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# Using Analytical Hierarchy Process and TOPSIS Methods in Positioning Emergency Base in Northwest Shiraz

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## Abstract

This research tries to find the best place for building the emergency base in northwest Shiraz, based on considered criteria. In this research, 5 locations are considered as the alternatives, along with 6 selection criteria. The main objective in this research was the positioning of the emergency base considering specific criteria. Weighting, prioritizing and selecting locations was conducted through AHP technique. As it was shown, the ultimate weight for the proposed location of P3 was higher than other locations. Hence, considering AHP method, this location is considered for building the emergency base.

**Key words:** Hierarchy process, TOPSIS methods, Positioning emergency, Northwest shiraz

## INTRODUCTION

Multi attributed decision-making methods (MADM) are proposed in the science of decision-making, in which choosing one solution among available solutions or prioritizing solutions are of importance. Among these methods, analytical hierarchy process has been used more than other methods in the science of management. AHP is one of the most famous multipurpose decision-making techniques which was invented by Thomas L. Sa'ati in 1970s. AHP is the reflection of human natural behavior and thinking. This technique studies complex problems based on their interactions through breaking them into simpler forms in order to solve them.

AHP could be used where decision-making process deals with several competing alternatives or decision-making criteria. The proposed criteria could be either qualitative or quantitative. This decision-making method is based on paired comparison. The decision-maker begins the decision-making process by providing hierarchical tree. The decision hierarchical tree shows the comparing factors and analyzing competing alternatives. Subsequently, a set of paired comparisons is carried out. These comparisons show the weight of each of the factors in regards with the analyzing competing alternatives in the decision. Ultimately, AHP logic combines the matrices derived from paired comparisons so that the most optimal decision is reached.

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### Modeling

In this stage, the issue and objective of decision-making is provided in the form of decision elements which are in contact with each other. The decision elements include "decision-making indices" and "decision alternatives". AHP requires breaking a problem into a hierarchy of levels through several indices. The higher level expresses the main objective of the decision-making process. The second level expresses the main indices which might be broken into peripheral indices in the next level. The last level presents the decision alternatives.

### Paired Comparisons

Conducting comparisons between various decision alternatives, based on each index and judgment on the importance of the index through paired decisions, after designing the hierarchy of the decision issue, the decision maker should create the set of matrices which numerically measure the relative importance and priority of the indices comparing to each other and any decision alternative, considering the indices relative to the other alternatives.

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**Table 1: Indices' valuation relative to each other**

| Preferred value | i to j comparison score | Description |
|---|---|---|
| 1 | Equal importance | Alternative or index i has the same importance as j, or they are equal |
| 3 | Moderate importance of one factor over another | Alternative or index i is slightly more important than j |
| 5 | Strong or Essential importance | Alternative or index i is more important than j |
| 7 | Very Strong importance | Alternative or index i is strongly more important than j |
| 9 | Extreme importance | Alternative or index i is extremely more important than j |
| 2, 4, 6, 8 | Intermediate values | The intermediate values between the preferred values.For instance, 8 shows the importance higher than 7 and lower than 9 |

**Table 2: Random index**

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0/58 | 0/9 | 1/12 | 1/24 | 1/32 | 1/41 | 1/45 | 1/51 |

**Table 3: Project selection criteria**

| Row | Criteria |
|---|---|
| 1 | Duration |
| 2 | Covered Population |
| 3 | Transpiration Facilities |
| 4 | Geographic Location |
| 5 | Expenses |
| 6 | Facilities |

**Table 4: Paired comparison matrix of duration criterion**

| Duration | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| P1 | 1 | 0.333 | 0.5 | 1 | 0.167 |
| P2 | 3.003003 | 1 | 2 | 0.5 | 4 |
| P3 | 2 | 0.5 | 1 | 0.333 | 3 |
| P4 | 1 | 2 | 3.003003 | 1 | 7 |
| P5 | 5.988024 | 0.25 | 0.333333 | 0.142857 | 1 |

**Table 5: Paired comparison matrix of duration criterion (Normalized)**

| Weight | P5 | P4 | P3 | P2 | P1 | Duration |
|---|---|---|---|---|---|---|
| 0.083722941 | 0.118 | 0.078 | 0.073 | 0.082 | 0.08 | P1 |
| 0.281800323 | 0.235 | 0.293 | 0.293 | 0.245 | 0.24 | P2 |
| 0.171368672 | 0.176 | 0.146 | 0.146 | 0.122 | 0.16 | P3 |
| 0.362038782 | 0.412 | 0.439 | 0.439 | 0.489 | 0.48 | P4 |
| 0.101069283 | 0.059 | 0.049 | 0.049 | 0.016 | 0.04 | P5 |

This could be carried out by paired comparison of two decision elements (paired comparison) and through dedicating numerical scores which show the priority or importance between two elements. To achieve this, the $i^{th}$ alternatives or indices are compared with the $j^{th}$ alternatives or indices, and the process of the indices'valuation relative to each other are presented in the table below.

