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The equitable use concept in sidewalk design

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ABSTRACT

Equitable use (EU) is the first principle of universal design and promotes the usefulness and marketability of products for people with diverse abilities. Sidewalks, as the main circulation path for pedestrian transportation, can be designed and assessed based on this principle to improve their usability for all pedestrians. Currently, there is no clear definition of EU in the sidewalk design criteria; consequently, no design and assessment guidelines are based on this concept. This study aims to remedy this shortcoming in knowledge by defining and translating the theoretical and conceptual components of the characteristics of EU for sidewalks. This study also attempts to identify the contributions of sidewalk design factors in the main dimensions of EU applied to sidewalks. To achieve these objectives, we conduct an extensive literature review of available universal design guidelines and handbooks as well as scientific articles regarding the implementation of EU in outdoor environments and sidewalks. The results of this review contribute to the development of conceptual models to define EU in sidewalk design. A questionnaire was administered to collect data to test the fitness of these conceptual models. Fitness tests are conducted with structural equation modelling (SEM). The EU translation can be useful for designing and assessing sidewalks to ensure that sidewalks serve people with various abilities on an equal basis.

1. Introduction

Walking is the most common form of physical activity (Kelly, Schootman, Baker, et al., 2007; Saelens, Sallis, & Frank, 2003), and sidewalks are the main channels upon which walking can be undertaken (Hooker and Architecture, 2007). Since sidewalk users are diverse in terms of age, gender, and physical condition, it is necessary to design sidewalks that serve the broadest range of users (Aghaabbasi, Moeinaddini, Shah, et al., 2017; Asadi-Shekari, Moeinaddini, & Zaly Shah, 2013). It is also vital to constantly assess existing sidewalks to ensure that sidewalks accommodate all people on an equal basis regardless of their sociodemographic characteristics and physical, sensory, and cognitive conditions (Aghaabbasi et al., 2017; Asadi-Shekari et al., 2013; Kadali & Vedagiri, 2016).

Design for all users and the non-discriminatory use of pedestrian facilities are crucial. Various regulations, such as the Americans with Disabilities Act (ADA), have been enacted to end discrimination against people with disabilities. While the ADA produced many benefits for the disabled (Beasley & Davies, 2001), full accessibility for persons with different abilities has not been achieved. In other words, limited studies consider only special users with special abilities (e.g. Asadi-Shekari et al., 2013; Asadi-Shekari, Moeinaddini, & Shah, 2015; Asadi-Shekari, Moeinaddini, & Zaly Shah, 2012; Asadi-Shekari, Moeinaddini, & Zaly Shah, 2014; Asadi-Shekari, Moeinaddini, & Zaly Shah, 2015), and the majority of works in the literature assume that all sidewalk users have the same backgrounds and abilities.

The main idea of universal design (UD) is to consider people regardless of their socio-demographic characteristics and abilities (Baer, Bhushan, Taleb, et al., 2016). Surprisingly, this idea has not been applied to sidewalks to meet the needs of all pedestrians. Specifically, applying equitable use (EU), which is the first principle of UD, can provide pathway systems that serve all users regardless of their abilities. The use of the EU guidelines can minimize specialized designs and products for special needs groups (Balaram, 2010).

Accessibility can be defined based on UD ideas. While accessibility deals with compliance with regulations or criteria that establish a minimum level of design necessary to accommodate people with disabilities, UD is the practice and art of design to accommodate the widest range and number of people in their lifetime (Salmen, 2010). In fact, UD and its principles embed choice for all people into the process of the creation of things, especially the creation of built environments. The practice of UD and its principles evolve and change with greater knowledge of humans and their needs and abilities. To the best of the authors' knowledge, the existing body of knowledge does not cover the

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application of UD and EU guidelines in designing and improving sidewalks and walking areas.

To propose a platform for inclusive sidewalk design and assessment, this research uses EU concepts. This is the first research work that defines the characteristics of EU in sidewalk design. Based on the results of a literature review, this study proposes EU conceptual models for sidewalks. The literature review in this research is structured in three main phases. Phase one reviews the UD principles, particularly EU, and their application in assessing the built environment. Phase two translates the general concept of EU into the sidewalk design criteria and identifies the main characteristics of EU for sidewalks. The last phase identifies the contribution of sidewalk design factors in the main dimensions of EU for sidewalks. Based on the results of this literature review, we propose some conceptual models that define EU for sidewalks. We test the fitness of these conceptual models using the structural equation modelling (SEM) technique and collect the required data using a questionnaire based on the conceptual models.

2. Prior evidence and conceptual framework

2.1. Universal design

UD is an approach that serves people regardless of their socio-demographic characteristics and abilities (Baer et al., 2016). The Centre for UD, with the cooperation of American experts, developed seven principles of UD in 1997 and clarified the definition of and evaluation procedure for the usability of design elements. The principles of UD and their associated guidelines aim to articulate the UD concept in a comprehensive manner. These principles aim to guide the process of design, allow the systematic assessment of design, and assist in educating both consumers and designers on the characteristics of more usable design solutions (Mueller, 1997; Story, Mueller, & Mace, 1998). As a holistic approach, UD ranges from non-discriminatory design approaches in infrastructure, architecture, urban environments, and automobiles to information technology (D'souza, 2004; Preiser, 2007).

At the urban environment scale, the aim of UD is to help people provide sustainable, comfortable, adaptable, safe, and flexible living spaces (Kadir & Jamaludin, 2013). Sustainable communities created by UD are those that achieve the following goals: "meet the diverse needs of existing and future residents, their children and other users; contribute to a high quality of life; and provide opportunity and choice." This type of community can be achieved through the effective use of natural resources to enhance the environment, promote social cohesion and inclusion, and strengthen economic prosperity (Egan, 2004: 10). These universally designed, sustainable communities allow everyone, including people with disabilities and seniors, to frequent the city and neighbourhood centre independently without having to overcome great distances that require transportation (Preiser, 2007). However, challenges remain in the embracing of UD by urban design and planning policies for new developments. To overcome these challenges, UD must focus on the need to ensure equal access to public realms such as streets and sidewalks (Manley, 2010).

