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# PRIORITIZING CONSTRUCTING PROJECTS OF MUNICIPALITIES BASED ON AHP AND COPRAS-G: A CASE STUDY ABOUT FOOTBRIDGES IN IRAN

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**Abstract.** Each municipality has a certain budget for constructing, maintaining and repairing every year. Prioritizing projects is one of the difficult issues of decision making and takes time for evaluating and programming. The main aim of this study is to make a framework for municipalities to prioritize their projects based on this framework and for this a footbridge project of Sari City in Iran was selected as a case study for this research to show prioritizing of boulevards that have no footbridge for constructing footbridge. The cost of constructing footbridge is sometimes high and the footbridge site place is important for pedestrians. Besides, selecting of an area for constructing new footbridges includes quantitative and qualitative factors, such as the Total cost, Environmental factors, and Socio-economic factors. For these reasons, selecting area for constructing footbridges can be viewed as a kind of Multi-Attribute Decision Making (MADM) problem. The aim of this study is the use of Analytic Hierarchy Process (AHP) and COPRAS-G methods for evaluating and selecting an area for constructing new footbridges alternatives. More precisely, AHP was used for calculation of the relative importance of criteria and COPRAS-G method was used for ranking location alternatives.

**Keywords:** constructing projects, footbridge, MADM, AHP, COPRAS-G.

## 1. Introduction

Every municipality deals with many projects including constructing, maintaining, repairing and etc. every year. Among these projects, constructing projects are one of the critical problems for municipality because many fields such as, manufacturing engineering, transportation engineering, civil engineering, etc. have to work together and the results are very important for the government. Also, the numbers of constructing projects are many and municipality budget is limited. Besides, a proper construction project selection is a very important activity for every municipality due to the fact that improper selection can negatively affect the overall performance and productivity of a project. In addition, sometimes determining an appropriate area for constructing project is as important as the project.

Most of constructing projects deal with civil engineering. In civil engineering some projects deal with designing and constructing new bridges. Bridges are important structures of our lives and make transportation easier for us. Also, bridge projects sometimes are very expensive and vital for the country. Most studies in this field are about designing or constructing bridges and merely no studies could be found about selecting an area for bridge constructing. The common features of these studies are focused on designing, constructing and mathematical calculations of structure of the bridge.

Footbridges are kind of bridges that pedestrians use for their movements. Generally, all groups of people use footbridges. These bridges help pedestrians to cross the street without making any problem for vehicle traffic.

Selecting an area for constructing new footbridge is a sophisticated, time-consuming and difficult process, requiring advanced knowledge and expertise. So, the process can be very hard for engineers and managers. For a proper and effective evaluation, the decision maker may need a lot of data and many factors for evaluation. For these reasons, selection of an area for constructing new footbridge can be viewed as multi-attribute decision making process (MADM) problem.

The aim of this study is the use MADM methods for evaluating and selection the best area as alternative for constructing a new footbridge. There are many MADM methods in the literature including Priority based, outranking, distance-based and mixed methods (Pomerol,

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Barba-Romero 2000). Some of famous MADM methods in the literature are: analytic hierarchy process (AHP) (Saaty 1980), analytic network process (ANP) (Saaty, Vargas 2001), axiomatic design (AD) (Kulak, Kahraman 2005), TOPSIS (Hwang, Yoon 1981), ELECTRE (Wang, Triantaphyllou 2008), VIKOR (Opricovic, Tzeng 2007), COPRAS-G (Zavadskas *et al.* 2008) and PROMETHEE (Behzadian *et al.* 2010; Dağdeviren 2008). But among these methods, Analytic Hierarchy Process (AHP) is one of the bests, and that was introduced by Saaty (1980; 2001). The idea behind this method is obtaining the relative weights among the factors and calculating the total values of each alternative based on these weights. This study uses the AHP to calculate each criterion weight from subjective judgments of the decision maker group. The rating of each alternative and the weight of each criterion, which are determined using the AHP, are then passed to the complex proportional assessment method with grey interval numbers (COPRAS-G), which is MADM method.

This paper is organized in five sections. In section "Introduction" the studied problem is introduced. Section "Principles of AHP and COPRAS-G methods" briefly describes the two proposed methodologies. In section "Proposed AHP – COPRAS-G integrated approach", proposed AHP – COPRAS-G integrated approach for footbridge site place selection is presented and the stages of the proposed approach and steps are determined in detail. How the proposed approach is used on a real world case study is explained in section "Case study". In section "Conclusions and future research" conclusions and future research areas are discussed.

## 2. Principles of AHP and COPRAS-G methods

### 2.1. The AHP method

This technique was developed by Saaty (1980) and the main point behind this technique is how to determine the relative importance of a set of activities in a multi-criteria decision problem. Based on this approach decision maker could incorporate and translate judgments on intangible qualitative criteria alongside tangible quantitative criteria (Badri 2001). The AHP method is based on three principles: first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities (Dağdeviren 2008). The recent developments of decision making models based on AHP methods are listed below:

- Medineckiene *et al.* (2010) applied AHP in sustainable construction;
- Podvezko *et al.* (2010) used AHP in evaluation of contracts;
- Sivilevicius (2011a) applied AHP in modeling of transport system;
- Sivilevicius (2011b) used AHP in quality of technology;
- Fouladgar *et al.* (2011) applied AHP in prioritizing strategies.

