UNIVERSITY OF SOUTHAMPTON

Faculty of Engineering and Physical Sciences
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Spatial Representation Framework for Indoor Navigation by People with Visual Impairment

by

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ABSTRACT

FACULTY OF ENGINEERING AND PHYSICAL SCIENCE
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SPATIAL REPRESENTATION FRAMEWORK FOR INDOOR NAVIGATION BY PEOPLE WITH VISUAL IMPAIRMENT

by Watthanasak Jeamwatthanachai

A map is an artefact used for navigation that helps people find information on locations, landmarks and routes. Using GPS, outdoor travelling is easy with a free map service such as Google Map, which provides geographic information for navigation. However spatial information is rarely provided by any commercial products for indoor navigation. Navigation inside buildings is a problem for people with visual impairment, due to a lack of useful information about the interior space, e.g. landmarks, navigational cues, and hazards. The research problem is thus to find an appropriate framework for spatial representation (SRF) that can be used to define spaces and buildings, and is aimed at indoor navigation by people with visual impairment. In this work, a spatial representation framework was developed using a list of problems and challenges that were uncovered through a field study. This was then validated by 30 visually impaired people, and also 15 experts working in related fields such as caregiver, orientation and mobility, and accessibility. The validated SRF consists of 11 components, arranged in five layers: *structural*, *object*, *sensor*, *path*, and *wayfinding*. A building rating system (BRS) was developed as an example of a SRF implementation, aimed at improving the accessibility of spaces and buildings for people with visual impairment. BRS grades spaces and buildings, and informs people with visual impairment about the level of accessibility provided. It uses a similar approach to WCAG 2.0, using Conformance A, AA, and AAA representing minimum, sufficient, and full accessibility, respectively. The BRS was validated by 5 experts in each of three groups: research and development, accessibility, and building and interior design. Then, the BRS was evaluated using System Usability Scores. It was rated 72.2 SUS (Good) by 3 focus groups of 3 building and interior risk assessors. The outcomes from using BRS can be used as recommendations to improve spaces and building organisation. The SRF can be used as a platform for other indoor-based applications.

In memory of my grandmother, Hai Tang

A beloved woman in heaven whom I miss every day.

To my beloved parents

Thank you mom and dad for all your love and support throughout my life, and for raising me to be the person I am today.

To Tithinun Sirirumpaivong, my crush

Thank you for always making me smile when I needed the most. You are so soft, gentle, and beautiful, especially your smile that brightens my world. As always, you are my love and inspiration. I am so lucky, honoured, and privileged to know you in my life, sweetie.

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Last but not the least, I would like to thank my family and friends, especially Tithinun Sirirumpaivong, for supporting me spiritually throughout writing this thesis and my life in general.

Declaration of Authorship

I, Watthanasak Jeamwatthanachai, declare that this thesis and the work presented in it is my own and has been generated by me as the result of my own original research.

Title of thesis: Spatial Representation Framework for Indoor Navigation by People with Visual Impairment

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
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7. Parts of this work have been published as:
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    - Jeamwatthanachai, W., Wald, M. & Wills, G. (2017), 'Map data representation for indoor navigation by blind people', *International Journal of Chaotic Computing* **4**(1), 70–78.
    - Jeamwatthanachai, W., Wald, M. & Wills, G. (2019), 'Indoor navigation by blind people: Behaviors and challenges in unfamiliar spaces and buildings', *British Journal of Visual Impairment* **32**(2), 140-153.

- Jeamwatthanachai, W., Wald, M. & Wills, G. (2019). 'Building rating system: An instrument for building accessibility measurement for better indoor navigation by blind people', *Journal of Enabling Technologies* **13**(3), 158–172.
- Jeamwatthanachai, W., Wald, M. & Wills, G. (2019), 'Spatial representation framework for better indoor navigation by people with visual impairment', *Journal of Enabling Technologies*, **13**(4), 212–227.

Signed: ______________________________

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List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
BRS	Building Rating System
GIS	Geographic Information System
GPS	Global Positioning System
IPS	Indoor Positioning System
INS	Indoor Navigation System
MVE	Multi-sensory Virtual Environment
O&M	Orientation and Mobility
POI	Point of Interest
RFID	Radio Frequency Identification
SRF	Spatial Representation Framework
SRQ	Sub Research Question
VI	Visually Impaired People
VLC	Visible Light Communication
Wi-FI	Access Point, Wireless Lan Network

List of Definitions

Accessible	describes a space and facility that can be approached and used by people with visual impairment.
Accessible Route	A continuous unobstructed path connecting all accessible elements and spaces in a building or facility that can be negotiated safely by people with visual impairment. This term includes doorways, corridors, floors, ramps, lifts and clear floor spaces. It does not include any stop, drop-offs, stair, turnstile, revolving door, escalator or other impediment which would prevent the route from being safely negotiated.
Accessible Bedroom	A bedroom with ensuite sanitary facilities designed for the convenience and safety of people with disabilities.
Accessible Washroom	A public, unisex washroom that is available for use by an individual and an accompanying child, family member or caregiver of the same or opposite sex.
Circulation Path, circulation area, or transition space	An interior way or passage from one place to another for pedestrians, including walkways, hallways, courtyards, stairways, and stair landings.
Curb/Kerb	A side barrier to a road or pavement.
Curb Ramp	A short ramp cutting through a curb or built up to it.
Detectable Warning Surface	A feature of contrasting colour, tone, or texture, built in or applied to walking surfaces or other elements to alert people with visual impairment of hazards on a circulation path.
Drop-off/Incline	An attribute of a floor that has a sudden downward slope.
Fixed Object	A predictable object installed or attached inside the building at any height (ground, body, or head level) for a long period of time, or permanently, such as floor-mounted furniture, wall-mounted furniture, stairs, escalators, travelators, lifts, and railings.

Grab Bar	A bar that is used to maintain balance and to give stabilising assistance or support in locations such as bathrooms, toilets, and lifts.
Guide Dog	A helper that guides people with visual impairment while travelling.
Handrail	A rail used to give stability and support in circulation areas (e.g., corridors, passageways, ramps, and stairways) to assist in continuous movement.
Hole/Pit	A hollow place on surfaces (ground, floor or road).
Illumination	A unit of light, referring the amount of light falling on a surface, measured in lumens per square metres, or lux.
Individual Washroom	A compartment having the basic requirements of a water closet compartment, wash basin, and other essential washroom accessories required by people with disabilities.
Moving Object	An object with movability that can moved itself without external force, e.g. people, animals, autonomous systems and robots.
Object	A representation of a physical object, which can be anything that has a surface and is touchable. Objects can be split into three types based on their movability factor: fixed object, rearrangeable object, and transient object.
Operable Part	That part of a piece of equipment or appliance used to insert or withdraw objects or to activate, deactivate, or adjust the equipment or appliance, e.g. coin slot, push-button, handle.
People with Disabilities	Those whose mobility and use of a building are affected as a consequence of one or more of the following physical or sensor disabilities or impairments: (a) mobility impairment; (b) mobility impairment which requires the use of wheelchair; (c) hearing impairment or deafness; or (d) visual impairment or blindness.
People with Visual Impairment	Severely sight impaired (blind) people and sight impaired (partially sighted) people.
Primary Access Route	Main access route used by the occupants or visitors from the road to the main entrance and the key functional or activity area for the place or building.
Ramp	An inclined way connecting one level to another.

Rearrangeable Object	A random object placed inside the building that can be rearranged, or remain in its position for a medium to long period of time. For example, furniture, electric appliances, portable things.
Secondary Access Route	Another access route provided in addition to the primary access route to a lower volume of human traffic.
Space	An area inside a building or part of the building.
Stair	A set of steps up/down leading from one floor of a building to another, typically inside the building.
Super Object	A collection of objects that collectively form another object which is bigger than each one separately. For example, a group of objects placed in the construction and event areas.
Transient Object	A random object that remains in its position for a short period of time, and usually have self-moving ability, e.g. people, crowds, autonomous systems, and robots.
Transition Object	An object that provide capacity to transfer objects from one state to another state e.g. escalators, travelators, and lifts.
Visually Impaired People	Severely sight impaired (blind) people and sight impaired (partially sighted) people.
Water Closet Compartment	A compartment having a water closet with grab bars installed to assist people with disabilities.
White Cane	A mobility-aid helper to guide people with visual impairment in navigation, and for detecting obstructions while travelling in the environment.
Width	A clear distance from one surface to another surface.

Chapter 1

Introduction

In 2014, the World Health Organization (WHO) estimated the number of people with visual impairment (VI) at around 285 million worldwide (World Health Organization, 2014), of which 39 million are blind, and 246 million have low vision. WHO has classified vision into four levels: (1) normal vision and low vision; (2) moderate impairment; (3) severe visual impairment; (4) blindness. Any impairment directly affects people's ability to navigate by themselves, especially through a city or within buildings, which is a difficult task. Orientation and Mobility (O&M) is essential training that teaches visually impaired people[1] how to navigate using a white cane and sensory compensation. They are then able to navigate themselves by sensing and learning their surrounding environment, and by developing mental maps during such navigation.

People with visual impairment encounter many challenges such as obstacles, noise, and other barriers, which directly affect their daily activities and navigation (Zeng, 2015). Even though the global positioning system (GPS) has brought huge benefits to outdoor navigation, accuracy in estimating positions inside buildings is unacceptable due to loss of the GPS signal indoors and cumulative errors caused by multi-path propagation (Soubielle, Fijalkow, Duvaut, & Bibaut, 2002). Consequently, an indoor positioning system (IPS) was invented using various sensor technologies, which provides the user with a facility for finding locations inside a building (Liu, Darabi, Banerjee, & Liu, 2007). This resulted in an indoor navigation system (INS) that used IPS (e.g. Drishti (Helal, Moore, & Ramachandran, 2001), BlindSquare[2], indoo.rs[3], Wifarer[4]). Such systems usually provide maps with information about the internal layout of the building used in a route-finding process. However, for visually impaired people, such maps are not enough to help navigate inside a building since extra information is needed, such as landmarks, obstacles, and hazards.

[1]The term *visually impaired people* will be used interchangeably with the term of people with visual impairment in this work.

[2]Blindsqare - http://blindsquare.com/about/

[3]Indoo.rs - http://www.indoo.rs

[4]Wifarer - http://www.wifarer.com

Inside buildings, walking for visually impaired people creates difficulties because they cannot sense and use landmarks, also known as navigational cues, to help them move around the spaces. They may take a long time to familiarise themselves with spaces and to construct a spatial representation of the spaces and spatial orientation skills. This process is also know as a spatial mapping (Balan, Moldoveanu, & Moldoveanu, 2015). For visually impaired people, maps are widely used in appropriate formats, such as tactile maps and accessible maps, which enable them to learn the environment beforehand, and help them prepare for the experience as pre-visit information. Thus, the map has played in a significant role in improving and accelerating the acquisition of spatial mapping and orientation skills (Golledge, 1999; Golledge, Klatzky, & Loomis, 1996; Schinazi, Thrash, & Chebat, 2016).

This research proposes a framework for spatial representation (SRF) that can solve some of these problems. The framework was developed initially with 7 components by a review of the relevant literature and state-of-the-art technologies, shown in Appendix A. The framework was then improved and validated, in a field study. It consists of 11 components which represent the buildings and information.

The SRF was deployed and evaluated by developing an instrument called Building Rating System (BRS), an extension built on SRF. The BRS aims to measure accessibility of a building for people with visual impairment, as shown in Chapter 6.

1.1 Problem Statement

A search of the literature identified problems for indoor navigation by people with visual impairment in unfamiliar spaces and buildings, see Chapter 2. Some research has been conducted, such as an indoor navigation system (INS). The system works well in guiding sighted people inside buildings, but it does not work well for people with visual impairment. This is due to a lack of useful information about the interior space to support indoor navigation by the blind, such as landmarks, navigational cues, and hazard information. Without INS, navigating spaces and buildings by visually impaired people is very difficult due to the lack of navigational cues, movable obstacles, and most of the spaces and buildings lacking accessibility information along the main circulation and within facilities.

Visually impaired people inevitably have difficult tasks if they have no companion to accompany them since the building usually has obstacles throughout.

1.2 Research Questions

The research problem is how to help visually impaired people independently navigate inside buildings with safety. The literature suggests that a map is part of every navigational activity. General information provided in the map would not be much help for visually impaired people. It is conjectured that if people with visual impairment have sufficient information about the interior of a building and its accessibility in their spatial representation, they would be independent when navigating unfamiliar spaces and buildings. This has therefore led to the research question listed below.

Research Question: *What is an appropriate framework for indoor spaces with unfamiliar features to support independent navigation in freedom and safety by people with visual impairment?*

This research question can be broken down into five sub-research questions.

SRQ 1: What problems do visually impaired people encounter when moving in unfamiliar interior spaces? See Chapter 5.

SRQ 2: What information should be provided to support indoor navigation by visually impaired people when moving inside buildings with unfamiliar features? See Chapter 5.

SRQ 3: What components need to be included in a spatial representation framework to support indoor navigation by visually impaired people, and to construct an indoor map? See Chapter 4.

SRQ 4: What tools based on the framework could help architects design spaces within buildings that make it easier for visually impaired people to navigate? See Chapter 6.

SRQ 5: Can such a tool be used by assessors to measure risks in spaces navigated by visually impaired people? See Chapter 7.

1.3 Contributions

This research has produced the following contributions.

1. The problems and challenges faced while moving inside unfamiliar interior spaces by people with visual impairment has been confirmed, as well as the strategies to overcome those challenges, which has resulted in a list of information required to enact those strategies.

2. The validated spatial representation framework (SRF) for indoor navigation by people with visual impairment can be used to solve some problems of indoor navigation found in the review of literature and the field study in Section 5.4, Chapter 5.

3. The validated building rating system is an instrument for building accessibility measurement for people with visual impairment. This system enables architects and risk assessors to identify deficiencies and weaknesses in the built environment and includes:

   3.1 Building accessibility classification: three levels of standardisation (Conformance A, AA, and AAA) plus NO conformance level, used to classify levels of accessibility provided in building (top level), floors (mid level) and spaces (bottom level).

   3.2 Success Criteria: a set of requirements for 13 types of spaces have been developed and validated for building accessibility classification.

1.4 Publication

The following peer-reviewed conference papers and journal articles based on this work have been published.

1. Jeamwatthanachai, W., Wald, M. & Wills, G. (2016), Map data representation for indoor navigation, in '2016 International Conference on Information Society (i-Society)', IEEE, pp. 91–96.

2. Jeamwatthanachai, W., Wald, M. & Wills, G. (2017), 'Map data representation for indoor navigation by blind people', *International Journal of Chaotic Computing* **4**(1), 70–78.

3. Jeamwatthanachai, W., Wald, M. & Wills, G. (2019), 'Indoor navigation by blind people: Behaviors and challenges in unfamiliar spaces and buildings', *British Journal of Visual Impairment* **32**(2), 140–153.

4. Jeamwatthanachai, W., Wald, M. & Wills, G. (2019). 'Building rating system: An instrument for building accessibility measurement for better indoor navigation by blind people', *Journal of Enabling Technologies* **13**(3), 158–172.

5. Jeamwatthanachai, W., Wald, M. & Wills, G. (2019), 'Spatial representation framework for better indoor navigation by people with visual impairment', *Journal of Enabling Technologies*, **13**(4), 212–227.

1.5 Thesis Outline

Chapter 2 reviews the literature about navigation by people with visual impairment, the challenges they find in everyday activities, and technologies that have been used. It also emphasises the important factors, obstacles that impede visually impaired people when navigating inside buildings.

Chapter 3 discusses the research methodology used to answer the research questions, where the research methodology processes can be split into desk-based study, field study, and finally the deployment through a specially-developed instrument.

Chapter 4 describes a spatial representation framework for indoor navigation by people with visual impairment, including the definitions of its 11 components. The framework was designed in the desk-based study and later, in the field study, validated by 30 visually impaired people and 15 experts in relevant fields.

Chapter 5 analyses the findings of the field study. It shows that many problems have been found in unfamiliar spaces, which makes people with visual impairment afraid of visiting these spaces alone. The findings were later used to validate and to refine the spatial representation framework in Chapter 4. The results showed that all proposed information must be included, while some revisions are needed.

Chapter 6 discusses the example of SRF extension deployed through the building rating system (BRS), the developed instrument. This chapter describes the design of the building rating system with its components.

Chapter 7 discusses findings from 15 expert reviewers from three fields: research and development, accessibility, and building and interior design. The findings were then used to refine the BRS. Finally, the BRS was evaluated by 3 focus groups of building and interior risk assessors for usability.

Chapter 8 summarises and draws conclusions, suggesting future work.

Chapter 2

Literature Review

This chapter presents the background, principles and fundamental knowledge about visually impaired people. In Section 2.1, navigation by visually impaired people is described including the role of sensory compensation supported during navigation. Section 2.2 explains how blind people develop their spatial representation using various strategies. Major problems and challenges impact navigation by visually impaired people and the role of technologies is described in Sections 2.3 and 2.4. Section 2.5 presents the role of the map that helps visually impaired people achieve their daily activities, and the current technology of map use. Section 2.6 reviews building accessibility nowadays and how buildings and spaces can be assessed via a variety of technologies and theory.

2.1 Blindness and Sensory Compensation

For visually impaired people, being able to connect with social activities and having a social life are such difficult tasks due to the physical challenge that it makes them feel left out of activities. Helping these people by improving their confidence in participating in activities is significant. Vision loss has impacted visually impaired people in most of the activities that are essential to their development (Coleman, 2016). For example, a physical activity like exercise that helps people stay healthy, or shopping for daily food and groceries. Furthermore, socialising with people is important since most visually impaired people usually have a difficult time meeting people, even those who sometimes help them to achieve their activities such as shopping for groceries, walking in wide-open areas, or finding a room in a building.

For visually impaired people, doing such things would thus not be as easy as sighted people do every day. A lot of challenges and difficulties apply directly to these people, and most of their activities are usually related to *navigation*. Travelling without vision is, in fact, challenging for the congenital blind, adventitious blind and even blindfolded sighted people (Picinali, Afonso, Denis, & Katz, 2014). Therefore, orientation and mobility (O&M) training was created, professional training that is provided for visually impaired people to gain more confidence and safety awareness while travelling individually through the environment (VisionAware, 2016). Lacking vision, other senses may come into play in the role of complementary information to fill the gap of perception, and is called a sensory compensation (Cattaneo & Vecchi, 2011). By concentrating on residual senses, people can simultaneously sense and learn the surrounding environment through multi-sensory channels (Millar, 1994). For travelling indoorsexample, walking into a garden they can smell a flower's odour by nose, feel the terrain through their feet, hear a conversation or noise nearby. Through O&M and multi-sensory channels, learning the environment is another necessary process that makes visually impaired people familiar with spaces. To learn the environment, visually impaired people usually learn it by landmark, also known as *environmental cues*.

For travel under normal conditions, Golledge (1999) presents four senses required for a navigation task.

Touch Tactile perception is an ability of feeling and learning an object by touch or pressure on the skin, which is activated by a mechanoreceptor. Mechanoreceptor is one of the neural receptors that detecting a pressure on human skin when something touches it. For example, pressure occurs on hands, feet, follicles, tongue and also other body skin.

Sight Vision perception is an ability to focus, interpret and detect a visible light that bounces off and reflects from an object into the eyes. As a result, it provides a lot of information such as images, colours, brightness, contrast, and an approximate distance of the object.

Audition Sound perception is an ability to detect and interpret the vibration various frequencies of noise in the inner ears. Hearing capability also provides another ability of detect orientation (Milne, Goodale, & Thaler, 2014; Wallmeier & Wiegrebe, 2014), e.g. where the sound (source) comes from by using both ears. This technique is called echolocation.

Olfaction Odour perception is an ability to smell objects in the surrounding environment, which is processed by an olfactory receptor. Olfactory receptor is one of the neural receptors responsible for detecting a molecular odour coming into the human nose.

For visually impaired people, three out of four senses for navigation remain after sight loss. With the training provided and the white cane, these people are still able to navigate by themselves with the residual senses but take a long time. Guided by the white cane, a mobility tool that helps visually impaired people safely navigate as well as detect and avoid obstacles along the way. Williams, Galbraith, Kane, and Hurst (2014); Williams, Hurst, and Kane (2013) show visually impaired people have more confidence travelling with the white cane, by increasing their perception and familiarity of spaces through the environment cues they receive when the white cane hits during navigation outside. Furthermore, crossing a street with high traffic, walking towards a tree with branches at head level, or a construction area at night, and weather change, have a great impact on their navigation. However, a visit to unfamiliar places like wide-open indoor spaces is an entirely different story due to a limitation of their capabilities and obstacles which are randomly placed (Williams et al., 2014, 2013). These will be discussed in Section 2.3.2. Currently, sighted people or use of a guide dog are therefore preferred in these cases.

One state-of-the-art technique was invented from the way bats navigate, called *echolocation*. This technique is easy to use for visually impaired people who have the ability to locate surrounding objects by a clicking sound. The mechanism of this technique is the property of sound travelling out and bouncing off the objects and then back through ears (aka *echo*). The returning echo stimulates visual processing in the brain (Brogaard & Marlow, 2015) to process the feedback. With such a powerful technique, echolocation itself provides a lot of information brought by the echo such as depth, distance, position, contour, density, size and also a shape of the object (Finkel, 2012) which is of use for the construction of the spatial representation and provides confidence and safety during navigation (Picinali et al., 2014).

An expert in this technique, Daniel Kish[5], a notable congenitally blind individual who employs echolocation effectively, (Finkel, 2012) said that it required a lot of inner effort in training, which is not suitable for the elderly, since the most important part of this training is to improve hearing sensitivity and concentration on the environment. On the other hand, Daniel Kish warned that there are several limitations of echolocation which barely cope with the problem, such as detecting a hole on the ground or small dropoffs (Finkel, 2012), as shown in Table 2.1. The table implies the echolocation itself does not cover all of the limitations, but can be covered by the white cane. The white cane is, therefore, necessary for visually impaired people in daily activities; without a white cane, people would be getting injured and end up in hospital as a consequence.

2.2 Spatial Mapping and Wayfinding

Mental mapping is one of the most important components and serves as a mental representation that every person has in mind in order to obtain, store, code, decode, even recall information from what they have experienced. However, for people with visually impairment, a spatial mapping is more important (Golledge et al., 1996). The spatial

[5]Daniel Kish - https://en.wikipedia.org/wiki/Daniel_Kish

Table 2.1: Use of Internal Perception, External Helpers, and Echolocation in different activities and situations

Activities	**Internal Perception**[1]			**External Helpers**[2]			**Echolocation**[3]
	Touch	**Audition**	**Olfaction**	**White Cane**	**Guide Dog**	**Sighted Guide**	
Ground-level Obstacle Detection				✓		✓	
Body-level Obstacle Detection	✓		✓	✓	✓	✓	✓
Head-level Obstacle Detection			✓			✓	✓
Obstacle Avoidance					✓	✓	
Crossing the street with high traffic		✓		✓	✓	✓	✓
Walking through a loud noise area[a]	✓	✓	✓	✓	✓	✓	
Walking through a silent area[b]	✓		✓	✓	✓	✓	✓

[a] Noise areas: urban, shopping mall, construction area
[b] Silent areas: inactive construction area
[1] Cattaneo and Vecchi (2011); Golledge (1999); Millar (1994); Milne et al. (2014); Wallmeier and Wiegrebe (2014)
[2] Kulyukin, Gharpure, Nicholson, and Pavithran (2004); Williams et al. (2014, 2013)
[3] Finkel (2012)

mapping has helped visually impaired people to have a spatial representation that visualises images to assist them in recalling and learning information acting as a mind's eye. To construct the spatial representation, many perceptions are used to gather information about the surrounding environment which helps them navigate individually (Finkel, 2012). However, the development of a spatial representation is entirely different between visually impaired people and sighted people (Cattaneo & Vecchi, 2011) because one is used to seeing the world, but another is not.

The study shows that congenital blind can report only tactile, auditory and spatial features which contrasts with the sighted who can explain visual details. Even though blind individuals are at a disadvantage, they may have an exceptional memorising ability which implies that congenital blind and adventitious individual have a different perspective on spatial knowledge acquisition. Schinazi et al. (2016) present two frameworks to account for spatial knowledge acquisition, *discrete* and *continuous* framework.

Discrete Framework posits three stages towards the construction of the spatial representation. The first stage is *landmark*, a stage that visually impaired people need to learn and memorize the environment (cues). The second stage is *route*, a stage when a *mini map* is being constructed by forming a connection between a landmark and other landmarks via a route. The last stage is *survey*. The stage that people integrate into their mind, is called *spatial representation* (Shettleworth, 2009).

Continuous Framework merges *landmark*, *route* and *survey* into the same stage since people are capable of perceiving all of them simultaneously. In this framework, Euclidean spatial knowledge is learnt faster and more efficiently than the discrete framework that happens only in the *survey* stage.

Similarly, Lahav and Mioduser (2000, 2008); Lahav, Schloerb, Kumar, and Srinivasan (2008) studied the acquisition of spatial knowledge by visually impaired people navigating through unknown spaces. Two focus groups had to explore unknown spaces through the real environment and through multi-sensory virtual environment (MVE) respectively, and then explain to examiners how objects[6] were located in the area. These studies led to the construction of data structures and relationships of spaces, the so-called *spatial coding*. The findings show that people learn, memorize and construct a spatial representation using four categories: *perimeter* description, *object-to-object* description, *item-list* description, and *entrance-door point of view* description. Perimeter and object-to-object description, also known as *allocentric* reference (Schinazi et al., 2016; Tinti, Adenzato, Tamietto, & Cornoldi, 2006), were the most repeatedly used by people who learnt the environment through MVE. Likewise, Gaunet and Thinus-Blanc (1996); Hill, Rieser, Hill, Hill, et al. (1993); Tellevik (1992) have respectively presented other strategies like *grid-line*, a search strategy based on wall-to-wall, *reference point*, a search strategy based on a reference point, and finally *cyclic search*, a search strategy focusing on finding objects sequentially. For a comparison of strategies, see Table 2.2.

Many studies are related to spatial mapping, but two important questions are how visually impaired people build their spatial representation and what can help them construct the spatial representation more easily. Many tools can be used for the construction of a spatial representation, for example, 3D sound-based environment (Lahav & Mioduser, 2000, 2008; Picinali et al., 2014), tactile map (Ungar, Blades, & Spencer, 1995; Ungar, Simpson, & Blades, 2004), and virtual reality (Gomez, Bologna, & Pun, 2012; Sánchez & Mascaró, 2011).

2.3 Navigation by visually impaired people

This section reviews behaviour and navigation by visually impaired people regarding the problems, challenges, and some basic tools that have been used, divided into outdoor journey (Section 2.3.1) and indoor journey (Section 2.3.2).

[6] Such as door, window, chair, table, etc.

