzy numbers situated on the same level of the hierarchy structure.

Step 2: The value of the fuzzy synthetic extent with respect to the it object is defined as

$$S_i = \sum_{j=1}^{m} M_{ij} \otimes \left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij} \right]^{-1}$$

$$s.t. \sum_{j=1}^{m} M_{ij} = \left[ \sum_{i=1}^{n} I_{ij}, \sum_{j=1}^{n} M_{ij}, \sum_{j=1}^{n} u_{ij} \right], i = 1,2,3, \dots, n$$

**Table 2.** Linguistic terms for evaluation criteria

| Important scale | Reverse Important scale | Definition | Explanation |
|---|---|---|---|
| (1, 1, 1) | (1, 1, 1) | Equal importance | Two elements contribute equally |
| (2/3, 1, 3/2) | (3/2, 1, 2/3) | Moderate importance | One element is slightly favored over another |
| (3/2, 2, 5/2) | (2/5, 1/2, 2/3) | Strong importance | One element is strongly favored over another |
| (5/2, 3, 7/2) | (2/7, 1/3, 2/5) | Very strong importance | An element is very strongly favored over another |
| (7/2, 4, 9/2) | (2/9, 1/4, 2/7) | Extreme importance | One element is the highest favored over another |

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij} = \left[\sum_{j=1}^{n}\sum_{j=1}^{m} I_{ij}, \sum_{j=1}^{n}\sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{n}\sum_{j=1}^{m} u_{ij}\right]$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}\right]^{-1} = \frac{1}{\sum_{j=1}^{n}\sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{j=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{j=1}^{n}\sum_{j=1}^{m} I_{ij}}$$

Step 3: The values of Si are compared and the degree of possibility of Sj = (lj, mj, uj) _ Si = (li, mi, ui) is calculated. That can be equivalently expressed as follows:

$$V(Sj \geq Si) = \text{height}\,(Si \cap Sj) = uSj\,(d) = \begin{cases} 1, & if\ m_j \geq m_i \\ 0 & if\ I_i \geq u_j \\ \dfrac{I_i - u_j}{(m_j - u_j) - (m_i - I_i)} & otherwise \end{cases}$$

where d is the ordinate of the highest intersection point between uSi and uSj. We need both the values of V(Sj ≥ Si) and V(Sj ≥ Si) to compare Si and Sj.

Step 4: The minimum degree possibility d(i) of V(Sj ≥ Si) for i, j = 1, 2,., k is calculated.
V(Sj ≥ S1; S2; S3;.; Sk); for i = 1; 2; 3;…; k
= V(Sj ≥ Si) and (Sj ≥ S2) and (Sj ≥ Sk)
= min V(Sj ≥ Si) for i = 1; 2; 3;…; k
Assume that
d′ (Ai) = min V(Sj ≥ Si); for i = 1; 2; 3;…; k
Then the weight vector is defined as
W′ = (d′ (A1); d′ (A2);…; d′ (An)) T
Step 5: The weight vectors are then normalized as follows.
W′ = (d (A1); d′ (A2); … ; d′ (An)) T
where W is a non-fuzzy number.

## 6. RESULT AND DISCUSSION

As mentioned, Delphi method was used for developing information layers and fuzzy AHP method for assessing and analyzing conditions of the residential blocks in the 2 region of Tehran with emphasis on observation of principles of stability and utilization of renewable energies. After weighting the criteria, they were inputted in MATLAB. The weights obtained through fuzzy AHP modeling were applied on input layers. Then the weights were multiplied by corresponding layers in GIS and the layers were combined. Afterward, the final raster maps were developed. Table 1 lists the data from Delphi group for the fuzzy weights. Table 4 represents the criteria and table 3a, 3b, 3c and 3d list the sub-criteria. The map illustrates status of the zones (Figure 3).

**Table 3a.** Fuzzy decision matrix for sub- criteria of Climate

| | C 11 | C12 | C13 | C14 | C15 | C16 | weight |
|---|---|---|---|---|---|---|---|
| C11 | 1, 1, 1 | 3/2,2,5/2 | 5/2 , 3 , 7/2 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 0.280 |
| C12 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 0.201 |
| C13 | 2/7,1/3,2/5 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 2/3 , 1 , 3/2 | 2/5, 1/2 , 2/3 | 2/5, 1/2 , 2/3 | 0.010 |
| C14 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 1, 1, 1 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 0.188 |
| C15 | 2/5, 1/2 , 2/3 | 2/5, 1/2 , 2/3 | 3/2,2,5/2 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 3/2,2,5/2 | 0.153 |
| C16 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 0.166 |