Various aspects of built environment design prevent the disabled and seniors from using town centres and streets (Hanson, 2004). The poor condition of pavement, changes in level, poorly lit bus stops, inadequate seating areas, a lack of adequate public toilets, and negative perceptions of the safety of urban environments are the main hindrances to travel for older and disabled people (Aghaabbasi et al., 2017; Asadi-Shekari et al., 2013; Atkins, 2001; Hanson, 2004). Many of these problems are related to street facilities and design. To achieve equality of opportunity for everyone, it is essential to apply the UD principles at the street level to allow people to experience unhindered travel to their intended destination. This so-called seamless travel is achievable if a journey is considered a series of accessible links (Manley, 2001; Manley, 2010). A strategic approach for implementing UD is required to create barrier-free pedestrian routes and facilitate effortless travel.

Equitable use (EU) is the first principle of universal design and means that "the design is useful and marketable to people with diverse abilities" (Story et al., 1998). The socio-political ideal of "equality" is related to six other principles of the usability features of design. However, the inherent aim of EU represents UD's strengths (Erkiliç, 2011). UD calls for the integration of people with different abilities based on the socio-political mission of equality. EU is defined based on UD objectives and has been expanded in a set of guidelines describing key elements that should be present in a design that adheres to this principle (The Center for Universal Design, 1997). The equitable use guidelines are defined as follows:

- Provide the same means of use for all users: identical whenever possible, equivalent when not.
- Avoid segregating or stigmatizing any users.
- Make provisions for privacy, security, and safety equally available to all users.
- Make the design appealing to all users.

The designs and products must integrate rather than segregate users (Nasar, 2010). Since any form of segregation can lead to discrimination, which contradicts the spirit of EU, it is best to minimize specialized designs and products for special needs groups (Balaram, 2010). A relevant example of minimizing special design for people with disabilities is replacing stairs with ramps in pedestrian environments and especially along sidewalks. This replacement prevents the segregation and stigmatization of people with disabilities, and all people, regardless of their physical condition, can use ramps. Adding accessible design features that serve people with special needs from the beginning of the design and planning procedure reduces the visibility of disabilities and benefits a wider range of people (Mueller & Story, 2010). It also increases the product's usability by sharing interests among people with diverse abilities (Balaram, 2010).

Applying UD principles, particularly EU, at the street scale could lead to the unhindered travel of pedestrians by considering a series of links that are accessible to all people. Preiser (2007) suggests that EU for sidewalks means to "provide horizontal pathway systems that separate travel paths and surfaces from vehicular traffic, thus easing pedestrian and wheelchair movement, at ground level, above ground, or underground". This definition is very general and impractical because it does not consider various characteristics of pedestrian environments and sidewalks, such as safety, security, accessibility, and attractiveness. However, Preiser (2007) includes relevant instances of EU in built environments. Notable examples are the provision of accessible entrances to public buildings to accommodate people with disabilities, the installation of tactile pavement and sound signals at intersections and street crossings to assist people with visual and hearing impairments, and skywalk systems and underground passages in areas with severe weather conditions.

2.2. Equitable use and sidewalk design criteria

The first two guidelines of equitable use refer to the usability and anti-discrimination aspects of the design. As specialized design for people with disabilities can segregate them from others (Aslaksen, Bergh, Bringa, et al., 1997), the UD principles, particularly EU, emphasize the design of products and built environments to be usable by the greatest number of people.

Usability and accessibility are the main features of EU. Stephanidis, Akoumianakis, Sfyrakis, et al. (1998) defined usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". In terms of the usability of the outdoor environment, particularly pedestrian environments, it is important to identify the factors that affect the satisfaction of sidewalk users. A number of studies and guidelines have found that factors such as width, lighting, signage,

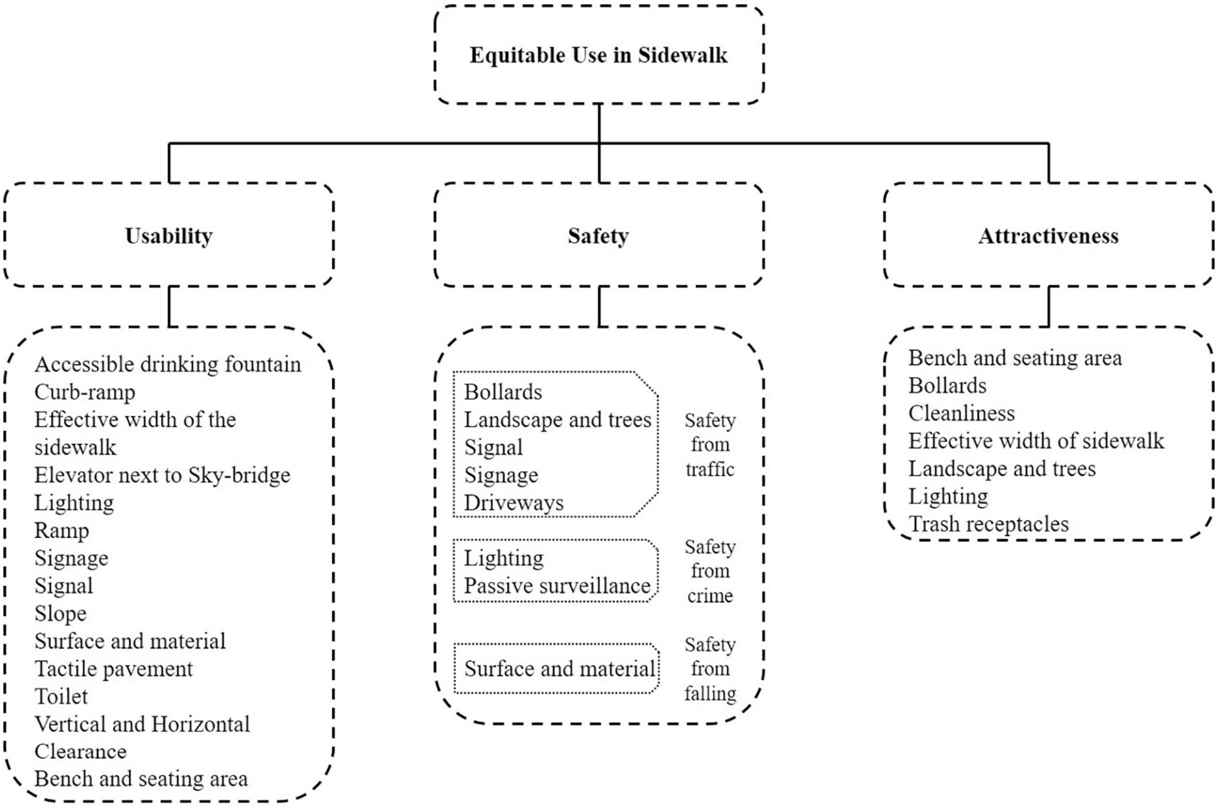

Fig. 1. Classification of sidewalk design factors based on their contribution to the main dimensions of equitable use in sidewalk.