TABLE 2.2: Search Strategies of Indoor Navigation by People with Visual Impairment

Search Strategies	**Description**	Tellevik (1992)	Hill et al. (1993)	Gaunet and Thinus-Blanc (1996)	Lahav and Mioduser (2008)
Gridline	Walking from wall to another opposing wall.	✓	✓		
Perimeter/ Object to Wall	Walking along the walls of room to find objects located nearby	✓	✓		✓
Object to Object	Focusing on how each objects are connected with each other.		✓		✓
Object to Starting Point	Focusing on how each object is located based on the start.		✓		✓
Reference Point	Walking from known location to each object and back to reference point.	✓		✓	
Cycling Search	Walking to objects in sequence.			✓	
Item List	Focusing on list of items nearby.				✓

2.3.1 Outdoor Journey

Powered by GPS, outdoor journeys are much easier given a range of tools such as free mapping services (Google Map[7], OpenStreetMap[8]), and handheld navigation (Garmin[9], Navizon[10], Sygic[11]). Many features have been provided as such Points of Interest (POI), route planning, turn-by-turn navigation, 3D map display, traffic information, etc.

Despite the advantages of GPS, other factors act as hindrances to navigation by visually impaired people. Zeng (2015) presents nine important barriers to visually impaired people while travelling outdoors. A lack of *accessibility* information provided, such as audible information when crossing the street or using public transportation (Edison, 2011), a non-standard length of sidewalk and stairs (Williams et al., 2013), warning information while walking through a construction (hazard) area, roadside and by cliffs. He also identified unexpected obstacles like moveable objects (car, people and mobile home),

[7] Google Map - http://map.google.com
[8] OpenStreetMap - http://www.openstreetmap.org
[9] Garmin - http://www.garmin.com
[10] Navizon - https://www.navizon.com
[11] Sygic - http://www.sygic.com

and unpredictable weather (rain and snow). Head-level accidents and trip accidents especially have been reported (Manduchi & Kurniawan, 2011); there is up to 46% chance that visually impaired people have head-level accidents and up to 53% chance of tripping and falling accidents, despite a white cane or guide dog being used. These findings show that the main barriers are a lack of warning, lack of attention by the guide dog, unexpected obstacles, and wrongful measurement of distance and angle, as confirmed by Table 2.1.

2.3.2 Indoor Journey

When travelling indoors, visually impaired people have slight advantages since most of the outdoor challenges are not present, but head-level and trip accidents and even movable objects are still taken into consideration. Indoor travelling has its own set of challenges, for example, travelling through unfamiliar spaces, crowded spaces and wide-open spaces. Learning a new environment like a hospital, department store or large and complex buildings can lead to difficulty of navigation due to lack of *accessibility* information and environment cues (Williams et al., 2013). It is very hard to decide which way to reach the destination in such a complex and crowded environments (Ganz et al., 2012).

A guide dog would be a reasonable choice to accompany, but sometimes the guide dog is not permitted in some buildings by specific regulations, for example, infection control policies in the hospital or an Intensive Care Unit (ICU) (The Guide Dogs for the Blind Association (UK), 2013), theatres, and zoo that would cause disruption to people and animals, respectively (Guide Dogs Australia, 2016). In the case of visiting an unfamiliar place, the guide dog is not capable of navigating through the area since it needs training beforehand to make it familiar with the environment and to let it remember a standard or appropriate route. After least three to five trials, guide dogs typically can pick the right route (Kulyukin et al., 2004).

A sighted guide is therefore required in these cases; especially walking into a supermarket, or department store because indoor spaces and layouts often change. Unfortunately, when visually impaired people ask sighted people for assistance, most of the time they are usually given misunderstood information that makes them confused. This results in different understanding of what useful information is needed by visually impaired people (Williams et al., 2014). Furthermore, asking for assistance from sighted people in unfamiliar places is difficult, and sighted people are usually strangers themselves most of the time.

2.4 Assistive Technologies for Visually Impaired People

Thanks to advances in technology, the role of the smartphone has come into play in various industries, even helping with disability and accessibility, with significant features such as *multi-touch* and *VoiceOver*[12], that make visually impaired people capable of accessing information by touching the screen with text-to-speech feedback using the VoiceOver service. Many commercial products and studies for visually impaired people have been investigating the use of smartphone technology. For example, TapTapSee[13] is a mobile application enables the camera to identify objects and speak out loud to the user via crowdsourcing computing. Another example is BlindSquare[14], which is a mobile application that cooperates with third parties like Foursquare[15], and OpenStreetMap in providing the accessibility information, such as points of interest, street, and intersections, to the user through audible feedback.

However, numerous challenges and problems still have not been fulfilled. Current studies are exploring various technologies for navigation and wayfinding to help blind individuals move around independently.

2.4.1 Outdoor Localisation and Navigation

GPS technology and its applications are now widely used for navigation to facilitate daily life. One well-known study by Helal et al. (2001), explored the first wearable computer with voice recognition, geographic information, GPS, and obstacle information delivered through a headphone. For visually impaired people, however, those advantages would still not be sufficient because of a lack of accessibility information, as presented by Zeng (2015). Recent work by Microsoft has been the Microsoft Soundscape[16] (Gartenberg, 2018). A research project that studies a use of 3D audio-based technology and GPS integrated within the mobile application to find the orientation of the visually impaired people while navigating, and also provides map contents, navigation, nearby landmarks, and *accessibility* information, which is the most important part of their navigation. Another Microsoft product is Alice band[17] (Evans, 2014), another wearable computing device capable of providing an itinerary plan beforehand. By producing a plan, visually impaired people are capable of memorising what they are going to face, routes, and landmarks. The device generates a suitable route by considering safety as the highest priority, which is consistent with Williams et al. (2013), since the shortest route sometimes does not suit visually impaired people due to profound difficulties such as crowds,

[12] Apple VoiceOver for iOS- http://www.apple.com/uk/accessibility/ios/voiceover/
[13] TapTapSee - http://www.taptapseeapp.com
[14] What is Blindsqare - http://blindsquare.com/about/
[15] Foursquare: https://foursquare.com
[16] Microsoft 3D Soundscape - https://www.microsoft.com/en-us/research/product/soundscape/
[17] Microsoft Alice band - http://tech.firstpost.com/news-analysis/microsofts-alice-band-help-blind-people-step-crowded-places-227395.html

high traffic, or poor signal area (for cellular or GPS). However, the attractiveness of this product is that it also works with RFID tags attached to objects, e.g. entrance, floors and others, and that offers freedom, confidence, safety, and context awareness which is the most useful feature for visually impaired people.

2.4.2 Indoor Localisation and Navigation

Indoor navigation is entirely different story from outdoor navigation due to the limitations of GPS, since estimating a current location relies on information received from at least 4 GPS and GLONASS satellites (Masumoto, 1993). Numerous studies have explored the gap of the indoor localisation and navigation system using a variety of technologies and methods of computation. For instance, radio frequency identification tags (RFID) (Ding, Yuan, Jiang, & Zang, 2007; Ganz et al., 2012; Willis & Helal, 2005), Radio Map (Bluetooth (Altini, Brunelli, Farella, & Benini, 2010; Subhan, Hasbullah, Rozyyev, & Bakhsh, 2011), Wireless LAN (Mazuelas et al. (2009); Vasisht, Kumar, and Katabi (2016), indoo.rs[18], Wifarer[19]), Ultra wideband (UWB) (Ingram, Harmer, & Quinlan, 2004; Sahinoglu, Gezici, & Guvenc, 2008)), Ultrasound (Holm, 2009; Medina, Segura, & De la Torre, 2013; Minami et al., 2004), Inertia and Sensor fusion (Harle, 2013; Rantakokko et al., 2011), Optical and Camera (Kohoutek, Mautz, and Donaubauer (2010); Mautz and Tilch (2011); Serrão, Rodrigues, Rodrigues, and du Buf (2012); OrCam[20]), and Visible Light (Hassan, Naeem, Pasha, Jadoon, & Yuen, 2015; Nakajima & Haruyama, 2013; Schmid, Ziegler, Corbellini, Gross, & Mangold, 2014).

However, each technology used by indoor localisation and navigation systems has its advantages and disadvantages with a trade-off between accuracy, robustness, reliability, time complexity and cost (Fallah, Apostolopoulos, Bekris, & Folmer, 2013; Harle, 2013; Liu et al., 2007; Mautz & Tilch, 2011; Rantakokko et al., 2011; Zhang, Ong, & Nee, 2008). Further, the trade-off of *accuracy* against *cost* directly impacts visually impaired people. Wise et al. (2012) suggests that an appropriate accuracy of INS for visually impaired people should be less than two metres and *real-time response* is also necessary, as well as *robustness* of the system that leads to *reliability* and the confidence of visually impaired people while using it.

2.4.3 Obstacle Detection and Avoidance

Another important factor that directly impacts visually impaired people is obstacle avoidance. Without vision, avoiding obstacles and drop-offs on the route is supremely difficult; thus, the white cane has been used for daily navigation. Many studies have been proposed on obstacle detection, such as a sensor-based approach (sonar and ultrasonic)

[18]Indoo.rs - http://www.indoo.rs
[19]Wifarer - http://www.wifarer.com
[20]OrCam - http://www.orcam.com

(Borenstein & Ulrich, 1997; Hoyle & Waters, 2008; Shoval, Ulrich, & Borenstein, 2003; Ulrich & Borenstein, 2001), and camera-based computer vision (CV) (Choi, Kim, Yoo, & Sohn, 2012; Jie & Yanbin, 2012; C.-H. Lee, Su, & Chen, 2012).

In the same way as echolocation, ultrasonic sensors (at least 2) are attached or installed on wearable computing devices, such as glasses, belt (Shoval et al., 2003), shoulder and even the white cane. These emit the ultrasound, then wait for feedback bouncing off the objects to determine different directions, sizes and distance of the objects. For a camera-based system, Jie and Yanbin (2012) presented an interesting algorithm that can identify the obstacles from the camera image with a real-time response using mathematical equations. Likewise, C.-H. Lee et al. (2012) present another approach by identifying the obstacles by depth-based detection, similar to D. Kim, Kim, and Lee (2014) who calculated the distance of obstacles by a finger pointed at the object.

Given an ability to detect the object, obstacle avoidance would be easier. From the information provided by the sensor, instructions are produced informing visually impaired people through various interfaces, *haptic* and *audio*, where the obstacle is and which direction would be the best to move accordingly, for example, Blind Maps[21], or *automatic locomotion* (Ulrich & Borenstein, 2001).

2.4.4 Requirement and Framework of Navigation System for People with Visual Impairment

There is not only the need for fast response, robustness and reliability, but also *Usability* and *Route Description* are important. Helal et al. (2001) stated that real-time information along the navigation paths is the one of the important keys that allow independent navigation. Similarly, May, Ross, Bayer, and Tarkiainen (2003) identified five information categories that are important during navigation. Landmarks are identified as the primary means of providing directions during navigation.

To create a suitable INS, Miao, Spindler, and Weber (2011) studied the functionalities and features of INS used by visually impaired people. For example, correct feedback and information must be meaningful to such people. A list of minimum requirements was acquired from visually impaired people, and split into: *Usability* and *Route Description*. This has design implications for the INS and map with context information (environment objects) incorporated into the system. More importantly, these requirements show the significant features that are needed for an INS for visually impaired people.

[21]Blind Maps - http://www.blindmaps.org

2.5 Map, Information, and Data Representation

A map is a symbolic illustration emphasising relationships between elements of some physical area, and have been used for centuries by travellers in the form of paper to interactive maps (e.g. Google Maps and Apple Maps). The map is an artefact that helps people find locations, destinations, and routes. For visually impaired people it is difficult to use this kind of map due to the loss of vision. In this case, exploring the spaces and environments without a map would take a long time, and some visually impaired people may need to explore again and again until a spatial representation has been constructed (Picinali et al., 2014).

For an indoor journey, this method will not work for visually impaired people, since navigating and finding their orientation in a new space or unfamiliar place is hard as it is lacking environment cues. The invention of the *tactile map* is intended to get round these limitations. The tactile map is one type of tactile graphics using raised surfaces to convey information to visually impaired people in various forms such as map, image, graph, and diagram. Some research has studied the role of the tactile map (Ungar, Bayal, Blades, Ochaita, & Spencer, 1997; Ungar et al., 1995; Ungar, Blades, & Spencer, 2000; Ungar et al., 2004) and found that it helps the visually impaired develop a spatial representation faster (Caddeo, Fornara, Nenci, & Piroddi, 2006). However, very few tactile maps are provided for visually impaired people, while most of them are incomprehensible and hard to understand (Miao et al., 2011).

Several studies and commercial products, based on indoor localisation and navigation, have been developed in standalone mode (Indoo.rs, 2015; Wifarer, 2016), and usually integrate the indoor map of particular places using raster or vector images. Some have integrated their map with public map providers such as Google Map (Hansen, Thomsen, Thomsen, & Adamsen, 2013), OpenStreetMap, and Bing Maps[22]. Google has proposed a revolution of the indoor map, called Google Indoor Map (Google, 2016), a crowdsourcing model allowing people to add floor plans and spatial information in 2D, which is good for indoor navigation in general. Unfortunately, its features are not sufficient for visually impaired people, who require more information such as entrances, obstacles, elevators, escalators, ladders, etc.

To represent map data, Li and Lee (2013) proposed basic elements for the construction of indoor spatial information in a 3D format called Indoor Geography Markup Language (IndoorGML), originally designed for robot navigation and influenced by CityGML, another standard mark-up language for city in 3D geography (T. Kolbe & Bacharach, 2006; T. H. Kolbe, Gröger, & Plümer, 2005). IndoorGML was developed in a similar way to data models (J.-S. Kim, Yoo, & Li, 2014; Y. Kim, Kang, & Lee, 2013). Ryu, Kim, and Li (2014) presents an IndoorGML framework with a data model that integrates Braille

[22]Bing Map (Microsoft) - `http://www.bing.com/maps/`

block network as an another layered representation of space for visually impaired people. However, such huge benefits arose from IndoorGML that this study became the standard mark-up language for indoor spatial representation (J. Lee et al., 2014), with data models designed to support an open data format. The framework of IndoorGML comprises two items: *core* module and *indoor navigation* module. The core module is designed as a multiple-layered model representing indoor spaces, consisting a topographic layer and a sensor layer. The *topographic layer* contains information about floor layouts of the building and the relationships between spaces, rooms, dimensions and physical features, which consists of spaces (state) and transitions (connectivity). The *sensor layer* contains information about sensors installed in the building, such as an access point (Wi-Fi), a radio-frequency identification (RFID), a camera, a visible light communication (VLC), where each space is used for defined purposes. Incorporated with the indoor navigation module, IndoorGML offers a set of nodes connected to other nodes, put on top of the topographic layers to determine if a path is navigable to areas such as corridors, rooms, and stairs.

The maps and technologies related to navigation in the literature and commercial products are reviewed in Table 2.3, which compares navigation features relevant to visually impaired people. The features are drawn from the literature of navigation by visually impaired people, relevant factors, essential, and accessibility information.

2.6 Buildings Accessibility and Rating

Many people with sight loss have difficulty in visiting buildings alone since they do not know the features in the spaces and buildings (Williams et al., 2014, 2013), which can lead to injury so that they end up in hospital. This has resulted from the lack of inclusive design in the built environment. If the buildings were designed to meet the needs of people with sight loss, they would feel more confident in visiting. Thus, it is essential and helpful to know the level of accessibility provided inside the building before making a visit. To move towards an inclusive built environment, many building regulations and much legislation have been implemented in most developed countries (e.g. UK (HM Government, 2015, 2016), USA (Department of Justice, 2010, 2015), Singapore (Building and Construction Authority, 2013)), highlighting barrier-free, accessible, and adaptable buildings and dwellings for all people, regardless of disability.

To provide access for all people, a number of building design standards have been published recommending how to create inclusive built environments. To check how a building performs in terms of access and ease of use involves site inspection throughout the building with checklists and recommendations to be followed, which is time-consuming. Because of this, a system that enables people to rate the accessibility in buildings would be useful, assessing how well buildings and environments perform in terms of access and

TABLE 2.3: Comparison of map services, commercial products and literature

	Google (2016)	Apple (2016)	OpenStreetMap (2016)	Wifarer (2016)	Indoo.rs (2015)	T. Kolbe and Bacharach (2006)	J. Lee et al. (2014)
Map Type	Standard Map	Standard Map	Standard Map	Indoor Map	Indoor Map	3D City Map	3D Indoor Map
Map Data Representation	GeoJSON	Vector	XML	Proprietary	Proprietary	XML	XML
License	Proprietary	Proprietary	Open Database	Proprietary	Proprietary	Open Source	Open Source
Outdoor Journey							
Driving Directions	✓	✓	third-party			✓	
Walking Directions	beta	✓	third-party			✓	
Navigation and Routing	✓	✓	third-party				
Live Traffic Information	✓		partial				
Public Transport	✓	limited	third-party				
Weather information			third-party				
Indoor Journey							
Indoor Positioning	limited		limited	✓	✓		
Navigation and Routing				✓	✓		
Indoor-outdoor navigation				✓			
Walking Directions							✓
Live Traffic Information				✓			
Map							
2D Mode	✓	✓	✓	✓	✓	✓	✓
3D Mode	limited	limited	limited			✓	✓
2D Landmark				✓	✓		
3D Landmark	✓	✓				✓	
Furnitures							
Movable objects							
Accessibility and Disabilities							
Wheelchair Directions			limited	✓			
Context Awareness				✓	✓		
Spatial Awareness				✓			
Obstacles and hazards							
Interactive directories				✓			

ease of use (Sawyer & Bright, 2014), as well as offering suggestions and recommendations for the creation and improvement of an inclusive built environment.

It is currently too difficult to assess building accessibility for existing buildings and environments (*access audit*), and even to assess building construction proposals (*access appraisal*) for new developments, refurbishments, and alterations. For example, the complexity of buildings results in a number of auditing processes, e.g. a large number of requirements/checklists (Wu, Lee, Tah, & Aouad, 2007), to be used to determine how well buildings and environments perform in terms of access and ease of use (Sawyer & Bright, 2014). Moreover, determining the *level* of accessibility in buildings is another problem. Audit processes require thorough building inspection, and a review of the construction proposals for access audit and access appraisal.

Much research with different methodologies has studied how building accessibility can be systematically assessed. For example, J. Kim, Brienza, Lynch, Cooper, and Boninger (2008) used virtual reality with wheelchair users' movement collecting 2D/3D images, and assessed building accessibility using building design criteria. Sakkas and Pérez (2006) suggested a conceptual framework for evaluating building accessibility in a structured and detailed way by using formal methods (Church & Marston, 2003) in evaluation focusing on accessible paths for wheelchair users. Similarly, Wu et al. (2007) developed a quantitative building accessibility assessment model, using the analytic hierarchy process to establish multi-attributes, also known as accessibility criteria hierarchy for physical features.

Measuring accessibility of spaces is essential and can be used in rating accessibility of buildings overall. A number of studies have proposed rating scales to be used in space. For example, Sawyer and Bright (2014) suggested a binary scale of *pass* (all requirements are met) and *fail* (at least one fail); Jamaludin and Kadir (2012) proposed a 3-point scale *Fully comply*, *Partly comply*, and *Not comply/not provide*; while Kamarudin, Ariff, Ismail, and Ismail (2013) offered a 5-point scale *Poor* (facility is not provided), *Satisfactory* (most requirements are not met), *Fair* (half requirements are met), *Good* (most requirements are met), and *Excellent* (all requirements are met). However, some studies have created their own ratings, for example using relative accessibility scores (Church & Marston, 2003; Sakkas & Pérez, 2006).

For rating accessibility of buildings, a percentage approach has usually been used for simplification and interpretation. All the above-mentioned studies used percentages as an indicator (Church & Marston, 2003; Jamaludin & Kadir, 2012; J. Kim et al., 2008; Sakkas & Pérez, 2006; Wu et al., 2007) by first calculating the space's accessibility score (Sakkas and Pérez (2006) multiplying by the weighted importance), summarising scores of all spaces, and then normalising the summary score into a percentage representing the accessibility of the buildings overall.

2.7 Summary

This chapter provided an introduction to the five main components relevant to navigation by visually impaired people, and described some of the publications. Starting with blindness and sensory compensation, it was shown that people (including visually impaired people) use multiple perceptions to compensate, with each sense providing complementary information. Sensory compensation and training in orientation and mobility (O&M) are making visually impaired people capable of moving independently by using surrounding environments, and also allowing them to learn, memorise, and develop, the spatial representation which is most important to blind people.

The literature has also shown the use of *echolocation*, adopted from sonar-based searching by bats, to locate, identify, and measure the object by a clicking sound of the tongue.

The mental map is one of the most used facilities that visually impaired people use to obtain, store, code, decode, and recall information from their experience of daily activities. However, spatial mapping is more important for visually impaired people, because it enables them to visualise images in their mind of such things as locations and their attributes, and is also called a spatial representation. Constructing a spatial representation differs between the adventitious blind and congenital blind, since one used to see the world but the other did not. The literature suggests that the congenital blind person is capable of roughly describing tactile, auditory and space features, whereas the adventitious blind can give some detail of objects. Nonetheless, the literature of constructing spatial representation has determined that several search strategies are used during spatial representation construction: (1) object-to-object, (2) perimeter, (3) item-list, (4) entrance-door point of view, (5) gridline, and (6) reference point. The literature further suggests that spatial knowledge acquisition can be improved by map and virtual environment simulation. The results showed that people using the tactile map and multi-sensory virtual simulation constructed a spatial representation faster and walked safer.

Navigation is an essential activity that is important to all people. For visually impaired people, navigating is difficult both outdoors and indoors. We have discussed many barriers in the contexts of the outdoor and the indoor journeys. Even though GPS is widely used, it still does not work inside buildings. However, it is not only the positioning aspect but also accessibility information that is also important. Most places, both outdoors and indoors, do not provide accessible information, such as auditory feedback at a pedestrian crossing and on public transport, warning information for a non-standard walkway, stair, etc. Navigating inside buildings is a different story, where the barriers found outdoors are not encountered, but indoors has its own challenges such as the performance of IPS and visually impaired people walking across a wide-open area. In this case, visually impaired people prefer a sighted guide or accessibility information. Some places have provided accessibility information such as a tactile map, but they are usually placed in an inappropriate area like a blackboard, and can sometimes be an obstacle itself. The literature suggests that a sighted guide is the best choice for a blind person to pick to help them, but most of such helpers are not trained to be a sighted guide, and they often give information that is misunderstood and sometimes ambiguous such as directions and distance, due to the different point of view between the sighted and blind.

Assistive technology is one that attempts to help visually impaired people. Many technologies, hand-held devices, applications and services, have emerged in various products. For instance, maps (Google, OpenStreetMap, etc.), travel aid devices, wearable computing devices (glove, glasses, belt, etc.). The purpose of all of these developments is to enable visually impaired people to walk independently with safety and confidence. Providing information like points-of-interest, landmarks, and obstacles along the way through an appropriate interface, such as haptic or auditory feedback, will allow the visually impaired respond faster and effectively. With GPS or an indoor positioning system, visually impaired people can walk independently without any assistance from a sighted guide or guide dog. To deploy this system, however, would be expensive, which is a trade-off with accuracy, and each approach also has its limitations that impact on the reliability and robustness of the system. Even though many products now work on indoor positioning, few of them have been developed for visually impaired people, and they are not well-designed to satisfy those requirements.

The map is another component that plays a significant role in navigation. In the literature, the map is used in various ways to help the blind to achieve their daily activities, and improve their ability to construct a spatial representation. Exploring by themselves would take a long time, and many repeated journeys of exploring the same place has to occur. Therefore, a tactile map was created especially for blind people. The literature also suggests that using a tactile map can improve the ability to construct a spatial representation. The results show that people gain more confidence while walking with the tactile map. An interesting study called *IndoorGML* was originally designed for robot navigation. It consists of a multi-layered model of indoor spaces, such as room topographic layer, sensor layer, WiFi layer, and other sensor layers.

Regardless of the advantages of technologies, building design has played an important role in the development of an inclusive built environment for all people. Assessing the accessibility of buildings results in a number inspection using checklists and recommendations, which is time-consuming. Many studies have proposed systematic accessibility assessment using a variety of technologies (e.g. virtual reality) and theoretical foundations, for example building accessibility evaluation framework and quantitative building accessibility assessment model.

The next chapter will discuss the research methodology used to answer the research questions, where the research methodology processes can be split into desk-based study, field study, and finally the deployment through a specially-developed instrument.

Chapter 3

Research Methodology

This chapter describes the overview of research methodology, as illustrated in Section 3.1, that has been used in this thesis, mainly split into three milestone such as desk-based study (Section 3.2), field study (Section 3.3), and finally deployment (Section 3.4).

3.1 Overview of Research Methodology

This section describes the research methodology used for investigating a spatial representation framework for indoor navigation by people with visual impairment. To satisfy the research question, the sub-research questions (SRQ) need to be tackled first.

The research method is roughly divided into three major tasks, shown in Figure 3.1. The overall research methodology consists of three major milestones to achieve the ultimate goal and answer all the research questions.

3.2 Desk-based Study

Desk-based study is the exploration which tries to identify the problems found in the literature. To better understand the problems, in-depth reading of the relevant material is required. This ranges from behaviour by those with visual impairment, the methods employed, the technology adopted, to reading specialist works on technology that can be used to help visually impaired people.

3.2.1 Objectives

To create the first version of SRF that can tackle the indoor navigation problems, two objectives were adopted:

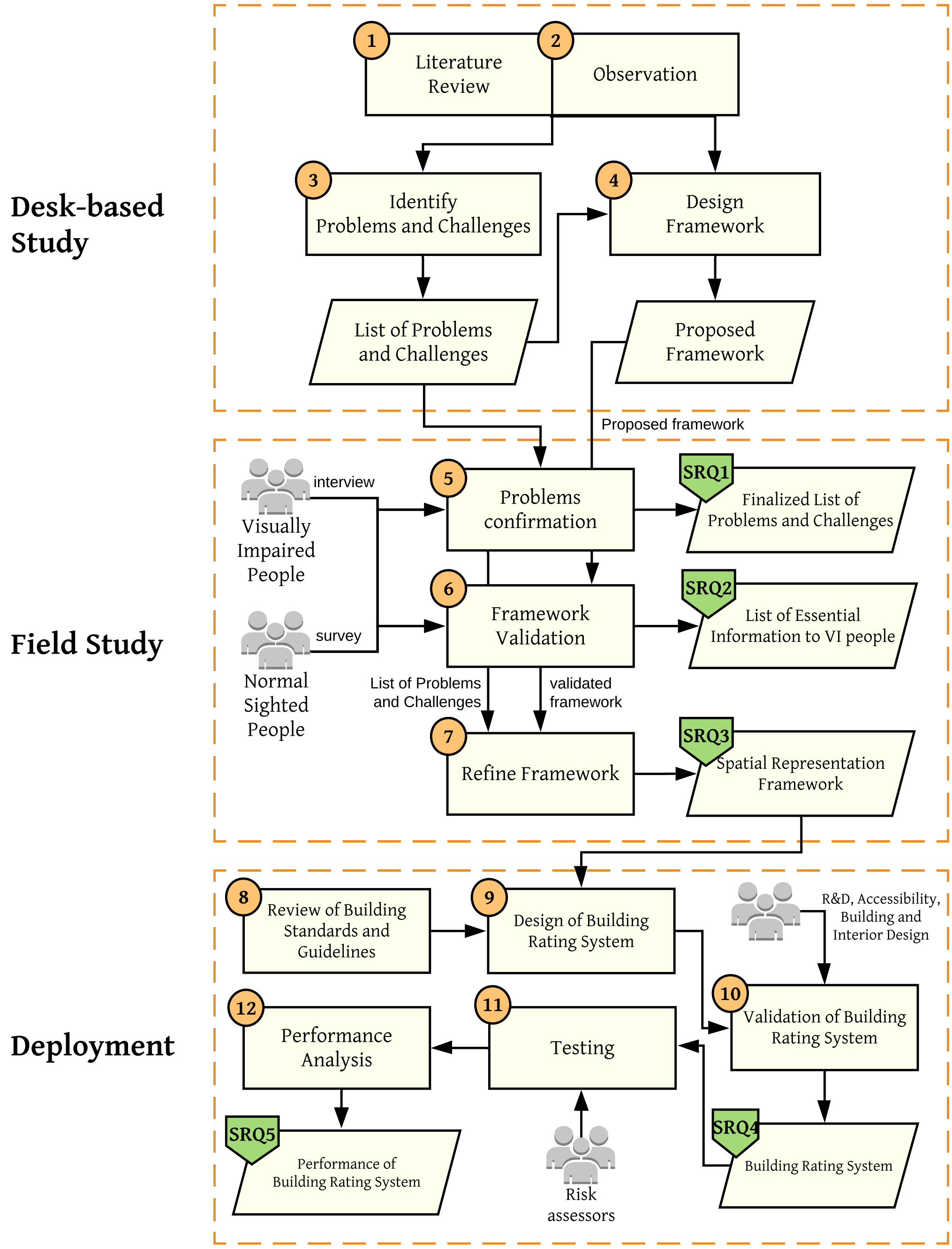


FIGURE 3.1: Overview of the research methodology

1. To understand the problems of indoor navigation by people with visual impairment discussed in the literature, which was a starting point to answer SRQ1 and SRQ2. A list of problems identified is shown in Section A.1.