**Table 3b.** Fuzzy decision matrix for sub- criteria of Environmental

| | C21 | C22 | C23 | C24 | C25 | weight |
|---|---|---|---|---|---|---|
| C21 | 1, 1, 1 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 0.267 |
| C22 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 2/5, 1/2 , 2/3 | 0.136 |
| C23 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 1, 1, 1 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 0.194 |
| C24 | 2/5, 1/2 , 2/3 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 1, 1, 1 | 2/3 , 1 , 3/2 | 0.168 |
| C25 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 1, 1, 1 | 0.232 |

**Table 3c.** Fuzzy decision matrix for sub- criteria of Infrastructure

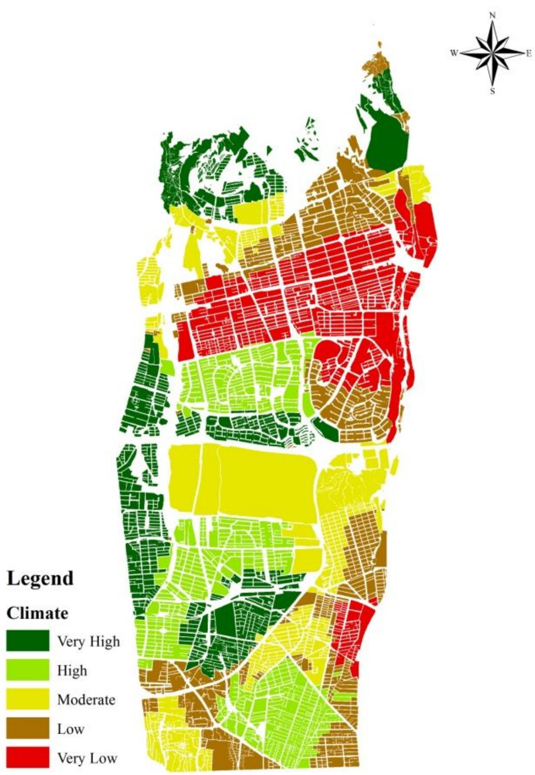
| | C31 | C32 | C33 | C34 | C35 | C36 | weight |
|---|---|---|---|---|---|---|---|
| C31 | 1, 1, 1 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 2/5, 1/2 , 2/3 | 2/3 , 1 , 3/2 | 0.170 |
| C32 | 2/5, 1/2, 2/3 | 1, 1, 1 | 2/5, 1/2 , 2/3 | 2/5, 1/2 ,2/3 | 2/7, 1/3, 2/5 | 2/7, 1/3, 2/5 | 0.091 |
| C33 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 1, 1, 1 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 0.156 |
| C34 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 2/3 , 1 , 3/2 | 1, 1, 1 | 2/5, 1/2 , 2/3 | 2/3 , 1 , 3/2 | 0. 170 |
| C35 | 3/2,2,5/2 | 5/2,3,7/2 | 2/3 , 1 , 3/2 | 3/2,2,5/2 | 1, 1, 1 | 3/2,2,5/2 | 0.237 |
| C36 | 2/3 , 1 , 3/2 | 5/2,3,7/2 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 0.170 |

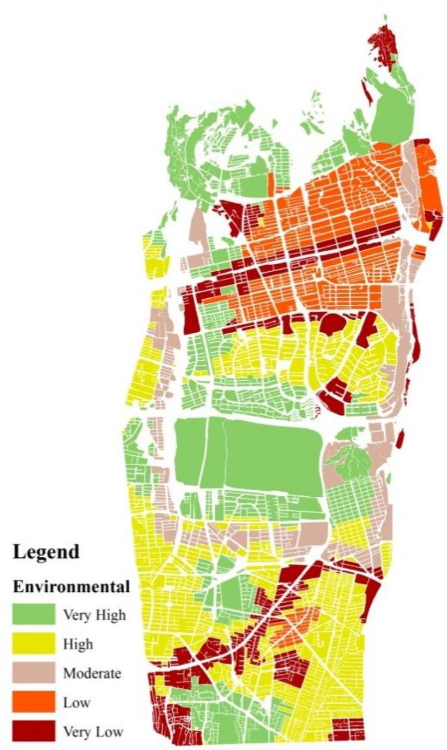
**Table 3d.** Fuzzy decision matrix for sub- criteria of Social - Economic

| | C41 | C42 | C43 | C44 | weight |
|---|---|---|---|---|---|
| C41 | 1, 1, 1 | 3/2,2,5/2 | 5/2 , 3 , 7/2 | 2/3 , 1 , 3/2 | 0.467 |
| C42 | 2/5, 1/2 , 2/3 | 1, 1, 1 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 0.123 |
| C43 | 2/7,1/3,2/5 | 2/3 , 1 , 3/2 | 1, 1, 1 | 5/2 , 3 , 7/2 | 0.314 |
| C44 | 2/3 , 1 , 3/2 | 2/3 , 1 , 3/2 | 2/7,1/3,2/5 | 1, 1, 1 | 0.094 |