In the first step, a sophisticated decision problem is structured as a hierarchy. This method breaks down a sophisticated decision making problem into hierarchy of objectives, criteria, and alternatives.

These decision elements make a hierarchy of structure including goal of the problem at the top, criteria in the middle and the alternatives at the bottom of this hierarchy.

In the second step, the comparisons of the alternatives and criteria are made. In AHP, comparisons are made based on a standard nine point scale (Table 1). Also, in this standard some numbers including 2, 4, 6, and 8 could be used as intermediate values.

**Table 1.** Nine-point intensity of importance scale and its description (Dağdeviren 2008)

| Definition | Intensity of importance |
|---|---|
| Equally important | 1 |
| Moderately more important | 3 |
| Strongly more important | 5 |
| Very strongly more important | 7 |
| Extremely more important | 9 |

Let $C = \left\{ C_j \mid j = 1, 2, \dots, n \right\}$ be the set of criteria. The result of the pairwise comparison on $n$ criteria can be summarized in an $(n \times n)$ evaluation matrix $A$ in which every element $a_{ij}$ ($i, j$ = 1, 2, ... , $n$) is the quotient of weights of the criteria, as shown in Eq (1):

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \; a_{ii} = 1, \; a_{ji} = \frac{1}{a_{ij}}, a_{ij} \neq 0. \quad (1)$$

At the third step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector ($w$) corresponding to the largest eigenvalue ($\lambda_{\max}$), as

$$Aw = \lambda_{\max} w. \quad (2)$$

If the pairwise comparisons are completely consistent, the matrix $A$ has rank 1 and $\lambda_{\max} = n$.

In this case, weights can be obtained by normalizing any of the rows or columns of $A$ (Wang, Yang 2007). The quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments (Dağdeviren 2008). The consistency is defined by the relation between the entries of $A$: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index ($CI$) is

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)}. \quad (3)$$

The final consistency ratio ($CR$), using which one can conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index ($RI$), as indicated in Eq (4):

$$CR = \frac{CI}{RI}. \quad (4)$$

The $CR$ index should be lower than 0.10 to accept the AHP results as consistent (Işıklar, Büyüközkan 2007). If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency (Dağdeviren 2008). The $CR$ index could be used to calculate the consistency of decision makers as well as the consistency of all the hierarchy (Wang, Yang 2007).

### 2.2. The COPRAS-G method

In order to evaluate the overall efficiency of an alternative, it is necessary to identify selection criteria, to assess information, relating to these criteria, and to develop methods for evaluating the criteria to meet the participants' needs. Decision analysis is concerned with the situation in which a decision-maker (DM) has to choose among several alternatives by considering a particular set of usually conflicting criteria. For this reason Complex proportional assessment (COPRAS) method that was developed by Zavadskas and Kaklauskas (1996) can be applied. This method was applied to the solution of various problems in construction (Tupenaite *et al.* 2010; Ginevičius *et al.* 2008; Kaklauskas *et al.* 2010; Zavadskas *et al.* 2010; Medineckiene, Björk 2011). The most alternatives under development always deal with vague future, and values of criteria cannot be expressed exactly. This MADM problem should be determined not with exact criteria values, but with fuzzy values or with values in some intervals. Zavadskas *et al.* (2008) presented the main ideas of complex proportional assessment method with grey interval numbers (COPRAS-G) method. The idea of COPRAS-G method with criterion values expressed in intervals is based on the real conditions of decision making and applications of the Grey systems theory (Deng 1982; 1988). The COPRAS-G method uses a stepwise ranking and evaluating procedure of the alternatives in terms of significance and utility degree.

The recent developments of decision making models based on COPRAS methods are listed below:

- Hashemkhani Zolfani *et al.* (2011) presented forest roads locating using COPRAS-G method;
- Chatterjee *et al.* (2011) presented materials selection model based on COPRAS and EVAMIX methods;
- Zavadskas *et al.* (2011) assessment of the indoor environment;
- Podvezko (2011) presented comparative analysis of MCDM methods (SAW and COPRAS);
- Chatterjee, Chakraborty (2012) presented materials selection using COPRAS-G method;
- Antucheviciene *et al.* (2011) presented comparative analysis of MCDM methods (COPRAS, TOPSIS and VIKOR).

