THE DEVELOPMENT AND ASSESSMENT OF ENVIRONMENTAL FEATURES ASSOCIATED WITH WALKABILITY OF URBAN STREETS

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Abstract
It is now crucial for cities to prioritize pedestrians in their plans to recognize the benefits of walking and physical activities. Given that, understanding the relationship between the urban environment features and walking is the ongoing issue in most transportation and urban studies. This study was an attempt to investigate the development of features affecting walking in urban environments in accordance with transportation and related studies. The issue was investigated using a framework with three urban scales: Cities, blocks, and streets. Since in this investigation the focus was on the urban streets, the features had been chosen on this scale for further assessments, including function, safety, and aesthetic aspects. To evaluate the relative importance of these features and their associated factors, 100 questioners were filled by urban science experts. Structural equation modeling (SEM) technique was chosen for assessing the results. The results showed that the safety feature has the utmost importance among all and it should be considered in the design of streets.
Keywords: pedestrian, walkability, urban environment, SEM.

1. INTRODUCTION

While there are so many benefits in choosing to walk in comparison to other modes of transportation, some issues are hotly discussed regarding how we can promote walking in today communities (Carlson et al., 2012; Clifton et al., 2007; Foster and Giles-Corti, 2008; Frank et al., 2010). Walking is an effective strategy to prevent many chronic diseases and their medical expenses (Van Cauwenberg et al., 2011). Based on the statistics released by World Health Organization (2016), inadequate physical inactivity has

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caused an estimated 3.2 million deaths globally. Moreover, it has been known as the fourth leading risk factor for global mortality. Interventions in cities which can increase physical activities can consequently enhance public health which is, in its own place, an essential thing (Foster and Giles-Corti, 2008).

Walking is the most common form of physical activities (U.S. Department of Health and Human Services, 1996). The most common places for this activity are streets and open spaces. That said, the features of those places would affect walking (Foster and Giles-Corti, 2008). Different studies claim that there are complex connections between build environment elements and walking in cities (Brown et al., 2007; Carlson et al., 2012; Clifton et al., 2007; Ewing and Clemente, 2013; Van Cauwenberg et al., 2011). These connections have been mainly the interest of professionals in the field of urban planning, and particularly in the fields of urban design and transportation planning. The theoretical, empirical, and practical works in these fields have generally aimed at enhancing the quality of life, improving system efficiency, or reducing environmental impacts—in other words, the physical health of the community rather than the personal health of its residents (Handy et al., 2002).

The current study had two main objectives: first, recognizing the environmental factors associated with walkability of urban streets. The previously conducted studies in this realm have considered some aspects of this issue. Consequently, they introduced distinct related variables. Unifying these variables and considering various aspects of walkability were among the main aims of this study. The second objective of this study was to evaluate the mentioned factors to find out how much they can affect walking in urban spaces when the professional viewpoint is the focus of investigation.

The present study went through all of the mentioned objectives. Firstly, the related literature had been reviewed to find out a comprehensive list of walkability features. Subsequently, a method for evaluating these features in the scale of a street was presented. Finally, the results of this technique were discussed. It is worth mentioning that similar research studies identified relative features of walkability; however, this study aimed at enhancing inclusive viewpoints based on the Iranian urban forms, presenting a comprehensive list of environmental features, and evaluating them based on the reliable methods.

2. LITERATURE REVIEW

Planning professionals aspire to develop a normative definition of a “walkable” environment (Clifton et al., 2007). What is “walkability”? This quality had been widely referred to, but it was not defined well (Southworth, 2005). In all related studies, it is important to connect the built environment and walking to represent a good and poor walkability in that one can understand which elements contribute to walking. These studies had been developed in a wide variety of disciplines, from transportation, planning, and design, to health incomes. Therefore, they had considered these environmental elements at different scales, such as the city or neighbourhood scale (Adkins et al., 2012; Brownson et al., 2009; Ewing et al., 2006; Ewing and Cervero, 2010; Lawrence et al., 2005; Saelens et al., 2003; Singh, 2016).