**Table 4.** Fuzzy decision matrix for criteria

| | C1 | C2 | C3 | C4 | weight |
|---|---|---|---|---|---|
| C1 | 1, 1, 1 | 2/3 , 1 , 3/2 | 5/2 , 3 , 7/2 | 2/3, 1 , 3/2 | 0.373 |
| C2 | 2/3 , 1 , 3/2 | 1, 1, 1 | 3/2,2,5/2 | 2/5 , 1/2 , 2/3 | 0.257 |
| C3 | 2/7,1/3,2/5 | 2/5 , 1/2 , 2/3 | 1, 1, 1 | 2/3, 1 , 3/2 | 0.065 |
| C4 | 2/3, 1 , 3/2 | 3/2,2,5/2 | 2/3, 1 , 3/2 | 1, 1, 1 | 0.303 |



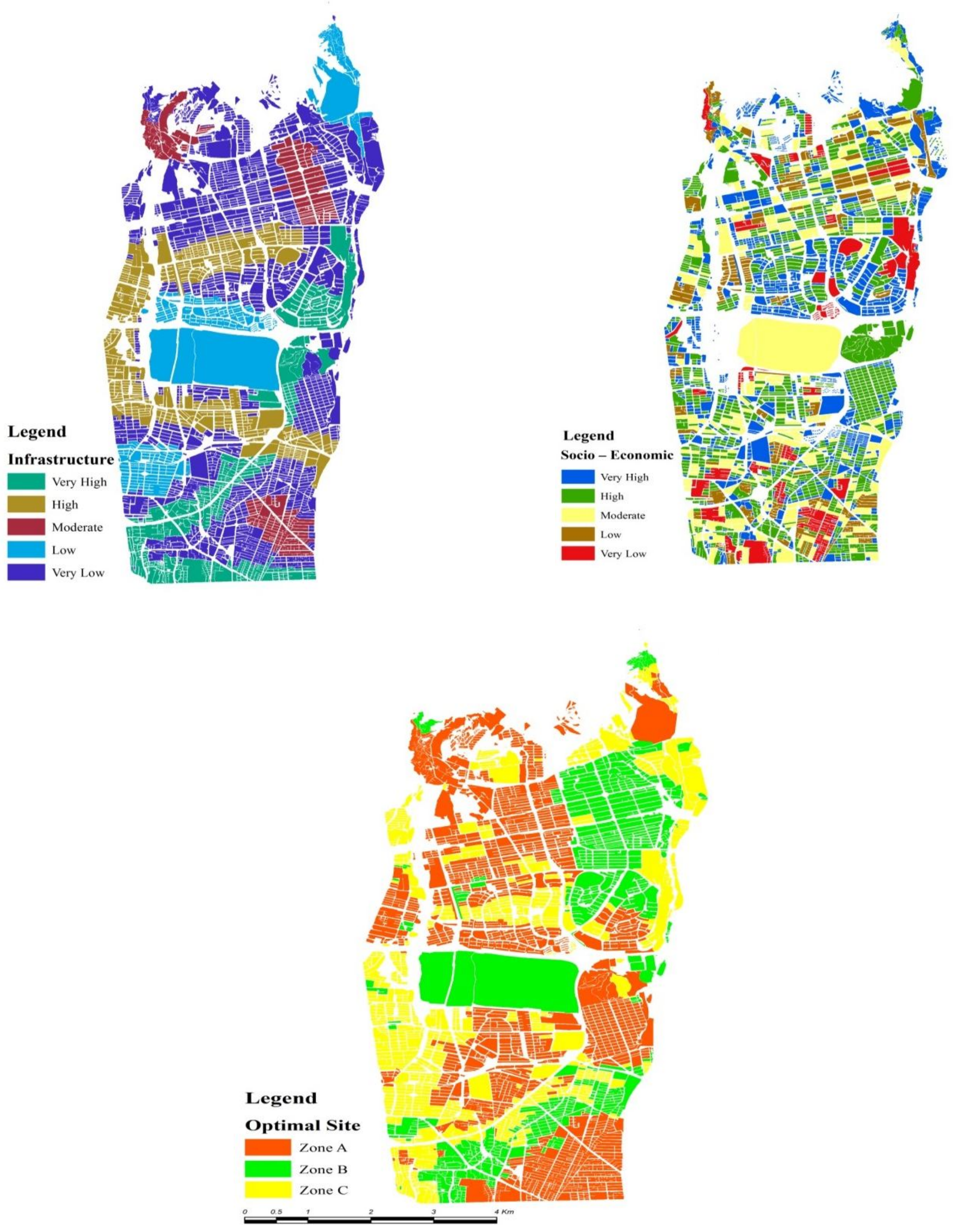



**Fig. 3**. Maps as input data layers into the using model

As the map shows, the residential blocks and the blocks in the region can be classified in three groups concerning observation of the criteria. Zone A in northwest and southwest, zone B in mid part from north to south, and zone C covering parts of northeast and west. Although the principles of stability and utilization of renewable energies are poorly observed in the region, taking into account the parameters and the criteria for assessing the residential blocks toward maximum utilization of the capacities of the region our results showed better condition of zone B comparing with the other two. Considering slop of the land in zone B, the building may more enjoy sunshine and high potential to used clean energy of sun by implementing logical approaches to create more convenient environment for the residents. This needs to equip the residential units with modern technologies for using clean energies. In addition, hazard of earthquake is much less than that of other two zones, while the zone enjoys better ecological conditions (temperature and humidity) thanks to more green spots. In addition, local winds blow direction is in better condition. From environmental viewpoint, natural corridors and wide green coverage (Park Pardisan) attenuate air pollution while giving scenic view to the zone. However, considering the good green coverage of the regions, it is recommended to employ sewage system designed to develop the parks while observing principles of stability and utilization of renewable energies.

Considering infrastructural issues such as residential blocks located in zone B, quality of structures and the material used, higher renewability characteristics and access ways to the blocks are more economic regarding consumed energy. Large yards and receiving great amount of sunshine by majority of the buildings is a great advantage in cold seasons through saving energies for warming the buildings. Moreover, residential sewage (after treatment) and precipitation can be used for irrigating green areas in residential units.

Regarding economic-social concerns, majority of the units are private villas with low congestion. During the day many houses are empty as parents leave the house for their work located outside the region. This means low energy consumption during the day.