horizontal clearance, surface material, and changes in level affect the usability of sidewalks (Boisseau, 1999; Centre for Excellence in Universal Design, 2014; Otak, 2003; Takamine, 2004; U.S. Department of Transportation, 2004).

Accessibility is the fundamental element of all pedestrian designs. Facilities and products need to be planned, designed, operated, and maintained to be usable by all people and by people with disabilities in particular. An independent definition of "accessible design" involves design for disabled people by meeting a prescribed code and considering specialized designs (Centre for Excellence in Universal Design, 2014; Erkiliç, 2011; Gamache, Vincent, McFadyen, et al., 2012; Story, 1998). To fulfil the needs of the broadest possible range of users, UD emphasizes the integration of accessibility features at the beginning of the design process, not as an addition to the project after the completion of its construction (Imrie, 2012).

In terms of pedestrian planning, the term "accessibility" refers to facility design for people with disabilities (Litman, 2012). It is important to note that facilities should not segregate and stigmatize disabled people. A relevant example of the incorporation of usability and accessibility features at the beginning of sidewalk construction to benefit diverse users is the construction of sidewalks with a slope of less than 2%, which can benefit not only wheelchair users or seniors but also other pedestrians.

The third guideline of EU refers to the provision of safety and security for the design. The implementation of UD principles will enhance the sense of safety and well-being among people with diverse abilities (Crews & Zavotka, 2006). With regard to urbanism, many planning efforts have attempted to provide safe and comfortable urban areas (Baris & Uslu, 2009). A safe and secure pedestrian environment is one of the most important indications of a liveable community. An inadequate level of safety in outdoor built environments is one of the main factors that impede people with and without disabilities from walking (Boisseau, 1999; Imrie & Kumar, 2010; Kihl, Brennan, Gabhawala, et al., 2005; Lid, 2013). Pedestrians' perception of safety from crime and traffic is critically associated with walking levels among neighbourhood residents (Doyle, Kelly-Schwartz, Schlossberg, et al., 2006; Lindelöw, Svensson, Sternudd, et al., 2014). Car speed has an important influence on pedestrians' perception of traffic as it increases the risk of accidents between vehicles and pedestrians (Cho, Rodríguez, & Khattak, 2009; Nilsson, 2004; Risser & Lehner, 1998).

The term "safety from traffic" refers to the reduction in the risk of conflicts between pedestrians and vehicles (Garrard, 2013). It is typically achieved by creating buffers between sidewalks and vehicle flows by means of trees, resting areas, and bollards (Mehta, 2008). "Safety from crime" is another aspect of safety in the urban context and refers to a reduction in the fear of crime and an increase in feelings of personal safety (Tiwari, 2014). Placing adequate pedestrian lighting (Jaskiewicz, 2000; Painter, 1996) and increasing the visibility of people from passive frontages (Tiwari, 2014) and windows can increase pedestrians' sense of safety. The last type of safety is "safety from falling," which refers to reducing the risk of falling due to slippery conditions, cracks, holes, or level changes. The selection of appropriate materials (Centre for Excellence in Universal Design, 2014; City of Minneapolis, 2009) and constant maintenance of sidewalk surfaces may prevent pedestrians from falling due to slippery conditions or holes and cracks. Falling is also preventable if adequate street lighting is placed at a reasonable height along the sidewalk (Van Cauwenberg, Van Holle, Simons, et al., 2012).

The fourth guideline of EU refers to the attractiveness of design for all people. Based on Preiser and Smith (2010), the design must attract a wide range of users and provide a comparable and non-stigmatizing opportunity for a diverse population to participate. Sidewalks must look appealing to all users and encourage them to choose to walk as their main mode of transportation to reach their destination. Attractiveness in sidewalks refers to the characteristics of the pedestrian facilities that create comfortable, attractive, and inviting walking paths. The attractiveness of the built environment is directly related to the quality of the pedestrian infrastructure and the presence of amenities. Because of the

Table 1
Main characteristics of equitable use in sidewalk design.

Equitable sidewalk definition
Sidewalks that serve all users regardless of their backgrounds and abilities.
Dimension I: Usability
The sidewalk facilities must be usable by all people regardless of their abilities and backgrounds.
The sidewalk facilities should provide equal opportunities for use for people with and without disabilities.
Specialized designs for people with disabilities, seniors, and children must be avoided as much as possible to prevent any form of segregation and stigmatization.
Dimension II: Safety
Safety and security of people must be guaranteed by sidewalks.
Sidewalks must minimize the risk of conflicts between pedestrians and vehicles, fear of crime, and falling.
Dimension III: Attractiveness
Sidewalks must be attractive to people with different abilities.
Sidewalks should be equipped with facilities that create a sense of comfort and invitation.

relatively low speed of pedestrians, they can experience desirable feelings from walking on well-designed sidewalks (De Cambra, 2012).

Tolkan (2008) notes that an attractive pedestrian environment goes one step further than making pedestrians feel comfortable and safe. Sidewalks with beautiful features and active public spaces attract people to use them and declare that "this is a place for pedestrians." Furthermore, the attractiveness of the pedestrian environment and sidewalks in neighbourhoods influences the number of walking trips for different purposes, such as shopping, recreation, and physical activity (Ball, Bauman, Leslie, et al., 2001; Giles-Corti & Donovan, 2002; Khisty, 1994). Proper fountains, benches, pedestrian street lighting, cleanliness, street trees, and shade trees contribute to the enhancement of the overall attractiveness of the pedestrian environment (City of Minneapolis, 2009; County of Brant, 2013; Otak, 2003).

