EFFECTIVENESS OF TACTILE SURFACE INDICATORS IN 'DESIGN FOR ALL' CONTEXT

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Abstract

The aim of the study is to determine and prioritise the characteristics of the built environment that increase the effectiveness of the walking surfaces for blind and vision-impaired people. Tactile walking surface indicators are installed on the floor of indoor and outdoor built environments for guiding blind or vision-impaired people. These people perceive the walking surface by a long white cane, through the soles of their shoes or impaired vision. Based on the relevant research and published standards there is a consensus on the characteristics of tactile working surfaces in terms of design specifications, visual contrast, material and installation requirements.

In order to have the right decision while using the related knowledge, the designer of a built environment should identify and prioritise the characteristics of the users. The findings of factorial analysis showed that the individual characteristics such as shoe width, stature, gender, and frequency of leaving residence and experience alone, or with help, determine the effectiveness of tactile surface indicators as the primary factor. The second important factor that can be named as perceptual characteristics of the individual is composed of long white cane usage, time of sight loss and visual efficiency type. It is found that ease of walking on tactile surfaces as ease of change in direction, ease of stay on proper course of walking and transition from truncated domes to bars are third in priority as long as they comply with the standards.

Keywords: Tactile Walking Surface Indicators, Design For All, Blind, Vision –Impaired People.

INTRODUCTION

Tactile ground surface indicators enable the safe movement of people with impaired vision. A tactile walking surface indicator (TWSI) is defined as a "standardized walking surface used for information by blind or vision-impaired persons" (ISO 23599: 2012:2.16). These surfaces make it easier for blind and vision-impaired people to move and find their way in the built environment. Also, they can help any pedestrian such as elderly, children, wheel chair user in wayfinding as a landmark. There is a vast amount of literature related to tactile surfaces on experimental basis in various countries such as USA, UK, Sweden and Japan (Bentzen, Barlow, Tabor 2000, Fujisawa et al. 2010, Nakamura, Noriyoshi, Tauchi 2010, Ovstedal, Lid, Lindland 2005). Investigations on practices and research for identifying the essential requirements of attention and directional guiding patterns are settled with the publication of an ISO standard titled "Assistive products for blind and vision impaired persons- Tactile walking surface indicators" (ISO/DIS 23599) in 2012. Consequently, there is an agreement among several sources on the dimensional characteristics and requirements for visual contrast of tactile surfaces. The objective of this paper shall be to evaluate how well these indicators that comply with the standards work for different individuals in real traffic situations. This paper tries to identify and prioritise the items for the effectiveness of these TWSIs.

DEVELOPMENT OF TWSIS

In wayfinding, blind or vision-impaired people use visual, auditory, kinaesthetic, tactile, thermal, and/or olfactory information from the natural or built environment. However, information from the environment is not always reliable. Therefore, tactile walking surface indicators (TWSIs) that are perceived by a long white cane, through soles of shoes or impaired vision are used. These indicators should be designed consistently and properly in all countries. Consequently, all people can independently travel in their environment as well as in places that they visit for the first time.

The earliest studies tried to specify the design, installation and effectiveness of detectable warning surfaces that are used in various countries. In the ANSI A117.1-1980 (American National Institute) Standard tactile warnings were specified for the entire walking surface of curb-ramps in the built environments. In the ANSI A117.1-1986 (American National Standard Institute), warning textures that are later called detectable warnings were specified "on the full width and depth of curb ramps, at uncurbed intersections, at tops of stair runs, and at reflecting pools" (Bentzen et al. 2000:21). Truncated dome warning surfaces were specified in 1988, but not required under the Building Code of Australia until 1999 and later the Australian/New Zealand Standard was published (AS/NZS 1428.4–2009). In 1991, truncated dome detectable warnings were specified for blind travellers for the safety of persons with mobility impairments in the Americans with Disabilities Act Accessibility Guidelines (ADAAG). In the ANSI A117.1-1998 (American National Institute) Standard on accessibility, specifications for truncated dome detectable warnings of ADAAG were included. Also, the texture and visual contrast specifications were the same as ADAAG.

Accessibility to the built environment was recognized internationally in 1993 by the United Nations Standard Rules on the Equalization of Opportunities for Persons with Disabilities (United Nations 1993). Almost every country in the world signed the standard rules, and rule 5 defined all the issues of accessibility including the accessibility to the built environment. For many years, standard organisations have been developing standards and issuing guidelines addressing the needs of people with disabilities in the built environment. However, these developments were segregating diversified groups instead of dealing with the whole population (Demirkan 2007).