### Calculation of Relative Weights

Determining the weight of decision elements in relation with each other through a set of numerical calculations. The next step in the AHP is conducting the required calculation for determining the priorities of each decision element, using the data from paired comparison matrices. The brief of the mathematical operation in this stage is as the following. The total of each column from the paired comparison matrix is calculated. Subsequently, any element of the column is divided by the total of the column. The new matrix which is derived is called the normalized comparison matrix. The mean of each row from the normalized comparison matrix is calculated. This mean provides the relative weight of decision elements with the matrix rows.

### Merging the Relative Weights

In order to rank the decision alternatives, the relative weight of each element is multiplied by the weight of the higher elements in order to reach the ultimate weight. The ultimate weight for each alternative is reached through conducting this stage.

### Consistency in Judgements

Almost all the calculations related to AHP are based on the initial judgement of the decision maker which is presented in the paired comparison matrix and any error or inconsistency in the comparison and determination of the importance of alternatives and indices leads complications in the calculations. The inconsistency ratio (IR), which is presented later, is a tool that determines the consistencyand shows to what extent the derived priorities could be trusted. For instance, if alternative A is more important than alternative B (preferred value of 5) and B is moderately more important (preferred value of 3), then it is expected that A is assessed strongly more important than C (preferred value of 7 or higher), or if the preferred value of A comparing to B is 2 and the preferred value of B comparing to C is 3, then value of A comparing to C provide the preferred value of 4. Comparing to alternatives might seem easy, but when the number of comparisons is increased, confidence in the consistencyof the comparisons is not easy and the confidence should be reached through applying the consistency ratio. Experience has shown that if IR is lower than 0.10, the consistency is acceptable, otherwise, the comparisons should be redone. The stages below are used to calculate the IR:

**Table 6: Paired comparison matrix of covered population criterion**

| Covered population | P1 | P2 | P3 | P4 | P5 | Weight |
|---|---|---|---|---|---|---|
| P1 | 1 | 6 | 3 | 2 | 7 | 0.43954261 |
| P2 | 0.166667 | 1 | 0.25 | 0.5 | 3 | 0.083540463 |
| P3 | 0.333333 | 4 | 1 | 0.333 | 5 | 0.170604888 |
| P4 | 0.5 | 2 | 3.003003 | 1 | 7 | 0.267455563 |
| P5 | 0.142857 | 0.333333 | 0.2 | 0.142857 | 1 | 0.038856476 |

**Table 7: Paired comparison matrix of transportation facilities criterion**

| Transpiration facilities | P1 | P2 | P3 | P4 | P5 | Weight |
|---|---|---|---|---|---|---|
| P1 | 1 | 0.5 | 0.25 | 2 | 5 | 0.145338388 |
| P2 | 2 | 1 | 0.3333 | 5 | 7 | 0.260966647 |
| P3 | 4 | 3.0003 | 1 | 4 | 9 | 0.467846916 |
| P4 | 0.5 | 0.2 | 0.25 | 1 | 6 | 0.095107899 |
| P5 | 0.2 | 0.142857 | 0.111111 | 0.166667 | 1 | 0.030740149 |

**Table 8: Paired comparison matrix of geographical location criterion**

| Geographical location | P1 | P2 | P3 | P4 | P5 | Weight |
|---|---|---|---|---|---|---|
| P1 | 1 | 7 | 0.3333 | 2 | 8 | 0.290369695 |
| P2 | 0.142857 | 1 | 0.2 | 0.25 | 4 | 0.069139624 |
| P3 | 3.0003 | 5 | 1 | 4 | 6 | 0.456888059 |
| P4 | 0.5 | 4 | 0.25 | 1 | 2 | 0.14077989 |
| P5 | 0.125 | 0.25 | 0.166667 | 0.5 | 1 | 0.042822733 |

**Table 9: Paired comparison matrix of expenses criterion**

| Expenses | P1 | P2 | P3 | P4 | P5 | Weight |
|---|---|---|---|---|---|---|
| P1 | 1 | 0.167 | 0.125 | 2 | 3 | 0.078053757 |
| P2 | 5.988024 | 1 | 0.25 | 5 | 7 | 0.2610337 |
| P3 | 8 | 4 | 1 | 9 | 9 | 0.569593812 |
| P4 | 0.5 | 0.2 | 0.111111 | 1 | 2 | 0.055232635 |
| P5 | 0.333333 | 0.142857 | 0.111111 | 0.5 | 1 | 0.036086096 |

**Table 10: Paired comparison matrix of facilities criterion**

| Facilities | P1 | P2 | P3 | P4 | P5 | Weight |
|---|---|---|---|---|---|---|
| P1 | 1 | 0.2 | 0.333 | 3 | 3 | 0.145482271 |
| P2 | 5 | 1 | 0.2 | 6 | 6 | 0.330010095 |
| P3 | 3.003003 | 5 | 1 | 2 | 2 | 0.36558122 |
| P4 | 0.333333 | 0.166667 | 0.5 | 1 | 2 | 0.090409116 |
| P5 | 0.333333 | 0.166667 | 0.5 | 0.5 | 1 | 0.068517298 |

- Stage 1. Calculating Weighted Sum Vector: Paired comparison matrix is multiplied in the column vector of relative weight. The new vector is called weighted sum vector (WSV).
- Stage 2. Calculating Consistency Index: The elements of WSV is divided on the relative priority vector. The new vector is called consistency index (CI).
- Stage 3. Calculating λmax: The mean of the elements of CI leads to λmax.
- Stage 4. Calculating Consistency Index: Consistency index is defined as the following:
  n is the number of alternatives in the problem.
- Stage 5. Calculating Consistency Ratio: Consistency ratio is derived from dividing consistency index on the random index (RI).