A large number of studies had considered methods which needed readily available and comparable data across many locations through secondary sources, such as the Census Bureau. In these methods, large scale measures such as population or employment density, land use mix, were usually calculated by residential to employment ratios. Furthermore, street network connectivity was estimated by using geographic information systems (GIS) or other similar methods (Carr et al., 2011; Clifton et al., 2007; Neckerman et al., 2009; Owen et al., 2007). Although these kinds of measures can have efficient results on urban managing, they do not have considered the pedestrian actual condition in urban spaces. In some other studies, both neighbourhood scale and regional scale had been considered. Handy, et al., (2002) suggested that there are at least five interrelated and often correlated dimensions of the built environment at the neighbourhood scale. They include density and intensity of development, mixed land uses, connectivity of the street network, scale of streets, and aesthetic qualities of a place (Handy et al., 2002).

When examining walkability studies, apart from the scale conception, efforts have been made to classify associated elements. In a study by Pikora, et al. (2003), the environmental features had been classified into four major groups: functional, safety, aesthetic, and destination. The functional features are related to the physical attributes of the street. The safety features reflect the need to provide the safe physical environments. The elements making physical environment interesting and pleasing are in the aesthetic group and destination features are related to the availability of community and commercial facilities in neighbourhoods (Pikora, et al., 2003).

Moudon and Lee (2003) presented a behavioural model for categorizing environmental elements. Applied to walking and bicycling, this behavioural model consisted three components of the environment: The origin and destination of the walk or bike trip, the characteristics of the route taken for these trips, the characteristics of the area within which the trip takes place (Moudon and Lee, 2003). Another model offered by Frank, Engelke, and Schmid (2003) utilized three broad categories- transportation systems, land use patterns, and urban design characteristics- aiming to provide coherent elements to the built environment (Frank, Engelke, and Schmid, 2003).

In a review done by Ramirez, et al. (2006), 230 potential indicators were identified in four community-level categories: Political and economic indicators, physical environment indicators, sociocultural environment indicators, and institutional and organizational indicators (Brennanramirez et al., 2006). In

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another study conducted by Day, et al. (2006), some other factors were nominated which might influence physical activity. The factors include the following characteristics of the built environment: Accessibility, pleasurability, the perceived safety from traffic, and the perceived safety from crime (Day, Boarnet, Alfonzo, and Forsyth, 2006).

TABLE 1 - CLASSIFICATION OF THE ENVIRONMENTAL FEATURES ASSOCIATED WITH WALKABILITY

Scale of function	Area of function	Feature	Indicator	Measurement method	Measuring aspect	Data source
Macro	City	Density	Population density	Census	Quantity	Census
			Household density	GIS	Quantity	Urban plans
		Land use diversity	Mean Entropy Index	GIS	Quantity	GIS
			Percentage of non-residential buildings	GIS	Quantity	GIS
		Continuity of street network	Intersection count or density	GIS	Quantity	GIS
			Street classification	GIS	Quantity	GIS
			Continuity of pedestrian path	GIS	Quantity	GIS
			Connectivity Index	GIS	Quantity	GIS
		Security	Crime rate	GIS	Quantity	Census
			Employment Density	GIS	Quantity	Census
			Equipment density	GIS	Quantity	Census
Macro-micro	Block	Proximity and accessibility	Average distance between destinations	GIS	Quantity	GIS
			Destination diversity	GIS	Quantity	GIS
			Destination count	GIS	Quantity	GIS
		Urban form	Block size	GIS	Quantity	GIS
			Average parcel size	GIS	Quantity	GIS
			Segments counts per street	GIS	Quantity	GIS
		Street pattern	Travel model	Computer software	Quantity	Traffic agency data
			Movement pattern	Computer software	Quantity	Traffic agency data
			Street type and design	Computer software	Quantity	Traffic agency data
		Diversity	Building age	Walkability audit	Quantity	Urban plans
			Building density	Walkability audit	Quantity	Urban plans
			Streetscapes	Walkability audit	Quality	Field data
			Building usage	Walkability audit	Quantity	Field data
Micro	Street	Function	Mixed land use	Computer software	Quantity	Urban plans
			Traffic role	Walkability audit	Quantity	Traffic agency data
			Accessibility	Computer software	Quantity	GIS
		Safety	Security	Walkability audit	Quantity/ Quality	Field data
			Traffic safety	Walkability audit	Quantity/ Quality	Field data
		Aesthetic	Public art	Walkability audit	Quality	Field data
			Building architecture	Walkability audit	Quality	Field data
			Street design	Walkability audit	Quantity/ Quality	Field data

			Landscape	Walkability audit	Quality	Field data

Later on, Van Dyck, et al., (2012) conducted a study in which neighbourhood scale elements associated with walkability were categorized as follow: Residential density, land use mix diversity, street connectivity, walking and cycling facilities, aesthetics, traffic safety, and crime safety. More recently, Sugiyama, et al., (2014) pointed out some other environmental attributes such as perceived residential density, land use mix, street connectivity, aesthetics, safety from crime, and proximity which affect adults recreational walking.