Thus, the Expert Group of the European Commission on Full Accessibility published a report entitled '2010, a Europe Accessible to All' (European Commission 2003). This report indicated the lack of awareness of designers as one of the obstacles in achieving accessibility to the built environment. In this report, "accessibility means providing buildings and places which are designed and managed to be safe, healthy, convenient and enjoyable to use by all members of society. It implies that buildings should be accessible, that they should be really usable from ground floor to the top, and that adequate means of autonomous exit should be provided" (European Commission 2003:6). Accessibility should be addressed in the wider perspective of spatial planning. An accessible environment is safer and healthier, thus avoiding accidents while allowing aging people to enter. An accessible environment is more comfortable, as it is more liveable. Furthermore, it is more adaptable, as it accommodates later changes. The Expert Group of the European Commission concluded that "all legislation, standards, guidelines, etc should be designed and implemented with an aim to make the built environment accessible and usable by all those who could be expected to use it" (European Commission 2003:13). In addition, the report stated that the construction works, products of information and communication technologies should be amended considering the essential requirements to include accessibility for all.

If the built environment is designed to take into account the physical dimensions of the human being, perceptual, motor and cognitive abilities should also be supported in human activities. 'Design for All' is an approach that aims to incorporate the needs and requirements of all individuals to the greatest extent, regardless of their abilities while using the built environment (Mace, Hardie, Plaice 1991). 'Design for All' approach is also referenced under the concept of 'universal design' in USA and 'inclusive design' in UK. 'Design for All' emphasizes that the demands of all users should be valued on equal terms and the ones that should be excluded should be made consciously (Olgunturk, Demirkan 2009). Therefore, " design for all" is the design for human diversity, social inclusion and equality. Accessibility for all is therefore no longer limited to a minority with special needs. Designers, architects, urban designers and others should be designing buildings and objects to accommodate a diversity of people concerned by accessibility issues (Demirkan 2007).

TACTILE WALKING SURFACE INDICATORS

In many countries, tactile indicators are used in indoor and outdoor built environments for guiding blind and vision-impaired people. In the early years, the development of sidewalks and streets with their identifying curbs were accepted to maintain orientation and safety for blind and vision-impaired people. However, "accessibility requirements that were developed in the 1960s resulted in the disappearance of curbs at many intersections (Bentzen et al. 2000:15). With the absence of a definite cue, it became dangerous for vision-impaired people to travel in the outdoor built environment. Different countries in the world are currently developing solutions for tactile surfaces. In Japan, the shape arrangement and height of the tactile walking surface indicators were standardized in 2001 (Japanese Industrial Standard, JIS, T-5291).

There are many studies that report their findings of science, technology and experience on TWSIs (Bentzen et al. 2000, Fujisawa et al. 2010, Kwok 2010, Nakamura et al. 2010). Based on these reports, 'ease of recognition' and 'ease of walking on tiles' and 'ease of recognizing transitions from bar tiles to dome tiles' can be efficiently achieved. While TWSIs are effective for people who are blind or vision-impaired, attention should also be paid to all pedestrians including elderly and those having mobility impairments for safe and effective use of indoor or outdoor environments. They may be installed in public facilities like subways, railway stations or on sidewalks at pedestrian crossings, railway platforms, stairs, ramps escalators, elevators and the like (Kwok 2010). The characteristics of TWSIs should be explored according to dimensional, material and durability properties.

Since 2002, the European Union is working to standardize tactile surfaces. In 2004, an international venture began to develop an ISO standard titled "Assistive products for blind and vision impaired persons- Tactile walking surface indicators" and it is eventually finalized in 2012 (ISO 23599:2012). The aim of this paper is to identify and prioritise the characteristics of TWSIs with respect to the users that comply with the standards for guiding designers of the built environment. Thus, these characteristics could provide a safe and efficient built environment for all users.

Characteristics of TWSIs

TWSIs are installed on the floor of indoor and outdoor built environments for guiding people who are blind or vision-impaired. They should be detectable from the immediate environment while giving specific information to blind or vision-impaired persons. These people are in contact with TWSIs by soles of their shoes and/or by a long white cane. The effectiveness of TWSis can be analysed under the subtitles of design specifications, visual contrast, materials and installation requirements.