The procedure of applying the COPRAS-G method consists of the following steps (Zavadskas *et al.* 2009):

1. Selecting the set of the most important criteria, describing the alternatives.
2. Constructing the decision-making matrix $\otimes X$:

$$\otimes X = \begin{bmatrix} [\otimes x_{11}] & \cdots & \cdots & [\otimes x_{1m}] \\ [\otimes x_{21}] & \cdots & \cdots & [\otimes x_{2m}] \\ \vdots & \cdots & \ddots & \vdots \\ [\otimes x_{n1}] & \cdots & \cdots & [\otimes x_{nm}] \end{bmatrix} =$$

$$\begin{bmatrix} [\underline{x}_{11}; \overline{x}_{11}] & [\underline{x}_{12}; \overline{x}_{12}] & \cdots & [\underline{x}_{1m}; \overline{x}_{1m}] \\ [\underline{x}_{21}; \overline{x}_{21}] & [\underline{x}_{22}; \overline{x}_{22}] & \cdots & [\underline{x}_{2m}; \overline{x}_{2m}] \\ \vdots & \vdots & \ddots & \vdots \\ [\underline{x}_{n1}; \overline{x}_{n1}] & [\underline{x}_{n2}; \overline{x}_{n2}] & \cdots & [\underline{x}_{nm}; \overline{x}_{nm}] \end{bmatrix};$$

$$j = \overline{1,n}, \; i = \overline{1,m}, \quad (5)$$

where $\otimes x_{ji}$ – determined $\underline{x}_{ji}$ (the smallest value, the lower limit) and $\overline{x}_{ji}$ (the biggest value, the upper limit).

3. Determining significances of the criteria $q_i$.
4. Normalizing the decision-making matrix $\otimes X$ are calculated by formula 6:

$$\underline{\tilde{x}} = \frac{\underline{x}_{ji}}{\frac{1}{2}\left(\sum_{j=1}^{n} \underline{x}_{ji} + \sum_{j=1}^{n} \overline{x}_{ji}\right)} = \frac{2\underline{x}_{ji}}{\left(\sum_{j=1}^{n} \underline{x}_{ji} + \sum_{j=1}^{n} \overline{x}_{ji}\right)},$$

$$\overline{\tilde{x}} = \frac{\overline{x}_{ji}}{\frac{1}{2}\left(\sum_{j=1}^{n} \underline{x}_{ji} + \sum_{j=1}^{n} \overline{x}_{ji}\right)} = \frac{2\overline{x}_{ji}}{\sum_{j=1}^{n} (\underline{x}_{ji} + \overline{x}_{ji})};$$

$$j = \overline{1,n}; \; i = \overline{1,m}. \quad (6)$$

In formula (6) $\underline{x}_{ji}$– the lower value of the $I$ criterion in the alternative $j$ of the solution; $\overline{x}_{ji}$– the upper value of the criterion $i$ in the alternative $j$ of the solution; $m$ – the number of criteria; $n$ – the number of the alternatives, compared. Then, the decision-making matrix is normalized are determined according to the formula 7:

$$\otimes \tilde{X} = \begin{bmatrix} [\underline{\tilde{x}}_{11}; \overline{\tilde{x}}_{11}] & [\underline{\tilde{x}}_{12}; \overline{\tilde{x}}_{12}] & \cdots & [\underline{\tilde{x}}_{1m}; \overline{\tilde{x}}_{1m}] \\ [\underline{\tilde{x}}_{21}; \overline{\tilde{x}}_{21}] & [\underline{\tilde{x}}_{22}; \overline{\tilde{x}}_{22}] & \cdots & [\underline{\tilde{x}}_{2m}; \overline{\tilde{x}}_{1m}] \\ \vdots & \vdots & \ddots & \vdots \\ [\underline{\tilde{x}}_{n1}; \overline{\tilde{x}}_{n1}] & [\underline{\tilde{x}}_{n2}; \overline{\tilde{x}}_{n2}] & \cdots & [\underline{\tilde{x}}_{nm}; \overline{\tilde{x}}_{nm}] \end{bmatrix}. \quad (7)$$

5. Calculating the weighted normalized decision matrix $\otimes \hat{X}$.The weighted normalized values $\otimes \hat{x}_{ji}$ are calculated as follows:

$$\otimes \hat{x}_{ji} = \otimes \tilde{x}_{ji} \times q_i; \; or \; \underline{\hat{x}}_{ji} = \underline{\tilde{x}}_{ji} \times q_i \; and \; \overline{\hat{x}}_{ji} = \overline{\tilde{x}}_{ji} \times q_i, \quad (8)$$

where $q_i$ – the significance of the $i$-th criterion. Then, the normalized decision-making matrix is:

$$\otimes\hat{X}=\begin{bmatrix}[\otimes\hat{x}_{11}] & [\otimes\hat{x}_{12}] & \cdots & [\otimes\hat{x}_{1m}]\\ [\otimes\hat{x}_{21}] & [\otimes\hat{x}_{22}] & \cdots & [\otimes\hat{x}_{1m}]\\ \vdots & \vdots & \ddots & \vdots\\ [\otimes\hat{x}_{n1}] & [\otimes\hat{x}_{n2}] & \cdots & [\otimes\hat{x}_{nm}]\end{bmatrix}=$$

$$\begin{bmatrix}[\underline{\hat{x}}_{11};\overline{\hat{x}}_{11}] & [\underline{\hat{x}}_{12};\overline{\hat{x}}_{12}] & \cdots & [\underline{\hat{x}}_{1m};\overline{\hat{x}}_{1m}]\\ [\underline{\hat{x}}_{21};\overline{\hat{x}}_{21}] & [\underline{\hat{x}}_{22};\overline{\hat{x}}_{22}] & \cdots & [\underline{\hat{x}}_{2m};\overline{\hat{x}}_{2m}]\\ \vdots & \vdots & \ddots & \vdots\\ [\underline{\hat{x}}_{n1};\overline{\hat{x}}_{n1}] & [\underline{\hat{x}}_{n2};\overline{\hat{x}}_{n2}] & \cdots & [\underline{\hat{x}}_{nm};\overline{\hat{x}}_{nm}]\end{bmatrix}. \quad (9)$$

