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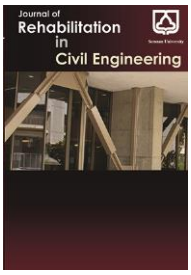

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An Improvement to Pedestrian's Mobility by rehabilitating the Sidewalk with Application of AHP (Case Study)

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ABSTRACT

This study investigated the effects of rehabilitation of sidewalks on improvement of the pedestrians' mobility. In order to successfully achieve this, sidewalk characteristics were determined via previous studies, expert elicitation and field studies and seven parameters which are available in Tehran's sidewalks were chosen. These seven parameters were "Side trees of sidewalks", "Width of sidewalks", "Type of sidewalks", "Side buildings of sidewalks", "Lighting of sidewalks", "Side facilities of sidewalks" and "Sidewalks' pavement conditions". Next, four pedestrians sidewalk were randomly chosen. Using AHP method and Collected questionnaires the four sidewalks were prioritized. Sensitivity analysis was applied to find the effects of each of the seven parameters. Considering the results, the effective parameters of each sidewalk were respectively rehabilitated by Photoshop CS3 software and the process of prioritizing was repeated. According to the obtained results, it is not necessary to improve all parameters of a sidewalk to achieve a suitable and attractive sidewalk. An attractive sidewalk will be able to achieve only by improving some certain parameters of sidewalks. The procedure used in this study will lead to save money and time in urban designs and city developments.

1. Introduction

Walking is an unavoidable activity people do in their daily lives. It increases public health and makes the city environment more active and fresh [1, 2]. Since walking is capable of enhancing social, economic, and cultural conditions in a society, a large deal of efforts have been recently made to improve public places, particularly

sidewalks [3, 4]. A suitable sidewalks can make a city more dynamic and safe; however, little attempts previously made to evaluate the conditions of sidewalks. This study intends to investigate the effects of rehabilitation of sidewalks on enhancement of the pedestrians' mobility.

2. Literature Review

The connection between the city's design and pedestrians' movement has been evaluated from numerous perspectives[5, 6]. Some studies assessed the role of improvement of the facilities in sidewalks on pedestrians' satisfaction [7-9]. Wells et al [10] indicated that enhanced sidewalks raised people's eagerness to move in. Many studies have been conducted to find the factors influencing pedestrians presence in sidewalks [11-13]. Some of the factors used in previous studies were summarized in Table 1.

Table 1. Factors influencing pedestrian movement in sidewalks

Researcher	Year	Investigated Factors	Comment
Schroeder and Cannon [14]	1987	Flower presence, beautiful green spaces, and residential areas near sidewalks	Concentration was on aesthetics and appearance components of sidewalks
Sarkar [15]	2003	Aesthetics, environmental, and psychological parameters	Theoretical manuals for qualitatively investigating pedestrians' comfort were presented
Pamanikabud and Pichittanapanya [16]	2003	Qualitative and quantitative indicators	Two different topics including physical characteristics such as width and environmental characteristics such as noise pollution were discussed
Nursyamsu and et al [17]	2011	Qualitative parameters which can be felt by pedestrians	Qualitative indicators have to be considered besides customary indicators such as velocity, volume, and capacity
Stradling and et al [18]	2007	Sidewalk's congestion, air quality, trees, flowers, beggars, and pavement	Critical parameters in sidewalks affects pedestrian walking were investigated
Moreno and Fernandes [19]	2011	Buildings, moving path designs, and weather conditions, advertisement spaces, schools, and existing facilities	A 100% increases in population density increases individuals' activity by 22.7% toll 37.1%.
Kim and Yamashita [20]	2011	Cleanness, beautification, environmental conditions, benches, sunshades, pavement, continuity, lack of irritating factors like smell, beggars, and vendors	Sidewalk's environment quality have important roles in attracting or rejecting pedestrians.