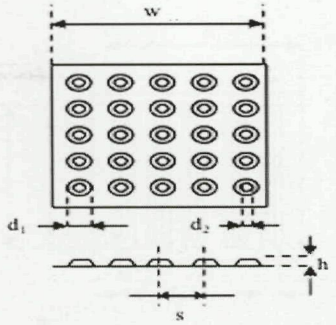

Figure 1. Attention patterns.

According to ISO/DIS 23599:2012, the design specifications can be evaluated in terms of attention patterns and guiding patterns. An attention pattern is defined as "TWSI to call attention to a hazard only, or a hazard and a decision point" and a guiding pattern as "TWSIs to indicate a direction of travel or a landmark" (ISO/DIS 23599:2012:2). The attention pattern consists of truncated domes on a square grid oriented at 0 or 45 degrees. In attention patterns, the height (h:4-5 mm), the top diameter (d_2:12-25 mm), the base diameter (d_1:10 mm ± 1mm greater than the top diameter) of truncated domes and the spacing between centres of adjacent truncated domes (s: min 15 mm) should comply with the standard (Figure 1).

According to ISO/DIS 23599:2012, a guiding pattern should be parallel flat-topped elongated bars or sinusoidal ribs. In flat-topped elongated bars, the height (h: 4-5 mm), the top width (b_2: 17-30 mm), the base width (b_1: 10 mm ± 1mm greater than the top width), the top length (l_2: min 270 mm), base length (l_1: 10 mm ± 1mm longer than the top) and the spacing as the distance between the axes of adjacent bars (s: min 30 mm) should comply with the standard (Figure 2). For the continuity between the ends of flat-topped elongated bars, the distance between should not be more than 30 mm. In sinusoidal rib patterns, the height of wave crests (4-5 mm), the length (min 270 mm), drainage gap (10-30 mm) and the spacing between the axes of adjacent wave crests (40-52 mm) should comply with the standard.

Visual contrast is important for people with low vision. According to ISO/DIS 23599:2012, there should be luminance contrast between TWISs and adjacent surfaces (greater than 30% using the Michelson Contrast formula with a minimum

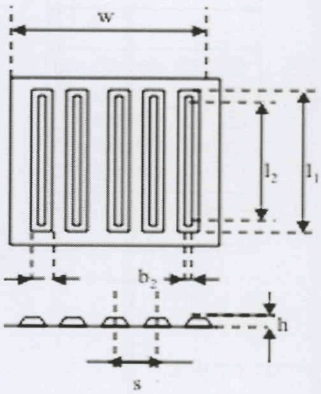

Figure 2. *Guiding patterns.*

reflectance value of the lighter surface of 30%). For hazards conditions, this value should be greater than 50%. These values should be maintained throughout the lifespan of TWISs.

Difference in colour between TWSIs and adjacent surfaces increase detectability. According to ISO 3864-1:2002, safety yellow is accepted to be the best colour for detectability for people with low vision. Furthermore, the surfaces should be illuminated properly to obtain visual detection of people with low vision.

According to ISO/DIS 23599:2012, TWISs should be made of materials that are durable and slip resistant. The slip resistance characteristics should comply with the standards of the relevant

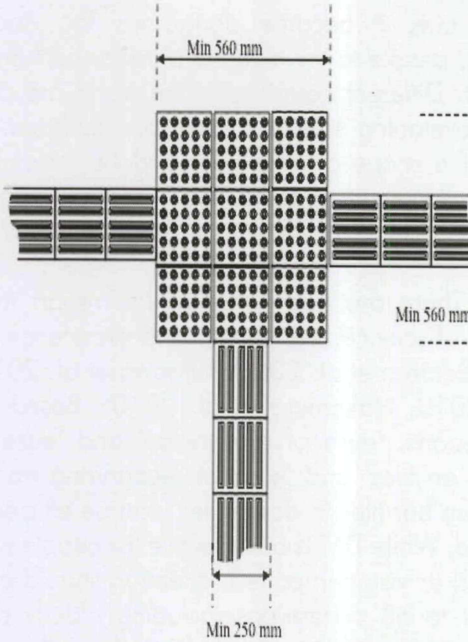

Figure 3. *Attention pattern at a decision point*

country. The installation of units should be in accordance with the relevant standards, regulations of built environment and shall take into consideration existing outdoor and indoor conditions. For safety reasons, the base surface of the TWISs should be less than 3 mm above the adjacent built environment surface and fixed to the ground.