6. Calculating the sums $P_j$ of criterion values, whose larger values are more preferable:

$$P_j=\frac{1}{2}\sum_{i=1}^{k}(\underline{\hat{x}}_{ji}+\overline{\hat{x}}_{ji}). \quad (10)$$

7. Calculating the sums $R_j$ of criterion values, whose smaller values are more preferable:

$$R_j=\frac{1}{2}\sum_{i=k+1}^{m}(\underline{\hat{x}}_{ji}+\overline{\hat{x}}_{ji}), i=\overline{k,m}. \quad (11)$$

In formula (11), $(m - k)$ is the number of criteria which must be minimized.

8. Determining the minimal value of $R_j$ as follows:

$$R_{\min}=\min_j R_j,\ \ j=\overline{1,n}. \quad (12)$$

9. Calculating the relative significance of each alternatively $Q_j$ the expression:

$$Q_j=P_j+\frac{\sum_{j=1}^{n}R_j}{R_j\sum_{j=1}^{n}\frac{1}{R_j}}. \quad (13)$$

10. Determining the optimally criterion by $K$ the formula:

$$K=\max_j Q_j,\ \ i=\overline{1,n}. \quad (14)$$

11. Determining the priority order of the alternatives.

12. Calculating the utility degree of each alternative by the formula:

$$N_j=\frac{Q_j}{Q_{\max}}100\%, \quad (15)$$

where $Q_j$ and $Q_{\max}$ are the significances of the alternatives obtained from Eq (13).

### 3. Proposed AHP – COPRAS-G integrated approach

The integrated approach composed of AHP and COPRAS-G methods for area selection problem consists of 4 basic stages (Fig. 1): (1) Data gathering, (2) AHP calculations, (3) COPRAS-G calculations, (4) Decision making.

In the first stage, alternatives and the criteria which will be used in their evaluation are determined and the decision hierarchy is formed. In the last step of the first stage, the decision hierarchy is approved by decision making team.

In stage two and after approval of decision hierarchy, criteria that were used in evaluation alternatives are assigned their weights via AHP. In this stage, criteria weights are calculated by pairwise comparisons. The decision making team used Table 1 as a standard for doing pairwise comparisons. The project team used Delphi technique as a group decision making tool for receiving general agreement.

Area priorities are found by using COPRAS-G computations in the third stage. Firstly, the project team evaluates alternatives and after these evaluations, COPRAS-G is used for ranking the alternatives. Finally, in the last stage, decision making team made decision about selecting the best place for footbridge.

### 4. Case study

Iran is one of the most dangerous countries for both drivers and pedestrians. This case study is based on one of the important projects in Sari and proposed approach is applied in one of the important municipality projects, in Sari, Iran.

Sari City is the capital of Mazandaran province in the north of Iran and near to Caspian Sea. Unfortunately, the number of pedestrians that got involved in the accidents in Sari is high. In recent years the principals of management and structures of municipality has changed while a new building of Sari Municipality was established less than two years ago, many projects started in the city like developing roads, boulevards, parks and etc. due to deserve of this city that is 3000 years old and was the first city in the whole north of Iran. Compared to developing roads in the city footbridges did not develop like roads and this issue can be dangerous for local people and tourists in the city. The municipality project team wants to evaluate and select area for constructing new footbridges. The budget of the municipality was limited and the best area had to be selected.

However it is hard to choose the most suitable one among the municipality projects which dominate each other in different characteristics. This research has tried to give a framework as a scientific way for prioritizing roads and boulevards for construction of new footbridges that can be helpful for municipality to follow their projects according to the budget and to identify priority projects. The three boulevards are selected by the project team because of their importance and situations as alternatives. These alternatives are Khazar Boulevard (KB), Artesh Boulevard (AB) and Taleghani Boulevard (TB) (Fig. 2).