Statistical approaches and tests such as linear and nonlinear regression analysis were employed to analyze data in some studies [20]. Lacking flexibility in these approaches causes to make pre-estimated models so they are not able to produce comprehensive methods. These kinds of deficiencies lead to use multi-criteria decision making approaches in recent studies [21]. From the different approaches

in this area Analytical Hierarchy Process (AHP) is chosen. This approach facilitates the decision-making procedure through arranging feelings, perception, predictions, and judgments. AHP was selected as it permits inclusion of respondent thought, opinions and behaviors within an analytical environment; furthermore, it allows for the quantification of interactions between myriad criteria in varying, structured and unstructured situations.

3. Methodology

The entire process of this study was illustrated in Figure 1. All potential affecting pedestrians' satisfaction pertaining to sidewalk usage were considered via previous research [16-23], field studies and author observations during the field study phase. Subsequently, significant local factors, considered particularly significant with respect to Tehran, were selected for in-depth examination. Selection was based upon the following:

1. Expert opinion: Transportation Engineering professors, Urban Design professors and Psychology professors from universities in Tehran were consulted.

2. Previous domestic studies: Previous studies have examined various sidewalk characteristics in Iran [11-13].
3. Author experience: Authors of the current study were familiar with Tehran's sidewalks conditions, having previously conducted studies on urban design, sidewalks and pedestrians in Iran[2, 24].

A 35-milimeter digital camera including a 50-milimeter lens was used to capture photos. Moreover, some photography methods which considered pictures' color and light distortion, lightning conditions, and apparent characteristics has been applied to select captured photos [25].

Considering the selected parameters and photos, a set of presentation slides and questionnaire forms were established and matched. Using the set and asking participants, the importance of each parameter was achieved. Next, four photos of four different sidewalks were randomly chosen. With regard to the achieved importance for each of the seven parameters, and using multi-criteria decision making approaches, AHP method, these four sidewalks were ranked. Then, sensitivity analysis was done on each sidewalk, determining the effect of parameters on sidewalks ranking.

Finally, considering the results of sensitivity analysis, the most important parameter of each sidewalk was rehabilitated by Photoshop CS3 software. Then the process of ranking mentioned above was repeated. In the next step, second important parameters, achieved from sensitivity analysis, was rehabilitated and ranking was done. This procedure was repeated for all of the rest parameters.