Consequently, equitably designed sidewalks can be defined as "sidewalks that serve all users regardless of their backgrounds and abilities." The EU dimensions are usability, safety provision, and attractiveness. Fig. 1 presents a classification of sidewalk design factors based on EU concepts. These factors can be used to develop micro-scale assessment tools for assessing sidewalks. Table 1 also presents the EU definition of sidewalks and the design guidelines that should be present in a design that adheres to EU.

Given the relationship between the general concept of equitable use and sidewalk design criteria, this study identifies a wide range of sidewalk design factors that contribute to each EU dimension. We derive twenty variables based on peer-reviewed and grey literature. Table 2 presents a list of the selected variables as well as their contribution to the identified EU dimensions. Annex 1 presents an overview of reviewed studies. Table 2 can be used as a base for developing EU conceptual models for sidewalks.

3. Methodology

We divided this research into different phases. In the first phase, we conducted a literature review to find a conceptual EU model for sidewalks. In the second phase, we designed a questionnaire based on the proposed conceptual models to collect data. The structural equation modelling (SEM) technique was applied to analyse the collected data in the final phase and to test whether the collected data fit the models.

3.1. Data collection

We developed EU conceptual models based on the literature review results (Tables 1 and 2). This study involved a questionnaire to identify the association between the observed variables and the latent variables in the EU conceptual models. In other words, this questionnaire was designed to identify the factors that can explain the main EU features in the case study. The survey included two main parts. The first part collected personal information and socio-demographic status from respondents, and the second part included the level of agreement with statements related to the EU conceptual model. The 28 statements measured the contribution of the derived sidewalk design factors to the three dimensions of EU. Each respondent was asked to rate his or her level of agreement with the attitudinal statements from 1 – strongly disagree to 5 – strongly agree. The respondents included individuals who walked frequently in the selected streets; thus, only randomly selected pedestrians who walked frequently on the selected streets were selected as respondents.

For review, we provided experts from the fields of planning and public health with a complete list of potential survey items. The reviewers were asked to provide their comments on each statement and were asked to identify important statements that were missing or should be deleted and to indicate whether the questionnaire adequately addressed issues of accessibility for people with disabilities as well as safety and attractiveness in cities. The majority of the statements were accepted by the reviewers, with only minor changes regarding clarification of unclear statements. The experts also suggested using students who were familiar with EU and its principles to conduct the survey. They mentioned that the respondents should receive a short briefing regarding the definition of EU and other statements that needed to be explained. The respondents had to consider the main aim of EU, that is, providing pathway systems that serve all users regardless of their abilities, while completing the questionnaire.

Since the proposed EU conceptual models were developed in English, the questionnaire was originally proposed in English and was then translated into Persian by language experts proficient in both English and Persian. To test the communicability and practicability and to improve the content validity of the statements, the questionnaire was pilot tested among 32 individuals. We made minor adjustments and clarified unclear statements by adding image guidance to the questionnaire.

The study was conducted in urban environments of Kerman City, Iran. The research team's field observations indicated that Kerman City, like other Iranian cities, suffers from a poor pedestrian network. The majority of the sidewalks are unconnected, narrow, and incomplete. To include responses for different streets with different sidewalk conditions, we conducted a careful field observation and identified three types of streets, namely, streets with poor sidewalks, streets with regular sidewalks, and streets with good sidewalks. Streets with poor sidewalks are streets that have not the main walking facilities on both sides of the street. For example, streets with sidewalk only for one side of the street or streets with disconnected sidewalks. Streets with regular sidewalks are streets that have the main walking facilities but the facilities are below the minimum acceptable level. For example, sidewalks with lots of obstacles that block the walking path. Streets with good sidewalks represent streets that have minimum acceptable main walking facilities. However, these streets may not have special waking facilities to be inclusive. For example, these streets may not have walking facilities that are needed for disabled pedestrians. The study stratified the samples to include all mentioned streets. We randomly selected one street from each street type within Kerman City: Beheshti St. (street with good sidewalks), Shariati St. (street with regular sidewalks), and Esteglal St. (street with poor sidewalks).

We conducted the survey between December 2016 and June 2017 and recruited twelve students who were enrolled in a town planning course. The students were familiar with the EU concept and its application in the design of sidewalks as it was widely discussed and taught in the related courses. The leader of the research team grouped the students into three teams and assigned a street to each team. The team leader also instructed the students to interview the respondents and explain the objectives, the value of the study, technical terms and the

Table 2
Selected variables and their contributions in equitable use dimensions.