2. To design the first version of the SRF, which was also the first step to answer SRQ3 shown in Section A.2.

3.3 Field Study

Field Study is the task where the SRF is revised by visually impaired and sighted people to be more usable, practical and realistic. To do that, surveys were conducted to confirm the problems found in the literature. Visually impaired and sighted people were also asked to validate the initial version of SRF for suggestions for missing components. At the end of this task, a list of problems was finalised which answered SRQ1 and SRQ2, and the SRF was validated and revised, so solving SRQ3.

This section describes the research methodology that was used for problem confirmation and validation of the SRF. Section 3.3.2 describes the research methods used in the field study, including the processes and characteristic of participants recruited to take part.

3.3.1 Objectives

The purpose of this study was to acquire an in-depth understanding of the indoor navigation behaviour and strategies used by visually impaired people when walking inside buildings full of unfamiliar features. The four objectives were:

1. To confirm the facts and problems identified from the literature review and observation for use in the construction of the framework. The results will be used to answer SRQ1.
2. To identify new problems that could influence the framework. This will answer SRQ1.
3. To identify the type of information that should be given to visually impaired people for indoor navigation when they are walking inside buildings full of unfamiliar features. SRQ2 is answered here.
4. To validate the SRF and information with those having visual impairment. This will answer SRQ3.

3.3.2 Methodologies

Two tasks were performed in the field study to construct the SRF. First, a problem confirmation task was performed to gain in-depth information and understanding of problems and situations while people are walking inside buildings and public spaces, as described in Section 3.3.2.1. Secondly, the framework and its components was validated to see if they were correct and clear, as described in Section 3.3.2.2.

Mixed methods were used for complementary purposes. To collect data, groups of people with visual impairment, and normal sight were asked to complete the questionnaires which will be used in both tasks. 29 questions (18 closed and 11 open) were listed for visually impaired people, while 27 questions (16 closed and 11 open) for sighted people. All questions were split into five sections regarding indoor navigation by people with visual impairment. The questionnaires were distributed to a group of sighted people whereas semi-structured interviews were conducted for people with visual impairment due to their physical challenges. The questionnaire design will be described in Section 3.3.2.5.

3.3.2.1 Problems Confirmation

To construct the questionnaire, the problems and factors were identified from the reviews of the literature and observations, as Appendix A shows. Using only this information to construct the SRF would not be efficient and practical for real use and deployment. There could perhaps be some problems not raised in the literature. Therefore, problem confirmation is important. Interviewing people with visual impairment individually is necessary since they are able to confirm the problems and in-depth discussion may uncover some new facts and problems (Recker, 2013). However, groups of sighted people were also asked to complete the questionnaire so that their results could be used to complement, clarify, and elaborate the findings.

3.3.2.2 Framework Validation

Validation is important when a measure is being developed (Sapsford & Jupp, 2006; Scaife, 2004). Validity refers to the confirmation of the truth or accuracy of an instrument in order to measure the construct in the context of the concepts being studied (Polit & Beck, 2006). Having the concept validated at an early stage provides useful feedback on the quality of the developed concept before future deployment, otherwise revision of the concept may be needed (Coombes, 2001). The literature review revealed no such framework for indoor navigation that offers people with visual impairment independence and freedom to navigate inside buildings and public spaces. The SRF and its components are entirely new and need to be validated to check whether they are correct and clear before the deployment. Validating the SRF was undertaken by both people with visual impairment and those with normal sight, also was called "face validation" (Balci, 1994). Both groups were asked to rate on a Likert scale their agreement with the factors provided in the initial SRF. Each factor to be included in the framework was chosen if its rating average was more than 3 and significant.

3.3.2.3 Participants

Participants were recruited and were split into visually impaired and sighted people. The sighted group were those who work closely with people with visual impairment, e.g. caregivers, chaperones, and O&M instructors (Orientation and Mobility). This group also includes experts working in the field of relevant technologies, e.g. accessibility, assistive technology, human-computer interaction, and interior design for elderly and disabled people.

3.3.2.4 Sample Size

In quantitative research, random sampling is employed which allow the findings of the study to be generalized to the population (Bhattacherjee, 2012). The sample size can be calculated mathematically, based on pre-selected parameters (Guest, Bunce, & Johnson, 2006). In the calculation of the minimum acceptable sample size, two types of error exist (Type I, and II). Type I error or significance level is the probability of incorrectly rejecting a true null hypothesis, a so-called false positive, whereas Type II error occurs when a false null hypothesis is not rejected, a so-called false negative. The likelihood of these phenomena can be minimised by increasing the sample size (Banerjee, Chitnis, Jadhav, Bhawalkar, & Chaudhury, 2009). By convention, Type I or α error is set to 0.05 for 95% confidence, while Type II or power of the test $(1 - \beta)$ is set to 0.9 for 10% (Banerjee et al., 2009). Another parameter considered in the calculation of acceptable sample size is effect size (d). The effect size refers to the magnitude of the association between the predictor and outcome variables. As a rule of thumb, the initial value of effect size suggested by (Cohen, 2013) is: small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$), which Sawilowsky (2009) expanded to very small ($d = 0.01$), very large ($d = 1.20$), and huge ($d = 2$).

In the field study, the minimum sample size was calculated by Power analysis software performed for a t-test to find the difference in mean from constant, The minimum sample size was suggested at 12 by using the following configuration:

- Effect size: 0.8 - representing a relatively large effect size
- α error probability: 0.05
- Power (1 - β): 0.8
- Test family: T-test
- Statistical test: Means - Difference from constant (one sample case)
- Tail: two - is appropriate when a difference in any direction is expected

On the other hand, qualitative research usually depends on non-probability sampling, where participants are selected based on their knowledge and experience in the area related to the study (Bhattacherjee, 2012). In this type of sampling, the sampling size number depends on saturation (Guest et al., 2006), where saturation is reached when no new knowledge can be extracted, which number is also suggested as 12.

3.3.2.5 Design of Questionnaire

Different types of question used for data collection have advantages and disadvantages, and the selection of the question type can elicit the information that the study wants to know (Preece, Rogers, & Sharp, 2015; Punch, 2013). The field study questionnaire chose a combination of closed and open questions to acquire in-depth information and also understand the facts and problems of indoor navigation.

The study questionnaire had both closed questions with single and multiple answer boxes, and open-ended questions with blank space provided. In constructing the questionnaire, the questions focused on previous studies in the literature, and the review of current technologies and commercial products. There were two questionnaires: 29 questions (18 closed questions, and 11 open questions) in the questionnaire for visually impaired people, 27 questions in the questionnaire for sighted people. All of questions in both groups of participants were divided into five sections:

1. *Basic.* This section asked participants with visual impairment for background information, e.g. gender, age, and sight condition, while the sighted participants were asked how many years they had been working closely with people with visual impairment.

2. *Behavior and Indoor Navigation.* This section was designed to gain an understanding of behaviour when the visually impaired are walking inside buildings and public spaces. For example, what tools they use to navigate indoors, and how often they used the tools. Sighted participants were asked to express opinions based on their perspectives and experience in the field.

3. *Unfamiliar Spaces.* This section was designed to discover the facts and problems people encounter when navigating inside unfamiliar buildings and public spaces. Also, to understand how people behave when navigating through indoor spaces regarding their navigation strategies and information used to help them reach their destination. Sighted participants were asked to express opinions based on their perspectives and experience in the field.

4. *Obstacles and Dangerous Area.* This section was designed to discover what types of obstacle have most impact on indoor navigation and the consequences if people are not able to detect the obstacles. Sighted participants were asked to express opinions based on their perspectives and experience in the field.

5. *Accessibility and Essential Information.* This section is very important and was designed to learn what types of information should be included in the

SRF to promote indoor navigation. All participants were asked to rate the importance of the proposed factors in impacting indoor navigation by visually impaired people. The findings from all participants were combined to decide what factors need to be included in the SRF.

The participants were based in the UK and in Thailand. Therefore, the questionnaires were created as English and Thai versions. A backward translation method by Larkin, de Casterlé, and Schotsmans (2007) was employed to check language consistency in both English and Thai questionnaires by natives from each country. Finally, both versions were proofread and enriched by suggestions of focus groups conducted in each country.

3.3.2.6 Piloting and Testing

A pilot study is a small-scale field study used to evaluate feasibility, time, cost and effect size (Cummings, Newman, & Hulley, 2007) in order to estimate sample size and improve the quality of the study design prior to a full-scale study. In this pilot study, interviews and a survey were pilot-tested by two native English researchers and two native Thai researchers, all at the University of Southampton. Since none of these four was visually impaired, the real situation for the interview was simulated by asking the participants to wear blindfolds during the pilot interview.

3.3.2.7 Interview with People with Visual Impairment

To recruit people with visual impairment, invitation letters were sent to a charity in the UK and in Thailand to ask a permission to conduct the interviews with service users, and request service users who would like to take part in this study. Participants with visual impairment were interviewed individually, with chaperones provided if any help was needed during the interview. Before taking part in this study, participants were asked to give verbal consent, e.g. "I agree..." or "I consent..." instead of using a signature. During the interviews, the investigator's role was to ask a set of questions and note all the responses, while the participants were asked to answer the questions, and approached again for clarification if necessary. All of interviews were audio recorded.

3.3.2.8 Survey for sighted People

Sighted people were recruited to take part in this study. Once they expressed an interest, paper-based questionnaires were sent to them while electronic-based questionnaires were sent via email to those who were comfortable with using an electronic-based version, or who were based in Thailand.

3.3.3 Ethical Approval

Prior to conducting the field study, ethical approval was sought and obtained from the University of Southampton's Ethics Committee. The reference for the ethics approval is ERGO/FEPS/23512.

3.4 Deployment through the Developed Instrument

Once the SRF has been validated, a building rating system (BRS) is designed and then developed based on the SRF. BRS is an instrument for building accessibility measurement. The two parts of this approach are (1) design of the BRS, and (2) usability evaluation of the BRS. The detailed methodology of each are discussed in Sections 3.4.2 and 3.4.3 respectively. The culmination is a BRS that was designed and validated, which answers SRQ4 and SRQ5.

3.4.1 Objectives

This study was split into two parts, where the first was to design and validate the BRS to make sure that the instrument can measure the level of accessibility provided inside buildings. The second was to evaluate the usability of the BRS, in order to assess how well it can perform in practice.

The four objectives in this study were:

1. To validate the BRS created from the use of SRF and building design standards and guidelines. This result will be used to answer SRQ4.
2. To identify new components (e.g. success criteria and design specification) that may have been missed in the BFS.
3. To evaluate the usability of the BRS in practice. The result will be used to answer SRQ5.
4. To identify improvements using feedback given in the evaluation of the BRS.

3.4.2 Design of Building Rating System

The first draft of the BRS was designed using SRF as a skeleton, and reviewing building standards and guidelines. Then, three groups of five experts were invited to review and validate the BRS to check its comprehensiveness and relevance, and to make suggestions where improvement was needed.

3.4.2.1 Triangulation

Triangulation is a technique to simplify validation of data through cross-verification from two or more source (Bogdan & Biklen, 1997), and can be used in both quantitative and qualitative research. Triangulation is used in qualitative research to certify the validity and reliability of the results (Golafshani, 2003). By considering multiple sources such as theories, observers, evidence (literature), and empirical studies, the weaknesses, issues, and biases that arise from a single source can be identified.

In designing the BRS, the triangulation method was used for validating and improving the system. Figure 3.2 shows the methodological triangulation based on the design of the BRS by

1: Use of building design standards and guidelines;
2: Expert validation;
3: User evaluation.

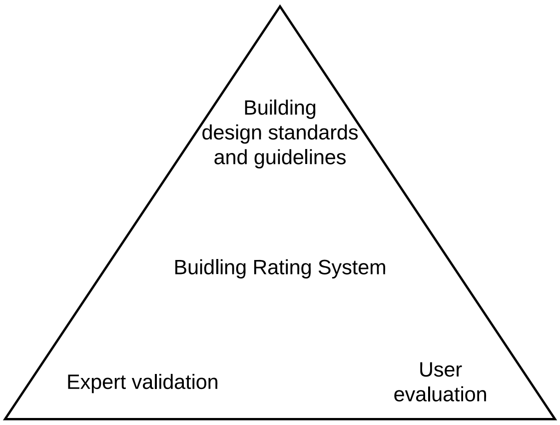


FIGURE 3.2: Triangulation for designing the building rating system

The BRS described in Chapter 6 was based on the use of SRF (described in Chapter 4) with uses of building design standards and guidelines available around the world, i.e. Singapore, United Kingdom, United States. The expert validation and reviews were undertaken by paper-based questionnaire followed by face-to-face discussion individually with each expert. The 15 experts came from three groups, with five experts in each group:

Group 1: Research and Development
Group 2: Accessibility
Group 3: Building and Interior Design

The current section discusses the expert validation used in gathering information and improving the BRS prior to its user evaluation, which is described in Section 3.4.3.

3.4.2.2 Expert Validation and Review

Using an informal face validation technique (Balci, 1994), the experts were required to validate and review the BRS before the user evaluation by those who will use this system to design the space that meet the needs of people with visual impairment. Validation is required to certify the BRS is designed with satisfactory, accurate, and consistent before deployment (Balci, 1994). Since validity can confirm the accuracy (Polit & Beck, 2006) and reliability of the system, the experts will be asked to validate the BRS at an early stage to provide useful feedback and especially identify unresolved problems, even with components of the system. This feedback is significant and will be used to improve the future system. Likewise, the expert review is a process for asking opinions, suggestions, feedback or comments from those who are highly experienced in relevant fields. The experts were asked to provide feedback and suggestions in three areas: research & development, accessibility, and building & interior design.

To recruit experts for the validation and review of BRS, an invitation letter and participation information sheet were sent to selected experts in the UK and Thailand. Once an expert expressed an interest in taking part of this study, a meeting was arranged. Before taking part in this study, each expert was asked to give consent.

During the face-to-face discussion, the investigator's role was to note all the responses, while the participants answered the questions, and questioned for clarification if necessary.

3.4.2.3 Experts Size and Selection

For this work, the number of experts was calculated using Power analysis performed for a t-test to find the difference from a norm. The minimum expert size of 12 was suggested from the following configuration:

- Effect size: 0.8 - representing a relatively large effect size
- α error probability: 0.05
- Power (1 - β): 0.8
- Test family: t-test
- Statistical test: Means - Difference from constant (one sample case)
- Tail: two - is appropriate when a difference in any direction is expected

Initially, there were supposed to be four experts in each group. With this number, if there was disagreement among the group, there would be a tie. Thus, to avoid this situation, 15 experts (five for each group) were used instead of 12, in which a majority vote could be used for a final decision.

The experts, who had at least three years' experience in the required field, were chosen for each group and are listed below with role description.

Group 1: Research and Development (RDE), a group of five experts who are highly experienced in the field of research and development. The experts were selected for their expertise with a computer science and/or engineering background over three years. This group was asked to focus on the overview of the system, and the feasibility of implementing and using this system in reality.

Group 2: Accessibility (AE), a group of five experts who are highly experienced in the field of accessibility or assistive technology design for people with disabilities. The experts were selected for their extensive understanding of helping people with disabilities (especially people with visual impairment). This group was asked to focus on the building rating scale (or Conformance A, AA, and AAA, in other words) and how to classify each space into a particular conformance level.

Group 3: Building and Interior Design (BIE), a group of five experts who are highly experienced in the field of building and interior design. The experts were selected for their extensive understanding in designing buildings and interiors and, especially in designing inclusive built environment to meet the needs of people with disabilities. This group was asked to focus on the criteria and design specifications used in the space classification, such as components and dimensions.

3.4.2.4 Design of Questionnaire

The paper-based questionnaire was supplemented with face-to-face discussion because the extensive contents may be unclear and confusing to respondents. Also, some in-depth information and understanding is difficult to elicit in a written document, so discussion in person is required to achieve understanding. Because of this, other methods would not be suitable for this study.

The study questionnaire had both closed questions with single and multiple answer boxes, and open-ended questions with blank space provided. In constructing the questionnaire, the questions mainly focused on three subjects: design of a building rating system, space classification, and success criteria. In this work, only one questionnaire with 88 questions is used for all groups of experts. The questions were divided into three categories:

1. *Basic.* This section asks the experts for background information, e.g. field of expertise, working experience with people with disabilities.
2. *Design of a building rating system.* This section divides the building rating system into three categories, started from the big picture, the overview of the building rating system, space classification, and floor and building classification.

3. *Success criteria.* This section consists of 13 parts, describing sets of success criteria used in space classification, corresponding to the 13 spaces commonly found inside public buildings:

- Entrance space
- Foyer space
- Horizontal circulation space (e.g. passageway and corridor)
- Vertical circulation - Lift space
- Vertical circulation - Ramp space
- Vertical circulation - Stair space
- Sanitary - Ambulant disabled water closet space
- Sanitary - Accessible washroom space
- Sanitary - Bathroom and Shower space
- Bedroom space
- General spaces (e.g. office, living room, and other uncategorized space)
- Utility spaces (e.g. kitchen and storage)
- Hall and stadium spaces (e.g. hall, lecture hall, stadium, or theatre)

The experts used were based in the UK and in Thailand. Therefore, the questionnaire was created in English only, since most of the building design standards and guidelines are usually written with technical terms in English. The questionnaire was proofread, and enriched by suggestions in a pilot test.

3.4.2.5 Piloting and Testing

A pilot test is a small-scale field study used to evaluate feasibility, time, cost and effect size (Cummings et al., 2007) in order to improve the quality of a study design prior to a full-scale study. In this pilot, the questionnaire was tested by two developers, two accessibility researchers, and two interior designers. The procedure use in the pilot was the same as the full scale, using the paper-based questionnaire and later the face-to-face discussion. The results of the pilot test are discussed in Section 7.1.

3.4.2.6 Analysis of Expert Validation and Review

The analysis was tackled in two parts: an overview (by expert validation), and details (by expert review). First, the expert validation, the responses from all 15 experts were analysed for each category shown in Section 3.4.2.4. If there was disagreement among the group, the majority opinion was used for the final decision. For the expert review, all responses were organised in groups related to the categories shown in Section 7. The next step was to read all of the responses carefully and then code these responses into a 5-point Likert scale, where 1 is "Strongly disagree", 2 is "Disagree", 3 is "Neutral", 4 is "Agree", and 5 is "Strongly agree", using the system shown in Table 3.1.

Table 3.1: The coding system for agreement scales, quantifying qualitative data used in the analysis of the expert review

Scale	Coding	Criteria and Descriptions
1	Strongly disagree	Disagree; Proposed element is not sensible or workable in practice. The proposed element needs to be redesigned.
2	Disagree	Somewhat disagree; Some part of a proposed element does not seem to be sensible and workable in practice. Suggestions are made with what to be concerned and fixed for the proposed element.
3	Neutral	Neither agree or disagree
4	Agree	Agree but there is a room for improvements; The proposed element seems to be sensible and workable in practice. Suggestions are made for improving the proposed element.
5	Strongly agree	Agree; The proposed element is well-designed, sensible and workable in practice.

To analyse the experts' agreement, all responses were coded using the agreement scale and then averaged in order to see the general direction. A response of "Not applicable" (N/A) or "Cannot tell" were counted as "Neutral" for the analysis. Later, the proposed element is considered as Agree if the agreement scale is more than 3 "Agree".

3.4.3 Evaluation of Building Rating System

To complete the design of BRS shown in Figure 3.2, user evaluation is required. This was carried out with three focus groups of three experts in building risk assessment, to verify the usability of the system. The process involved site inspections of Building 53 (Mountbatten) at the University of Southampton, which was selected for this purpose.

Prior to holding the focus groups, the experts were asked to assess the accessibility for many types of space shown below. After that, the experts were asked to give opinions based on their user experience in using the BRS. To evaluate usability, System Usability

Scales (SUS) was used (Kortum & Bangor, 2013), all responses being converted into a 5-point Likert scale that ranging from 1 - *Strongly Disagree* to 5 - *Strongly Agree* (Bangor, Kortum, & Miller, 2009; Brooke, 2013).

- Main Foyer (Wide-open area)
- Seminar Room (Large, and movable space)
- Zepler Student Laboratory (Large, and fix space)
- Office (Small space)
- WCs - Accessible washroom
- WCs - Public toilets
- Horizontal Circulation (e.g. passageways and corridors)
- Vertical Circulation - Stairs
- Vertical Circulation - Lifts.

Analysis of the user evaluation was split into two parts: overview and detailed analysis as shown in Chapter 7.6. First, the overview analysis was done using SUS with adjective rating proposed by Bangor et al. (2009) while the detailed analysis was a question-by-question in-depth analysis, the results for each question being compared with the benchmark shown in Table G.57 (Appendix G), and feedback from the focus groups.

3.4.4 Ethical Approval

Prior to conducting the field study, ethical approval was sought and obtained from the University of Southampton Ethics Committee. The reference for the ethics approval is ERGO/FEPS/40754.

3.5 Summary

This chapter provided an overview of the research methodology and steps used to answer the research questions for the development of SRF. The advantages and disadvantages of qualitative, quantitative, and mixed methods, were discussed. In the methodology chosen, three phases were used, consisting of desk-based study, field study, and deployment, with rough outline included.

Section 3.3 detailed the research methodology that was used for problem confirmation and validation of the SRF, including the processes and characteristics of participants recruited to take part, the number of participants being chosen by power analysis. The questionnaire used for the data collection in both tasks, with both visually impaired and sighted people, was designed with five sections: *basic*, *behaviour and Indoor Navigation*, *unfamiliar spaces*, *obstacles and dangerous area*, and *accessibility and essential information*.

Section 3.4 detailed the research methodology used for validation and review of the BRS, including the process and characteristics of the experts recruited to take part. The 15 expert participants, five each were from the areas of research and development, accessibility, and building and interior design. The questionnaire used for the data collection comprised three sections: *basic*, *design of building rating system*, and *success criteria*. The BRS was evaluated for usability using System Usability Scales (SUS) as to assess how well the BRS can perform in practice.

The SRF was first created through the desk-based study (shown in Appendix A), and later validated and reviewed in the field study to produce the final version of SRF (Chapter 4). Finally, the SRS was deployed through the developed instrument BRS (Chapter 6).

Chapter 4

Spatial Representation Framework

This chapter describes the spatial representation framework (SRF) for indoor navigation by people with visual impairment that was developed from the review of literature and the study of indoor navigation behaviour. It is intended to help visually impaired people have freedom and confidence when navigating inside buildings and public spaces on their own. It provides a skeleton of essential information needed in order to build maps for indoor navigation systems for visually impaired people, autonomous systems, and robots. Section 4.1 shows the framework development process. In Section 4.2, main and sub-components of the framework are described with examples of information stored in each component. Section 4.2.1 shows the reference model used to define the component levels for the construction of indoor-based applications. The framework's components are later discussed with definitions and examples provided, especially the objects classification component.

4.1 Framework Development Process

This section describes the steps used to develop the SRF for indoor navigation by people with visual impairment. Figure 4.1 illustrates the three phases in the process: desk-based study, field study, and refine framework.

In the desk-based study, the spatial representation framework was created by a review of the relevant literature and state-of-the-art technologies. The problems discovered in the literature are: behaviour, navigation strategies, wayfinding, obstacle detection, and avoidance. This process resulted in 7 main components: *structural*, *fixed objects*, *rearrangeable objects*, *transient objects*, *sensor*, *path*, and *information*. Appendix A gives more detail about the design of spatial representation framework in the preliminary stage.

A field study was conducted to ensure that the SRF is good enough and deployable in a real situation. It comprised two tasks: problems confirmation and framework validation.

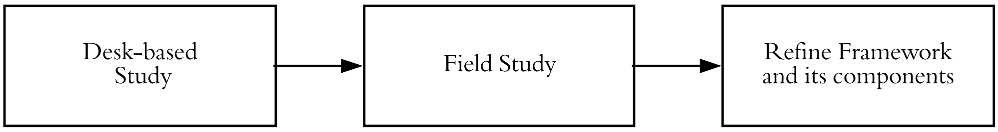


FIGURE 4.1: Development processes of the spatial representation framework

In both tasks, participants (visually impaired and sighted people) were recruited and given interviews and completed questionnaires. Chapter 3 has more detail about the research methodology. As a result, this process showed that problems discovered in the review of literature are correct, but identified some new issues. Section 5.7.1 gives detail of the findings in the problems confirmation task.

The finding of the framework validation task showed that all the components in the proposed version of the SRF were validated and confirmed for inclusion in the final version of the SRF. Since new issues were found in the problems confirmation teak, the SRF was refined with the addition of 4 components: *navigational cues*, *warning*, *profile*, and *state* components, and the removal of the information component. The final SRF is shown in Figure 4.2.

4.2 Spatial Representation Framework

This research aims to provide basic principles that can be used to promote indoor navigation by people with visual impairment, and used as a skeleton for further development, especially maps for indoor-based applications and systems such as: indoor navigation for people with disabilities, autonomous systems, and robots. Here is the final version of the SRF with details of each component. The framework has eleven components, eight of which are grouped as a multi-layered model and describe the buildings, two components are placed beside the multiple-layered model and act as metadata, while the last component is external information, e.g. weather and noise from outside the buildings.

Each of the layers represents a different purpose and are defined below.

1. **Structural** The bottommost layer represents the floor layout showing relationships between rooms and transition spaces (e.g. doors) for each floor inside the building, where each floor can be linked to another floor by the transition spaces (e.g. stairs, escalators, and lifts) in order to form the buildings in 3D. This also includes information about physical dimension, size, wall type, floor type, etc. This layer is compulsory as it provides information about the structure of the building.