From environmental, natural, economic-social, and infrastructural viewpoints zones A and C were in poorer condition comparing with zone B. residential blocks in these two zones are under great earthquake hazard and high congestion has placed the block in positions that avoid sunshine to the building during cold seasons, while during hot seasons the building have now shield against the direct sunshine. This means considerable energy use by air conditioning facilities. In addition, small green areas and high population congestion prevents wind flow in the region. Garbage production is high and old constructions are wear and tear because of low quality materials used in their structure. Considering these, utilization of modern architecture methods in harmony with the climate is required to provide more convenient living condition for the population. Current statue of the buildings needs to be improved through utilization of optimum and reasonable approaches toward stability and development of ecologic city based on use of closed renewable energy sources.

## 7. Conclusion

Condition of the residential blocks with an emphasis on observation of the principles of stability and use of renewable energy sources was studied. As mentioned, design and layout of residential blocks in harmony with such principles, in fact, is a process to utilize local potential to minimize consumption of fossil energy source, which are not renewable. In addition, creation of convenient and dynamic residential blocks with proper architectural design is another concern. Therefore, assessment and analysis of status quo of the residential blocks was the first step toward simultaneous utilization of approaches to supply renewable energy sources and achieving stable blocks. Delphi method along with fuzzy AHP method was employed to find most effective criteria in measurement of current condition and to find potentials to use renewable energy sources. Each criterion was comprised of sub-criteria.

The results, considering the parameters and criteria for assessment of the current situation of the residential blocks, showed that there are three different zones (A, B, and C) and among them zone B had the best condition regarding the principles of stability and potentials for using renewable energy sources.

The results may be used for lying out and designing residential blocks optimally to ensure observation of principles of stability and utilization of renewable energy sources. Taking into account natural, environmental, infrastructural, and economic-social issues as a picture of potentials of the residential blocks for utilization of renewable energy sources, we may take a successful step toward permanent urban development.

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