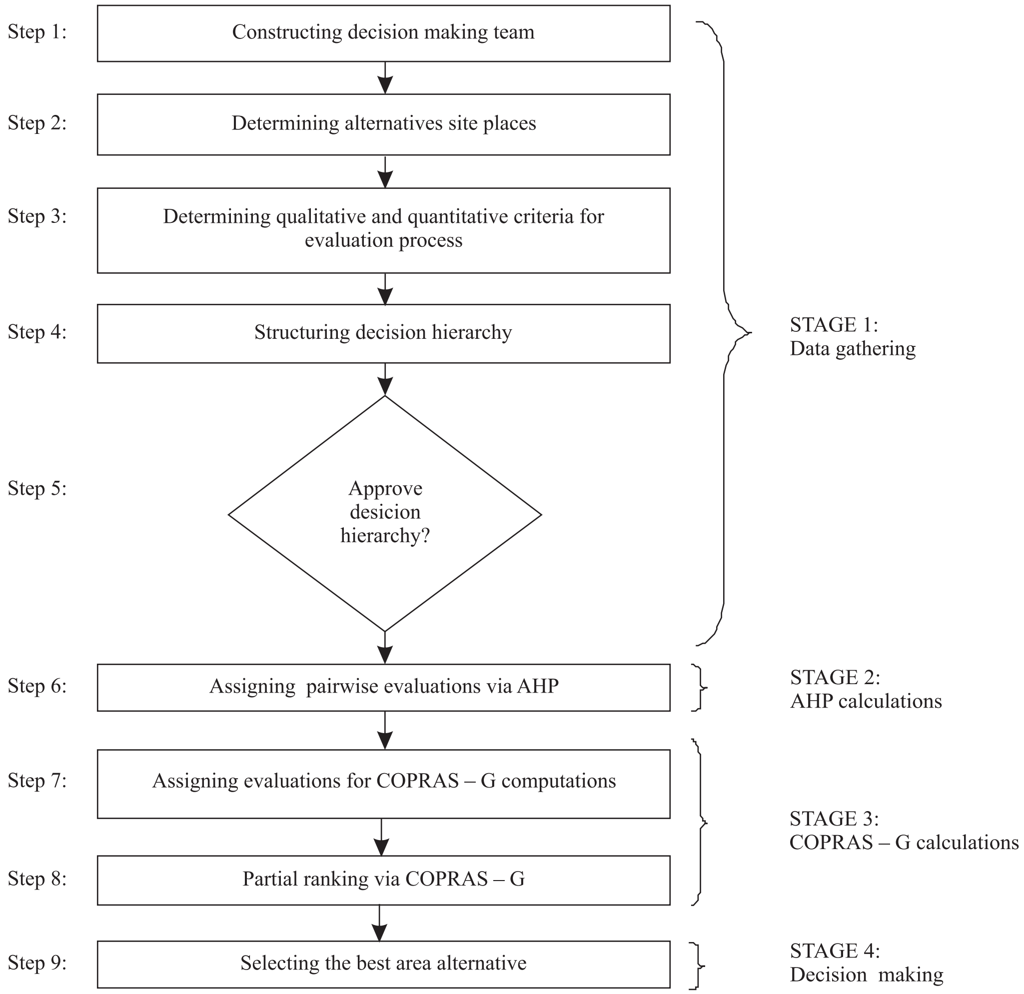


**Fig. 1.** Schematic representation of the process proposed for area selection process

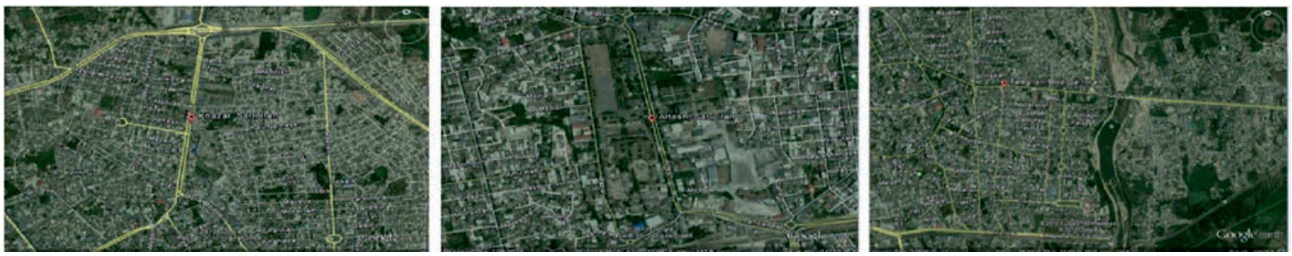

**Fig. 2.** The view of three boulevards in Sari: a – Khazar Boulevard (KB); b – Artesh Boulevard (AB); c – Taleghani Boulevard (TB)

### 4.1. Data gathering

At first, the top managers of Sari municipality and a group of experts in civil engineering, economic, and social sciences participated in a conference meeting on footbridge project (Table 2) and with a preliminary work the decision making team determined three possible areas suitable for the needs of the municipality. The three criteria with eight sub-criteria are used for evaluation of the alternatives. Decision hierarchy structured and criteria are provided in Fig. 3. There are four levels in the decision hierarchy structured for selection.

### 4.2. AHP calculations

After constructing the decision hierarchy and alternatives, the project team assigns pairwise comparisons via AHP for evaluating all the criteria and weighting each criterion. In this step, the experts in the decision making team are given the task of forming individual pairwise comparison matrix

**Table 2.** Background information of experts

| Variable | Items | NO | Variable | Items | NO |
|---|---|---|---|---|---|
| 1) Civil Engineering | Bachelor | 1 | 3) Social Sciences Experts | Bachelor | 0 |
| | Master | 3 | | Master | 2 |
| | Ph.D. | 1 | | Ph.D. | 1 |
| 2) Economic Experts | Bachelor | 0 | 4) Top Managers | Bachelor | 0 |
| | Master | 2 | | Master | 3 |
| | Ph.D. | 1 | | Ph.D. | 1 |

by using the scale given in Table 1. As mentioned before, the project team for receiving the general agreement on their evaluations used Delphi technique as a group decision making tool. The all pairwise comparisons and the weights of criteria are showed in Tables 3–8. Eqs (1) to (4) were used for AHP calculations. The last column of every table shows the weight of each criterion.