2. **Fixed Objects** This component contains information about fixed objects permanently installed inside the buildings e.g. fixed furniture and transition objects like doors, stairs, escalators, and lifts. This component also encompasses

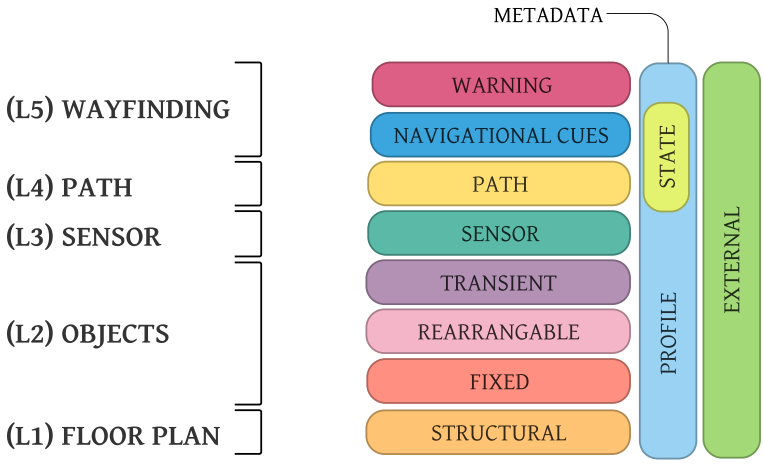


FIGURE 4.2: Spatial Representation Framework for Indoor Navigation by People with Visual Impairment

barriers that impact indoor navigation, such as drop-offs, curbs, events, and restricted areas (e.g. construction and renovation areas). This component provides information regarding landmarks, which is useful for navigation inside buildings full of unfamiliar configurations. A scaling method will be provided to classify the objects, examples of which are in Section 4.2.2.

3. **Rearrangeable Objects** This component contains information about objects that can be rearranged like furniture (e.g. table, chairs, waste bins) or other objects that remain in their position for a medium to long period of time, depending on a movability factor scaled in Figure 4.4. This component provides information about random objects, which are navigation barriers and thus obstacles. A scaling method will be provided to classify the objects, examples of which are in Section 4.2.2.

4. **Transient Objects** This component contains information about objects that can be rearranged, but last for a short period of time, e.g. self-moving objects like people, pets, autonomous systems, and robots. This component provides information about random objects that are navigation barriers and obstacles. This component is used to measure indoor traffic, detect objects, find an appropriate route. A scaling method will be provided to classify the objects, examples of which are in Section 4.2.2.

5. **Sensor** A special object that possesses the ability to detect events and send out information to the spaces for specific purposes, e.g. lighting, smoke detector, Wi-Fi, RFID, closed-circuit television (CCTV), camera, door switch sensor. This component contains information on sensors installed within the buildings. This component is useful for many applications and extensions beside visually impaired navigation such as indoor localisation and navigation, obstacle detection, and security and surveillance.

6. **Path** A component that contains information about the walkable area (e.g. hallways) and restricted area (e.g. Emergency Exit), enabling people with visual impairment to know which area and path are approved for walking. This component can be used as part of the route planning process for indoor navigation systems, and construction of accessible maps.

7. **Navigational cues** This component contains markers and information about the objects (e.g. edges and corners), areas (e.g. intersection), especially transition spaces e.g. stairs: stair width, tread width, riser height, and depth width. This information can be used as a navigational cue to help find the way more easily in a building full of unfamiliar configurations.

8. **Warning** This component contains warning markers and information about hazards, e.g. sharp edges, stairs and escalators, slippery surfaces, holes, drop-offs, and especially glass doors and automatic sliding doors. This component enables free mobility.

9. **Profile** A metadata component that contains a description of the areas and objects placed or installed inside buildings, including physical dimensions, sizes, wall type, etc. This component also includes general information about the building, e.g. building profile, pre-visit information.

10. **State** A sub-component of the Profile that contains information about the current state of the objects, especially transition spaces, e.g. doors, elevators, escalators, and travelators, e.g. door (open, closed), escalator (going up, going down), or lift (going up, going down, current floor).

11. **External** A component that contains sensory information that potentially impacts indoor navigation. such as light through windows, noise from rain, car horn, or outside construction sounds. This component is useful to people with visual impairment, especially those who are partially sighted and use light to detect orientation in the wayfinding process.

4.2.1 Reference Model

From the conceptual framework, shown in Figure 4.2, and the definition of components, the framework has been arranged as a reference model, in which indoor spatial information is represented by a collection of data and relationships mapping between layers, as shown in Figure 4.3. To visualise the buildings in 3D, the spatial representation is designed by first creating the floor plan layer (level 1). The objects layer combines components to become the second layer (level 2), which represents the information about the objects installed and placed in the building. The sensor layer was originally designed for indoor positioning systems, but it also provides information about lighting for people

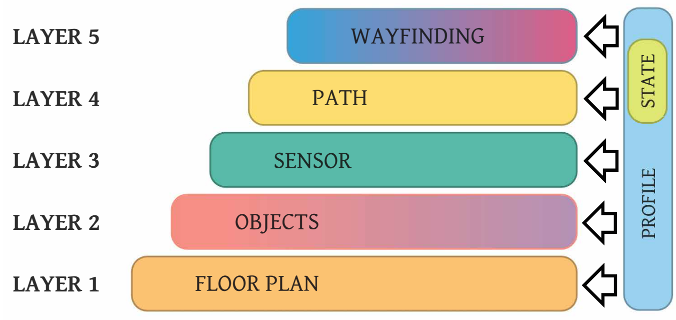


FIGURE 4.3: Reference Model for Spatial Representation Architecture

who have light perception, and other purposes such as cameras for obstacle detection. The path layer (level 4) provides information about walkable areas and paths, while the wayfinding layer (level 5) provides free mobility and warning information about hazards.

TABLE 4.1: Bottom-up design of the SRM and its potential applications

Level	**Description**	**Potential Applications**
L5: Wayfinding	Navigational cues and warning information	Indoor navigation system for disabled people, Interactive accessible map
L4: Path	Walkable areas and paths	Indoor navigation system for autonomous systems and robots, Indoor route planning
L3: Sensor	Camera, Wi-Fi, RFID, others	Indoor positioning system, Obstacle detection and avoidance, Security and surveillance system, Access control system
L2: Objects	Fixed, rearrangeable, and transient objects	Floor plan with interior, Spatial awareness, Accessible map
L1: Structural	Relationships between rooms, spaces, entrances	Floor plan, General indoor map

Table 4.1 shows how each layer comes into play with the others to support development. The lowest layer (L1) may be used to construct the floor plan of all floors in the building – the general indoor map. Including objects (L2), the floor plan now has interior information which can increase spatial awareness for people with visual impairment. Enhanced with sensor information (L3), applications can be extended, e.g. Camera: obstacle detection and avoidance, and Wi-Fi: indoor positioning and navigation systems. In the path layer (L4), information about the walkable area and paths satisfies the indoor navigation systems, and informs people with visual impairment which areas are approved for walking. Finally, including the wayfinding layer (L5), enables maps to be of use for people with disabilities, providing free mobility information.

4.2.2 Objects Classification

Before classifying the objects, four terminologies used to define the objects.

Object A representation of a physical object that can be anything that has a surface and is touchable. The objects can be split into three types based on their movability factor: fixed object, rearrangeable object, and transient object.

Super Object A collection of objects that collectively formed into one another object which is bigger than each one separately. For example, group of objects placed in the construction and event areas.

Transition Object An object that provide capacity to transfer objects from one state to another state e.g. escalators, travelators, and lifts.

Moving or Self-Moving Object An object with movability that can be moved by itself without external force e.g. people, animals, autonomous systems and robots.

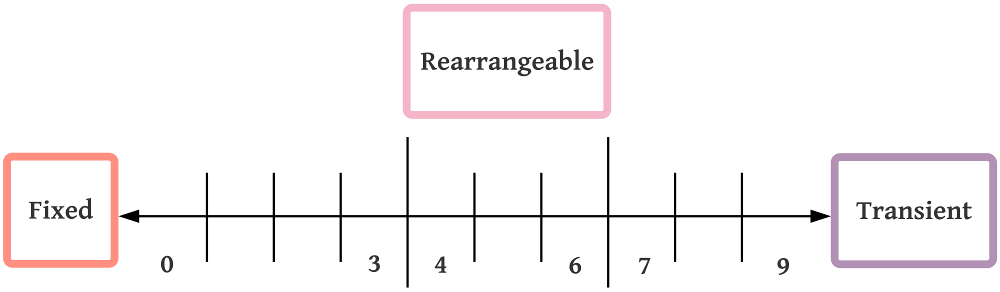


FIGURE 4.4: Objects Classification.

To classify the objects into three types: *fixed*, *rearrangeable*, and *transient*, a movability factor is used factor scaled in a range from 0 (fixed) to 9 (transient), shown in Table 4.2. The definitions of each type of object are given below, based on this scaling.

Fixed Objects Predictable objects installed or attached inside the building at any height (ground, body, or head level) for a long period of time, or permanently, such as floor-mounted furniture, wall-mounted furniture, stairs, escalators, travelators, lifts, and railings.

Rearrangeable Objects Random objects placed inside the building that can be rearranged, or remain in their position for a medium to long period of time. For example, furniture, electric appliances, portable things.

Transient Objects Random objects that remain in their position for a short period of time, and usually have self-moving ability, e.g. people, crowds, robots, autonomous systems, and robots.

TABLE 4.2: Classification of Objects: Scaling Definitions and examples

Types	**Scale**	**Definitions**	**Examples**
Fixed Objects	0	Permanently part of the building, cannot be changed	Stair, Sidewalk, Pavement Drop-off, Sloped floor, Kerb, Hole in the ground
	1	Installed in the building, impossible or hard to uninstall	Elevator, Escalator, Travelator, Fence
	2	Installed in the building, can be removable	Floor-mounted furniture, Wall-mounted furniture, Built-in furniture, Bathroom equipment (basin, shower bowl, toilet, urinal)
	3	Temporarily installed in the building, with time limit	Construction area, Building renovation, Events
Rearrangeable Objects	4	Large object that is difficult to reposition due to a physical appearance	Refrigerator, freezer (Family sized)
	5	Medium object that is sometime difficult to reposition	Table, Chair, Freezer, Small refrigerator, Personal Computer, Workstation, Office plant
	6	Small object that is easy to reposition or detachable	Litter bin, Rug, Portable Equipment, Fire extinguisher
Transient Objects	7	Unintentional or accidental objects	Wet floor, Litters
	8	Objects created by schedules	Cleaning area
	9	Self-moving objects	People, Pet Robots, Autonomous System

4.3 Summary

The problems found in a review of the literature, and problems found in the field study, provided input to detailed discussion of the findings, shown in Sections A.1 and 5.4. A framework was originally proposed based on the review of literature, shown in Appendix A, and validated by visually impaired people and sighted people (e.g. chaperones, O&M instructors, and a group of experts), see Section 5.7.2.

The definitive version of the SRF was developed, as shown in Section 4.2, consisting of eleven components categorised into five layers to give the reference model shown in Figure 4.3. Three additional components acted as description and metadata of objects placed inside buildings were used to compliment the layers.

The next chapter will analyse the findings of the field study. Many problems of indoor navigation by people with visual impairment have been found in unfamiliar spaces, which makes them afraid of visiting these spaces alone. The findings were later used to validate and to refine the spatial representation framework shown in this chapter.

Chapter 5

Field Study: Findings, Results, and Discussion

This chapter describes the findings and discussion of the field study. 30 visually impaired participants were interviewed and 15 sighted participants were asked to complete the questionnaires, following the methodology described in Section 3.3.2.

Section 5.1 shows the findings of the pilot which were used to improve the questions for the interviews with visually impaired people and the survey with sighted people. Section 5.2 describes characteristics of participants recruited for the field study, while Section 5.3 examines whether different conditions affected the participants' responses. Section 5.4, the problems confirmation task, the findings reveal that visually impaired people experience a lot of problems navigating inside unfamiliar spaces such as universities, hospitals, department stores, museums, and airports while Section 5.5 reports that all the factors proposed were validated and should be included in the SRF. In the discussion, Section 5.7 reports that five additional factors were found. These factors were used to refine the framework and are included in the validated version of SRF shown in Section 5.8.

5.1 Findings of the Pilot

During the pilot interviews, 4 participants were asked to respond while blindfolded thus acting as people with visual impairment. The results suggested that some revisions needed be made and some questions should be removed because it took around one hour for an interview. Further, some questions were too difficult to understand due to technical and unfamiliar terms. Revisions were therefore made to make the process clearer, and easier to understand by people who are not familiar with scientific terms and definitions.

5.2 Demographic

Two groups of people were recruited. The first 30 were those with visual impairment, as shown in Table 5.1. 10 of these were from the UK, and 20 from Thailand, randomly chosen with an even distribution of males and females. 10 participants self-reported as congenitally blind (CB), whereas 20 were adventitious blind (AB). 23 participants self-reported as severely sight impaired (SS) and blind, while 7 participants were sight impaired (partially sighted, PS).

The second group comprised 15 sighted participants who were experts working in following fields: (i) chaperones and orientation and mobility (O&M) instructors, (ii) developers and researchers in technical fields: human-computer interaction, accessibility, assistive technology, and interior design for elderly and disabled people, as shown in Table 5.2.

Table 5.1: Demographics of the people with visual impairment

ID	Visual condition	ID	Visual condition
P01	CB, SS, no usable vision	P16	AB, SS, some light perception
P02	AB, SS, some light perception	P17	AB, SS, some light perception
P03	CB, SS, no usable vision	P18	CB, SS, no usable vision
P04	AB, PS, burry vision	P19	AB, SS, some light perception
P05	AB, SS, gradual vision loss from age 6, low vision	P20	CB, SS on left eye, some light perception on right eye
P06	AB, PS, burry vision since 8 years	P21	AB, PS, Glaucoma age 54, burry vision
P07	CB, SS on right eye, and vision loss on left eye at age 6	P22	CB, SS, some light perception
P08	AB, SS, some light perception	P23	AB, PS, burry vision
P09	CB, SS, no usable vision	P24	AB, SS, some light perception
P10	AB, PS, burry vision	P25	AB, SS, some light perception
P11	AB, PS, gradual vision loss from age 4, low vision	P26	AB, SS age 16
P12	CB, SS, no usable vision	P27	PS, PS, AMD, gradual vision loss, cloudy vision
P13	AB, SS, gradual vision loss from age 4, no usable vision	P28	CB, SS on left eye, some light perception on right eye
P14	CB, SS, no usable vision	P29	AB, PS, AMD, gradual vision loss, cloudy vision
P15	AB, SS, gradual vision loss from age 10, no usable vision	P30	AB, SS, some light perception

AB Adventitious blindness
AMD Age-related Macular Degeneration
CB Congenital blindness
PS Partially Sighted Impairment
SS Severely Sighted Impairment

TABLE 5.2: Demographics of the experts

ID	EXP.	Expertise	ID	EXP.	Expertise
E01	31 years	O&M Instructor, care-giver	E09	8 years	Accessibility, HCI, speech technology
E02	17 years	O&M Instructor, care-giver	E10	3 years	Accessibility, HCI, speech technology
E03	4 years	O&M Instructor, care-giver	E11	5 years	Accessibility, people with disabilities
E04	7 years	O&M Instructor, care-giver	E12	5 years	Accessibility, people with disabilities
E05	26 years	O&M Instructor, care-giver	E13	5 years	Accessibility, people with disabilities
E06	8 years	O&M Instructor, care-giver	E14	4 years	Accessibility, people with disabilities
E07	32 years	O&M Instructor, care-giver	E15	4 years	Accessibility, Interior Design for
E08	7 years	Accessibility, HCI			

O&M Orientation and Mobility
HCI Human-computer Interaction

5.3 Difference in perspectives affected responses

Studies suggest that the development of spatial mapping differs between visually impaired and sighted people, as one is used to seeing the world but the other does not (Cattaneo & Vecchi, 2011), while another study reported that the congenital blind have an exceptional memorising ability compared to sighted people (Schinazi et al., 2016). These imply they may have a different perspective on spatial knowledge acquisition and spatial mapping that could affect the participants' responses in the field study.

Thus, it would be interesting to see whether or not the degree of impairment affects participants' responses, not only for the visually impaired group, but also for the experts. Therefore, a number of conditions were tested by repeated measures of one-way multivariate analysis of variance (MANOVA). The results are shown in Table Table 5.3 for the visually impaired group, and in Table 5.4 for the sighted group. Full statistical results can be found in Appendix D.1. The conditions were:

- Congenital blindness (CB, N=10) vs. Adventitious blindness (AB, N=20)
- Severely sighted impairment (SS, N=23) vs. Partially sighted impairment (PS, N=7)
- O&M instructor and care-giver (OMC, N=7) vs. Accessibility (ACC, N=8)

Table 5.3 shows that there was no statistically significant effects on the group of visually impaired people in both conditions: congenital blindness vs. adventitious blindness. Wilks' Lambda = 0.04, $F(28.00, 1.00) = 0.93$, $p = 0.692$, and severely sighted impairment vs. partially sighted impairment, Wilks' Lambda = 0.02, $F(28.00, 1.00) = 1.98$, $p = 0.517$. For sighted people, Table 5.4 suggests that there was also no statistically significant effect in different perspectives between O&M instructor and care-giver experts, and accessibility experts.

TABLE 5.3: How degree of visual impairment affected the responses

Effect		**Value**	***F***	**Hypothesis df**	**Error df**	***p***
CB vs. AB	Pillai's Trace	0.96	0.93	28.00	1.00	0.692
	Wilks' Lambda	0.04	0.93	28.00	1.00	0.692
	Hotelling's Trace	25.95	0.93	28.00	1.00	0.692
	Roy's Largest Root	25.95	0.93	28.00	1.00	0.692
SS vs. PS	Pillai's Trace	0.98	1.98	28.00	1.00	0.517
	Wilks' Lambda	0.02	1.98	28.00	1.00	0.517
	Hotelling's Trace	55.38	1.98	28.00	1.00	0.517
	Roy's Largest Root	55.38	1.98	28.00	1.00	0.517

TABLE 5.4: How different perspectives in sighted people affected the responses

Effect		**Value**	***F***	**Hypothesis df**	**Error df**	***p***
OMC vs. ACC	Pillai's Trace	0.99	9.31	13	1	0.252
	Wilks' Lambda	0.01	9.31	13	1	0.252
	Hotelling's Trace	121.07	9.31	13	1	0.252
	Roy's Largest Root	121.07	9.31	13	1	0.252

5.4 Indoor Navigation

In this task, five sections on indoor navigation in unfamiliar spaces had to be answered. First, Section 5.4.1 describes what common tools visually impaired people have used, including restrictions of the use of assistance in particular places. Section 5.4.2 discusses how visually impaired people estimate distance in unfamiliar spaces. Wayfinding strategies and how people find their orientation in such places are described in Section 5.4.3, while Section 5.4.4 discusses problems and challenges. Section 5.4.5 discusses obstacles and hazards.

5.4.1 Use of Assistance

Participants were asked if they had received O&M training or not, and what types of assistance they usually use for daily activities. 19 of the participants (63%) indicated that they received such training while 11 of the participants (34%) did not. Some of the latter gave reasons such as another physical challenge and age-related learning ability.

In Table 5.5, the chi-squared tests for independence indicated no significant association between groups of visually impaired and sighted people in Guide dog (χ^2 (4, 45) = 8.79, p = 0.067) and Sighted guide (χ^2 (5, 45) = 6.52, p = 0.259), but White cane (χ^2 (5, 45)

Table 5.5: Use of Assistance - Pearson Chi-Squared Tests

	Value	**df**	***p***
White cane	12.04	5	0.034*
Guide dog	8.79	4	0.067
Sighted guide	6.52	5	0.259
Tactile map	16.00	3	0.001*
N of Valid Cases	45		

* There were statistically significant associations between groups.

Table 5.6: Use of Assistance

			NEV	**OCC**	**OAM**	**OAW**	**FAW**	**EVD**	**Total**
White Cane	Visually Impaired	Count	4^a	9^a	1^a	4^a	7^a	5^a	30
		% within Groups	13.3%	30.0%	3.3%	13.3%	23.3%	16.7%	100.0%
	Sighted	Count	0^a	2^a	0^a	1^a	2^a	10^a	15
		% within Groups	0.0%	13.3%	0.0%	6.7%	13.3%	66.7%	100.0%
Guide dog	Visually Impaired	Count	26^b	2^b	1^b	0^b	0^b	1^b	30
		% within Groups	86.7%	6.7%	3.3%	0.0%	0.0%	3.3%	100.0%
	Sighted	Count	8^b	5^b	0^b	1^b	0^b	1^b	15
		% within Groups	53.3%	33.3%	0.0%	6.7%	0.0%	6.7%	100.0%
Sighted guide	Visually Impaired	Count	3^c	3^c	0^c	2^c	10^c	12^c	30
		% within Groups	10.0%	10.0%	0.0%	6.7%	33.3%	40.0%	100.0%
	Sighted	Count	0^c	4^c	1^c	2^c	3^c	5^c	15
		% within Groups	0.0%	26.7%	6.7%	13.3%	20.0%	33.3%	100.0%
Tactile map	Visually Impaired	Count	26^d	3b	0^d	1a, b	0a, b	0^d	30
		% within Groups	86.7%	10.0%	0.0%	3.3%	0.0%	0.0%	100.0%
	Sighted	Count	5^d	9b	0^d	0a, b	1a, b	0^d	15
		% within Groups	33.3%	60.0%	0.0%	0.0%	6.7%	0.0%	100.0%

Headings are abbreviations for NEV: *Never*, OCC: *Occasionally*, OAM: *Once a month*, OAW: *Once a week*, FAW: *Few a week* and EVD: *Every day*

[a] Each subscript letter denotes a subset of White cane categories whose column proportions do not differ significantly from each other at the 0.05 level.

[b] Each subscript letter denotes a subset of Guide dog categories whose column proportions do not differ significantly from each other at the 0.05 level.

[c] Each subscript letter denotes a subset of Sighted guide categories whose column proportions do not differ significantly from each other at the 0.05 level.

[d] Each subscript letter denotes a subset of Tactile map categories whose column proportions do not differ significantly from each other at the 0.05 level.

= 12.04, $p = 0.034$) and Tactile map (χ^2 (3, 45) = 16.00, $p = 0.001$) found associations between groups.

All assistances in Table 5.7 were tested using a z-test, comparing column proportions with suitably adjusted p-values and the Bonferroni correction[23], to find which pairs in each assistance were significant. Despite the significances found in White cane and Tactile

[23] Bonferroni correction is an adjustment made to *p*-values when several dependent or independent statistical tests are being performed simultaneously on a single data set. It is used to reduce the chances of obtaining false-positive results (type I errors) when multiple comparison tests are performed on a single set of data (Dunn, 1961).

map, the results showed there were no significant differences in pairs from both White cane and Tactile map at the 0.05 level. The detailed chi-squared tests can be found in Appendix D.2.

Table 5.7 shows how frequently assistance has been used to navigate indoors, where the results were used to calculate scores for how often participants used it overall. The scores were calculated using the Borda Scoring Rule, where every day = 5, few times a week = 4, once a week = 3, once a month = 2, occasionally = 1, and never = 0 (Shoham & Leyton-Brown, 2008). The result showed that the white cane and a sighted guide were the most promising assistance used to perform daily activities, with the preference for a sighted guide as the first choice. This contradicts the common belief of sighted people that the white cane is preferred.

TABLE 5.7: Different perspectives on assistance usages between visually impaired and sighted people using Borda Scoring Rule

Type of Assistance	**Visually Impaired People**	**Sighted People**
Sighted Guide	109	49
White Cane	76	63
Tactile Map	9	13
Guide Dog	6	13

People with visual impairment identified some challenges the white cane cannot overcome such as detecting slippery floor caused by water or fabric dropped on the floor, as well as body-level and head-level obstacles that they run into while inside buildings. Stepping down from a pavement is especially challenging, and some head-level obstacles collide with their heads and they fall to the floor. A sighted guide is the most popular assistance ahead of a white cane, while a guide dog and tactile map were not chosen for a number of reasons. Most of the participants chose the sighted guide as a first option because the white cane is no help when navigating in buildings full of unfamiliar features. They need to be accompanied by a sighted guide once, in order to learn and familiarise themselves with the spaces before independent navigation with a white cane or other assistance.

A guide dog is not affordable due to the cost, which is up to £27,300 for the special training until it is ready for people with visual impairment (The Guide Dogs for the Blind Association (UK), 2016) , while some countries have no guide dog training centre, e.g. Thailand. In the UK, guide dogs are offered to people with visual impairment cost-free, responsibility being borne by the guide dog organization. However, to use a guide dog in unfamiliar spaces it needs to be trained beforehand to memorise the standard and safe route, which usually takes 2-3 or more times walking through the building until it can remember the route. This can be undertaken by the guide dog trainers, but one participant said that a guide dog is not permitted in Islamic religious spaces because the dog is used for hunting, not as a pet or helper.

Similarly, a tactile map is not widely used since it is not so easy to use, and to interpret its contents. Most said that the tactile map required a lot of effort to understand the contents provided. In this study, 4 (13%) participants had used a tactile map to find their way to a destination. 2 participants had successfully reached the destination, while the other 2 did not as the content provided was confusing and non-standard which led to miscalculating the distance.

5.4.2 Distance Estimation

The chi-squared test for independence suggested there was no association between the groups of visually impaired people and sighted people, $\chi^2(4, 45) = 4.56$, $p = 0.336$ as shown in Table 5.8.

TABLE 5.8: Distance Estimation - Pearson Chi-Squared Tests

	Value	**df**	***p***
Pearson Chi-Square	4.56	4	0.336
N of Valid Cases	45		

TABLE 5.9: Distance Estimation

		Can't estimate	**Footsteps**	**Length units**	**Time**	**Others**	**Total**
Visually Impaired	Count	3^a	9^a	1^a	4^a	13^a	30
	% within Groups	10.0%	30.0%	3.3%	13.3%	43.3%	100.0%
Sighted	Count	0^a	7^a	1^a	0^a	7^a	15
	% within Groups	0.0%	46.7%	6.7%	0.0%	46.7%	100.0%

[*] Each subscript letter denotes a subset of Distance Estimation categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table 5.9 shows distance estimation strategies in both familiar and unfamiliar spaces by a group of visually impaired people and a group of sighted people. The sighted suggested walking in the unfamiliar spaces, while people with visual impairment do not know the features inside the spaces, so a strategy of counting footsteps is appropriate instead of the use of landmarks. Those with visual impairment usually employ a combination of strategies instead of just one. For instance, about half of them rely on their sense and feeling, focusing on the use of environment information to estimate distance, e.g. smell, light, floor texture, and landmarks.

Not all of the participants are able to estimate distance. Some people cannot estimate distance at all, especially those who were born blind, and have never seen the world. People with visual impairment also suggested that counting footsteps is sometimes difficult and takes a lot of effort in the mind, which is easily distracted if they are walking into obstacles (e.g. furniture and landmarks), or into people, especially in spaces full of unfamiliar features and full of crowds and noise.

Two participants, confident in navigating in familiar spaces, said that some visually impaired people have employed a combination of strategies for navigation instead of using one particular strategy. For example, one has simultaneously used their sense and feeling while counting footsteps during indoor navigation. Another used a timing strategy together with their sense and feeling. For unfamiliar spaces, however, people with visual impairment usually rely on a sighted guide and landmark and environment information.