An attention pattern should be installed

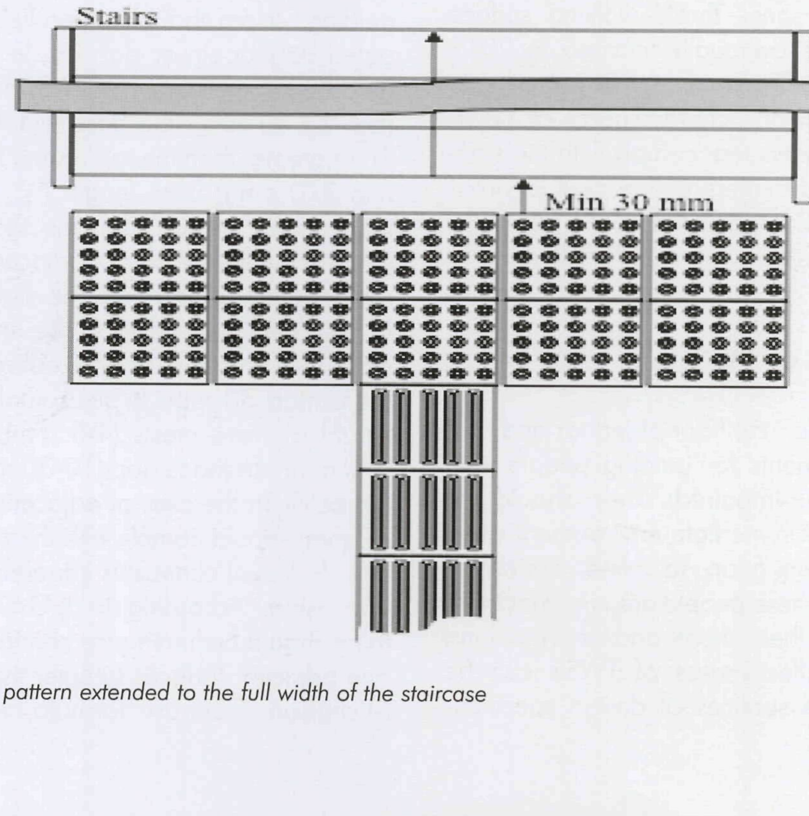

Figure 4. . *Attention pattern extended to the full width of the staircase*

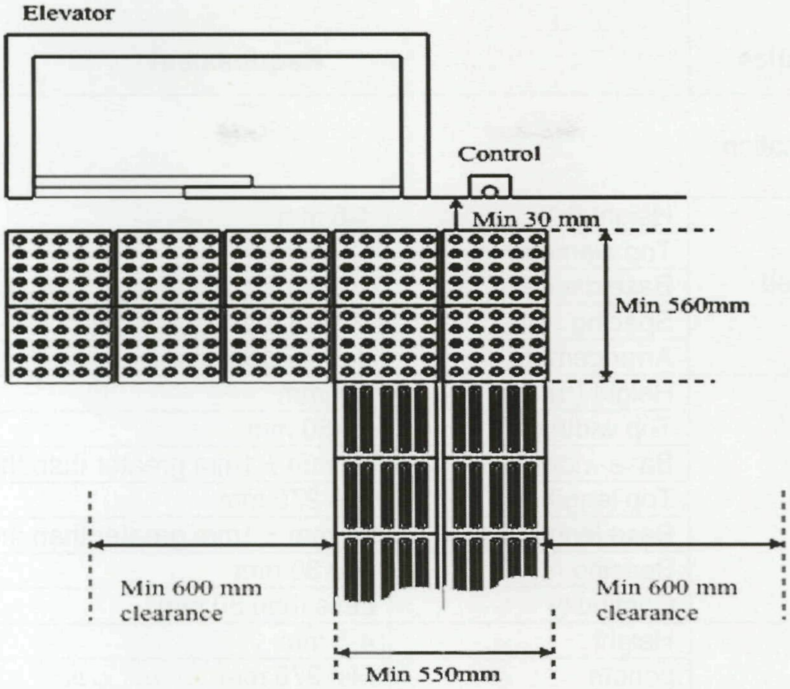

Figure 5. Approach at an angle to the elevator

Figure 6. View from site (Photo by Halime Demirkan)

with minimum 560 mm of width and depth and this is the minimum width (w) to be used if it indicates a decision point (Figure 3). If the attention pattern is used to indicate a hazard, it should be extended to the full width of the hazard at a minimum distance of 300 mm from the hazard (Figure 4)

A guiding pattern should be installed with a minimum width (w) of 250 mm for direction of travel on the same line with the traveller (Figure 3). If it is approached with an angle, the minimum effective width should be 550 mm (Figure 5). There should be clearance of 600 mm at both sides. Characteristics of TWSIs are summarised in Table 1.