The Socio-economic, Environmental factors and Total cost are determined as the three most important criteria in the area selection process by AHP.

**Table 3.** Criteria, sub-criteria, sub-sub criteria and their descriptions

| Criteria | |
|---|---|
| $C_1$. Environmental factors | $C_{1\text{-}1}$ Traffic related factors: $C_{1\text{-}1\text{-}1}$ Vehicles |
| | $C_{1\text{-}1\text{-}2}$ Pedestrians |
| | $C_{1\text{-}2}$ Accident related factors $C_{1\text{-}2\text{-}1}$ Number of injuries $C_{1\text{-}2\text{-}2}$ Dead |
| | $C_{1\text{-}3}$ Average speed limit |
| | $C_{1\text{-}4}$ Influence of physical area attributes on footbridges |
| $C_2$. Socio-economic factors | $C_{2\text{-}1}$ Rate of transportation of families, children and business dates |
| | $C_{2\text{-}2}$ situation of area growth in the future |
| | $C_{2\text{-}3}$ Special importance of each road or boulevard to the city |
| | $C_{2\text{-}4}$ Vision of roads or boulevards about issues like: population, economical condition and other strategic issues |
| $C_3$. Total cost | |

**Table 4.** Pairwise comparison matrix for criteria and weights

| | $C_1$ | $C_2$ | $C_3$ | Weights |
|---|---|---|---|---|
| $C_1$ | 1 | 3 | 1/2 | 0.3 |
| $C_2$ | 1/3 | 1 | 1/6 | 0.6 |
| $C_3$ | 2 | 6 | 1 | 0.1 |

**Table 5.** Pairwise comparison matrix for Traffic related factors and their weighs

| | $C_{1\text{-}1\text{-}1}$ | $C_{1\text{-}1\text{-}2}$ | Weights |
|---|---|---|---|
| $C_{1\text{-}1\text{-}1}$ | 1 | 1/2 | 0.333 |
| $C_{1\text{-}1\text{-}2}$ | 2 | 1 | 0.667 |

**Table 6.** Pairwise comparison matrix for Accident related factors and their weights

| | $C_{1\text{-}2\text{-}1}$ | $C_{1\text{-}2\text{-}2}$ | Weights |
|---|---|---|---|
| $C_{1\text{-}2\text{-}1}$ | 1 | 1/5 | 0.167 |
| $C_{1\text{-}2\text{-}2}$ | 5 | 1 | 0.833 |

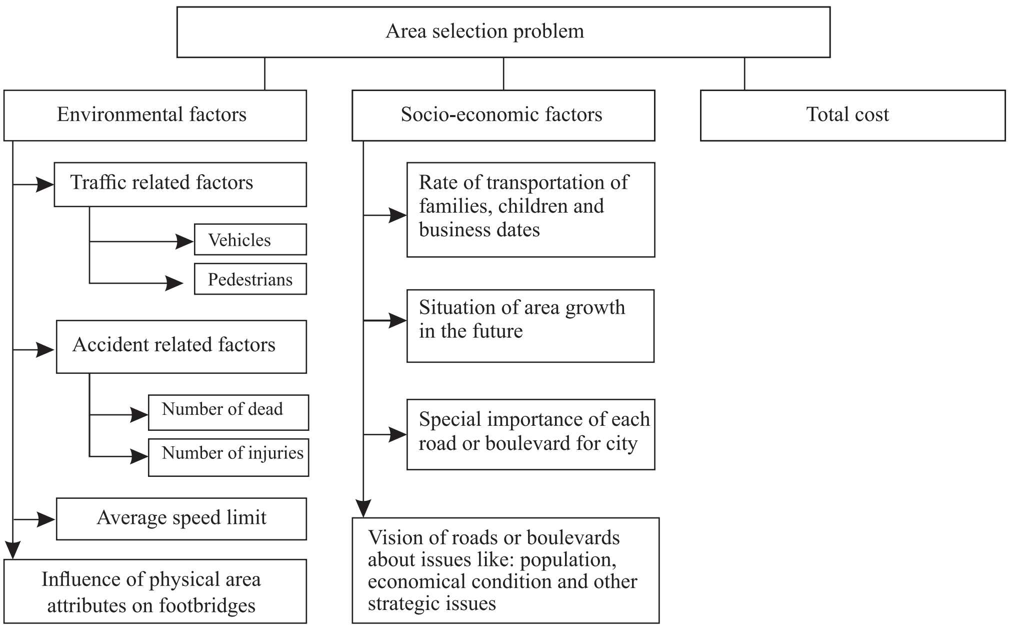


**Fig. 3.** The decision hierarchy of the area selection for footbridges constructing project

**Table 7.** Pairwise comparison matrix for Environmental factors and their weights

| | $C_{1\text{-}1}$ | $C_{1\text{-}2}$ | $C_{1\text{-}3}$ | $C_{1\text{-}4}$ | Weights |
|---|---|---|---|---|---|
| $C_{1\text{-}1}$ | 1 | 1/4 | 5 | 2 | 0.254 |
| $C_{1\text{-}2}$ | 4 | 1 | 3 | 2 | 0.441 |
| $C_{1\text{-}3}$ | 1/5 | 1/3 | 1 | 1/6 | 0.074 |
| $C_{1\text{-}4}$ | 1/2 | 1/2 | 6 | 1 | 0.231 |