5.4.3 Wayfinding and Orientation

This section explores the problems that visually impaired people face in wayfinding and orientation when travelling in unfamiliar spaces. Previous works in the literature showed that most navigation problems in unfamiliar spaces resolve into three challenges: find the current location, find the way to a destination, and find and maintain orientation. This suggestes what kind of information people are looking for when entering unfamiliar spaces.

TABLE 5.10: Wayfinding - Pearson Chi-Squared Tests

	Value	**df**	***p***
Find Location	3.82	5	0.576
Find Way to Destination	8.58	3	0.035*
Find Orientation	7.95	6	0.242
Confusing information	1.18	1	0.277
N of Valid Cases	45		

* There were statistically significant associations between groups.

In Table 5.10 shows there was a significant association between the groups in Finding Way to Destination, $\chi^2(3, 45) = 8.58$, $p = 0.035$. Table 5.11 shows there was a difference in mixed method (MXM) between both groups, where only 2 (6.7%) responses were from visually impaired people, and 6 (40%) responses came from sighted people. Despite that, there was no statistically significant difference between them in the category as shown in Table 5.11. Detailed statistics for chi-squared can be seen in Appendix D.4 and D.5.

For finding the current location, both visually impaired people and sighted people similarly mentioned that participants usually estimate where they are, using three different sources: sighted guide, landmarks, and mixture of methods (or strategies), while using a smartphone is rare due to its limitation and accuracy of estimating location indoors. On the other hand, to navigate to the destination, people asked a sighted guide to take them there, or asked for instructions and walked themselves using three simultaneous

Table 5.11: Wayfinding

			SIP	LDM	FLT	ENV	SNF	OTH	MXM	Total
Find Location	Visually Impaired	Count	11^a	9^a	3^a	1^a	0^a	1^a	5^a	30
		% within Groups	36.7%	30.0%	10.0%	3.3%	0.0%	3.3%	16.7%	100.0%
	Sighted	Count	6^a	4^a	0^a	0^a	0^a	0^a	5^a	15
		% within Groups	40.0%	26.7%	0.0%	0.0%	0.0%	0.0%	33.3%	100.0%
Find Way to Destination	Visually Impaired	Count	21^b	3^b	4^b	0^b	0^b	0^b	2^b	30
		% within Groups	70.0%	10.0%	13.3%	0.0%	0.0%	0.0%	6.7%	100.0%
	Sighted	Count	8^b	0^b	1^b	0^b	0^b	0^b	6^b	15
		% within Groups	53.3%	0.0%	6.7%	0.0%	0.0%	0.0%	40.0%	100.0%
Find Orientation	Visually Impaired	Count	12^c	8^c	0^c	4^c	1^c	1^c	4^c	30
		% within Groups	40.0%	26.7%	0.0%	13.3%	3.3%	3.3%	13.3%	100.0%
	Sighted	Count	3^c	2^c	1^c	2^c	0^c	1^c	6^c	15
		% within Groups	20.0%	13.3%	6.7%	13.3%	0.0%	6.7%	40.0%	100.0%

Headings are abbreviations for SIP: *Sighted people*, LDM: *Landmarks*, FLT: *Floor Texture*, ENV: *Surrounding environment*, SNF: *Sense and Feeling*, OTH: *Other* and MXM: *Mixed methods*
[a] Each subscript letter denotes a subset of Wayfinding: Find Location categories whose column proportions do not differ significantly from each other at the 0.05 level.
[b] Each subscript letter denotes a subset of Wayfinding: Find Way to Destination categories whose column proportions do not differ significantly from each other at the 0.05 level.
[c] Each subscript letter denotes a subset of Wayfinding: Find Orientation categories whose column proportions do not differ significantly from each other at the 0.05 level.

clues (mixed methods): floor texture, environment cues, and landmarks. However, most visually impaired participants suggested that it is very difficult to use the mixed method due to unfamiliarity of spaces. Similarly, one of the participants, who used a guide dog, said that finding the way to a destination in unfamiliar spaces is impossible if the dog has not been trained beforehand. Furthermore, it takes three to five repetitions for the dog to remember the standard and safe way, which is performed by guide dog trainers from the guide dog organisation. Thus, at the end, sighted people is still preferred in this case as both groups participants

For orientation, many sources have been used to estimate their orientation while visiting unfamiliar spaces and buildings as indicated in both groups of participants' results. However, it is still the case due to unfamiliarity of spaces. 12 (40%) participants preferred using sighted people, which contradicted what the sighted participants said about visually impaired people being able to use the mixed methods to estimate their orientation during the visit. Based on the findings from the interviews, visually impaired people usually get confused by asking local people or a sighted guide. Since they are unfamiliar with the space, visually impaired people are not able to use any source of information in the area, e.g. landmarks on which the sighted usually rely, in order to estimate their location and orientation. One participant said that to find his orientation while navigating in his home, he has drawn an image of the relationships between each landmark and other landmarks, while another one has employed echolocation in wayfinding to detect her orientation.

TABLE 5.12: Miscommunication

			No	Yes	Total
Confusing Information	Visually Impaired	Count	13^a	17^a	30
		% within Groups	43.3%	56.7%	100.0%
	Sighted	Count	4^a	11^a	15
		% within Groups	26.7%	73.3%	100.0%

* Each subscript letter denotes a subset of Help: Confusing Information categories whose column proportions do not differ significantly from each other at the 0.05 level.

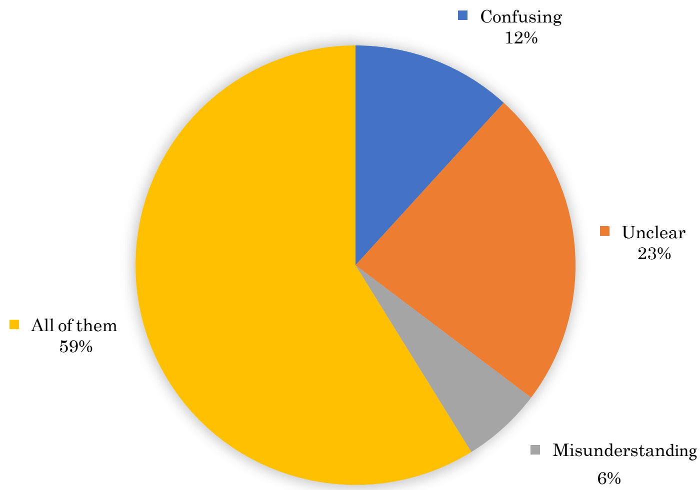


FIGURE 5.1: Miscommunication Survey

To find the way to the destination, in Table 5.12, 17 of the visually impaired participants (57%) agreed that they suffered from asking for instruction from a sighted guide or local people. Figure 5.1 showed the number of reasons given by the participants who have experienced miscommunication: 23% unclear, 12% confusing, and 6% misunderstanding information, while 59% of the participants have experienced all of them while visiting unfamiliar spaces.

These categories of unclear, confusing, and misunderstanding, are defined below.

Unclear The information is lacking in detail which a visually impaired person is not able to imagine or draw a picture in the mind.

Confusing This could be the result of poor use of language, and lack of situation awareness. For example, go to the right hand side, but it is to the left hand side of the visually impaired person.

Ambiguous (and **Misunderstanding**), information can have more than one meaning which can make it difficult for a visually impaired person to know exactly what was meant.

5.4.4 Unfamiliar Spaces

This section discusses the level of difficulty of, and the level of confidence required in, unfamiliar spaces, e.g. university, hospital, department store, museum, and airport.

Table 5.13: Unfamiliar Spaces: Pearson Chi-Squared Tests

	Value	**df**	***p***
Difficulty: University	5.58	2	0.061
Difficulty: Hospital	0.52	2	0.773
Difficulty: Department Store	2.93	2	0.231
Difficulty: Museum	1.39	2	0.498
Difficulty: Airport	7.66	2	0.022*
Confidence: Wide-open	0.08	1	0.771
Confidence: Hallway	0.45	1	0.502
Confidence: Room	7.31	2	0.026*
Confidence: Large Room	4.22	2	0.121
N of Valid Cases	45		

* There were statistically significant associations between groups.

The chi-squared tests of independence in Table 5.13 showed there were associations in Difficulty: Airport ($\chi^2(2, 45) = 7.66$, $p = 0.022$) and Confidence: Room ($\chi^2(2, 45) = 7.31$, $p = 0.026$). There were no significant differences from both contingency tables for difference and confidence shown in Tables 5.14 and 5.15, respectively. More information about the chi-squared tests for difficulty in space can be found in Appendix D.6, while confidence in spaces is shown in Appendix D.7.

The results show that most participants (up to 70%) have not usually visited such venues due to the physical challenges, where they need assistance from a sighted guide or a local person. Most participants in the survey agreed that navigating inside the buildings listed in Table 5.14 was too difficult by themselves for many reasons, discussed below by building.

TABLE 5.14: Survey of Unfamiliar Spaces: Difficulty

			Easy	**Medium**	**Hard**	**Total**
University	Visually Impaired	Count	3^{a}	9^{a}	18^{a}	30
		% within Groups	10.0%	30.0%	60.0%	100.0%
	Sighted	Count	1^{a}	10^{a}	4^{a}	15
		% within Groups	6.7%	66.7%	26.7%	100.0%
Hospital	Visually Impaired	Count	1^{b}	8^{b}	21^{b}	30
		% within Groups	3.3%	26.7%	70.0%	100.0%
	Sighted	Count	0^{b}	4^{b}	11^{b}	15
		% within Groups	0.0%	26.7%	73.3%	100.0%
Department Store	Visually Impaired	Count	3^{c}	9^{c}	18^{c}	30
		% within Groups	10.0%	30.0%	60.0%	100.0%
	Sighted	Count	2^{c}	8^{c}	5^{c}	15
		% within Groups	13.3%	53.3%	33.3%	100.0%
Museum	Visually Impaired	Count	2^{d}	7^{d}	21^{d}	30
		% within Groups	6.7%	23.3%	70.0%	100.0%
	Sighted	Count	1^{d}	6^{d}	8^{d}	15
		% within Groups	6.7%	40.0%	53.3%	100.0%
Airport	Visually Impaired	Count	$2^{e,f}$	7^{f}	21^{e}	30
		% within Groups	6.7%	23.3%	70.0%	100.0%
	Sighted	Count	$2^{e,f}$	9^{f}	4^{e}	15
		% within Groups	13.3%	60.0%	26.7%	100.0%

[a] Each subscript letter denotes a subset of Difficulty: University categories whose column proportions do not differ significantly from each other at the 0.05 level.
[b] Each subscript letter denotes a subset of Difficulty: Hospital categories whose column proportions do not differ significantly from each other at the 0.05 level.
[c] Each subscript letter denotes a subset of Difficulty: Department Store categories whose column proportions do not differ significantly from each other at the 0.05 level.
[d] Each subscript letter denotes a subset of Difficulty: Museum categories whose column proportions do not differ significantly from each other at the 0.05 level.
[e,f] Each subscript letter denotes a subset of Difficulty: Airport categories whose column proportions do not differ significantly from each other at the 0.05 level.

Universities, Colleges Complex and medium to large buildings.

Most participants aged between 18-29 said that navigating within the buildings of colleges and universities is either medium or hard, depending on the size of population inside the buildings, and the type of building. For example, engineering buildings are usually complex and have a lot of engineering stuff and furniture, which are usually relocatable and able to cause them any harm.

Preferred Solutions:

- Ask for assistance from sighted guide, e.g. receptionist.
- Ask sighted guide/friend/partner to accompany them.
- Put Braille on the door labels or audio-feedback door labels.
- Install tactile pavement.

Hospitals, Public Healthcare

Busy, noisy, complex and large sized buildings.

Up to 22 of the participants (73%) agreed that walking inside a hospital is very difficult due to the size of population, e.g. patients, nurses, doctors, and visitors, and a lot of obstacles, e.g. hospital beds and furniture. Most participants were distracted by the noise and the many obstacles surrounding them, which therefore made them lose their way, and also lose orientation since they cannot use any landmark and environment information.

Preferred Solutions:

- Arrange a hospital service to take them to hospital, and take them back home.
- Ask sighted guide/friend/partner to accompany them.
- Ask for assistance at Reception when travelling alone.
- Install tactile pavement.

Shopping Malls, Department Stores, Supermarkets

Shopping Mall: Busy, large, wide-open and crowded buildings.
Department Store: Busy, large, but well-organized buildings.
Supermarket: Small to medium buildings

Even though the buildings are well-structured, participants still found it difficult to walk by themselves. 18 of them (60%) agreed that shopping is challenging due to the obstacles, e.g. people and trolleys, and problems in reading information, e.g. price and product name. Most shops do not provide any accessibility information on the label of the products, e.g. Braille or audio feedback, but some, like medicine, are embossed with Braille. This is useful, but Braille cannot be put on every package due to its limitation and cost. As a result, people with visual impairment cannot find what they are looking for.

Preferred Solutions:

- Ask for assistance from shop staff.
- Ask sighted guide/friend/partner to accompany them.
- Put Braille on product packaging.

- Put Braille on front of shelf informing what products are placed on the shelf.
- Provide audio feedback on the shelf or a machine to detect what the product is.

Museums, Exhibitions

Complex, well-organised and medium to large buildings.

This type of building is usually full of exhibitions, e.g. antique statues or paintings, which are valuable. 22 of the participants (73%) said that they need to be careful when walking inside this type of building since they could damage the exhibits. The signage cannot be seen or read. To prevent physical contact, most buildings usually set up a coloured line (on the floor) or a rope to indicate that the area behind the line is prohibited. This can be a problem since visually impaired cannot see the line when walking in a museum. Participants suggested a rope, edge, and handrail are useful, possibly, illuminated which provides good contrast for partially sighted people. A few participants mentioned that they sometimes used tactile pavement to help them navigate inside museums.

Some exhibitions provide audio-feedback devices for the contents, e.g. handheld from the Reception, or audio-contents at the exhibition.

Preferred Solutions:

- Ask sighted guide/friend/partner) to accompany then.
- Provide audio-feedback (handheld) devices at the exhibitions or Reception.
- Install tactile pavement on the permitted area.
- Provide tactile maps for blind to let them learn before navigating inside the museum.

Airports

Busy, noisy, complex and large buildings. Some areas are wide-open.

These buildings are typically large and full of people walking around, and airport furniture, e.g. check-in counters and seating, which are all counted as obstacles (moving to fixed). Most participants (73%) said that walking inside an airport alone is very difficult, since they are often bumping into people. However, noise is also an obstacle, making them lose their orientation while navigating indoors. Walking in the wide-open areas is still difficult as it makes it easier to get lost, since they cannot find landmarks in the noisy and busy environment.

To reach the Gate is still difficult due the complexity of the buildings and long distances they need to walk, although they can request support services. Furthermore, escalators must be used, which most people with visual impairment are afraid of because they do not know where the steps are, and the edge of the steps is not high contrast. This case is seriously dangerous in case they trip and fall, which can endanger their life.

Preferred Solutions:

- Ask for support services at airports to guide them through check-in, baggage check, until they are on-board. However, this request has to be made at least 48 hours beforehand.
- Ask for assistance to take them to the Gate by using the special routes for VIP and disabled people, or electric vehicles for people with disabilities.
- Install tactile pavement for all routes in the airport.

The participants also suggested a further four types of buildings that they usually visit for daily activities: train stations, libraries, canteens/cafeterias, and auditoriums/halls.

Train Stations Noisy, busy, small to medium buildings, and dangerous spaces.

Two participants had problems when they visited train stations. The first is noise that distracts them a lot while they attempt to find their orientation and gather train information. In this type of building it is hard to find a landmark where a crowd of people gather in the day time. The second problem is gap between the trains and the platforms. All the partially sighted participants said that they are afraid of stepping up to the train because they cannot find the edge, even though it is usually indicated in yellow colour with high contrast.

Preferred Solutions:

- People with visual impairment can request staff trained to help special needs and disabled people, but it need to be arranged in advance.
- Ask sighted guide/friend/partner) to accompany them.

Libraries Well-organized, busy, and small to medium buildings, but too silent.

This type of building is usually silent and full of furniture, e.g. chairs, tables, bookshelves, but well-organised. Most partially sighted participants said that it is very difficult to find a book themselves due to blurry vision which requires using a magnifying glass or device in order to identify the name of the book. Most books do not have Braille embossed on their covers. In Thailand, most of the libraries do not have any Braille books. Looking for books on your own becomes impossible. One participant said that she always accompanies somebody to the library to find the book required.

Likewise, all the partially sighted participants said that some libraries have automatic sliding door systems installed at the entrance or elsewhere. This type of door usually has no any warning signs saying that it is glass and transparent. This could be a problem to people who are partially sighted because they cannot distinguish between the door and empty space. Some buildings, on the other hand, have put warning label on the doors, but can be hardly seen because it is not sufficiently high contrast. In addition, this type of door sometimes does not work due to some technical difficulty, e.g. sensors or mechanical issues, and could harm its users.

Preferred Solutions:

- Ask sighted guide/friend/partner) to accompany them.
- Put Braille on the bookshelves.
- Put illuminated safety or warning labels on every transition object, e.g. door, stairs, escalator, travelator.

Canteens, Cafeteria

Canteens and cafeterias are usually filled with tables and chairs which can be relocatable within the space. This problem sometimes affects visually impaired when visiting, depending on the number of people in the area. For example, lunch time at the universities and shopping centres are usually filled with crowds and noise.

Preferred Solutions:

- Ask sighted guide/friend/partner) to accompany them.
- Use white cane to find the way.

Auditoriums, Stadiums, Concerts, Theaters, Halls

Busy, large buildings.

Walking inside this type of building is sometimes difficult, depending on situations, events and number of people. One participant said that it was very hard, when she attended the concert, to find her seat even though accompanied by friends. Also, this type of building often does not usually provide any labelling and accessibility for disabled people.

Preferred Solutions:

- Ask sighted guide/friend/partner to accompany them.
- Put Braille on every seat.
- Adjust the vibrancy and luminance contrast of the seat label.

There are four types of space inside buildings and public spaces whose difficulty in navigating need to be considered separately: wide-open area, hallway, small room, and large room.

Table 5.15 shows that 21 to 26 of the participants (70-87%) said that they are not confident in navigating through wide-open areas, hallways and large rooms, as it is too difficult to navigate independently. Most participants got lost usually while just standing or navigating through wide-open areas. Most said that there are not many

Table 5.15: Unfamiliar Spaces: Confidence

			No	**Not sure, depending**[+]	**Yes**	**Total**
Wide-open	Visually Impaired	Count	25^{a}	0^{a}	5^{a}	30
		% within Groups	83.3%	0.0%	16.7%	100.0%
	Sighted	Count	13^{a}	0^{a}	2^{a}	15
		% within Groups	86.7%	0.0%	13.3%	100.0%
Hallway	Visually Impaired	Count	21^{b}	0^{b}	9^{b}	30
		% within Groups	70.0%	0.0%	30.0%	100.0%
	Sighted	Count	9^{b}	0^{b}	6^{b}	15
		% within Groups	60.0%	0.0%	40.0%	100.0%
Room	Visually Impaired	Count	15^{c}	0^{d}	$15^{c,d}$	30
		% within Groups	50.0%	0.0%	50.0%	100.0%
	Sighted	Count	4^{c}	3^{d}	$8^{c,d}$	15
		% within Groups	26.7%	20.0%	53.3%	100.0%
Large Room	Visually Impaired	Count	26^{e}	0^{e}	4^{e}	30
		% within Groups	86.7%	0.0%	13.3%	100.0%
	Sighted	Count	11^{e}	2^{e}	2^{e}	15
		% within Groups	73.3%	13.3%	13.3%	100.0%

[+] Depending on environment surrounding participants.
[a] Each subscript letter denotes a subset of Confidence: Wide-open categories whose column proportions do not differ significantly from each other at the 0.05 level.
[b] Each subscript letter denotes a subset of Confidence: Hallway categories whose column proportions do not differ significantly from each other at the 0.05 level.
[c,d] Each subscript letter denotes a subset of Confidence: Room categories whose column proportions do not differ significantly from each other at the 0.05 level.
[e] Each subscript letter denotes a subset of Confidence: Large Room categories whose column proportions do not differ significantly from each other at the 0.05 level.

landmarks they can use to help them detect their orientation, such as wall, door, curb, edge, or pavement. With noise and people walking about, a lot of distractions to visually impaired people are created.

Large room refers to auditoriums, stadiums, concerts, theatres, and halls. Up to 26 of the participants (87%) said that large rooms are usually full of (auditorium) chairs and tables, and hallways are too wide to navigate by themselves. The problem is that, when they do attend events, e.g. concerts, movie theatres, or conferences, they could not find their seat as it has no Braille indication. As with stairs where tread depth and rise height are not standard, the dimension of chairs is not standard or the offset space between each row in the seating area.

For hallways and corridors, some of the participants are confident (30%) in navigating them, while others are not (70%) because some hallways and corridors are too wide, and that makes them afraid of walking alone. When they tried to walk along the wall, there was furniture installed in the space, and obstacles attached on the wall, but too high to be detected by the white cane, e.g. wall-mounted telephone and fire extinguisher. Two participants suggested that some visually impaired people have used the edge of a door to detect their orientation in order to find their way. However, this edge is usually sharp and sometimes harm people encountering it.

For the small rooms, half of the participants said that they had a lot of confidence, since it is small and they can find landmarks easier than other types of space, even though the settings are changing all the time. The other half countered that it is still difficult to navigate these spaces if they are not familiar with them. This situation is similar to walking in museums. They are afraid that they could damage things inside the room.

5.4.5 Obstacles and Hazards in Indoor Navigation

Obstacles and barriers are something that people with visual impairment face every day. Most participants reported being hit by obstacles that can cause them lose their body-balance and orientation, which is the most important while navigating.

The chi-squared tests of independence in Table 5.16 reported there was an association in Noise, $\chi^2(4, 45) = 9.97$, $p = 0.051$, between the visually impaired people and sighted people, The contingency table, however, showed there was no significant difference in Noise in Table 5.17. Detailed chi-squared tests can be found in Appendix D.8

Table 5.17 shows how often most visually impaired people experience hitting various obstacles. It is clear that noise is the most impact factor they face, while silence is the least. In a wide-open area, too much noise creates a lot of distraction, which results in a loss of orientation. This situation usually happens when the space is full of crowds,

TABLE 5.16: Obstacles and Hazards in Indoor Navigation: Pearson Chi-Squared Tests

	Value	**df**	***p***
Ground Obstacle	4.52	4	0.340
Body Obstacle	2.70	4	0.609
Head Obstacle	2.87	4	0.579
Noise	9.97	4	0.041*
Silence	1.41	3	0.704
Light	0.55	4	0.969
Moving Obstacle	2.87	4	0.580
N of Valid Cases	45		

* There were statistically significant associations between groups.

e.g. wide-open area in a department store. On the other hand, a too quiet space tends to panic people with visual impairment.

They may think that the direction they are walking in is wrong. This situation is serious. People may end up injured if they are walking inside a building where some area is being renovated, and warning notices are not provided. Most participants said that the majority of obstacles they hit are at body-level and head-level, e.g. wall-mounted furniture and objects, and hanging labels, since they cannot detect them with a white cane or a guide dog, which are only able to detect ground-level obstacles. In addition, the white cane cannot detect some slippery floor hazards, especially a wet floor or the objects that make the floor slipperier when dropped on the floor, e.g. fabric. However, moving obstacles, e.g. people and trolleys, were also mentioned as the obstacles that up to 70% of people with visual impairment face.

This study also found that light is useful and important to partially sighted people. People have used the light as a helper to detect distance and orientation while navigating inside buildings. However, in some areas, if the light is too bright and illuminates the eyes, it causes temporary blindness.

Table 5.17: Obstacles and Hazards in Indoor Navigation

			Never	Rare	Sometimes	Often	Always	Total
Ground Obstacle	Visually Impaired	Count	4^a	3^a	8^a	12^a	3^a	30
		% within Groups	13.3%	10.0%	26.7%	40.0%	10.0%	100.0%
	Sighted	Count	1^a	1^a	6^a	7^a	0^a	15
		% within Groups	6.7%	6.7%	40.0%	46.7%	0.0%	100.0%
Body Obstacle	Visually Impaired	Count	4^b	3^b	8^b	12^b	3^b	30
		% within Groups	13.3%	10.0%	26.7%	40.0%	10.0%	100.0%
	Sighted	Count	1^b	1^b	6^b	7^b	0^b	15
		% within Groups	6.7%	6.7%	40.0%	46.7%	0.0%	100.0%
Head Obstacle	Visually Impaired	Count	6^c	5^c	6^c	11^c	2^c	30
		% within Groups	20.0%	16.7%	20.0%	36.7%	6.7%	100.0%
	Sighted	Count	1^c	4^c	4^c	6^c	0^c	15
		% within Groups	6.7%	26.7%	26.7%	40.0%	0.0%	100.0%
Noise	Visually Impaired	Count	7^d	2^d	7^d	14^d	0^d	30
		% within Groups	23.3%	6.7%	23.3%	46.7%	0.0%	100.0%
	Sighted	Count	2^d	0^d	4^d	5^d	4^d	15
		% within Groups	13.3%	0.0%	26.7%	33.3%	26.7%	100.0%
Silence	Visually Impaired	Count	12^e	5^e	6^e	7^e	0^e	30
		% within Groups	40.0%	16.7%	20.0%	23.3%	0.0%	100.0%
	Sighted	Count	5^e	3^e	5^e	2^e	0^e	15
		% within Groups	33.3%	20.0%	33.3%	13.3%	0.0%	100.0%
Light	Visually Impaired	Count	10^f	4^f	8^f	7^f	1^f	30
		% within Groups	33.3%	13.3%	26.7%	23.3%	3.3%	100.0%
	Sighted	Count	5^f	2^f	4^f	4^f	0^f	15
		% within Groups	33.3%	13.3%	26.7%	26.7%	0.0%	100.0%
Moving Obstacle	Visually Impaired	Count	4^g	3^g	7^g	10^g	6^g	30
		% within Groups	13.3%	10.0%	23.3%	33.3%	20.0%	100.0%
	Sighted	Count	0^g	2^g	4^g	7^g	2^g	15
		% within Groups	0.0%	13.3%	26.7%	46.7%	13.3%	100.0%

[a] Each subscript letter denotes a subset of Hazards: Body Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.
[b] Each subscript letter denotes a subset of Hazards: Body Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.
[c] Each subscript letter denotes a subset of Hazards: Head Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.
[d] Each subscript letter denotes a subset of Hazards: Noise categories whose column proportions do not differ significantly from each other at the 0.05 level.
[e] Each subscript letter denotes a subset of Hazards: Silence categories whose column proportions do not differ significantly from each other at the 0.05 level.
[f] Each subscript letter denotes a subset of Hazards: Light categories whose column proportions do not differ significantly from each other at the 0.05 level.
[g] Each subscript letter denotes a subset of Hazards: Moving Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.

5.5 Framework Validation

In this section, both groups (visually impaired people, and sighted people) were asked to rate the importance of components to be included in the framework. 23 components were suggested regarding information necessary to navigate unfamiliar indoor spaces by people with visual impairment. The responses were based on a five point Likert scale, where 1 is *not important*, 2 is *not very important*, 3 is *somewhat important*, 4 is *important*, and 5 is *very important*.