Table 1 depicts the classification category of environmental features associated with walkability; scrutinized in related literature. This classification has been divided into two major distinctions; including macro and micro scales and secondary scale of city, community, and street. Next, the features and indicators of walkability and measuring method of every indicator are presented. Measurement methods consist census tract, Geographic Information System, desktop appliances and walkability audits. In addition, measuring aspect which can be quantitative or qualitative is defined for indicators. The quantity of walking may be more related to how often the walking activity takes place and the quality of the walking activity, determining how convenient, pleasant, interesting, and safe it becomes.

2.1. Urban Street Design Based on Walkability Indices

Walkability features in street scale can be classified into three categories: function, safety, aesthetic. The first category consists the functional features which can be categorized in three groups: Mixed land use, traffic role, and accessibility. Although these factors can be measured on a larger scale, their importance on street scale cannot be ignored. The mixed land use which has a great impact on walkability and bike-ability of streets is defined as the relative proximity of different land uses within a given area. A mixed-use neighbourhood would include not only homes but also stores, offices, parks, and perhaps the other land uses (Handy et al., 2002). Fine-grained and varied land use patterns refer to accessible patterns of public services, activities and daily needs accessible on foot (Southworth, 2005).

Traffic role of a street, referred as street standards, measures the shapes of pedestrian and automobile paths-such as width, slope, general condition, facilities, and etc. Accessibility is another important factor in creating a walkable place. Accessibility is all about the fact that people should be able to access businesses and activities along the street easily (Jacobs and Recorded Books, 2016). On top of this, having safe walking is an important determinant in choosing walking over other modes of transportation. Safety of pedestrian can be reviewed in two categories: safety from traffic and safety from crime (Foster and Giles-Corti, 2008). Feeling safe in a neighbourhood is associated with its physical and social characteristics (Gauvin et al., 2005). when street level is at focus, designing elements that provide

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safety from traffic are important components of a walkable environment (Jacobs and Recorded Books, 2016). The aesthetic features are examined through four categories of public art, building architecture, street design, and landscape.

In this research, these factors were considered as urban design qualities due to their importance in assessing urban environments. In a study by Ewing and Clemente (2013), urban design qualities related to walkability were reviewed and assessed. They found 51 qualities based on the literature review in this field. From these 51 qualities, eight qualities had more association with walkability: Image-ability, enclosure, human scale, transparency, complexity, coherence, legibility, and linkage. From these eight, the first five were successfully measured in that the validity and reliability of them were assured.

3. METHOD AND MATERIALS

In the current study, a questionnaire was used to obtain the experts' opinion about the weight of walkability features. In so doing, 100 experts in urban planning profession were asked to rank different features related to the walkability of environments. Moreover, they were asked to choose which of the features were more important from their perspective. For analysing data, structural equation modelling (SEM) method was used. SEM is a very general statistical modelling method, which is widely used in the behavioural sciences. SEM uses different types of models to envision relationships among observed variables by testing theoretical model hypothesized by a researcher (Schumacker, et al., 2004).

It is now obvious that due to its generality and flexibility SEM is used among different disciplines. A large number of statistical models can be done through SEM. These model are used to assess and evaluate the validity of substantive theories. Moreover, SEM can be used with regard to experimental and non-experimental data (Lei and Wu, 2007). Particularly, research questions with SEM method can be answered in a single, systematic and comprehensive analysis by modelling the relationships among multiple independent and dependent constructs (the structural model) simultaneously (Hair, 2010).

There are two main approaches for SEM which the researchers can select each of them based on their research purposes since each approach has its own specific assumptions and aims. The two approaches are covariance base analysis (CB-SEM) and a variance based analysis, known as partial least squares (PLS-SEM). Particularly PLS-SEM is attractive when the research objective concentrates on the prediction and explanation of the variance of key target constructs by various explanatory constructs; the sample size is comparatively small and/or the available data is non-normal. In addition, when assessing explanatory constructs, the formatively measured constructs should be used. For the same reason, PLS-SEM has been chosen for analysing the obtained data (Hair, et al., 2012).