**Table 8.** Pairwise comparison matrix for Socio-economic factors and their weights

| | $C_{2\text{-}1}$ | $C_{2\text{-}2}$ | $C_{2\text{-}3}$ | $C_{2\text{-}4}$ | Weights |
|---|---|---|---|---|---|
| $C_{2\text{-}1}$ | 1 | 1/8 | 1/5 | 1/3 | 0.059 |
| $C_{2\text{-}2}$ | 8 | 1 | 2 | 2 | 0.464 |
| $C_{2\text{-}3}$ | 5 | 1/2 | 1 | 2 | 0.294 |
| $C_{2\text{-}4}$ | 3 | 1/2 | 1/2 | 1 | 0.183 |

The pedestrians and vehicles are determined as the two most important criteria in the area selection process, in the sub-criteria of Traffic related criteria by AHP.

In the criterion of Accident related factors the dead and number of injuries are determined as the two most important criteria in the area selection process by AHP.

For the four sub-criteria of Environmental factors, Accident related, Traffic, Influence of physical and Average speed are determined as the four most important criteria in the area selection process by AHP.

In the Socio-economic factors, situation of area, special importance of each road or boulevard to the city of and Rate of transportation of families, children and business dates as the three most important criteria in the area selection process by AHP. Consistency ratio of the pairwise comparison matrix calculated for all of the tables was lower than 0.1. So the weights are shown to be consistent and they are used in the selection process.

### 4.3. COPRAS-G calculations

First of all in this step, alternatives are evaluated based on the evaluation criteria and the evaluation matrix is constructed. The evaluations of these three alternatives according to the previously stated criteria, i.e., evaluation matrix, are displayed in Table 9.

In Table 9 weights of each criterion and sub-criterion was calculated based on results of AHP about criteria and sub-criteria.

Normalized weighted decision matrix $\otimes\hat{X}$ was recalculated by formulas 6–8 (Table 10).

Final results calculated by the formulas 10–15 are presented in Table 11.

**Table 9.** Initial decision making matrix $\otimes X$ with the criteria values described in intervals

| | $\otimes x_{1\text{-}1\text{-}1}$ | | $\otimes x_{1\text{-}1\text{-}2}$ | | $\otimes x_{1\text{-}2\text{-}1}$ | | $\otimes x_{1\text{-}2\text{-}2}$ | | $\otimes x_{1\text{-}3}$ | | $\otimes x_{1\text{-}4}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Opt. | max | | max | | min | | min | | max | | max | |
| $q_j$ | 0.025 | | 0.05 | | 0.021 | | 0.115 | | 0.021 | | 0.068 | |
| Region | $\underline{x}_{1-1-1}$; | $\overline{x}_{1-1-1}$ | $\underline{x}_{1-1-2}$; | $\underline{x}_{1-1-2}$; | $\underline{x}_{1-2-1}$; | $\underline{x}_{1-2-1}$; | $\underline{x}_{1-2-2}$; | $\underline{x}_{1-2-2}$; | $\underline{x}_{1-3}$; | $\underline{x}_{1-3}$; | $\underline{x}_{1-4}$; | $\overline{x}_{1-4}$; |
| KB | 60 | 70 | 70 | 80 | 50 | 60 | 20 | 30 | 50 | 60 | 70 | 80 |
| AB | 70 | 80 | 60 | 70 | 60 | 70 | 30 | 40 | 60 | 70 | 60 | 70 |
| TB | 60 | 70 | 60 | 70 | 40 | 50 | 20 | 3 | 50 | 60 | 60 | 70 |

**Table 9.** (continuation). Initial decision making matrix with the criteria values described in intervals

| | $\otimes x_{2\text{-}1}$ | | $\otimes x_{2\text{-}2}$ | | $\otimes x_{2\text{-}3}$ | | $\otimes x_{2\text{-}4}$ | | $\otimes x_{3}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | max | | max | | max | | max | | min | |
| $q_j$ | 0.035 | | 0.278 | | 0.177 | | 0.11 | | 0.1 | |
| Region | $\underline{x}_{2-1}$; | $\underline{x}_{2-1}$; | $\underline{x}_{2-2}$; | $\underline{x}_{2-2}$; | $\underline{x}_{2-3}$; | $\underline{x}_{2-3}$; | $\underline{x}_{2-4}$; | $\underline{x}_{2-4}$; | $\underline{x}_{3}$; | $\underline{x}_{3}$; |
| KB | 60 | 70 | 70 | 80 | 60 | 70 | 60 | 70 | 50 | 60 |
| AB | 70 | 80 | 60 | 70 | 70 | 80 | 70 | 80 | 40 | 50 |
| TB | 70 | 80 | 50 | 60 | 60 | 70 | 70 | 80 | 50 | 60 |