Table 5.18: Repeated measures one-way ANOVA – Multivariate tests: Difference in means within subjects

Effect		**Value**	***F***	**Hypothesis df**	**Error df**	***p***
SRF	Pillai's Trace	0.83	5.20	22	23	< 0.001
	Wilks' Lambda	0.17	5.20	22	23	< 0.001
	Hotelling's Trace	4.98	5.20	22	23	< 0.001
	Roy's Largest Root	4.98	5.20	22	23	< 0.001

Since there were multiple comparisons, a repeated measures one-way analysis of variance (ANOVA) was then used on the 23 components. Table 5.18, first showed that there was a statistically significant difference in the mean rating of these 23 components indicated by Wilks' Lambda = 0.167, $F(22, 23) = 5.202$, $p < 0.001$. This suggests that suitable adjustments in the confidence interval must be made. The results of that are shown in Table 5.19 which examines the 95% confidence intervals, suitably adjusted by the Sidak correction[24], against the neutral point of 3. Statistical significances for each component were then determined by looking at whether the neutral point was within ($p > 0.05$, not significant) or outside ($p < 0.05$, significant). The proposed component is considered to be included in the framework as long as its mean value ≥ 3. Components are considered to be statistically significant if p-value < 0.05. Full detail of the statistical analysis can be found in Appendix D.9.

The Table 5.19 shows the results of the analysis. It is clear that all of the proposed components were considered to have impact on indoor navigation by people with visual impairment as the mean value of each component is more than 3. Most of the proposed components were found to be statistically significant as their p-values are less than the significant level, except for Lighting and Wi-Fi coverage. This resulted in difference perspectives between visually impaired participants and sighted participants, which will be discussed later.

[24]Sidak correction is an alternative p-value adjustment for multiple comparison tests. It is more powerful and less conservative than the Bonferroni correction, producing a family-wise Type I error rate of exactly α when assuming each comparison is independent of the others and all null hypotheses are true (Abdi, 2007).

Table 5.19: Repeated measures one-way ANOVA: Estimated marginal means

SRF	**Mean**	**Std. Error**	**95% Confidence Interval**		***p***
			Lower Bound	**Upper Bound**	
Building Profile	3.78	0.17	3.43	4.12	< 0.05
Floor Layout	3.87	0.16	3.53	4.20	< 0.05
Floor Number	4.28	0.13	4.02	4.56	< 0.05
Room Number	4.33	0.12	4.09	4.58	< 0.05
Toilet and Bathroom	4.36	0.10	4.16	4.55	< 0.05
Entrance and Exit	4.51	0.08	4.36	4.66	< 0.05
Door	4.62	0.08	4.46	4.78	< 0.05
Emergency exit	4.29	0.11	4.07	4.50	< 0.05
Lighting	3.29	0.21	2.87	3.71	> 0.05*
WiFi Coverage	3.09	0.22	2.68	3.50	> 0.05*
Walkable Path	4.18	0.12	3.94	4.42	< 0.05
Tactile Pavement	4.16	0.15	3.85	4.46	< 0.05
Stairs	4.27	0.11	4.05	4.48	< 0.05
Steps, Dropoff, Curb	4.31	0.08	4.14	4.48	< 0.05
Elevator	4.20	0.08	4.04	4.36	< 0.05
Escalator	4.02	0.11	3.81	4.24	< 0.05
Event and Exhibition	3.67	0.12	3.44	3.90	< 0.05
Furniture	4.04	0.11	3.82	4.27	< 0.05
Dangerous area	4.33	0.12	4.09	4.57	< 0.05
People	3.89	0.14	3.62	4.16	< 0.05
Weather	3.42	0.18	3.06	3.79	< 0.05
Reception	3.84	0.17	3.51	4.18	< 0.05
Noise	3.47	0.20	3.06	3.88	< 0.05

* Component was found not statistically significant

Table 5.20: Two-way ANOVA: Difference in means between groups of visually impaired people and sighted people.

	Mean Difference (VI-E)	**Type III Sum of Squares**	**Mean Square**	***F***	***p***
Building Profile	-0.23	0.54	0.54	0.41	0.526
Floor Layout	-0.60	3.60	3.60	3.12	0.084
Floor Number	-0.57	3.21	3.21	4.31	0.044*
Room Number	-0.50	2.50	2.50	3.91	0.054
Toilet and Bathroom	-0.17	0.28	0.28	0.66	0.420
Entrance and Exit	-0.33	1.11	1.11	4.72	0.035*
Door	0.03	0.01	0.01	0.04	0.846
Emergency Exit	-0.47	2.18	2.18	4.45	0.041*
Lighting	1.03	10.68	10.68	6.16	0.017*
WiFi Coverage	0.03	0.01	0.01	0.01	0.940
Walkable Path	0.07	0.04	0.04	0.07	0.797

... Continued on next page

	Mean Difference (VI-E)	Type III Sum of Squares	Mean Square	***F***	***p***
Tactile Pavement	-0.67	4.44	4.44	4.61	0.037*
Stairs	-0.10	0.10	0.10	0.19	0.666
Steps, Dropoff, Curb	-0.33	1.11	1.11	3.81	0.057
Elevator	-0.10	0.10	0.10	0.33	0.570
Escalator	-0.07	0.04	0.04	0.08	0.774
Event and Exhibition	0.30	0.90	0.90	1.54	0.221
Furniture	0.17	0.28	0.28	0.51	0.481
Dangerous area	-0.40	1.60	1.60	2.61	0.114
People	0.33	1.11	1.11	1.35	0.251
Weather	0.73	5.38	5.38	3.88	0.055
Reception	0.07	0.04	0.04	0.03	0.854
Noise	-0.90	8.10	8.10	4.77	0.035*

* There was statistically significant difference in mean interest in groups of visually impaired people and expert.

Table 5.20 shows the difference in means tests between visually impaired participants and sighted participants using two-way ANOVA. Both groups agreed with most components, as the means were not statistically significant. However, these components were significantly different: Floor Number, Entrance and Exit, Emergency Exit, Lighting, Tactile Pavement, and Noise.

The mean differences of all significant-different components were found to be small, such as Entrance & Exit, Emergency Exit and Tactile Pavement, while Lighting and Noise were large numbers. Sighted people thought lighting would not be useful to visually impaired people. On the contrary, lighting is very useful since the partially sighted use it for wayfinding during indoor navigation. Noise was found to be useful by sighted people, which is actually somewhat useful for some spaces. However, in unfamiliar spaces full of crowds such as train stations, noise cannot be of use since the spaces are full of people surrounding them who generate much noise, for example conversations and moving luggage.

5.6 Reliability

The reliability of the framework validation results was determined using Cronbach's Alpha. Table 5.21 shows the overall Cronbach's alpha returned a value of 0.832, which was good (Gliem & Gliem, 2003).

In Table 5.22, column *Corrected Item-Total Correlation* demonstrates that some components do not correlate ($r < 0.3$) with each other, as follows: Building Profile ($r = 0.284$), Emergency Exit ($r = 0.239$), and Wifi Coverage ($r = 0.211$). With these results, it made

Table 5.21: Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.832	0.859	23

sense as there were difference in means between groups of visually impaired participants and sighted participants, shown in Table 5.20.

It is possible that deleting the uncorrelated components may increase the overall reliability. However, the deletion may not be necessary as omitting Building Profile and Emergency Exit causes lower reliability, but not WiFi Coverage. Even though dropping WiFi Coverage can increase the overall reliability from 0.832 to 0.838 (by just 0.006), this is very small. Thus, no deletion of components was performed in the framework validation. Details of the reliability tests can be found in Appendix D.11.

Table 5.22: Item Totals

Components	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Building Profile	88.44	89.62	0.284*	0.520	0.831
Floor Layout	88.36	89.14	0.324	0.656	0.828
Floor Number	87.93	88.29	0.475	0.776	0.821
Room Number	87.89	89.51	0.441	0.668	0.823
Toilet and Bathroom	87.87	91.62	0.409	0.584	0.825
Entrance and Exit	87.71	92.57	0.438	0.542	0.826
Door	87.60	92.38	0.430	0.609	0.826
Emergency Exit	87.93	93.20	0.239*	0.572	0.830
Lighting	88.93	86.84	0.320	0.518	0.831
WiFi Coverage	89.13	89.66	0.211*	0.470	0.838+
Walkable Path	88.04	91.00	0.354	0.603	0.826
Tactile Pavement	88.07	88.34	0.401	0.656	0.824
Stairs	87.96	89.45	0.523	0.802	0.821
Steps, Dropoff, Curb	87.91	92.17	0.430	0.674	0.825
Elevator	88.02	91.98	0.458	0.752	0.825
Escalator	88.20	89.57	0.511	0.817	0.821
Event and Exhibition	88.56	89.30	0.495	0.501	0.822
Furniture	88.18	89.42	0.511	0.796	0.821
Dangerous Area	87.89	90.06	0.422	0.664	0.824
People	88.33	86.05	0.605	0.735	0.816
Weather	88.80	85.89	0.431	0.759	0.823
Reception	88.38	85.06	0.517	0.728	0.819
Noise	88.76	87.55	0.302	0.711	0.832

* Component was not correlated between each component and the total score

+ Component can increase a higher overall reliability if removed

5.7 Discussion of the Findings

The framework validation was done by both groups of people: visually impaired people, and sighted people shown in the previous section. The findings showed that one particular factor need to be considered as a main factor in the spatial representation framework. In the following sections, the findings from both tasks: problems confirmation and framework validation are discussed.

5.7.1 Problems Confirmation

This task has shown that visually impaired people first use sighted guides as helpers when visiting unfamiliar spaces in order to learn and familiarise themselves with navigational cues, e.g. landmarks and hazards. Five additional factors were revealed that provide them with confidence and safety while navigating inside buildings and public spaces, as outlined below.

Navigational cues This factor contains markers and information about the objects, e.g. edges and corners, areas, e.g. intersection, especially transition spaces, e.g. stairs: tread width, riser height, and depth width. This information is important and can be used as a navigational cue to help people find their way more easily when navigating inside buildings full of unfamiliar features.

Warning This factor contains warning markers and information about hazards, e.g. sharp edges, stairs and escalators, slippery surfaces, holes, drop-offs, and especially glass doors and automatic sliding doors. This component is useful in providing free mobility when navigating indoors.

Profile This factor acts as metadata containing a description of the areas and objects placed or installed inside the buildings, including information about their physical dimension, size, wall type, etc. This component also includes general information about the building, e.g. building profile, pre-visit information, etc.

State This is a sub-factor of the profile component and contains information about the current state of the objects, especially transition spaces, e.g. doors, elevators, escalators, and travelators. For example, door (open, closed), escalator (going up, going down), or lift (going up, going down, current floor).

External This factor contains sensory information that potentially impacts indoor navigation such as light from windows, noise from rain, car horn, or construction outside the building. This component is of use to people with visual impairment, especially those who are partially sighted that use light to detect orientation in the wayfinding process.

5.7.2 Framework Validation

In this task, employing the repeated-measures one-way ANOVA, all the factors proposed in the desk-based study were included in the SRF, and most were found to be statistically significant, as shown in Table 5.19. Two factors were found not to be statistically significant: Lighting and Wi-Fi Coverage.

Although Wi-Fi is not statistically significant, this factor is useful for the construction of an indoor navigation system and may be of use in future development, and so it has been included in the framework as part of the sensor factor. Similarly, the Lighting was found to be useful by all the partially sighted participants. They said that lighting is most important since they can see and use it to identify directions, and some have used it as a reference point. In addition, some blind people still have light perception, and so have used it to detect direction. Thus, the lighting component has also been considered part of the framework.

5.8 Revision of Spatial Representation Framework

We show below the revisions that have been made for the validated framework, as a result of the preliminary study. In the framework revision, the Information layer from the preliminary study framework (see Appendix A) has been removed and transformed into main factors, as shown in Table 5.23 and Figure 5.2.

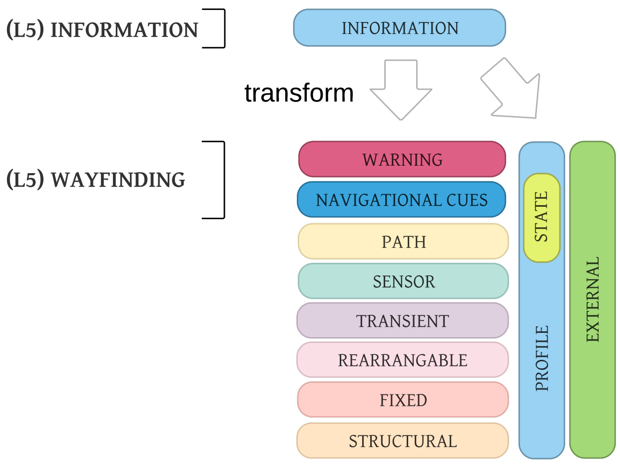


FIGURE 5.2: Revision of the SRF

Thus, the information layer has been removed and replaced by four factors (navigational cues, warning, profile, and state), and the external factor included, shown in Figure 5.3.

TABLE 5.23: List of the revisions of the Spatial Representation Framework

Factor/Layer	**Type**	**Action**	**Description**
Information	Layer/Factor	Removed	
Information/Basic	Information	Transformed	Profile Factor
Information/Floor Plan	Information	Transformed	Profile Factor
Information/Wayfinding	Information	Transformed	Navigational cues, and Warning Factors
Information/Exhibition	Information	Transformed	Profile Factor
Information/Event	Information	Transformed	Profile Factor
Information/External	Information	Removed	
Profile	Factor	Added	Description and metadata of the objects
State	Factor	Added	Sub-factor under Profile factor
External	Factor	Added	Extracted from Information layer
Navigation Cues	Factor	Added	Level 5 Wayfinding
Warning	Factor	Added	Level 5 Wayfinding

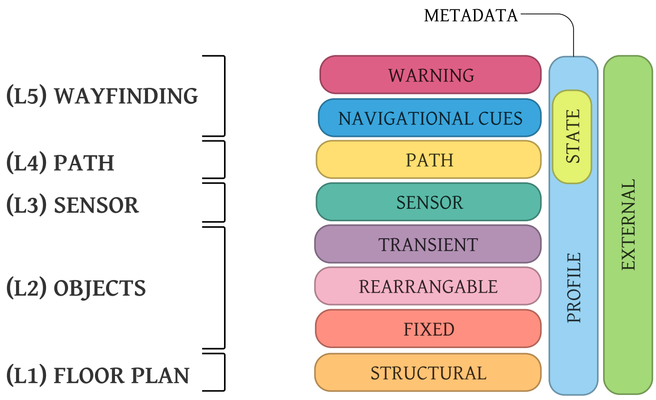


FIGURE 5.3: Validated version of SRF for indoor navigation by people with visual impairment

5.9 Review of the Research Questions

From all this, the three research questions have been answered by the field study. The problems and challenges (SRQ1) were finalized and categorized into five sections in Section 5.4 for indoor navigation in spaces full of unfamiliar features. In the framework validation task (Section 5.5), all the proposed factors were validated by both visually impaired and sighted people, as shown by Table 5.19. All of the factors were considered to be essential information as all means were above 3, which answered SRQ2. After validating the factors, the proposed version of the SRF was finalised and enriched by the information acquired from the problems confirmation task by both visually impaired and sighted people. The validated version of spatial representation framework, shown in Figure 5.3 in Section 5.8, is used to answer the SRQ3.

5.10 Summary

This chapter has shown that problems identified during the literature review are correct, and new issues were found during interviews with people with visual impairment. Navigating inside buildings and public spaces full of unfamiliar features is too difficult to attempt the first time for a number of reasons, reducing their confidence in independent navigation, as shown in Section 5.4. Later, the proposed spatial representation framework, from the desk-based study, was validated by both visually impaired and sighted people. Some factors were found not to be statistically significant, such as Wi-Fi coverage, while other factors were found not to be statistically significant like lighting by visually impaired people, and noise by sighted people. Both factors were included in the framework for comprehensiveness. All the proposed factors were included in the framework, but their status as components was transformed into main factors.

The next chapter will reveal an instrument, *Building Rating System*, that is developed for building accessibility measurement for better indoor navigation by people with visual impairment. The instrument is developed based on the use of spatial representation framework.

Chapter 6

Building Rating System

This chapter discusses the building rating system (BRS) with its description and details. An overview of the building rating system is covered by Section 6.1, the design of the BRS in Section 6.2, the definition conformance in Section 6.3, space classification in Section 6.4, floor and building classifications in Section 6.5, and finally success criteria to be used in the classification of the 13 types of space, used for measuring general building and public spaces in Section 6.7.

6.1 Overview of Building Rating System

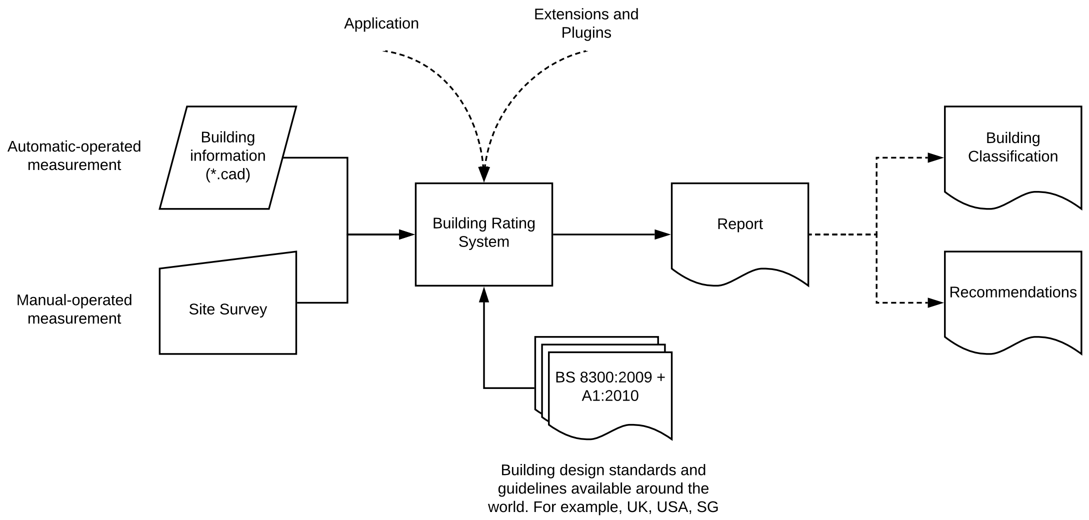


FIGURE 6.1: Overview of the Building Rating System

A building rating system is an application extended from an SRF. It is an instrument for measuring a level of accessibility provided in the buildings. The BRS can carry out both manually-operated and in the future automatically-operated measurements. In order to carry out an automatic measurement, a manual measurement must first be in place, described herein.

To measure building accessibility, many building design standards and guidelines from around the world (e.g. United Kingdom, United States of America, Canada, Switzerland, Singapore, and Australia) have been studied for the construction of Success Criteria, to be used in space classification, as described in Section 6.7.

The end result generated consists of building classification with details of each floor and spaces, and recommendations.

6.2 Design of the Building Rating System

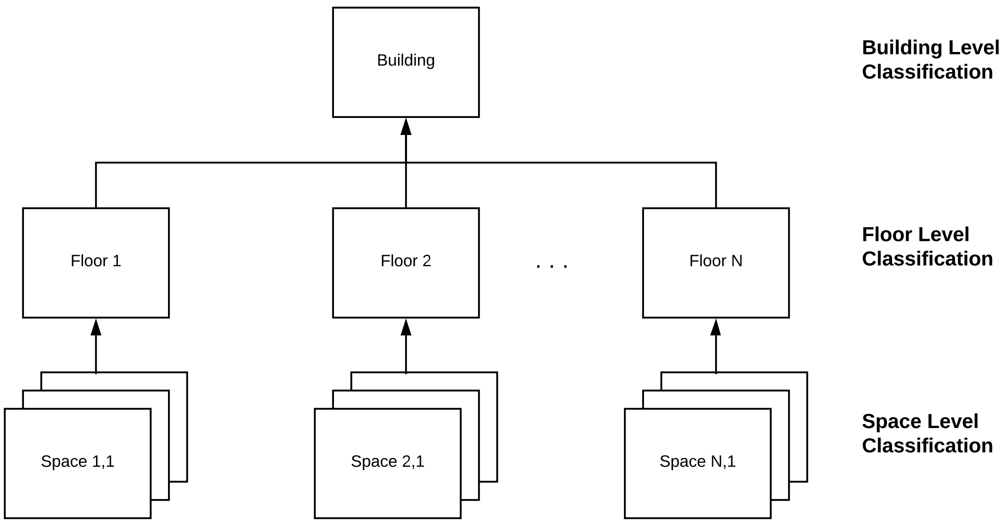


FIGURE 6.2: Bottom-up Design of the Building Rating System.

Measuring the level of accessibility provided inside buildings is still very difficult. For instance, the complexity of the building results in a number of activities in the auditing process; there is no set of success criteria that can be used for accessibility classification of the building; etc. However, when it comes to auditing the environment, there is a set of checklists used to guide users wishing to create inclusive built environments (Sawyer & Bright, 2014), but this is hardly used for accessibility measurement. Since no BRS is yet available, this work creates a standard for accessibility measurement, which focuses on accessibility for people with visual impairments.

Because of the complexity in designing the system, it is essentially to think of how the building is going to be rated and how that rating score is used and interpreted. In fact, buildings comprise a number of spaces within them, e.g. entrance, horizontal circulation, vertical circulation, WCs, etc. It is reasonable to scale the building down into three levels as shown in Figure 6.2 as follows:

Level 1: Building Level Classification

Level 2: Floor Level Classification

Level 3: Space Level Classification

With bottom-up design, measuring the level of accessibility for each space is a sensible starting point and can result in rating the level of accessibility of floors, and later the building overall, by a use of majority scoring method, as discussed in Section 6.5.

6.3 Conformances

By definition, conformance refers to certification and confirmation that goods or services meet or satisfy the requirements, legislation, standards, or accepted practices (Caldwell, Cooper, Reid, & Vanderheiden, 2008). In the BRS, the "requirements" are defined as Success Criteria, details of which are given in Section 6.7, which will be used in the space classification. To meet the conformance, a space being measured must meet or satisfy the Success Criteria. 13 types of space are used in the BRS (see Section 6.7).

In order to accommodate different situations, which may require or permit greater levels of accessibility for building classification as shown in Figure 6.2, the BRS has three levels of conformance (Conformance A, AA, and AAA), as well as No conformance level. Therefore, three levels of Success Criteria for all 13 spaces must be created (See Section 6.7). The WCAG 2.0 (Caldwell et al., 2008) also uses a similar rating scale for web pages.

To achieve each conformance in the BRS, Success Criteria for each are based on the use of MoSCoW prioritisation approach (Hatton, 2008), where "Must-Have", "Should-Have", and "Could-Have" are used to define success criteria for Conformance A, AA, and AAA, respectively.

The success criteria used in the BRS are based on the impact on the design and improvement of spaces and building for better independent indoor navigation by people with visual impairment. This means that the higher the level of conformance, the high the level of accessibility is provided to people with visual impairment, and the more restraint in the design of spaces is required.

However, the field study has shown that the most important factor for indoor navigation is safety. People with visual impairment are afraid of visiting somewhere where they do not know the features installed or cannot access the facilities provided. As a result, this work created three levels of conformance, which are described with their requirements in Table 6.1.

Table 6.1: Conformance Level - Definitions and Requirements

Conformance	**Requirements**	**Definitions**
No Conformance	-	No conformance level, providing no accessibility in the space due to failure to meet the minimum level requirement. At this level, people with visual impairment are advised not to visit unless accompanied by an assistant within the building.
A	Space must satisfy all the Must-Have success criteria. OR The Level A conforming alternate version is provided.	A minimum level, providing an ability to navigate the space without any hazard to people with visual impairment. At this level, people with visual impairment are likely to need assistance to perform some activities, otherwise perform activities with caution.
AA	Space must satisfy all the Level A and the Should-Have success criteria. OR The Level AA conforming alternate version is provided.	A sufficient level of accessibility, providing features in addition to improving the independent navigation by people with visual impairment. At this level, people with visual impairment may need assistance to perform some activities. Note that this level is used as a general policy that all buildings must apply.
AAA	Space must satisfy all the Level A, Level AA, and all the Could-Have success criteria. OR The level AAA conforming alternate version is provided.	An enhanced level, providing features in addition to enabling an ability to access all of the facilities provided in the space to people with visual impairment. At this level, people with visual impairment are unlikely to need any assistance to perform the activities.

6.4 Space Classification

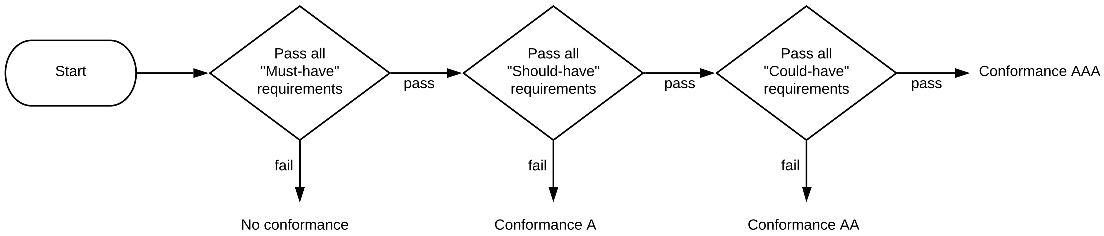


FIGURE 6.3: Determination of Space Classification in each space

Table 6.1 shows that to conform to the maximum level (Conformance AAA), the space must meet and satisfy all requirements of Conformance A, AA and AAA. Thus, if the space fails at least one requirement of Conformance A, the space will be classified as No conformance, as shown in in Figure 6.3. An alternate version of conformance may be provided, for example Section 6.7.5 - ramp space, that can acquire Conformance AAA if an alternative approach is adopted.

6.5 Floor and Building Classifications

The bottommost level is where many spaces can be combined into a bigger space (e.g. floors of a building). In general, the floor classification is determined by the majority scores, where the most conformance acquired from the space classification is chosen as the overall level of accessibility. Likewise, for building classification, using the same method where its accessibility is determined by the majority scores, where the most conformance acquired from the floors classification is chosen.

Where the floor and building classifications differ, a rule is employed where the conformance levels are converted to a numerical score from 0: No Conformance, to 3: Conformance AAA. An average score is calculated, as shown in Table 6.2.