3.1. Formative-reflective Model of Walkability Measures

To assess the latent constructs, two kinds of measurement models might be applied. The first model which is called reflective measurement model is based on the theory which defines measures as the effects of an underlying latent construct. Therefore, causality is due to the construct to the measures. The second form of specification is called the formative measurement model. In this model, the indicators determine the latent variable which receives its meaning from the former variable. Formative indicators have no individual measurement error terms. It is worth mentioning that according to Diamantopoulos et al. (2008) they are presumed to be error-free.

Based on the above discussion, the walkability model can be introduced as a multiple formative-reflective model. Latent variables in this model are related to the main construct in two steps. The first aspect is walkability and the second one is the functional, safety, and aesthetic aspects. This step is considered as a formative model since walkability does not have independent nature and it has been made from the other indicators. Hence, the direction of arrows is from triple variables to the walkability variable as they define it. In general, in these kinds of models, the main variable which is walkability should be defined by specific indicator apart from indicators of secondary variables. In this case, the walkability has been defined by indicators consists data which is directly obtained from respondent opinions about triples variables efficacy on the overall walkability of environments.

The second constructs which include relations between the indicators and secondary variables (functional, safety, and aesthetic aspects) are considered as reflective models because they have independent natures from their indicators and whenever they change, the change in indicators is inevitable. Moreover, all indicators have the same background. The relationship between the functional aspect and the other two aspects was considered in the study based on the first examination of data and correlation among them. Furthermore, in the first examination, the results show that scores on of sub-criteria questions cannot be used directly in the model in conjunction with scores of main criteria questions because of being in different levels. Consequently, the average scores of questions about sub-criteria was calculated and used in the model. Indicators in the safety model comprised direct data obtained from safety and crime questions and average scores of its sub-criteria questions. Besides, it contained the direct data obtained from safety and traffic questions and average scores of its sub-criteria questions. In the function construct, indicators comprised direct data obtained from questions about the relationship between mixed land use, traffic role, and accessibility, overall walkability, and average scores of their sub-criteria questions. As is clear, aesthetic constructs indicators included data

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achieved from questions about direct relations of every five presumed qualities with walkability of urban streets and average scores of their sub criteria questions. List of indicators is presented in Table 2.

TABLE 2 - INDICATORS IN CONSTRUCTS

Safety		Function		Aesthetic	
SC	Safety from crime	FA	Accessibility	AC	Complexity
SCA	SC sub criteria average scores	FAA	Accessibility sub criteria average scores	ACA	Complexity sub criteria average scores
ST	Safety from traffic	FL	Mixed land use	AE	Enclosure
STA	ST average s sub criteria average scores	FLA	Mixed land use sub criteria average scores	AEA	Enclosure sub criteria average scores
		FT	Traffic role	AI	Image-ability
		FTA	Traffic role sub criteria average scores	AIA	Image-ability sub criteria average scores
				AS	Human scale
				ASA	Human scale sub criteria average scores
				AT	Transparency
				ATA	Transparency sub criteria average scores

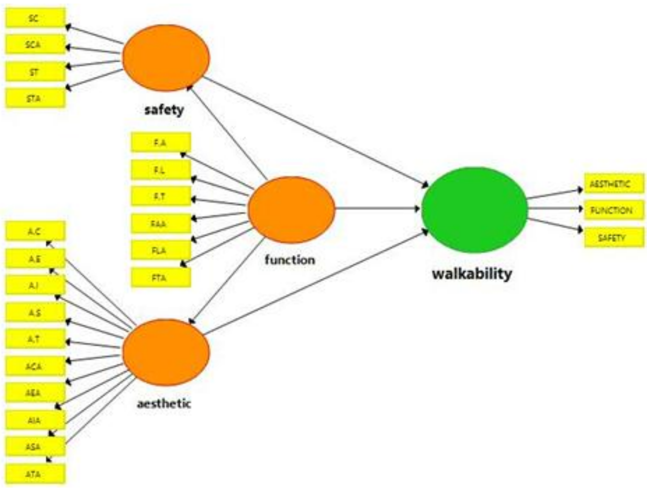

FIGURE 1 - THE REFLECTIVE-FORMATIVE MODEL OF WALKABILITY

4. DATA ANALYSIS

To assess the walkability model and determine the correlation among the latent variables based on PLS-SEM method, SmartPLS application was used. This application is able to design the structural model based on the sample data (Ringle, et al., 2015). PLS Path Modelling was to the relationships among Q blocks of variables, which were the expression of unobservable constructs. Essentially, PLS is made of a system of interdependent equations based on simple and multiple regressions. One can obtain the network of relations which exists among latent variables using this system. On top of this, Vinzi et al. (2010) states that the relations existing between the manifest variables and their latent variables can be achieved through using this system.