**Table 10.** Normalized weighted decision making matrix $\otimes\hat{X}$

| | $\otimes x_{1\text{-}1\text{-}1}$ | | $\otimes x_{1\text{-}1\text{-}2}$ | | $\otimes x_{1\text{-}2\text{-}1}$ | | $\otimes x_{1\text{-}2\text{-}2}$ | | $\otimes x_{1\text{-}3}$ | | $\otimes x_{1\text{-}4}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Opt. | max | | min | | max | | max | | max | | max | |
| Region | $\underline{x}_{1-1-1}$; | $\overline{x}_{1-1-1}$ | $\underline{x}_{1-1-2}$; | $\underline{x}_{1-1-2}$; | $\underline{x}_{1-2-1}$; | $\underline{x}_{1-2-1}$; | $\underline{x}_{1-2-2}$; | $\underline{x}_{1-2-2}$; | $\underline{x}_{1-3}$; | $\underline{x}_{1-3}$; | $\underline{x}_{1-4}$; | $\overline{x}_{1-4}$; |
| KB | 0.007 | 0.008 | 0.018 | 0.02 | 0.006 | 0.007 | 0.028 | 0.041 | 0.006 | 0.007 | 0.024 | 0.026 |
| AB | 0.008 | 0.009 | 0.015 | 0.018 | 0.007 | 0.008 | 0.041 | 0.054 | 0.007 | 0.008 | 0.019 | 0.024 |
| TB | 0.007 | 0.008 | 0.015 | 0.018 | 0.005 | 0.006 | 0.028 | 0.041 | 0.006 | 0.007 | 0.019 | 0.024 |

**Table 10.** (continuation). Normalized weighted decision making matrix

| | $\otimes x_{2\text{-}1}$ | | $\otimes x_{2\text{-}2}$ | | $\otimes x_{2\text{-}3}$ | | $\otimes x_{2\text{-}4}$ | | $\otimes x_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| Opt. | max | | max | | max | | max | | max | |
| Region | $\underline{x}_{2-1}$; | $\overline{x}_{2-1}$; | $\underline{x}_{2-2}$; | $\overline{x}_{2-2}$; | $\underline{x}_{2-3}$; | $\overline{x}_{2-3}$; | $\underline{x}_{2-4}$; | $\overline{x}_{2-4}$; | $\underline{x}_3$; | $\overline{x}_3$; |
| KB | 0.011 | 0.013 | 0.1 | 0.114 | 0.052 | 0.061 | 0.031 | 0.036 | 0.033 | 0.039 |
| AB | 0.013 | 0.015 | 0.086 | 0.1 | 0.061 | 0.070 | 0.036 | 0.042 | 0.026 | 0.033 |
| TB | 0.013 | 0.015 | 0.08 | 0.086 | 0.052 | 0.061 | 0.036 | 0.042 | 0.033 | 0.039 |

**Table 11.** Evaluation of utility degree

| Region | $P_i$ | $R_i$ | $Q_i$ | $N_i$ |
|---|---|---|---|---|
| KB | 0.2661 | 0.0773 | 0.5997 | 100.00% |
| AB | 0.2629 | 0.083 | 0.5736 | 95.64% |
| TB | 0.2440 | 0.076 | 0.5832 | 97.42% |

According to results of Table 11, Khazar Boulevard is in the first priority for the construction of footbridge, after that is Taleghani Boulevard and finally Artesh Boulevard is the last in prioritizing.

### 4.4. Decision-making

Each municipality has limited budget and needs to make the best decisions for doing their projects. The defined project was area selection and the problem was to select one of the areas based on quantitative and qualitative criteria. The aim of this study was the use of MADM tools for solving this problem of the municipality projects in Sari.

According to the AHP and COPRAS-G computations, it is decided to select KB. For reaching more accurate analyzing, project team used conference meeting and consistency ratio in AHP calculations. The use of grey analysis helped the project team to deal with the uncertain and insufficient information and to build a relational analysis or to construct a model to characterize the system.

## 5. Conclusions and future research

In this paper, a decision approach is provided for prioritizing projects particularly of constructing new footbridges. Municipality projects are important for every city and best decisions must be made on it. Budgets of each municipality are confined and the needs are wide. Appropriate prioritizing is very important and influences the time of finishing project or the quality of carrying it out. This selection problem is based on the comparisons of area criteria and evaluations of the alternatives, according to identified criteria. An integrated AHP and COPRAS-G methods have been used in proposed approach. AHP is used to assign weights to the criteria to be used in area selection, while COPRAS-G is employed to determine the ranking of the alternatives.

The weights obtained from AHP are included in decision making process by using them in COPRAS-G computations and the alternative priorities are determined based on these weights. The proposed model has only been implemented on an area selection for constructing new footbridges in the municipality project in Sari; however, the project team has found the proposed model satisfactory and implementable in others bridge selection decisions. Also, this approach could be used in any other kind of prioritizing constructing projects of municipalities. Besides, this approach can be used for prioritizing other municipality projects such as roads, bridges, highways.

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