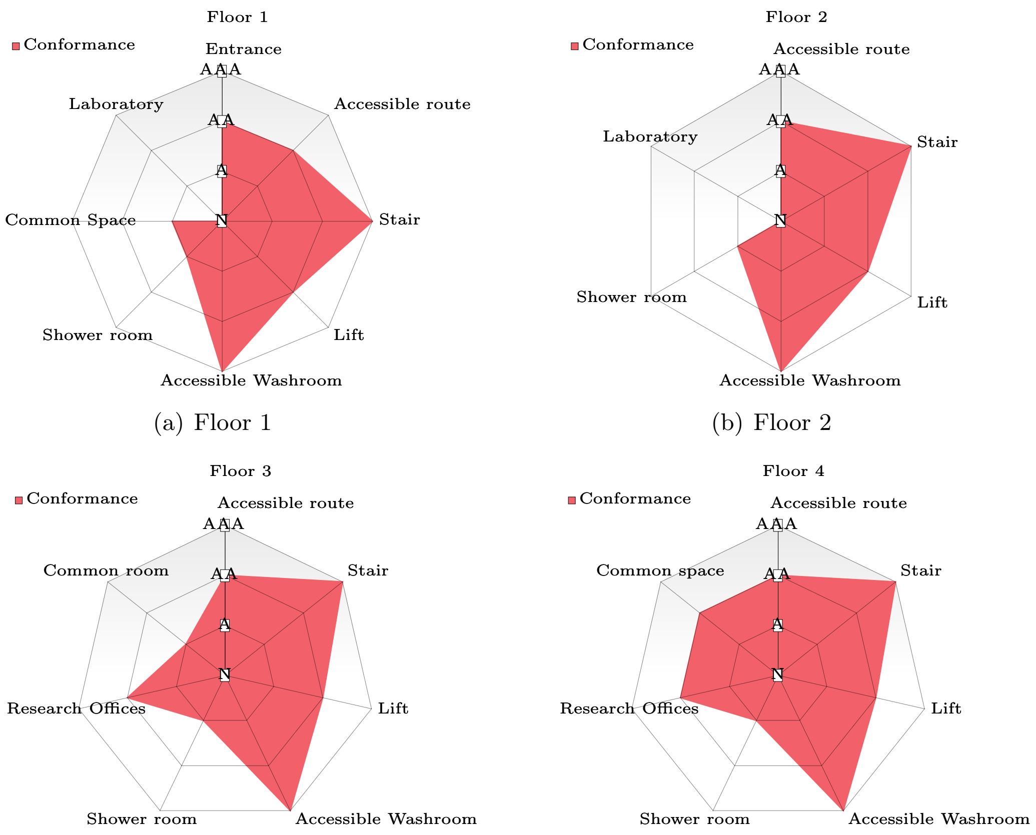
6.6 Results and Interpretation

Once the building (all spaces) has been measured, the results are reported in the form of spider charts, representing the level of accessibility at one particular floor achieved for each category of spaces in four scales. One example of space classification is shown in Figure 6.4.

TABLE 6.2: Average scoring approach used in the case of a tie

Tie Combination	**Average scoring approach**	**Classification**
2 in a tie		
N + A	(0+1)/2 = 0.5	A*
N + AA	(0+2)/2 = 1	A
N + AAA	(0+3)/2 = 1.5	A
A + AA	(1+2)/2 = 1.5	A
A + AAA	(1+3)/2 = 2	AA
AA + AAA	(2+3)/2 = 2.5	AA
3 in a tie		
N + A + AA	(0+1+2)/3 = 1	A
N + A + AAA	(0+1+3)/3 = 1.33	A
N + AA +AAA	(0+2+3)/3 = 1.66	A
A + AA + AAA	(1+2+3)/3 = 2	AA
4 in a tie		
N + A + AA + AAA	(0+1+2+3)/4 = 1.5	A

* Even though the average score is 0.5 (below 1: Conformance A), it is still above 0 (No Conformance), and there is still some accessibility. Thus, a minimum level of conformance is given in this case.



(c) Floor 3

(d) Floor 4

FIGURE 6.4: Example of space classification in Building 53 (Mountbatten), University of Southampton

TABLE 6.3: Building 53 (University of Southampton), Floor and Building Classifications using majority scoring approach

	N	A	AA	AAA	Classification
Floor 1	1	2	3	2	AA
Floor 2	1	1	2*	2	AA
Floor 3	0	2	3	2	AA
Floor 4	0	1	4	2	AA
		Building Classification			**AA**

* Conformance AA is selected by the rule applied to the case "AA + AAA" in Table 6.2.

From Figure 6.4 and Table 6.3, the building was measured using the space classification method. Conformance AA was given for all floors, which gave the building classification as Conformance AA. This means that the building satisfies Conformance AA, a general policy to which all buildings must conform. With this result, people with visual impairment may ask for assistance when navigating around this building.

6.7 Success Criteria

Success Criteria are requirements used in space classification, measuring the building's accessibility overall. 13 types of space are considered for measurement in the BRS, each of which space is classified into Conformance A, AA, and AAA. Thus there are 39 success criteria needed for building accessibility measurement.

1. Entrances — Section 6.7.1
2. Foyers — Section 6.7.2
3. Horizontal circulation (e.g. corridor and passageway) — Section 6.7.3
4. Vertical circulation - Stairs — Section 6.7.4
5. Vertical circulation - Ramps — Section 6.7.5
6. Vertical circulation - Lifts — Section 6.7.6
7. Sanitary - Ambulant Disable WCs — Section 6.7.7
8. Sanitary - Accessible Washroom — Section 6.7.8
9. Sanitary - Bathrooms and shower rooms — Section 6.7.9
10. Bedrooms — Section 6.7.10
11. General space (e.g. office, living room, refreshment room) — Section 6.7.11
12. Utility spaces (e.g. kitchen, laundry, and storage room) — Section 6.7.12
13. Hall and statium (e.g. lecture room, conference room, auditorium, and stadium) — Section 6.7.13

Determining the success criteria to be included for each conformance for each space, inevitably requires an understanding of an inclusive built environment design for building to meet the needs of people with visual impairment.

A number of building design standards, guidelines, and regulations were studied.

1. 2010 ADA Standards for Accessible Design – *United State*
2. Accessible Sports Facilities Design Guidelines – *United Kingdom*
3. Accessible Sports Facilities Management Guidelines – *United Kingdom*
4. Architectural Barriers Act (ABA) Standards – *United State*
5. Better Access to Healthcare Buildings – *United Kingdom*
6. BS 8300:2008 Code of practice for fire safety in the design, management and use of buildings – *United Kingdom*
7. BS 8300:2009+A1:2010 Design of buildings and their approaches to meet the needs of disabled people - Code of practice – *United Kingdom*
8. BS 6180:2011 Barriers in and about buildings - Code of practice – *United Kingdom*
9. BS 9266:2013 Design of accessible and adaptable general needs housing - Code of practice – *United Kingdom*
10. BS 9991:2015 Fire safety in the design, management and use of residential builidings – Code of practice
11. City of Toronto: Accessibility Design Guideline – *Canada*
12. Code on Accessibility in the Built Environment 2013 – *Singapore*
13. Design Guidelines for the Visual Environment – *United State*
14. Design Standards for Accessible Railway Stations – *United Kingdom*
15. Homes and living spaces for people with sight loss: A guide for interior designers – *United Kingdom*
16. The access manual: Designing, auditing and managing inclusive built environments – *United Kingdom*
17. Wayfinding design guideline – *Australia*

All success criteria will be first used in the manual audit as a pass/fail checklist for measuring the level of accessibility. In the auditing process allows four options, which will affect the score at the end of the process.

Pass A feature met the Success Criteria.

Fail A feature fail the Success Criteria.

Can't tell A feature cannot be measured due to technical difficulties. The feature is skipped for the accessibility measurement which will require further (visual) inspections. The space with "can't tell" results is indicated by (*) asterisk in the spider chart. Note that the option of "can't tell" is not be provided in the "Must-Have" Success Criteria.

Not applicable (N/A) Users cannot tell whether a feature passed or failed the requirement due to non-existence. The feature is ignored in the accessibility measurement.

6.7.1 Entrance

Entrance Space - Conformance A		
Categories	**Provisions: Must-have items**	
Entrance	E.1	The main entrance is clearly visible when approaching the building
	E.2	The entrance doors are recessed unless a guarding is provided
	E.3	Appropriate lighting is provided for people entering the building
Entry System (if provided)	E.4	The position of the entry system is clearly identified using visual contrast
Surface	E.5	A surface on the entrance area must be smooth, flat and slip-resistant
Change in Level	E.6	The maximum threshold upstand is 15 mm with chamfered or rounded edges
	E.7	No ramp is provided at the entrance door
Entrance Door	E.8	The minimum clear operating width through one leaf is 750 mm to 800 mm
	E.9	The swing area is protected adequately to prevent collisions
Glass Doors (if provided)	E.10	If glass doors are provided, the frame contrasts with the surrounding wall/screen OR the presence of the doors is differentiated from the rest of the wall/screen
	E.11	Edges of doors are clearly visible when held in the open position
	E.12	Door furniture is distinguishable in terms of visual contrast with the door
	E.13	Manifestations are provided at 850-1000 mm and 1400-1600 mm above floor level (where possible)
	E.14	Manifestation is effective at all times the building is in use
Automatic Doors (if provided)	E.15	Automatic doors are provided with either manually or automatically operated control mechanism
	E.16	Warning of the presence of the automatic doors is provided
	E.17	Warning of the direction of opening of the automatic doors is provided

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Entrance Space - Conformance A		
Categories	**Provisions: Must-have items**	
	E.18	Opening and closing door speed is appropriate
	E.19	Doors remain open for an appropriate time
	E.20	Appropriate safety arrangements are provided to prevent doors closing if there is an obstruction
Revolving Doors (if provided)	E.21	If a revolving door is provided, there is an accessible entrance
	E.22	The accessible entrance is provided with an automatic opening device
	E.23	The accessible entrance is operational at all times when the revolving door is in use
Flooring systems (if provided)	E.24	Flooring systems must not present a tripping hazard
	E.25	Flooring systems must be securely fixed on the surface
Lobbies (if provided)	E.26	The minimum space between two hinged doors or pivoted doors in a series shall be 1200 mm plus the width of the door swinging into that space

Entrance Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Entrance	E.27	Appropriate signage is provided from the boundary of the property to identify the location of the main entrance
	E.28	The location of the main accessible entrance (if this not the main entrance) is clearly signposted from the boundary of the site and the main entrance
Entry System (if provided)	E.29	Entry systems are suitable for use by visually impaired people
	E.30	The position of the entry system is logical
Entrance Door	E.31	There is a 300 mm clear space beside the leading edge.
	E.32	The maximum pressure needed to open the door should be appropriate for visually impaired people to open the door
	E.33	Delayed action closers are provided
	E.34	Door opens inwards OR If door opens outwards, it must be recessed

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Entrance Space - Conformance AA		
Categories	**Provisions: Should-have items**	
	E.35	Vision panels with a visibility zone extending between 500 mm and 1500 mm above floor level are provided
Glass Doors (if provided)	E.36	Door handles can be reached, gripped and used with minimum effort

Entrance Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Entrance	E.37	A canopy providing adequate shelter is provided over the entrance doors
Entry System (if provided)	E.38	Swipe card entry systems are appropriately positioned 750 mm to 1000 mm above floor level
	E.39	The top operational button of the entry is 1200 mm above floor level or less
	E.40	Appropriately designed signage is provided with instructions on how to use the entry system
	E.41	Appropriately designed signage is provided with instructions on how to get assistance if a disabled person cannot use the entry system

6.7.2 Foyers

Foyer Space - Conformance A		
Categories	**Provisions: Must-have items**	
Approaching	F.1	The approach to the reception area is smooth and level
Reception Desk	F.2	The reception desk is logically placed
	F.3	The position of the reception desk is identifiable from the entrance to the building
	F.4	Lighting at the desk is appropriate to allow the face of the receptionist to be clearly seen
	F.5	Reflective glass screen is not provided at the reception desk
Lighting	F.6	Lighting to the reception area is appropriate to allow easy communication and comfort for users
	F.7	The minimum average illuminance at floor level in the reception area is 300 lux

Foyer Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Approaching	F.8	Directional signage to identify the position of the reception area is appropriate in terms of provision and design
Reception Desk	F.9	There is sufficient maneuvering space in front of the reception desk
	F.10	Lighting at the desk is sufficient to enable the completion of any forms, etc.

Foyer Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Reception Desk	F.11	Lighting provides a minimum illuminance at reception desk level of 500 lux
	F.12	Illuminance at the desk is controllable
Seating	F.13	A variety of seating with arms is provided

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Foyer Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
	F.14	Seating is sufficiently robust to allow someone to use the arms as assistance when sitting or standing
	F.15	Seating contrasts visually with all backgrounds against which it will be viewed

6.7.3 Horizontal Circulation

Horizontal Circulation Space - Conformance A		
Categories	**Provisions: Must-have items**	
Corridors and Passageways	H.1	Corridors have a minimum clear width of 1200 mm
	H.2	Doors along the corridors must not open into circulation routes OR The doors must be recessed
	H.3	Corridors are splayed or rounded at corners
Surfaces	H.4	The floor surface finishes are firm
	H.5	The floor surface is matte OR low reflectivity
	H.6	The floor surfaces are slip-resistant, especially when wet
	H.7	The floor surfaces are not shiny and potentially slippery
	H.8	The pattern of any floor covering is plain or with a subtle pattern
	H.9	Junctions between finishes are level and firmly fixed
Wall	H.10	Appropriate visual contrast is provided at the junction of the floor with the wall
	H.11	Wall surfaces are smooth to touch
Glazed walls	H.12	Appropriately designed manifestation is provided to glass screens
Screens and Doors	H.13	Manifestation contrasts with the background against which it is viewed, both from inside and outside, in all lighting situations
Internal Doors	H.14	The minimum clear opening width of all internal doors is 750 mm
	H.15	If double doors are provided, the minimum clear opening width of one leaf of the doors is 750 mm
	H.16	There is swing protection for all doors that open into the circulation routes OR The doors must be recessed
	H.17	All door furniture (handles, kicking plates and finger plates) contrast visually with the surface of the door
	H.18	The internal door is capable of being operated in manual, powered and/or power-assisted mode
	H.19	Internal doors are clearly identifiable in terms of visual contrast with the surrounding wall

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Horizontal Circulation Space - Conformance A		
Categories	**Provisions: Must-have items**	
	H.20	The leading edge of all internal doors is visually contrasted and is clearly visible when open
	H.21	For glass doors that may be held open, they are protected with appropriate guarding to prevent people from colliding with the leading edge
	H.22	Glass doors (within a glazed screens) are clearly differentiated from the adjacent glazed screens by a visually contrasting strip to the top and both sides of the door
	H.23	For glass doors that may be held open, they are protected with appropriate guarding to prevent people from colliding with the leading edge
Lobbies	H.24	Internal lobbies are appropriately designed to allow easy maneuverability (1200 mm minimum space is preferred)
Lighting	H.25	The minimum illuminance at floor surface level is 100 lux
Acoustics	H.26	The surfaces of the floor or walls must not adversely affect the acoustics

Horizontal Circulation Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Corridors and Passageways	H.27	A series of double doors of unequal width are provided along the circulation routes; the wider leaf is on the same side of the corridor throughout its length
Glazed walls, screens and doors	H.28	The manifestation is located at two levels: Lower area: 850 mm - 1000 mm above floor level Upper area: 1400 mm - 1600 mm above floor level
	H.29	Manifestation on glass doors is in the form of a logo or sign at least 150 mm high and repeated on adjacent screens OR Manifestation is provided in the form of a decorative feature such as broken lines or continuous bands at least 50 mm high

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Horizontal Circulation Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Internal Doors	H.30	There is a minimum 300 mm clear space beside the leading edge
	H.31	Door handles are lever style
	H.32	Door and side panels wider than 450 mm are provided with minimum zones of visibility (vision panels) that extend between 500 mm and 800 mm above floor level, and between 1150 mm and 1500 mm above floor level

Horizontal Circulation Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Handrails	H.33	A handrail is provided along the length of the corridors
Internal Doors	H.34	Delayed action door closers are provided

6.7.4 Vertical circulation - Stair

Vertical circulation - Stair Space - Conformance A		
Categories	**Provisions: Must-have items**	
Stairs	VS.1	The stairs are made up for a straight flight or flights of stairs
	VS.2	None of the stairs are spiral or contain sections which have winders
	VS.3	The stairs do not have open risers
	VS.4	Underside stairs are protected to prevent users colliding with the stairs
	VS.5	The minimum surface width of the stairs is 900 mm
	VS.6	The minimum width between handrails is 900 mm
	VS.7	No change in level is provided with only one step
	VS.8	There is a tactile warning surface or a change of floor color and texture at the head and foot of the stairs that give adequate warning of the presence of the stairs
	VS.9	There is a clear landing of 900-1200 mm at the top of each flight
	VS.10	There is a clear landing of 900-1200 mm at the bottom of each flight
	VS.11	There is no door swing that encroaches onto the landing area
	VS.12	The risers on each step are the same dimension
	VS.13	The thread on each step are the same dimension
	VS.14	The height of the risers are between 150 - 190 mm
	VS.15	The going of each step is between 280 - 400 mm
	VS.16	The minimum headroom on stairs giving access between levels is 2000 mm
Handrail	VS.17	A handrail is provided to each side of the stair
	VS.18	The surface finish to handrails is not reflective
	VS.19	The handrail extends horizontally at least 300 mm beyond the first and last nosing in the flight
	VS.20	The handrail is continuous around landings (including intermediate landings)
	VS.21	The handrails are securely fixed to the supporting wall
Nosing	VS.22	There is no projecting nosing on the steps OR Nosing is at the acceptable standard of 25 mm

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Vertical circulation - Stair Space - Conformance A		
Categories	**Provisions: Must-have items**	
	VS.23	The nosings are in good order and securely fixed on the steps
	VS.24	The nosings must not present a tripping hazard or be in poor condition
Contrast	VS.25	The nosing on each step are visually contrasted
	VS.26	The contrast to the nosing can be seen when ascending and descending the stairs
Lighting	VS.27	Illuminance at tread/floor level is a minim of 100 lux
	VS.28	The lighting is not provided is in the riser of the steps
	VS.29	The lighting to the stairs is even
	VS.30	The lighting to the stairs must not cause glare or disorientation to users

Vertical circulation - Stair Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Stairs	VS.31	A flight has no more than 16 risers
Handrail	VS.32	The handrail is between 32 mm - 50 mm diameter OR The handrail is oval with dimensions of 50 mm wide and 39 mm deep
	VS.33	The handrail can be easily gripped along its full length (meaning that it is smooth, no rough surface)
	VS.34	The handrail is made easy and comfortable to grip, slip-resistant and smooth
	VS.35	On a wide flight of stairs (> 2000 mm), a central handrail is provided
	VS.36	There is a clear space 50 mm - 75 mm between handrail and the adjacent wall
	VS.37	There is a clear space of at least 50 mm between the underside of the handrail and any supporting wall
	VS.38	The top of the handrail is 900-1000 mm above the nosing
Nosing	VS.39	Nosing extends between 50-65 mm on the treads
	VS.40	Nosing extends between 30-55 mm on the risers

Vertical circulation - Stair Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Tactile Information	VS.41	Tactile information indicating floor levels is provided on the handrails
	VS.42	Tactile information indicating floor destination is provided on the handrails

6.7.5 Vertical circulation - Ramp

In this space, the conforming alternate version is applied. If the ramp is designed with an alternative stepped approach, this space will require Conformance AAA, as the alternative stepped approach is mainly designed for people with people with visual impairment.

Vertical circulation - Ramp Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Alternative Steps	VR.39	Alternative stepped approach is provided when there is a change in level served by the ramp that is more than 300 mm
	VR.40	Alternative stepped approach is designed in accordance with “Vertical Circulation - Stairs”

Vertical circulation - Ramp Space - Conformance A		
Categories	**Provisions: Must-have items**	
Slope	VR.1	The gradient of the ramp does not exceed 1:20 when the length of the ramp is less than 10m
	VR.2	The gradient of the ramp does not exceed 1:15 when the length of the ramp is less than 5m
	VR.3	The gradient of the ramp does not exceed 1:12 when the length of the ramp is less than 2m
Surfaces	VR.4	The surface to the ramps is smooth
	VR.5	The surface of the ramps is slip-resistant when wet
	VR.6	The surface of the ramps is in a color that contrasts visually with that of the landings
	VR.7	Surface patterns (cross stripes, etc.) must not be used if they could visually appear as steps
Width	VR.8	The minimum surface width of the ramp between walls, upstands or kerbs is 1200 mm
	VR.9	There is a clear unobstructed view along the whole length of the ramp
Handrails	VR.10	A handrail is securely installed on the supporting wall
	VR.11	The surface finish to the handrails is not reflective
Landings	VR.12	There is a landing at least 1200 mm long at the top of the ramp

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Vertical circulation - Ramp Space - Conformance A		
Categories	**Provisions: Must-have items**	
	VR.13	There is a landing at least 1200 mm long at the bottom of the ramp
	VR.14	There is no door swing that encroaches onto the landing area
	VR.15	All landings are level
	VR.16	No landings allow water to stand on the surface
Lighting	VR.17	Illuminance on the floor surface of the ramp is at a minimum of: 100 lux in general environments 200 lux in communal environments
	VR.18	The lighting to the ramp is even
	VR.19	The lighting to the ramp must not cause glare or disorientation to users
Protections	VR.20	Appropriate guarding is provided for ramps and landings with an open side to prevent falling
	VR.21	A kerb of 100 mm minimum height is provided
	VR.22	The kerb contrasts visually with the ramp and the landing
	VR.23	The minimum clear headroom to ramps and landings is 2m
Detectable Warning Surface	VR.24	A detectable warning surface is provided at the top of the ramp, with the full width of the ramp and a depth of 600 mm, commencing 300 mm back from the ramp
	VR.25	A detectable warning surface is provided at the bottom of the ramp, with the full width of ramp and a depth of 600 mm, commencing 300 mm back from the ramp
	VR.26	If an intermediate landing is present, a detectable warning surface is provided at the intermediate landing, with the full width of ramp and a depth of 600 mm, commencing 300 mm back from the ramp

Vertical circulation - Ramp Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Handrails	VR.27	A handrail is provided on both sides of the ramp

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Vertical circulation - Ramp Space - Conformance AA		
Categories	**Provisions: Should-have items**	
	VR.28	If a very wide ramp is provided, there is a central handrail
	VR.29	The handrail is between 32 mm - 50 mm in diameter OR The handrail is oval with dimensions of 50 mm wide and 39 mm deep
	VR.30	The handrail can be easily gripped along its full length (meaning that it is smooth, not a rough surface)
	VR.31	The handrail is made easy and comfortable to grip, slip-resistant and smooth
	VR.32	There is a clear space 50 mm - 75 mm between the handrail and the adjacent wall
	VR.33	There is a clear space of at least 50 mm between the underside of the handrail and any supporting wall
	VR.34	The handrail is continuous around landings
	VR.35	The top of the handrail is 900-1000 mm above the nosing
	VR.36	The top of the handrail is 900-1100 mm above the nosing
Landings	VR.37	There is an intermediate landing provided at each change of direction of the ramp
	VR.38	If an intermediate landing is provided, it is at least 1500 mm long
Surfaces	VR.39	If different surface finishes are used on the ramp, landings and approach paths, the coefficients of friction of all surfaces are similar
Width	VR.40	The minimum surface width of the ramp between walls, upstands or kerbs is 1500 mm

6.7.6 Vertical circulation - Lifts

Vertical circulation - Lifts Space - Conformance A		
Categories	**Provisions: Must-have items**	
Lift Cars	VL.1	The entrance door to the lift has a clear opening width of at least 800 mm
	VL.2	The floor surface inside the lift is firm
	VL.3	The floor surface inside the lift is slip-resistant
	VL.4	Flooring to the lift is light in color which is visually contrasted
Calling the lift	VL.5	The position of the lift landing and car doors are distinguishable visually from the adjoining walls
Using the lift	VL.6	The door remain open for at least 5 seconds
	VL.7	The door-reactivating device operates on infrared or photo eye sensors
	VL.8	Audible warnings of the doors opening and closing are provided
Contrast and Lighting	VL.9	The position of the lift is adequately identified using visual contrast and is well-illuminated
	VL.10	Minimum illuminance within the car is 100 lux
General	VL.11	The surface finishes used within the lift are not highly reflective
	VL.12	The surface finishes used within the lift do not create an unacceptable acoustic environment

Vertical circulation - Lifts Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Lift Cars	VL.13	A handrail is provided on three sides inside the lift
	VL.14	The handrail can be easily gripped (32-50 mm diameter or 50 mm wide and 39mm deep)
	VL.15	The handrail is located at 900 mm above floor level
Calling the lift	VL.16	The position of the buttons to call the lift is logical
	VL.17	The call panel is clearly distinguishable in terms of visual contrast from its background
	VL.18	The buttons illuminate when pressed

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Vertical circulation - Lifts Space - Conformance AA		
Categories	**Provisions: Should-have items**	
	VL.19	The buttons are placed between 900 mm and 1100 mm above floor level
	VL.20	The buttons are placed at least 500 mm from any return wall
	VL.21	Lift arrival indication is given by using text or a symbol
	VL.22	Lift arrival indication is given by appropriate use of audible sound
Using the lift	VL.23	The volume and clarity of the audible sound is appropriate
	VL.24	The floor level arrived at is announced audibly and visually
Control within the lift	VL.25	The control panel is situated logically within the lift
	VL.26	Call or control buttons are located between 900 mm and 1200 mm above floor level and at least 400 mm away from any return wall
	VL.27	Call buttons illuminate when pressed
	VL.28	Call buttons are not touch-sensitive
Braille and Tactile information	VL.29	The information on the buttons is appropriately embossed (e.g. tactile)

Vertical circulation - Lifts Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Calling the lift	VL.28	The information on the buttons is appropriately embossed (e.g. tactile)
Using the lift	VL.29	Audible warnings of the doors opening and closing are provided
	VL.30	Floor level indicators can be seen when the lift is full
	VL.31	Tactile and visual floor level indicators are provided outside the lift with clear visibility to users when the life door opens

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Vertical circulation - Lifts Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Control within the lift	VL.32	Information on the call buttons is provided in Braille embossed at 1 mm

6.7.7 Ambulant Disable WCs

Ambulant Disable WCs Space - Conformance A		
Categories	**Provisions: Must-have items**	
Number of accessible toilet	AD.1	There is at least one ambulant-accessible compartment in each standard male/female toilet
Layout	AD.2	The internal dimensions of the compartment allow at least 750 mm activity space clear of door swings in front of the WC
Door	AD.3	The door to the cubicle opens outwards OR If the door opens inwards, it can be opened outwards or removed easily in case of emergency
Lighting	AD.4	The minimum average illuminance at floor level is 100 lux
	AD.5	The light must not produce glare
Visual contrast	AD.6	The sanitary fittings and facilities provide adequate visual contrast with their background
	AD.7	Visual contrast is provided between the wall and floor junctions

Ambulant Disable WCs Space - Conformance AA		
Categories	**Provisions: Should-have items**	
WC	AD.8	The WC is placed centrally across the width of the WC
	AD.9	The flush is a spatula type OR operated by a proximity sensor
Grab rails	AD.10	There are two horizontal grab rails (each 600 mm long) placed 680 mm above floor level with their center line 650 mm from the rear wall of the cubicle
	AD.11	There is a 600 mm grab rail placed vertically on one side wall. There bottom of the rail is 800 mm above floor level
	AD.12	Grab rails protrude less than 90 mm into the cubicle space

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Ambulant Disable WCs Space - Conformance AA		
Categories	**Provisions: Should-have items**	
	AD.13	If a urinal is provided for use by ambulant disabled people (including people with visual impairment), a 500 mm grab rail is provided on both sides of the urinal

Ambulant Disable WCs Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Other essential items	AD.14	Coat hooks are provided at 1050 mm and 1400 mm above floor level