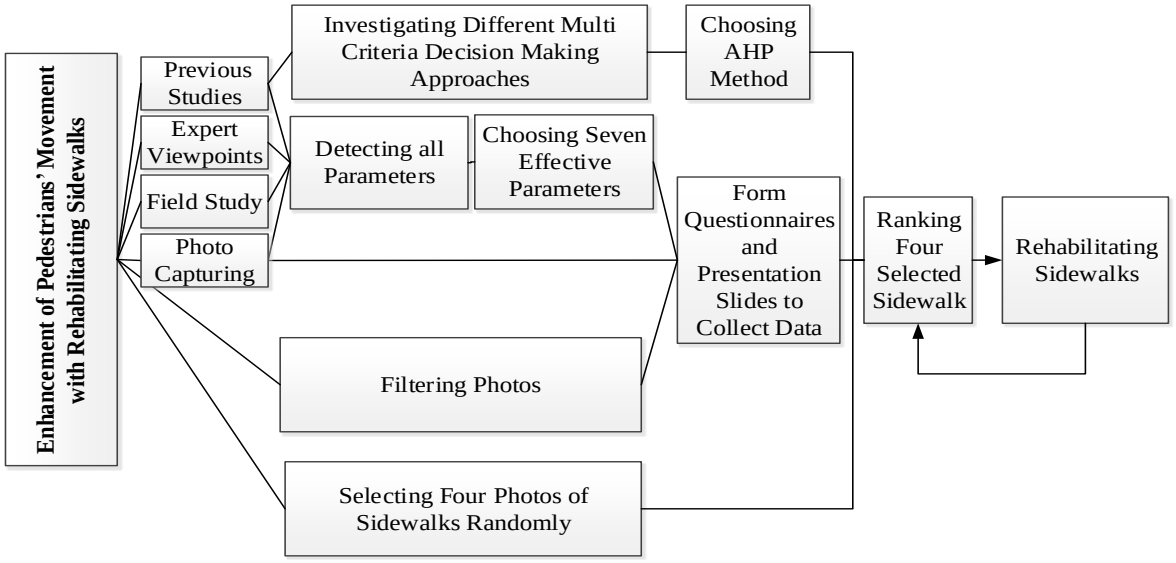

Fig. 1. Flow chart of the process of research work

4. Questionnaire and Data Collection

Considering previous studies [16-23], experts' viewpoints, and field studies the important parameters leading to the pedestrians attraction to sidewalks were determined, then of those, seven parameters applicable to Iran, and specifically Tehran, capital of Iran, are chosen. These seven parameters were "Side trees of sidewalks", "Width of sidewalks", "Type of sidewalks", "Side buildings of sidewalks", "Lighting of sidewalks", "Side facilities of sidewalks", "Sidewalks' pavement conditions". Subcategories of these parameters were ` shown in Table 2.

Table 2. Subcategories of sidewalks parameters

parameters	Abbr	Subcategories
Side Trees	ST	Both sides, Only one side, The middle of the sidewalk, None
Width	WS	Narrow, Medium, Big, Wide
Type	TS	Straight Way, Oblique Way, Stairway in Width, Stairway in Length
Side Buildings	SB	Residential, Commercial, Official, None
Lighting	LS	Quite Light, Semi Light, Semi Dark, Quite Dark
Side Facilities	SF	advertising commercial and banners, charity funds and trash buckets, facilities such as chairs, None
Pavement Conditions	SP	12 different types of pavements

Study data were collated via the concurrent use of a developed pedestrian questionnaire and captured sidewalk images. Prior to the initiation of the questionnaire, respondents were supplied with a general overview of the study, in addition to detailed instructions pertaining to appropriate completion of the

questionnaire. Participants were asked to objectively complete the questionnaire i.e. provide thoughts and opinions in the absence of any prior knowledge or experience of the sidewalks under investigation. The questionnaire was completed on the basis of presented slides. In order to investigate the parameters, in each slide, 4 pictures representing each of the subcategories in Table 2 were put, and the participants were asked to put the slides in order from 1 to 4 (in order to investigate sidewalk's pavement conditions, 12 pictures were put in a slide and the participants were asked to put 6 pictures of them in order from 1 to 6). Not only was the survey done on the presented slides, the participants, also, were asked to put a number between 1-10 to each of the parameters in order to investigate their importance.

Initially 83 participants were asked to fill the questionnaires. Of these participants 56 ones were finally succeeded in completing all steps of the study. These steps were to find importance of parameters and seven times of rehabilitation. Considering mentioned procedure, totally 448 filled questionnaires were obtained.

5. Analyzing the data and results

5.1. Ranking sidewalks

The obtained data of the questionnaires along with multi-criterion decision making approaches were applied to extract the weights of each parameter and rank four understudied sidewalks.

In this study, the AHP method was chosen amongst other kinds of multi-criterion decision making approaches. The reason of this selection was that it makes the decision-maker able to present the interaction between different criteria in different and non-structural situations [26, 27]. In Fig. 2, the hierarchy structure in the presence of the related sub criteria of the physical and mental characteristics are presented.

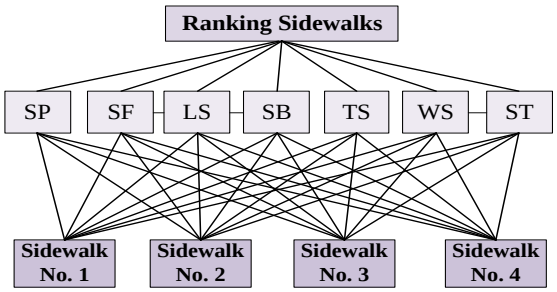

Fig. 2. The structure of AHP

The first stage in analyzing data using the AHP method is to form the pair-wise comparisons matrix. A pair-wise comparisons matrix is shown as follows:

$$A = \begin{bmatrix} a_{11}a_{12} & \dots & a_{1n} \\ a_{21}a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots \\ a_{n1}a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (1)$$

Where a_{ij} is the preference of element i to element j.

In Table 3, the pared comparison of the seven parameters are investigated. In the AHP method, the sum of the scores related to each alternative is calculated using the following equation:

$$A_{AHP_{Score}} = \sum_{j=1}^{n} a_{ij} \times W_j \; (i = 1, 2, \dots, m) \quad (2)$$

Where a_{ij} shows the relative importance of choice i related to the criterion Cj, and Wj shows the weight of criterion Cj.