Variable	Contribution(s) in EU dimensions	
Accessible drinking fountain	1) Usability	Providing shorter/smaller drinking fountains serves wheelchair users and children (ADA, 2010; Centre for Excellence in Universal Design, 2014; City of Toronto, 2004; Stark, Hollingsworth, Morgan, et al., 2007).
Bollards	1) Safety	Bollards provide safety from traffic by separating pedestrian movements from vehicle (Van Cauwenberg et al., 2012).
	2) Attractiveness	Appropriate height, horizontal and vertical alignment, and bollard shape add aesthetic value to sidewalks (Rosanove, 2009).
Cleanliness	1) Attractiveness	A clean sidewalk may attract people to walk. In some cases, a considerable amount of litter hinders people's desire to walk (Krambeck, 2006).
Curb ramp	1) Usability	Installing curb ramps at intersections provides accessibility for people who suffer from some types of disabilities (Otak, 2003).
Driveways	1) Safety	Less frequent spacing caused by driveways minimizes vehicle conflicts with pedestrians on sidewalks (Otak, 2003).
Effective width of the sidewalk	1) Usability	Clear and adequate width can provide desirable space for wheelchair users to use sidewalks, and a clear zone without obstacles can help people with visual impairments travel along sidewalks (Otak, 2003).
	2) Attractiveness	The width of the sidewalk contributes to the degree of comfort and enjoyment of walking along a street (Krambeck, 2006).
Elevator next to skybridge	1) Usability	A facilitated sky-bridge with an elevator allows people with disabilities to use the sky-bridge like other people.
Landscape and trees	1. Safety	Trees can provide a buffer between vehicles and pedestrians (Landis, Vattikuti, Ottenberg, et al., 2001; MacNeil, 2012; Samarasekara, Fukahori, & Kubota, 2013; Southworth, 2005; Todorova, Asakawa, & Aikoh, 2004); they also help to deter crime by defining the quality of spaces (public and private) (Cui, Allan, Taylor, et al., 2012; Hernandez, 2013; Kihl et al., 2005).
	2. Attractiveness	Make the street look beautiful and restful (Todorova et al., 2004).
Lighting	1) Usability	Desirable street lighting along the sidewalks can help people with visual impairment.
	2) Safety	Crime can be reduced and traffic safety can be enhanced by placing a sufficient number of streetlights along the sidewalks (Crews & Zavotka, 2006; Haans & de Kort, 2012; Painter, 1996).
	3) Attractiveness	Providing a uniform level of light contributes to the aesthetics, friendliness and comfort of sidewalks (Landis et al., 2001; Zacharias, 2001).
Passive surveillance	1) Safety	Allow others to observe sidewalks from windows, verandas, and gardens (Pikora, Bull, Jamrozik, et al., 2002).
Ramp	1) Usability	Where stairs are provided due to a significant change in level on the sidewalk, a ramp must be installed (at least) to serve wheelchair users and people with visual impairment (ISO/IEC, 2001).
Signage	1) Usability	Simple and easily understood signs are more accessible for people with diverse abilities, and signs with proper height are visible to pedestrians of different heights (Rickert & Reeves, 1998). Additionally, signs placed within the furnishing zone of the sidewalk do not obstruct the pedestrian path of travel.
	2) Safety	Signage plays an important role in improving the safety of the sidewalk by warning pedestrians and guiding them to their destinations (Otak, 2003).
Signal	1) Usability	Audible and flashing crossing signals assist people with visual and hearing impairments in using crosswalks and passing other pedestrian-vehicle conflict zones (Boisseau, 1999; Centre for Excellence in Universal Design, 2014).
	2) Safety	Signals are significant factors that impact the safety of pedestrians, especially those who intend to use crosswalks and pass junctions (Boisseau, 1999).
Sitting area and benches	1) Usability	Benches include standard components such as arms and back support; appropriate bench height can be useful to and accessible by people with diverse abilities (ADA, 2010).
	2) Attractiveness	Available benches and resting areas provide convenience for people with a wide range of characteristics (County of Brant, 2013; Galanis & Eliou, 2011; Kihl et al., 2005).
Slope	1) Usability	A standard slope of the sidewalk allows different people, such as disabled individuals and parents with strollers, to maintain their movement without extra force (Akiyama & Kim, 2005).
Surface and material	1) Usability 2) Safety	A firm and non-slip surface contributes to maintaining pedestrian movement (Centre for Excellence in Universal Design, 2014; City of Minneapolis, 2009).
Tactile pavement	1) Usability	Tactile pavement provides accessibility for people with visual impairment by warning them of a significant change in level and direction (Alberta Transportation and Utilities, 1996).
Toilet	1) Usability	Toilets with proper dimensions that are facilitated by handrails are accessible to people with diverse abilities (Austrailian Government, 2013; City of Toronto, 2004).
Trash receptacle	1) Attractiveness	The visual appeal and cleanliness of the sidewalks are deeply influenced by the availability of a sufficient number and proper placement of trash receptacles along sidewalks (Kansas City Walkability Plan, 2014).
Vertical and horizontal clearance	1) Usability	Vertical and horizontal clearance provides accessibility for people with different abilities and characteristics by preventing obstruction of the walking path (Otak, 2003).

main aim and importance of EU. To collect statistically representative samples for each street, each survey team was asked to record data for the target of a minimum of 150 pedestrians.

3.2. Structural equation modelling

Since we hypothesized the conceptual models in this study based on the current literature, we utilized structural equation modelling (SEM) to test whether the collected data fit these models. SEM is a combination of factor analysis and multiple regression analysis that analyses the structural relationship between observed variables and latent constructs (Hair Jr, Hult, Ringle, et al., 2014; Schumacker & Lomax, 2004). The first step in SEM is drawing and specifying the conceptual model using path diagram symbols (rectangles or squares to show observed variables and ellipticals, ovals and circles to show latent variables). The model parameters can be estimated after the conceptual model is drawn and specified using path diagrams. Since this study attempted to test whether the collected data fit the conceptual model (theory testing), the maximum likelihood (ML) technique was used to estimate the SEM parameters. ML is a factor extraction method that leads to parameters that are most likely to represent the observed correlation matrix. Squared factor loading values more than 0.40 are used to identify the significant factors with high level of associations.

We used Cronbach's alpha and Kaiser-Meyer-Olkin (KMO) tests to test the reliability. In this study, a high level of association (squared factor loading values more than 0.40) was used to identify the significant factors. We used common SEM model-fitting tests, such as the chi-square test (X2), the normed chi-square (X2/df), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the comparative fit index (CFI), the Tucker-Lewis Index (TLI), the normed fit index (NFI), and the root mean square error of approximation (RMSEA), to test the fitness of the proposed conceptual models.