Numbers will be shown on the path between constructs to show the relations. These numbers indicate the standard beta in regression or correlation coefficient between latent variables. The measurement (outer) weights connecting the latent variables to their indicator variables are estimated differently, depending on whether the model is reflective or formative. On the one hand, whenever a reflective model is used, in which the arrows are from the latent variable to the indicator variables, the measurement path weights are based on the covariance between the estimate of the latent variable and the indicator variable. On the other hand, If the model is formative, in which the arrows are from the indicators to the latent variable, the measurement path weights are based on regression of the latent variable on its indicator (Ringle, et al., 2015).

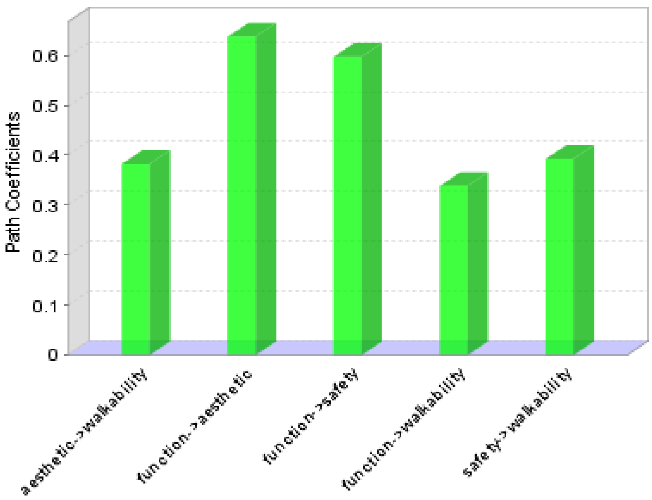

FIGURE 2 - PATH COEFFICIENT CHART

The path coefficient in walkability model is shown in Table 2. As it can be seen, walkability can be greatly defined by its variables; consequently, the model can appropriately describe the research construct. Since the sum of coefficients in the formative model is one, functional aspect weight is 0.339, safety aspect weight is 0.393 and aesthetic aspect weight is 0.383.

TABLE 3 - THE PATH COEFFICIENT OF CONSTRUCTS

	Aesthetic	Function	Safety	Walkability
Aesthetic				0.383
Function	0.638		0.597	0.339
Safety				0.393
Walkability				

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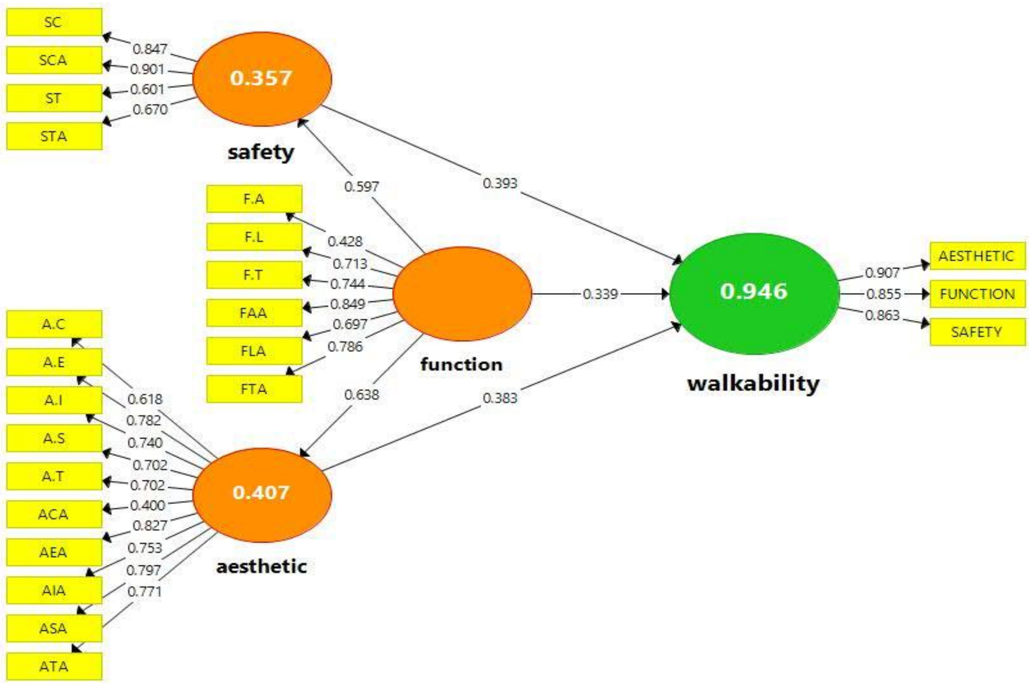