A samples of paired comparison alternatives are presented in Tables 4.

Using the calculated weight vectors from the pair-wise comparisons matrix of the criteria and the pair-wise comparisons matrix of the alternatives, the score of each sidewalk is calculated as it is shown in Table 5.

Table 3. Pair-wise comparisons matrix the seven parameters in sidewalks

	ST	WS	TS	SB	LS	SF	SP	Importance
ST	1.000	1.383	1.284	1.374	1.254	1.309	1.158	0.175
WS	0.747	1.000	0.981	1.039	0.911	0.997	0.878	0.131
TS	0.791	1.119	1.000	1.078	1.010	1.022	0.907	0.138
SB	0.731	1.023	0.931	1.000	0.925	0.950	0.842	0.128
LS	0.816	1.098	1.068	1.133	1.000	1.085	0.956	0.143
SF	0.772	1.088	0.979	1.054	0.983	1.000	0.887	0.135
SP	0.869	1.219	1.105	1.188	1.102	1.128	1.000	0.152

Table 4. paired comparison of alternatives from the side trees point of view

Sidewalk	No. 1	No. 2	No. 3	No. 4	Importance
No. 1	1.000	1.676	1.275	1.776	0.336
No. 2	0.615	1.000	0.796	1.114	0.207
No. 3	0.790	1.344	1.000	1.389	0.265
No. 4	0.570	0.975	0.720	1.000	0.192

Table 5. score of each of the sidewalks

Type of Sidewalk	Score
Sidewalk No. 1	0.371
Sidewalk No. 2	0.199
Sidewalk No. 3	0.266
Sidewalk No. 4	0.164

5.2. Sensitivity Analysis

In order to find the effects of the parameters on attracting pedestrian to sidewalks, the sensitivity analysis was carried out on parameters of each sidewalk. The obtained results led to find the sequence of rehabilitation steps.

Figure 3 shows the results of the sensitivity analyses for the parameters in Sidewalk No. 2. As it could be extracted from this diagram, planting trees is the fastest approach to increase people's movement in this sidewalk. The rank of parameters derived from sensitivity analysis for each of four sidewalks was shown in Table 6.

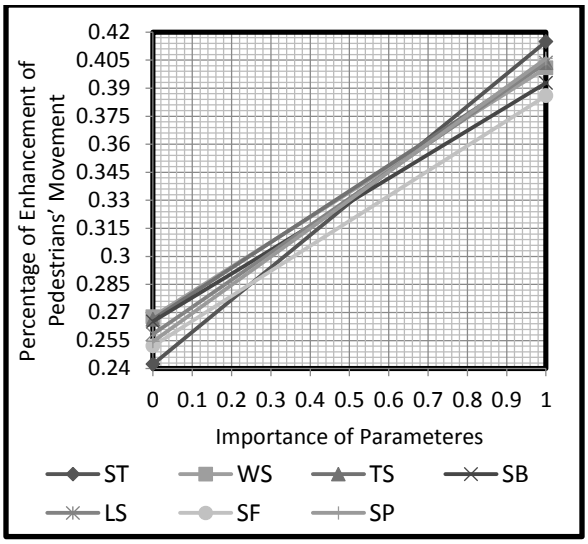

Fig. 3. Results of the sensitivity analysis of the parameters in sidewalk No. 2

Table 6. Ranking parameters of sidewalks related to sensitivity analysis

Sidewalk No. 1	Sidewalk No. 2	Sidewalk No. 3	Sidewalk No. 4
ST	ST	SF	WS
SF	WS	SB	ST
SP	SF	WS	TS
LS	TS	TS	SB
SB	LS	LS	SP
TS	SP	SP	SF
WS	SB	ST	LS

5.3. Rehabilitation Result

With regard to the Table 6, the parameter of each sidewalk which has the fastest effect on the enhancement of pedestrians' movements was chosen. Then, the chosen parameter for each sidewalk was rehabilitated using Adobe Photoshop CS3 software. Rehabilitation of parameter of "TS" on sidewalk No. 3 was shown in Figure 4.

a. Before Rehabilitation

b. After Rehabilitation

Fig. 4. Rehabilitation of parameter of "TS" on sidewalk No. 3

The procedure introduced in the section 4-1 was employed to find scores of each rehabilitated sidewalk. The results of first rehabilitation of sidewalks were shown in Table 7.