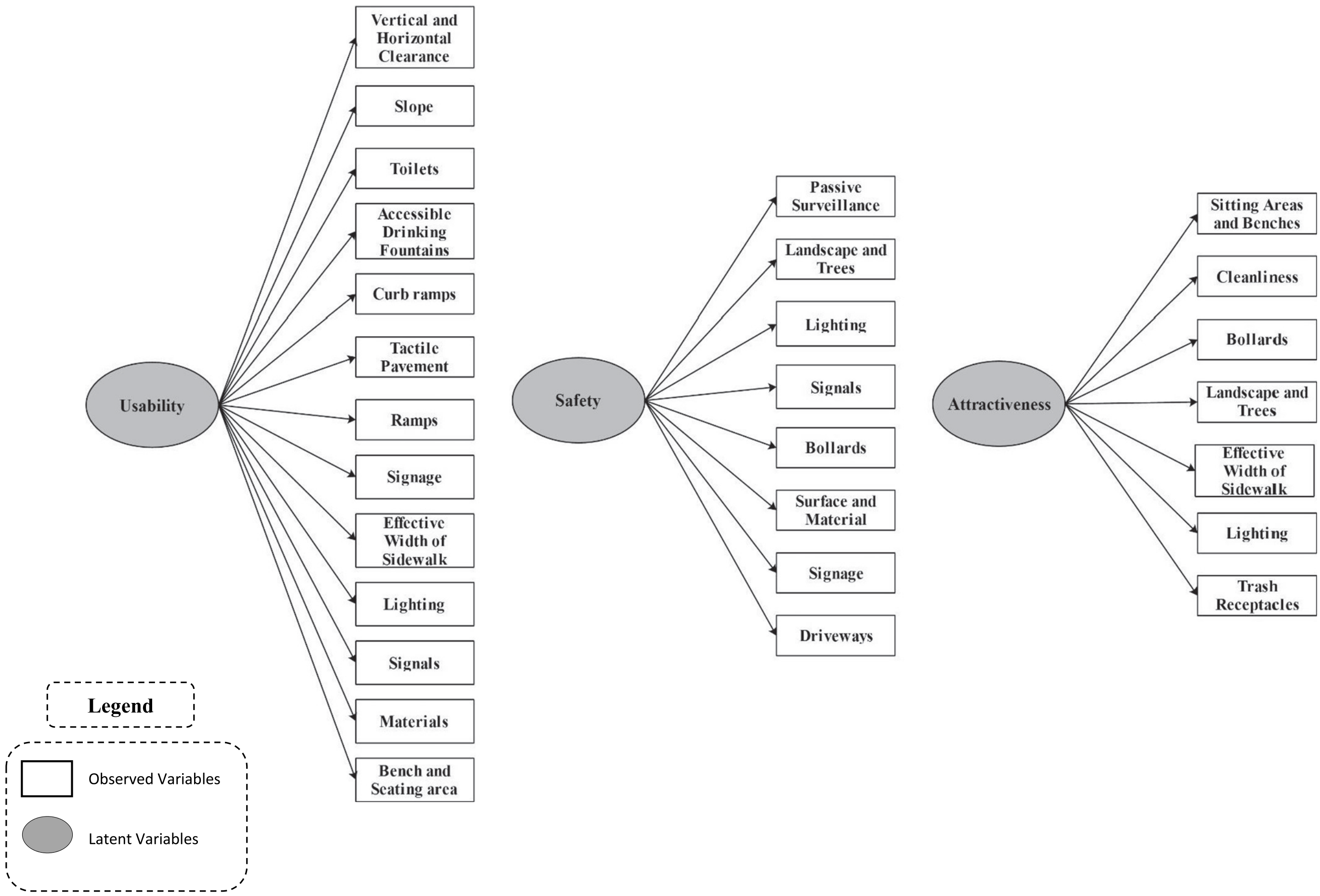

Fig. 2. EU for sidewalks conceptual models extracted from the literature.

4. Results

Equitable use, as the main principle of UD, inherits the main characteristics of UD, which include serving different people regardless of their abilities and backgrounds. To create an equitable sidewalk, we need to know which factors affect the usability, safety, and attractiveness of sidewalks. In addition, existing sidewalks need to be monitored and assessed to ensure that people are served on an equal basis. To practice UD and its main principle of EU for sidewalks, we translate the general concept of EU to the sidewalk criteria and then identify the variables that contribute to EU dimensions. The conceptual models of EU in sidewalks extracted from the literature review (Tables 1 and 2) are presented in Fig. 2. These conceptual models show various effective sidewalk design factors for the main dimensions of EU for sidewalks.

We designed a questionnaire to identify the factors that explain the main EU features in the case study based on the proposed conceptual models. We collected a total of 455 complete questionnaires. The first part of the questionnaire collected data on the respondents' socio-demographic data. The results of this section show that 59.8% of the pedestrians who walked in the selected streets frequently were male pedestrians. The results also show that the age range for 90% of the respondents was from 18 to 44 (52.3% for age range 18–24 and 38.5% for age range 25–44), and more than 63% were single. In addition, most of the pedestrians in these streets were from low and very low income levels (approximately 80%).

This study employed SEM, which allowed us to examine the relationship between our derived variables and to propose latent variables (usability, safety, and attractiveness). We tested the fitness of the models by the SEM technique. Tables 3 to 8 show the reliability of the

Table 3
Cronbach's alpha test results for the usability model.

Cronbach's Alpha	N of Items
0.770	13

Table 4
KMO and Bartlett's test results for the usability model.

Kaiser-Meyer-Olkin measure of sampling adequacy.		0.617.
Bartlett's Test of Sphericity	Approx. chi-Square	1677.297
	df	78
	Sig.	0.0001

Table 5
Cronbach's alpha test results for the safety model.

Cronbach's alpha	N of Items
0.721	8

Table 6
KMO and Bartlett's test results for the safety model.

Kaiser-Meyer-Olkin measure of sampling adequacy.		0.0.693
Bartlett's Test of Sphericity	Approx. chi-Square	809.454
	df	28
	Sig.	0.0001

Table 7
Cronbach's alpha test results for the attractiveness model.

Cronbach's Alpha	N of Items
0.646	7

Table 8
KMO and Bartlett's test results for the attractiveness model.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.668.
Bartlett's test of sphericity	Approx. chi-square	908.680
	df	21
	Sig.	0.0001

final constructed models for the main dimensions of EU for sidewalks. Figs. 3 presents the final constructed models for the main dimensions of EU for sidewalks, and Tables 9 to 11 show the goodness-of-fit tests for these models.

The SEM model shows that the vertical and horizontal clearance has the strongest relationship with usability and followed by slope, toilets, accessible drinking fountains, curb-ramps, tactile pavement, ramps, and signage. The model also shows that passive surveillance has the strongest relationship with safety dimension of EU and followed landscape and trees, lighting, signals, bollards, surface and materials. Sitting areas and benches has the strongest relationship with attractiveness and followed by cleanliness, bollards, and landscape and trees.