Consistency ratio of 0.1 or lower presents consistency in the comparisons. The RI is derived from the following table:

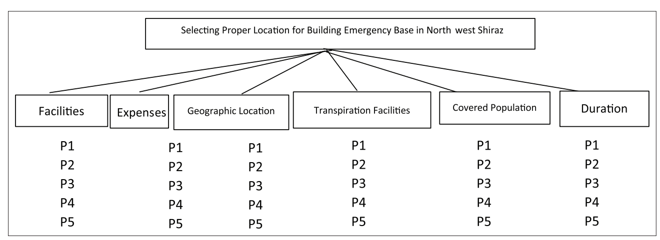
## METHODOLOGY

This research tries to find the best place for building the emergency base in northwest Shiraz, based on considered criteria. In this research, 5 locations are considered as the alternatives, along with 6 selection criteria.

### Project Selection Criteria

The selection criteria for the location of the emergency base are provided in Table 3:

### Problem Hierarchy




### Prioritizing and Weighting the Factors

The AHP stages in order to prioritize and weight these factors are as the following:

1. Creating a combined matrix of paired comparisons
2. Calculating the priority vector for all criteria
3. Calculating consistency ratio (CR)
4. Calculating λmax
5. Calculating consistency index (CI)
6. Selecting proper value considering the random index (RI)
7. Studying the consistency of paired comparison matrix to test the consistency or inconsistency of the decision maker's judgments

**Table 11: Paired comparison matrix of decision criteria**

| | Duration | Covered population | Transportation facilities | Geographical location | Expenses | Facilities | Weight |
|---|---|---|---|---|---|---|---|
| Duration | 1 | 2 | 3 | 6 | 6 | 5 | 0.376768 |
| Covered population | 0.5 | 1 | 3 | 6 | 6 | 5 | 0.299041 |
| Geographical location | 0.333333 | 0.333333 | 1 | 4 | 4 | 3 | 0.155478 |
| Expenses | 0.166667 | 0.166667 | 0.25 | 1 | 2 | 0.5 | 0.051378 |
| Facilities | 0.166667 | 0.166667 | 0.25 | 0.5 | 1 | 0.25 | 0.03633 |
| | 0.2 | 0.2 | 0.333333 | 2 | 4 | 1 | 0.081004 |

**Table 12: Alternatives prioritization matrix relative to the problem criteria**

| | Duration | Covered population | Transportation facilities | Geographical location | Expenses | Facilities | |
|---|---|---|---|---|---|---|---|
| 0.37676832 | 0.083723 | 0.439543 | 0.145338 | 0.29037 | 0.078054 | 0.145482 | P1 |
| 0.299041214 | 0.2818 | 0.08354 | 0.260967 | 0.06914 | 0.261034 | 0.33001 | P2 |
| 0.155478452 | 0.171369 | 0.170605 | 0.467847 | 0.456888 | 0.569594 | 0.365581 | P3 |
| 0.051377938 | 0.362039 | 0.267456 | 0.095108 | 0.14078 | 0.055233 | 0.090409 | P4 |
| 0.036329688 | 0.101069 | 0.038856 | 0.03074 | 0.042823 | 0.036086 | 0.068517 | P5 |

**Table 13: Projects ultimate weight**

| Weight | Project |
|---|---|
| 0.215121 | P1 |
| 0.211498 | P2 |
| 0.262105 | P3 |
| 0.247735 | P4 |
| 0.06354 | P5 |

In addition to the conduction of paired comparisons, the importance of the decision criteria comparing to each other should be determined, too. In other words, the priority of the available criteria comparing to each other should be compared so that the importance of each criterion in the objective of the problem is determined. The table presents the paired comparison matrix and the problem criteria priority vector.

Accordingly, the alternatives prioritization matrix should be formed relative to each criterion and the total prioritization vector should be calculated and consequently, the alternatives ultimate ranking should be carried out. Table 12 presents the alternatives prioritization along with the total prioritization vector for each alternative.

The ultimate prioritization vector for each alternative is derived through multiplying criteriaprioritization vector (the last column of Table 11) in the row related to the alternative in the alternatives prioritization matrix (Table 12) and sum of the derived numbers.

## CONCLUSION

The main objective in this research was the positioning of the emergency base considering specific criteria. Weighting, prioritizing and selecting locations was conducted through AHP technique. As it was shown, the ultimate weight for the proposed location of P3 was higher than other locations. Hence, considering AHP method, this location is considered for building the emergency base.

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