Characteristics		Requirement
Design specification		
Attention pattern/truncated dome	Height (h)	4-5 mm
	Top diameter (d_2)	12-25 mm
	Base diameter (d_1)	10 mm ± 1mm greater than the top diameter
	Spacing (s)	Min 15 mm
	Arrangement	0 or 45 degrees
Guiding pattern/parallel	Height (h)	4-5 mm
	Top width (b_2)	17-30 mm
	Base width (b_1)	10 mm ± 1mm greater than the top width
	Top length (l_2)	Min 270 mm
	Base length (l_1)	10 mm ± 1mm greater than the top length
	Spacing (s)	Min 30 mm
	Continuity	Less than 30 mm
Guiding pattern/sinusoidal	Height	4-5 mm
	Length	Min 270 mm
	Drainage gap	10-30 mm
	Spacing	40-52 mm
Visual contrast		
	Luminance contrast	Min 30%
	Hazard luminance contrast	Min 50%
	Reflectance value of light surface	Min 30%
	Surface colour difference	Yes
Material		
	Durable	Yes
	Slip resistance	Yes
Installation		
	Base height	Less than 3 mm
	Fixed	Yes
	Dimension	Min 560 mm of width and depth for attention pattern (guidance and decision point) (w)
		At full width of the hazard for attention pattern (hazard)
		Min width of 250 mm for guiding pattern (direct approach) (w)
		Min width of 550 mm for guiding pattern (angled approach)
	Clearance	600 mm at both sides

Table 1. Characteristics of TWSIs (ISO 23599:2012).

The experiment

A total of 120 blind or vision-impaired adult persons (age range of 18 to 65) participated in the survey that was selected by random sampling from the database of the Federation of the Blind of Turkey. The characteristics of TWSIs were complying with the ISO 23599:2012 standard (see Table 1) and the test route was 250 metres long. All participants were allowed to practice at the site until they were familiar with the experiment procedures. The experiment was conducted in the city and the participants were always on the pedestrian road without crossing any traffic (Figure 6). Among them, 30(25%) were wearing dress or formal shoes, 41(34.17%), casual shoes with thin sole, 45(37.5%) casual shoes with thick sole and 4(3.33%) high heels. In the sample there were 46 (38.3%) females and 74 (61.7%) males. Among the 120 participants, 39 (32.5%) were blind and 81 (67.5%) were vision-impaired persons.

Each participant has to complete a questionnaire. Information about their age, gender, stature, visual efficiency level, time of sight lost and frequency of leaving the residence were collected. Furthermore, data was collected related to the type, length and width of shoes of the participant.

Each participant had an experience with the tactile surface that was in accordance with the ISO/DIS 23599:2012 standard either alone or with help. After experiencing the tactile surface, 6 questions were administered to each participant. They were asked to rate the stability of their overall body and ankle; feel of the truncated domes and bars through the sole of their shoes; ease of stay on proper course of walking; ease of change in direction and transition from truncated domes to bars. These were rated on 5-point Likert scale for stability (stable to unstable), sense (weak to strong) and ease of use (easy to hard).

Findings

All the data collected about the participants were itemized. The factor analysis test was used to group the related items under a factor and to order these items according to their importance. In this manner, a list of prioritised factors and their items was obtained for the design of TWSI.

Initially, the principle component analysis was conducted on the correlations of 15 items. Correlation matrix was inspected to determine if the strength of the correlations among the items were

Factor	Scale	Eigenvalue	Variance (%)	Cumulative (%)
1	Individual characteristics	3.53	23.53	23.53
2	Perceptual characteristics	2.06	13.70	37.23
3	Ease of walking on tactile surfaces	1.81	12.06	49. 29

Table 2. *Summary of rotated factors.*

Factor	Scale	Items with loadings ≥0.50
1	Individual characteristics	Shoe width (0.928) Stature (0.908) Gender (0.885) Frequency of leaving residence (0.599) Experience alone or with help (0.535)
2	Perceptual characteristics	Long white cane usage (0.855) Time of sight loss (0.705) Visual efficiency type (0.661)
3	Ease of walking on tactile surfaces	Ease of change in direction (0.801) Ease of stay on proper course of walking (0.779) Transition from truncated domes to bars (0.626)

Table 3. . *Prioritised three factors with the corresponding items.*

reliable for factor analysis, since there were no items below 0.30, all the items were kept. Five factors were extracted with eigenvalues greater than 1. Eigenvalues indicate the amount of variance explained by each factor.