Our estimated models confirm the contribution of the majority of the observed variables with regard to the usability, safety and attractiveness of the sidewalks. However, some of the observed variables were dropped because of their insignificance, but this does not mean that the removed variables did not contribute to each of the latent variables. The majority of the current literature belongs to the Western context, and people in Iran may have different perceptions of their environment. The strong relationships of some of the observed variables with the latent variables, such as vertical and horizontal clearance with usability, passive surveillance with safety and seating areas and benches with attractiveness, confirm the conclusions in the literature regarding the contribution of the observed variables to the latent variables.

Table 9
Usability in sidewalks model-fitting indices.

Model indices	Default model	Saturated model	Independence model
CMIN	13.751	0.000	819.815
df	11	0	28
p	0.249	–	0.0001
CMIN/*df*	1.247	–	29.279
GFI	0.993	1.000	0.600
AGFI	0.976	–	0.485
NFI	0.983	1.000	0.000
TLI	0.991	–	0.000
CFI	0.997	1.000	0.000
RMSEA	0.023	–	0.250

CMIN = chi-square, *df* = degree of freedom, *p* = *p*-value for chi-square test, CMIN/*df* = the Normed chi-square, GFI = Goodness-of-Fit index, AGFI = Adjusted Goodness-of-Fit Index, NFI = Normed Fit Index, TLI = Tucker-Lewis Index, CFI = Comparative Fit Index, RMSE = Root Mean Square Error of Approximation.

5. Discussion and conclusion

The aim of this research was to translate the general concept of equitable use into sidewalk design criteria and to identify the main dimensions of EU for sidewalks. EU is the first principle of UD and

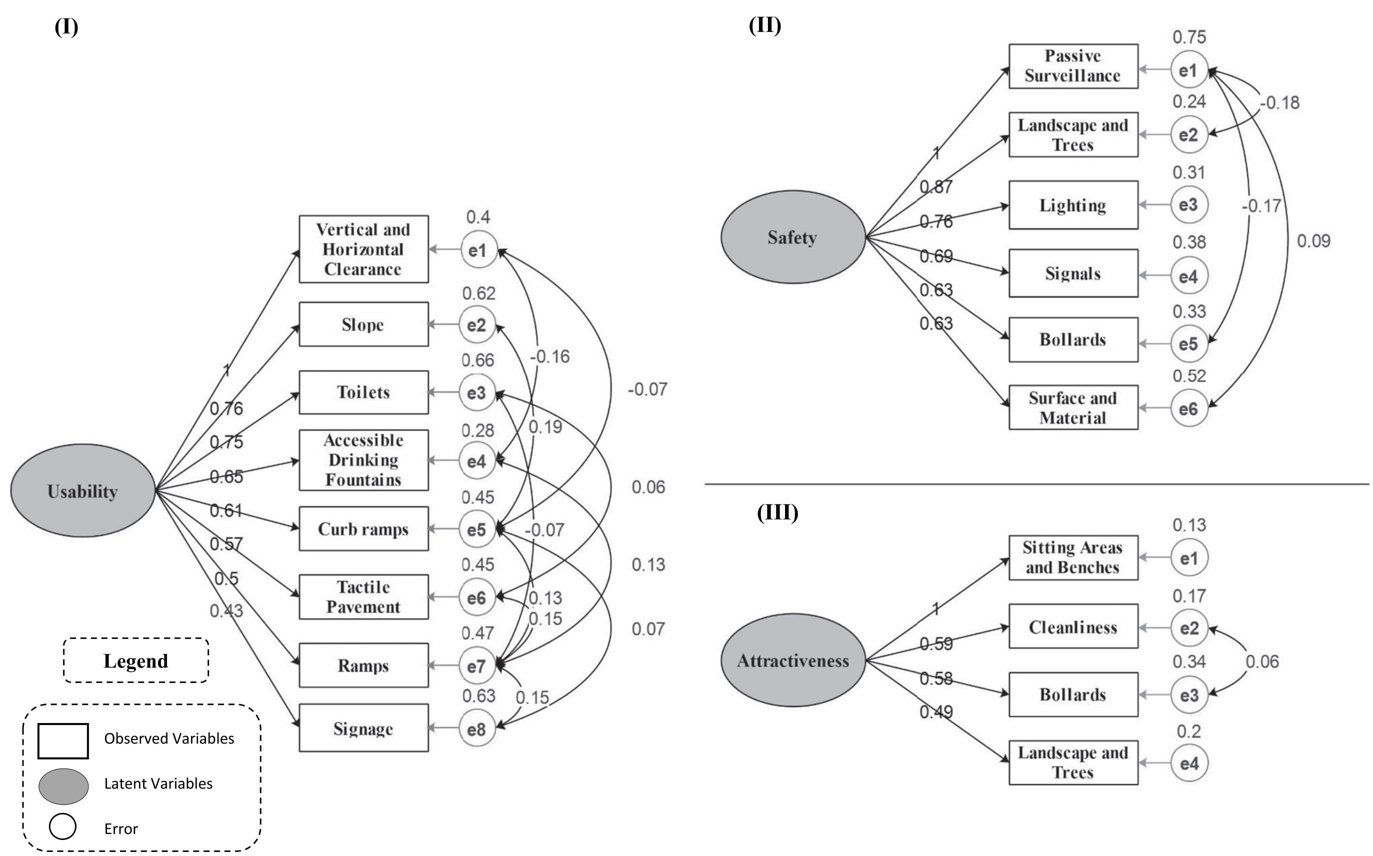

Fig. 3. EU in sidewalk estimated models model with error.

Table 10
Safety in sidewalks model-fitting indices.