FIGURE 3 - WALKABILITY MODEL

5. DISCUSSIONS

The reliability and validity of the model was taken into account based on SmartPLS software. This software provided different tests and their results have been represented in Table 3. First, Cronbach's alpha was calculated. By convention, the following cut-offs applied: Greater or equal to 0.8 for a good scale, 0.7 for an acceptable scale, and 0.6 for a normal scale for exploratory purposes. In a reflective model one can prefer Composite reliability over Cronbach's alpha (see below). In an adequate model for exploratory purposes, composite reliabilities should normally be equal to or larger than 0.6, equal to or larger than 0.7 for an adequate model for confirmatory purposes, and equal to or greater than 0.8 is considered well for confirmatory research (Ringle, et al., 2015). AVE may be used as a test of both convergent and divergent validities. AVE reflects the average communality for each latent factor in a reflective model. In an adequate model, AVE should be greater than 0.5 (Fornell and Larcker, 1981).

In walkability model, Cronbach's alpha for all variables is larger than 0.75, which shows that they are at an acceptable scale. Composite reliability scores for variables are more than 0.8, which shows that they are adequate for confirmatory purposes. AVE is more than 0.5 for all variables; and therefore, they explain at least half of the variance of their indicators; and for walkability variable, this number is 0.74, which shows that indicators explain the variance very well.

TABLE 4 - THE RELIABILITY INDICES

	Cronbach's Alpha	Composite Reliability	AVE
Aesthetic	0.891	0.912	0.517
Function	0.797	0.859	0.512
Safety	0.754	0.846	0.585
Walkability	0.847	0.907	0.766

The research hypothesis model that was based on literature review and experts' viewpoint about environment feature associated with walkability has been confirmed by the represented SEM method. Moreover, the relationships among walkability indices and function, safety, aesthetic features have been measured. Hence, all three features with the weight of 0.339, 0.393 and 0.383 define walkability of environments. Based on this model, the safety aspect of the environment is the most important factor in analysing walkability of environments. While the aesthetic aspect is at the second rank, the functional aspect is placed at the third rank. Based on outer loadings in this model, among aesthetic qualities, the enclosure had the greatest effect on walkability. Then after, human scale, transparency, Image-ability and complexity of the walking environment were placed. Among triple functions of streets, accessibility had the greatest importance. The second effective feature was traffic role and the last one was mixed land use. Between safety features, safety from crime had more effect on walking in urban spaces than safety from traffic.

TABLE 5 - OUTER LOADINGS

Outer Loading	Aesthetic	Function	Safety
complexity	0.400		
Enclosure	0.827		
Image-ability	0.753		
human scale	0.797		
Transparency	0.771		
Accessibility		0.849	
land use mixture		0.697	
traffic role		0.786	
safety from crime			0.901
safety from traffic			-.670

6. CONCLUSIONS

The literature on walkability of urban spaces led the researchers to introducing associated environmental features. The results of the current study indicated that these features could be fitted appropriately to three major groups including 1) function of street, 2) safety of pedestrian and 3) aesthetic aspects of the environment. Although in the previous studies in this real the environmental

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features were classified, none of them attempted to measure the importance of each criterion. Given that, this research tried to investigate the efficacy of each group and their related features on the overall walkability of streets. As it was discussed, the safety of pedestrian was the most important aspect in choosing to walk to desired destinations. Next, the function and aesthetic features were placed. These findings confirm those from previous studies which indicated that safety is the most repeated feature in walkability literature. These results can be used for the evaluation of walking environments through scored environmental features. For example, they can be used in walkability audits for scoring streets based on their walking friendly features. Nevertheless, it will be more conducive if pedestrian real condition (in term of these features and other subjective measures) can be studied as one the most important determinant of walkability in order to have a more comprehensive evaluation. The next step in the research is to conduct other experiments to evaluate residents and other users of urban space rather than expert's viewpoints.

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