Among the 5 factors, 3 of them that had at least 3 items and the rest had less, thus, these 3 factors were considered in this study. These 3 factors accounted for the 49.29% of the variance as seen in Table 2.

An orthogonal factor rotation was performed using the Varimax with Kaiser Normalisation. According to Tabachnick and Fidell (1996), the item's pure measure of the factor increases with greater loading. Items that had relationships 50% and above with the factor component were thought to describe the factor and its related scale the best, thus those items would provide the best assessment for that particular scale.

The loadings of the items on these 3 factors are shown in Table 3. The factors included only the items with 0.50 or more loading weights. The prioritised factors and their related items are listed from the most important to the relatively less important. Stability of their overall body and ankle, shoe type, feel of the truncated domes and bars through the sole of their shoes were the four items that were not prioritised and included in the first three factors.

DISCUSSION

As seen in Table 3, the individual characteristics of the blind or vision-impaired person have the highest priority. The shoe width (0.928) and stature (0.908) of an individual are the two important items in the first factor. Gender (0.885) is also an important item and it is highly correlated with shoe width (r=0.779) and stature (r=0. 838). Then it is followed by the frequency of leaving residence (0.599) and experience alone or with help (0.535) items.

In a preliminary study (Tactile Surface Workshop II 2011), the first factor was composed of shoe width (0.91), gender (0.89), stature (0.88), frequency of leaving the residence (0.70) and visual efficiency level (0.52), where the last item is considered as the second factor in this study. Also, Fujisawa et al. (2010: 3) found that "to recognize the shape of the TWSI, it was necessary to sense the TWSI by the foot-sole". As Nakamura et al. (2010:7) stated that "TWSIs more than 3.0 mm appeared to be still useful for visually impaired users". They concluded "bar- and dot-shaped TWSIs lower than 5.0 mm (standard height) and dot-shaped TWSIs smaller than 12.0 mm (control) seem to be useful when they are installed rather flat floor or ground surfaces". Therefore, it can be stated that the most important factor is composed of the relationship between individual characteristics (shoe width, stature and gender) and the contact amount and type (frequency of leaving residence and experience alone or with help) with TWSIs.

Perceptual characteristics of the individuals as long white cane usage (0.855), time of sight loss (0.705) and visual efficiency type (0.661) determine the second factor. In a preliminary study (Tactile Surface Workshop II 2011), the second factor is composed of ease of change in direction (0.76), sense of domes (0.74) ease of transition from truncated domes to bars (0.69). In Evyapan and Demirkan's (2000) study, it was also found that perceptual characteristics of the subjects were important in tactile discrimination and skills in manipulation of objects.

In this study, the third factor is composed of ease of walking on tactile surfaces as ease of change in direction (0.801), ease of stay on proper course of walking (0.779) and transition from truncated domes to bars (0.626).

CONCLUSION

As a result of this study, it is concluded that in the design of TWSIs that comply with the international standards, the tactile surface can be effective as much as they are in accordance with the individual and perceptual characteristics of the users. Therefore, each nation has to determine the related dimensions from the range of given dimensions in the standard that comply with the anthropometric dimensions of the nation while considering both genders.

The anthropometric dimensions that determine the shoe width and stature of the individual and the visual efficiency level should be taken substantially into consideration as well as the frequency of leaving the residence. Ease of walking on tactile surfaces that provide ease of change in direction, sense of domes and ease of transition from domes to bars should comply with the standards.

The wide spread of use of TWSIs that are designed according to the individual and perceptual characteristics of Turkish people would help visually impaired people to feel safe in their built environments while recognising the different messages through their feet or from limited vision. Accordingly, a properly designed built environment that takes into account the physical dimensions, and perceptual, motor and cognitive abilities of all people, supports all human activities. Further studies should include the integration of all people for social activities in these environments.

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