Model indices	Default model	Saturated model	Independence model
CMIN	9.444	0.000	461.151
df	6	0	15
p	0.150	–	0.0001
CMIN/*df*	1.574	–	30.743
GFI	0.993	1.000	0.689
AGFI	0.975	–	0.565
NFI	0.980	1.000	0.000
TLI	0.981	–	0.000
CFI	0.992	1.000	0.000
RMSEA	0.036	–	0.256

CMIN = chi-square, *df* = degree of freedom, *p* = p-value for chi-square test, CMIN/*df* = the Normed chi-square, GFI = Goodness-of-Fit index, AGFI = Adjusted Goodness-of-Fit Index, NFI = Normed Fit Index, TLI = Tucker-Lewis Index, CFI = Comparative Fit Index, RMSE = Root Mean Square Error of Approximation.

Table 11
Attractiveness in sidewalks model-fitting indices.

Model indices	Default model	Saturated model	Independence model
CMIN	2.272	0.000	424.173
df	1	0	6
p	0.132	–	0.0001
CMIN/*df*	2.272	–	70.696
GFI	0.998	1.000	0.642
AGFI	0.975	–	0.403
NFI	0.995	1.000	0.000
TLI	0.982	–	0.000
CFI	0.997	1.000	0.000
RMSEA	0.053	–	0.392

CMIN = chi-square, *df* = degree of freedom, *p* = p-value for chi-square test, CMIN/*df* = the Normed chi-square, GFI = Goodness-of-Fit index, AGFI = Adjusted Goodness-of-Fit Index, NFI = Normed Fit Index, TLI = Tucker-Lewis Index, CFI = Comparative Fit Index, RMSE = Root Mean Square Error of Approximation.

involves serving people regardless of their backgrounds and abilities. UD principles are not well implemented in sidewalk design, and existing sidewalks do not serve people on an equal basis. Thus, applying new concepts such as EU and developing tools to assess sidewalks based on this concept can assist urban and transportation planners in finding shortcomings related to sidewalks and taking action to improve them. The translation of EU into sidewalk design criteria will contribute to finding a mechanism to assess existing sidewalk conditions and quantifying the level of improvement required in a practical and systematic manner.

This research identified the contributory factors to the dimensions of EU. To the best of our knowledge, no literature is available on the translation of EU into sidewalk design criteria and the identification of contributory design factors in the translated EU dimensions. However, several studies and guidelines have noted the contribution of sidewalk design factors to the usability, safety and attractiveness of pedestrian-built environments. On the basis of the SEM results, the authors found that the majority of the identified design factors contributed to usability/accessibility. This result is consistent with those of Akiyama and Kim (2005), the Austrailian Government (2013), the Centre for Excellence in Universal Design (2014), the City of Toronto (2004), ISO/IEC (2001), Otak (2003), Rickert and Reeves (1998), and Stark et al. (2007), who noted that factors including vertical and horizontal clearance, slope, toilets, accessible drinking fountains, curb ramps, tactile pavement, ramps and signage contribute to usability/accessibility.

These findings are also consistent with Boisseau (1999), the Centre for Excellence in Universal Design (2014), Crews and Zavotka (2006), Cui et al. (2012), Haans and de Kort (2012), Landis et al. (2001), Pikora et al. (2002), Samarasekara et al. (2013), Southworth (2005), Todorova et al. (2004), and Van Cauwenberg et al. (2012), who showed the contribution of factors including passive surveillance, landscape/trees, lighting, signals, bollards, and surface/materials to sidewalk safety. Furthermore, the results are consistent with those of other studies that showed the contribution of sitting areas/benches, cleanliness, bollards and landscape/trees to the attractiveness of sidewalks (County of Brant, 2013; Galanis & Eliou, 2011; Kihl et al., 2005; Krambeck, 2006; Rosanove, 2009; Todorova et al., 2004).

The vertical and horizontal clearance had the strongest relationship with usability dimension of EU. It can be explained by the frequent obstacles on sidewalks that hindered the pedestrian to maintain their movement. The signage had the weakest relationship with usability. A possible explanation for strong relationship between the passive surveillance and safety dimension of the EU might be that the respondents were afraid of being victims of crimes more than conflict with a vehicle or falling. The surface and materials had the weakest relationship with safety. It seems possible that this result is due to that a considerable areas of sidewalks were covered by asphalt, which is not slippery. In addition, the surfaces rarely tend to wet and slippery as rain is very rare in Kerman City. The streets of Kerman City lacks a sufficient number of sitting areas and benches, which is important for pedestrian's level of ease and convenience. It can explain the strong relationship between sitting areas and benches with attractiveness.

Since the walking environment is not desirable for vulnerable users in Kerman city, the majority of pedestrians in this city include young and adult people without disabilities. This claim is supported by the results that show an age range of 18 to 44 years for 90% of the respondents. This issue leads to limitations regarding an inclusive sample, and the limited number of disabled and elderly pedestrians may lead to non-representative results for these groups. Therefore, the respondents were briefed on the basic needs of these groups and asked to consider the EU objectives and all users regardless of their abilities while completing the questionnaire. Future studies can develop the same models in case studies that have wider ranges of age and ability for pedestrians.

Although the fitness of the factors was tested in Kerman City, it is possible to test the proposed models worldwide due to universally applicable factors. Since the urban design and walking needs may be different in different areas, it would be interesting to assess the fitness of the factors in other countries and cities, particularly Western ones. Kerman City represents cities in developing countries where the overall condition of pedestrian environments is undesirable. Thus, caution must be applied as the results of fitting tests may not be transferable to developed countries.

The findings of this study can serve as a basis for developing tools to examine whether pedestrian environments, particularly sidewalks, serve pedestrians with various abilities on an equal basis. Future guidelines can be proposed on the basis of this study for the design of new sidewalks that are equally available and accessible to all people. There is a need for further critique and discussion of EU translation, including how this translation can help practitioners design equitable sidewalks and develop an assessment tool to ensure the equitability of sidewalks. Future assessment tools should objectively assess the equitability of sidewalks by means of detailed and easily followed methods based on EU concepts. Such tools can identify the levels of required improvements, which help planners direct investments to the correct components of sidewalks. These tools can also generate a series of recommendations to improve the equitability of sidewalks within a certain boundary. The factors identified in this study can also serve as a basis for developing new sidewalk assessment tools in various contexts, such as equitable use, walkability studies, and PLOS methods.

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Appendix A. Supplementary data

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