Table 7. The results of first rehabilitation

Sidewalk	No. 1	No. 2	No. 3	No. 4
Rehabilitated parameter	ST	SB	SF	WS
Score before rehabilitation	0.371	0.199	0.266	0.164
Score after rehabilitation	0.332	0.231	0.219	0.208

The aforementioned rehabilitation procedure was done for each parameter on each sidewalk. The results of which were shown in Figure 5.

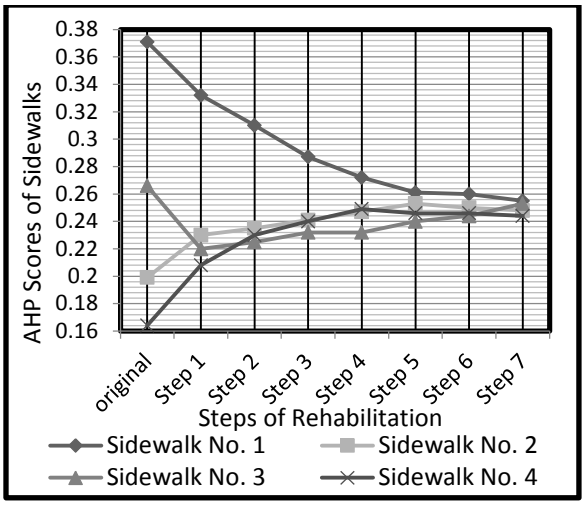

Fig. 5. The results of Rehabilitation procedures on each sidewalk

6. Discussion

The overall objective of this study was to enhance the pedestrians' mobility with rehabilitating Tehran's sidewalks. To do this, firstly, the seven important parameters, which encourage the pedestrians to walk in sidewalks, were detected. Then, of all captured pictures, 4 photos of 4 different sidewalks were randomly selected. The priority of the sidewalks was set considering the results obtained from questionnaires and AHP method. Next, in order to find the effect of each parameter on attraction of each sidewalk, sensitivity analysis was done. Finally, regarding the order of parameters of each sidewalk obtained from sensitivity analysis, seven steps of rehabilitations using Adobe Photoshop CS3 software were carried out.

With regard to the obtained results of sensitivity analysis, the winning parameter affecting enhancement of movements in sidewalks is not always the same as in all sidewalks. Therefore, the rehabilitation of a certain parameter is not capable of improving the sidewalks' movements in all sidewalks equally.

The results of the rehabilitation section showed that at first there is a sharp difference among the sidewalks attractions; however, after doing three rehabilitations this difference considerably reduced. For instance, the scores of the sidewalks No. 1 and No. 4 in original step were 0.37 and 0.16 respectively; while, their scores in the third step of rehabilitation merged together and got 0.28 and 0.24. This means that the attraction of these two sidewalks got relatively similar to each other after three steps of rehabilitations. The reason of differences in sidewalk's scores in different steps of rehabilitation was the relativity of scoring in AHP method. For example, the score of the sidewalk No. 1 reduced in process of rehabilitation indicated the improvements of other sidewalks attractions and not the getting worse of the sidewalk No. 1 situation.

The procedure of this study showed that to enhance the pedestrians' movement in sidewalks was not necessary to fully rehabilitate a sidewalks conditions and some certain improvement led to increase the attraction of the sidewalk. For example, rehabilitate three parameters of sidewalk No. 4 (width of sidewalk, side trees, and type of sidewalks) brought about a considerable enhancement of the sidewalk's movement conditions. The main advantage of this study is to minimize the cost and time of enhancement of sidewalks' movements, its practicality, and the possibility of investigating the effects of different parameters on attraction of sidewalks without any real change. Considering the entire process of this study accompanied by existing regulations can provide urban designers with suitable guidelines to enhance the pedestrians' movement in sidewalks.

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