6.7.8 Accessible Washroom

Accessible Washroom Space - Conformance A		
Categories	**Provisions: Must-have items**	
Layout	AW.1	The maximum travel distance (combined horizontal and vertical) to an accessible washroom with an appropriate transfer side is 40m
Door	AW.2	The door opens outwards, and it must not encroach into the accessible route OR The door opens inwards, and it must be removed easily in case of emergency
WC	AW.3	The space between the WC and the wall is kept clear to allow a carer to assist if required
	AW.4	The seat is securely fixed and is of good quality
Lighting	AW.5	A white pull cord for the light is provided adjacent to the door OR A device is installed which automatically switches on the light when the toilet door is opened
	AW.6	Lighting is not activated by a passive infrared (PIR) motion detector
	AW.7	The lighting provided a minimum 100 lux at floor level
	AW.8	The lighting must not produce glare
Visual contrast	AW.9	The sanitary fittings and facilities provide adequate visual contrast with their background
	AW.10	Visual contrast is provided between the wall and floor junctions
Other essential features	AW.11	The floor covering is slip-resistant
	AW.12	Wall tiles or finishes are non-reflective
	AW.13	Facilities for disposable items are provided in a manner that does not impinge upon the clear space (transfer and maneuvering) within the WC

Accessible Washroom Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Accessibility	AW.14	Signage indicating the route to, and position of, the toilet facilities is adequate
	AW.15	An accessible washroom is provided at every location where standard toilet facilities are provided
	AW.16	The accessible washroom is a unisex toilet facility that can be accessed independently of other toilet accommodations
	AW.17	The accessible washroom is able to be locked by lever type
Layout	AW.18	There is minimum clear space of 1750 mm by 1750 mm
WC	AW.19	The flush is a spatula type
	AW.20	The flush is on the open transfer side
Dispensers	AW.21	There is a single-sheet toilet paper dispenser within easy reach of the WC
Grab rails	AW.22	There is a drop-down rail that is easy to operate from the seated position placed 350 mm from the center line of the WC
	AW.23	There is a vertical grab rail that extends between 800 mm and 1400 mm above floor level, and is placed to the open side of the WC, its center line 470 mm from the center of the WC
	AW.24	There is a grab rail on the wall adjacent to the WC that is 600 mm long and is placed 680 mm above floor level. One end of the grab rail is 250 mm away from the wall supporting the WC
	AW.25	There is a grab rail on the door at a height that will enable the user to pull the door closed
	AW.26	The diameter of all grab rails is between 32mm and 35mm, and they are easy to grip even when wet
Washing and drying hands	AW.27	There is a wall-supported wash hand basin provided at the top of the basin, 720-740 mm above floor level
	AW.28	The basin is 140-160 mm away from the WC
Alarm	AW.29	An emergency assistance alarm should be provided with a pull cord reachable from the bath or shower and the adjacent floor area

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Accessible Washroom Space - Conformance AA		
Categories	**Provisions: Should-have items**	

Accessible Washroom Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
WC	AW.30	There is a low-level cistern that could be used as a backrest OR A backrest with a padded section is provided 680 mm above floor level
Dispensers	AW.31	There is a dispenser for hand wipes within easy reach of the WC
Grab rails	AW.32	There are two vertical grab rails placed on both sides of the wash hand basin, which extend between 800 mm and 1400 mm
Washing and drying hands	AW.33	A single-lever mixer tap is provided
	AW.34	A soap dispenser is provided
	AW.35	The temperature of the water is controllable
	AW.36	A manually operated or automatic proximity warm-air dryer (with the activation button at 1200 mm above floor level) is provided adjacent to the hand basin
Other essential features	AW.37	Coat hooks are provided at 1050 mm and 1400 mm above floor level
	AW.38	A mirror is provided above the hand basin

6.7.9 Bathrooms and Shower

Bathrooms and Shower Space - Conformance A		
Categories	**Provisions: Must-have items**	
Layout	BS.1	For each bathroom, the minimum clear space of 900 mm by 1500 mm is provided
Surface	BS.2	Each bath should have a flat, slip-resistant base, a transfer seat, a rim height of 480 mm and a horizontal or angled support rail
	BS.3	Flooring in bathrooms and shower rooms should be slip-resistant when both dry and wet
Lighting	BS.4	A white pull cord for the light is provided adjacent to the door OR A device is installed which automatically switches on the light when the toilet door is opened
	BS.5	Lighting is not activated by a passive infrared (PIR) motion detector
	BS.6	The lighting provides a minimum 100 lux at floor level
	BS.7	The lighting must not produce glare
Visual contrast	BS.8	The sanitary fittings and facilities provide adequate visual contrast with their background
	BS.9	Visual contrast is provided between the wall and floor junctions

Bathrooms and Shower Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Accessibility	BS.10	Signage indicating the route to, and position of, the shower facilities is adequate
Shower Space	BS.11	The accessible bathroom provides either a bathtub or a shower space
Grab rails (if bathtub is provided)	BS.12	Grab rails are is at least 1200 mm long, located horizontally and 180-280 mm above the bathtub rim

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Bathrooms and Shower Space - Conformance AA		
Categories	**Provisions: Should-have items**	
	BS.13	The grab rail is at least 1200 mm, located vertically at the control end of the bathtub, 180-280 mm above the bathtub rim
Washing and drying hands	BS.14	There is a wall-supported wash hand basin provided at the top of the basin, 720-740 mm above floor level
	BS.15	The basin is 140-160 mm away from the WC
	BS.16	There is a paper towel dispenser that can be reached while seated on the WC
Emergency	BS.17	An emergency assistance alarm should be provided with a pull cord reachable from the bath or shower and the adjacent floor area

Bathrooms and Shower Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Shower Space	BS.18	The accessible bathroom should contain a shower stall
	BS.19	The shower should be fitted with a tip-up seat, grab rails and a shower curtain enclosing the seat, and a shelf for toiletries
WC	BS.20	Each accessible bathroom contains a WC
	BS.21	The WC is in accordance with WC provisions
Washing and drying hands	BS.22	A single-lever mixer tap is provided
	BS.23	A soap dispenser is provided
	BS.24	The temperature of the water is controllable
	BS.25	A manually operated or automatic proximity warm-air dryer (with the activation button at 1200 mm above floor level) is provided adjacent to the hand basin
Other features	BS.26	Coat hooks are provided at 1050 mm and 1400 mm above floor level

6.7.10 Bedroom

Bedroom Space - Conformance A		
Categories	**Provisions: Must-have items**	
General	B.1	Accessible bedrooms should be located on accessible routes that are direct and obstruction-free
Bed	B.2	Sufficient space is provided around the room and transfer to one side of the bed
Door	B.3	A clear opening width at a minimum of 750 mm is provided
Lighting	B.4	Sufficient lighting is provided at a minimum of 100 lux
	B.5	There is an even level of light throughout the room and no dark areas
	B.6	Lighting is well-positioned to prevent shadows from objects or from people moving around the room
	B.7	Table and floor lamps are positioned to avoid trailing wires and risk of trips or bumps
Storage and Wardrobes	B.8	Wardrobe and cupboard doors do not cause obstructions when used

Bedroom Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Sanitary	B.9	Sanitary accommodation is satisfied in accordance with the WC and Bathroom provisions for at least Level AA
Door	B.10	Door handle should be easy to grip and operate by people with visual impairments, and should contrast visually with the door
Emergency	B.11	Each accessible bedroom is fitted with an emergency assistance alarm operated by a pull cord that can be reached from the bed and from an adjacent floor area

Bedroom Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Sanitary	B.12	People with visual impairments should be able to gain access to all the facilities in the room and sanitary accommodations
Door	B.13	Electronic card-activated locks or electrically-powered openers for bedroom entrance doors are provided with clear visibility and audible indications
Emergency	B.14	A telephone is provided next to an electrical socket suitable for lighting and connections of call systems or tele-care equipment
Lighting	B.15	Lights are individually switched and can be dimmed
	B.16	Task lighting is available wherever it may be required (e.g., over drawers, dressing tables, beside beds and at desks)
	B.17	Vertical blinds are provided in order to reduce glares
Other features	B.18	Each accessible bedroom has a connecting door to an adjacent room for a companion or assistant
	BS.19	Wardrobes and large cupboards have interior lights that are operated by an accessible switch or automatically turn on and off after a short period

6.7.11 General space

General Space - Conformance A		
Categories	**Provisions: Must-have items**	
General	G.1	Circulation routes around the room are free of obstacles
	G.2	Most furniture is against the walls in order to provide a clear space in the center of the room
Lighting	G.3	Sufficient lighting is provided at minimum of 100 lux
	G.4	There is an even level of light throughout the room and no dark areas
	G.5	Table and floor lamps are positioned to avoid trailing wires and risk of trips or bumps
	G.6	Lighting is well-positioned to prevent shadows from objects or from people moving around the room
Sockets, Controls, and Equipment	G.7	There are sufficient and suitably-placed electrical sockets for all equipment to be used without trailing wires

General Space - Conformance AA		
Categories	**Provisions: Should-have items**	
General	G.8	People with visual impairments should be able to gain access to all the facilities in the room
Lighting	G.9	Lights are individually switched and can be dimmed
Sockets, Controls, and Equipment	G.10	All sockets and controls for heating, windows, lights and electrical equipment can be used without moving furniture

General Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Lighting	G.11	Task lighting is available wherever it may be required (e.g., over drawers, dressing tables, beside beds and at desks)
	G.12	Vertical blinds are provided in order to reduce glare

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General Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Sockets, Controls, and Equipment	G.13	Tactile input is provided on the controls and equipment
Emergency	G.14	A telephone is provided next to an electrical socket suitable for lighting and connection of call systems or tele-care equipment
Guide dog	G.15	There is sufficient space for a guide dog's bed and equipment

6.7.12 Utility spaces

Utility Space - Conformance A		
Categories	**Provisions: Must-have items**	
General	KU.1	The layout is logical (e.g., the sink and cooker are close together)
	KU.2	There is clear space for people to move around and between different areas, and they are free of obstacles and hazards
Surface	KU.3	Surfaces in this space must be smooth, flat and slip-resistant
Cupboards	KU.4	Cupboard doors do not cause any hazards when opened
Lighting	KU.5	Sufficient lighting is provided at a minimum of 100 lux on the floor surface
	KU.6	There is an even level of light throughout the room and no dark areas
	KU.7	Lighting is well-positioned to prevent shadows from objects or from people moving around the room

Utility Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Cupboards	KU.8	Contrasting colors differentiate equipment or appliances and cupboard from floors, surfaces and walls
	KU.9	Shiny or reflective surfaces is minimized
Lighting	KU.10	Sufficient lighting is provided at a minimum of 300 lux on the kitchen surface
	KU.11	Lights are individually switched
Sockets, Controls, and Equipment	KU.12	There are clear and distinct controls and indicators that contrast with their background
	KU.13	The control settings are understandable by sound or touch

Utility Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Lighting	KU.14	Task lighting is available wherever it may be required (e.g. kitchen counter)
	KU.15	Vertical blinds are provided in order to reduce glares
Sockets, Controls, and Equipment	KU.16	Tactile input is provided on the controls and equipment

6.7.13 Hall and stadium

Hall and stadium Space - Conformance A		
Categories	**Provisions: Must-have items**	
Accessible Route	L.1	Routes are accessible and of sufficient width to allow visually impaired people with a guide dog to circulate
	L.2	Handrails are provided on stepped and ramped routes

Hall and stadium Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Seating	L.3	People with visual impairments should have access to the full range of seating locations and be able to sit alongside a disabled or non-disabled companion

Hall and stadium Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Guide dog	L.4	Space for the guide dog is provided adjacent to seating and clear of circulation routes
Emergency	L.5	Emergency egress procedures should take account of the needs of all people who need assistance, whether they are seated in designated areas or not

6.8 Summary

The BRS was introduced and described, using a bottom-up design approach from space classification, to floor classification, and lastly to building classification as shown in Section 6.2. In Section 6.3 three conformance levels were defined and their use demonstrated in terms of the accessibility classification, indicating the level of accessibility provided for the space.

In the space classification shown in Section 6.4, levels of accessibility are acquired by the spaces, and are used for the floor and building classification, using a majority scoring approach to determine the level of accessibility for each floor and for the building in overall.

For the building accessibility measurement, the Success Criteria for all 13 spaces were shown in Sections 6.7.1 - 6.7.13 by the studies and reviews of the building design standards and guidelines available around the world.

The building rating system was validated and reviewed by the groups of experts, which answers the research question SRQ4. The findings and discussion of expert validation and review is covered next in Chapter 7.5.

Chapter 7

Building Rating System: Expert Validation and Review, and User Evaluation

This chapter describes the findings of expert validation and review of the BRS. The BRS was validated and reviewed by three groups of five experts, representing the areas of research & development, accessibility, and building and interior design. Details of the methodology used in this study was described in Section 3.4.2. The BRS was later then evaluated using System Usability Scale (SUS) by nine risk accessors.

Section 7.1 describes the results of the pilot that was used to improve the interview questions for the expert validation and review. The demographics of the experts recruited is next described in Section 7.2, following by an analysis that tests the correlation and difference in means between the experts and the groups overall, as shown in Section 7.3. Later, assessment of the design is covered in Section 7.4.1.1, definition of the conformance levels used in the space classification in Section 7.4.1.2, and floor and building classifications are shown in Section 7.4.1.3. The findings of sets of success criteria for all 13 spaces are discussed in subsequent Sections.

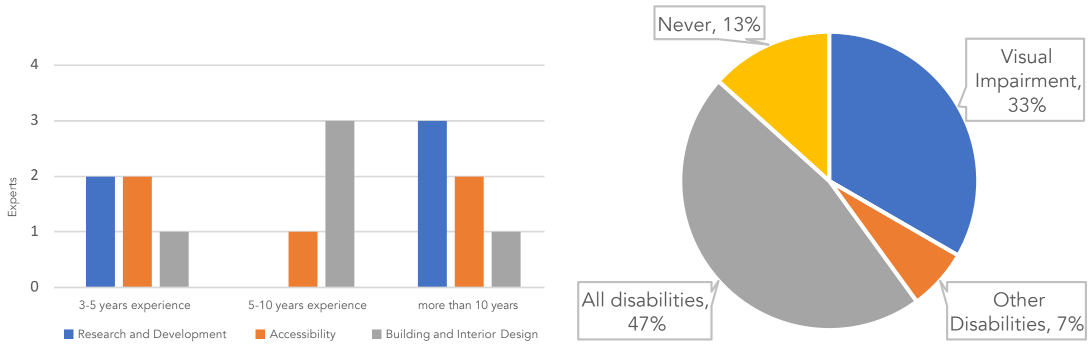
7.1 Findings of the Pilot

Prior to the expert validation and review, a pilot questionnaire was conducted to find if any improvement was needed. Six participants (of which two have worked as developer, accessibility designer, and building and interior design) were invited for this stage. Three main issues identified that need to be fixed are summarised in Table 7.1. The final version of questionnaire used for expert validation and review is shown in Appendix E.1.

TABLE 7.1: Findings of Piloting

Category of changes	**What to be improved?**	**Result of changes**
Revise the descriptions	Role of experts (research and development; accessibility; and building and interior design)	Make the scenario and role of experts clearer and more understandable
Revise the definition in Section 2.2 "Space Classification"	The definition of each level was unclear and slightly conflicted with another level	Make it clearer
Revise the criterion in Section 3 "Success criteria"	Some criteria are unclear due to technical terms in architecture	Easy to understand by adding images as a guideline in each section
	Participant took too long (3 hours and more) in reviewing the success criteria due to the technical terms	Reduce time to an hour for reviewing the document

7.2 Demographic



(a) Expert working experience

(b) Experience with disabled people

FIGURE 7.1: Working Experience

Three groups of five experts in each of research and development (RDE), accessibility (AE), and building and interior design (BIE), were recruited, whose experience fell into the ranges shown in Figure 7.1(a). The number of experts that have worked with disabled people is shown in Figure 7.1(b). Thus, 5 experts have worked with people with visual impairment, 7 with all disabilities (e.g. visual, hearing, and motor impairment), and 1 expert with other disability, Cerebral palsy[25], while two experts from the field of research and development that had not yet worked with disabled people. Table 7.2 give details about the experts recruited for this study.

[25] A type of muscle impairment that results in a permanent movement disorder due to the weak muscles and tremors that usually appear in childhood. This symptom may cause problems such as perception, sensation, vision, hearing, and speaking (Krigger, 2006)

Table 7.2: Details of the recruited experts

ID	Expertise and work experience	ID	Expertise and work experience
RDE1	Researcher/Developer; 12 years; working with people with visual impairment	AE4	Researcher/Accessibility; 10 years; working with people with visual impairment
RDE2	Researcher/Developer; 14 years; working with people with disabilities	AE5	Researcher/Accessibility; 3 years; working with people with visual impairment
RDE3	Researcher/Developer; 15 years; working with people with disabilities	BIE1	Building design/Safety inspection; 10 years; working with people with disabilities
RDE4	Developer; 3 years; never worked with disabled people	BIE2	Building/Interior design; 3 years; working with people with disabilities
RDE5	Researcher/Developer; 3 years; never worked with disabled people	BIE3	Building/Interior design; 6 years; working with people with disabilities
AE1	Accessibility; 10 years; working with people with visual impairment	BIE4	Building/Interior design; 8 years; working with people with Cerebral Palsy (muscle impairment)
AE2	Researcher/Accessibility; 8 years; working with people with disabilities	BIE5	Building/Interior design; 7 years; working with people with visual impairment
AE3	Researcher/Accessibility; 3 years; working with people with visual impairment		

7.3 Expert Validation and Review: Exploration

Prior to the main analysis of the expert validation and review, it is important to test how their responses correlated with each other and within the groups, since the experts belonged to three different groups. Moreover, some experts may give lower, higher, or biased ratings, so it is also important to see whether there were differences in the means. With this test, experts found to have given too low, high, or biased ratings may be excluded from the expert validation and review, since biased responses could cause undesired results.

7.3.1 Expert Correlation and Mean Difference

Table 7.3: Overall Expert Correlation

	N	Mean	p
Overall Expert Correlation	105	0.36	< 0.001

In this test, the correlations for each expert were individually conducted, as shown in Appendix G.1.1, to find difference in means of the experts' correlations. The overall correlations were calculated using t-tests given by the inter-experts correlation, the correlations of 15 experts being shown in Table G.2. The summarised result in Table 7.3 showed that there were significant positive correlations within the experts, $r = 0.36$, $N = 105$, $p < 0.001$. Detailed statistical tests of the overall expert correlation can be found in Appendix G.1.2.

TABLE 7.4: Differences in Means of the Experts

Effect		**Value**	***F***	**Hypothesis df**	**Error df**	***p***
Expert	Pillai's Trace	0.99	540.78	6.00	36.00	< 0.001
	Wilks' Lambda	0.01	540.78	6.00	36.00	< 0.001
	Hotelling's Trace	90.13	540.78	6.00	36.00	< 0.001
	Roy's Largest Root	90.13	540.78	6.00	36.00	< 0.001

In spite of the overall positive correlation, detailed analysis in Table 7.4 showed that there were difference in means of expert responses tested by a repeated measures one-way ANOVA: Wilks' Lambda = 0.01, $F(6.00, 36.00) = 540.78$, $p < 0.001$. The repeated measures one-way ANOVA are shown in Appendix G.1.3, and, using the estimated marginal means in Table G.11, the expert means were drawn as a profile plot shown Figure 7.2.

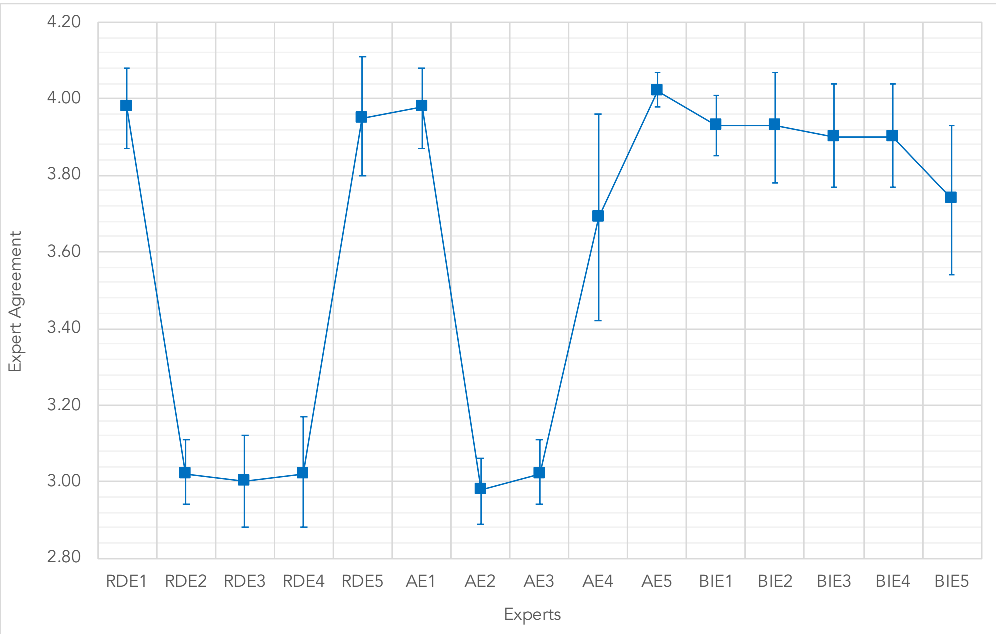


FIGURE 7.2: Means of Expert Ratings with Confidence Interval

It can be seen that some experts gave lower ratings on average, approximately 1 scale point, such as RDE2-RDE4 and AE2-AE3. Despite the difference in means found, there were no exclusions in this expert validation and review as the gap in mean differences was not too big, and the experts were recruited for their expertise whose comments would be of use in the improvement of the design of BRS and of the Success Criteria used in the BRS.

7.3.2 Expert Correlation and Mean Difference Between Groups

In this test, correlations were tested between the three expert groups to see if there were any associations. Table 7.5 shows that there were significant positive correlation: RDE correlated with AE ($r = 0.66$, $N = 42$, $p < 0.001$), and RDE correlated BIE ($r = 0.43$, $N = 42$, $p < 0.001$), while AE and BIE were not significantly correlated with each other.

TABLE 7.5: Group Correlations

		RDE	**AE**	**BIE**
RDE	Pearson Correlation	1	0.66**	0.43**
	Sig. (2-tailed)		< 0.001	0.004
AE	Pearson Correlation	0.66**	1	0.10
	Sig. (2-tailed)	< 0.001		0.526
BIE	Pearson Correlation	0.43**	0.10	1
	Sig. (2-tailed)	0.004	0.526	

** Correlation is significant at the 0.01 level (2-tailed)

In spite of the insignificant positive correlation, the result of correlations between groups seemed natural due to the characteristics of each group, because the accessibility experts specialise in assistive technology and disability matters, while the building and interior design experts specialise in designing and organising spaces. There was common knowledge between both groups, which resulted in the positive correlation ($r = 0.10$, $N = 42$) in the group correlation matrix. The detailed statistical test can be found in Appendix G.1.4.

TABLE 7.6: Differences in Expert Group Means

Effect		**Value**	***F***	**Hypothesis df**	**Error df**	***p***
Group	Pillai's Trace	0.63	33.54	2.00	40.00	< 0.001
	Wilks' Lambda	0.37	33.54	2.00	40.00	< 0.001
	Hotelling's Trace	1.68	33.54	2.00	40.00	< 0.001
	Roy's Largest Root	1.68	33.54	2.00	40.00	< 0.001

However, looking at the overall mean difference between groups, the Table 7.6 shows that there were differences in means, Wilks' Lambda = 0.37, $F(2.00, 40.00) = 33.54$, $p < 0.001$. The overall means for all groups are illustrated in Figure 7.3, where gaps between groups were around 0.14-0.50, which are considered small. For more information about the repeated measures one-way ANOVA, see Appendix G.1.5.

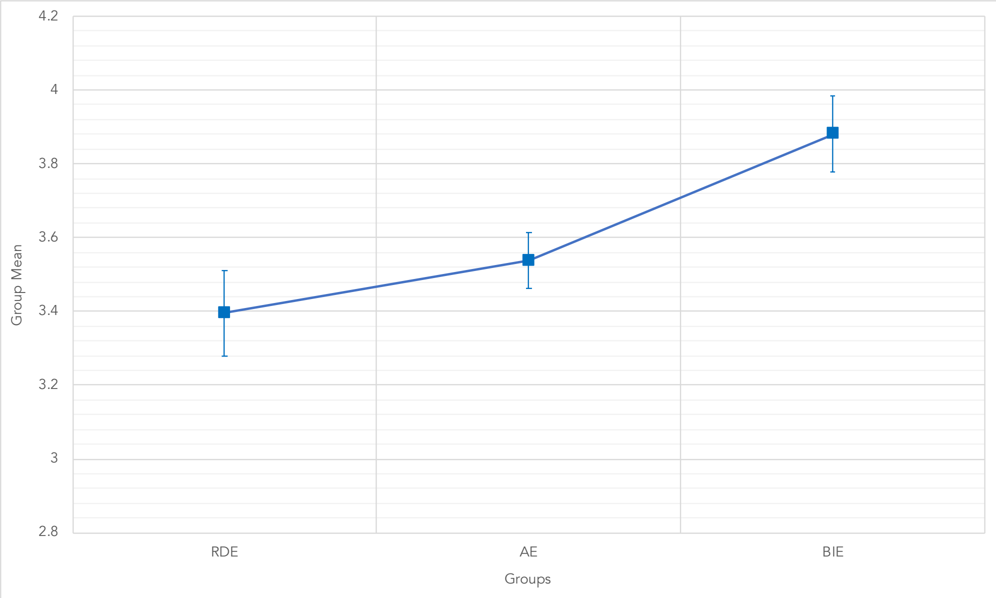


FIGURE 7.3: Means of Group Ratings with Confidence Interval

7.4 Expert Validation and Review

The BRS was validated and reviewed by three groups of experts. Section 7.4.1 reveals the findings of the validation and review of the design, while Section 7.4.2 describes the findings on success criteria used in all 13 spaces.

7.4.1 Design of Building Rating System

In Section 7.4.1.1 the experts were asked to validate and review a design of the BRS in overview. In Sections 7.4.1.2 and 7.4.1.3 the BRS is separated into space floor and building classification.

7.4.1.1 Overall of the Building Rating System

All experts read the design of the BRS, which is a bottom-up design (shown in Section 6.2), starting with the building classification, floor classification in the next, and space classification the last.

TABLE 7.7: Expert validation of the BRS

	Agree	**Disagree**	**Neutral**	**Validation**	**Mean**	***p***
Do you agree with the design of the building rating system?	13	0	2	Pass	4.13	< 0.001

Table 7.7 shows that the design of the BRS was successfully validated, with 13 experts' agreement, whose mean was 4 (Agree), and found to be statistically significantly higher

than the neutral ($p < 0.001$). Two of the building and interior design experts expressed Neutral opinions. Most experts agreed that the system was well-designed and sensible in practice, while others expressed opinions which could improve it.

For example, RDE2 suggested that the type of building to be measured should be specified beforehand, e.g. office building, university, hospital. BIE2 and BIE3 said that sets of success criteria used for rating each type of building should be separated because each type of building has its own set of success criteria, while BIE4 stated that the building rating should consider the buildings where most people usually visit, such as hospital and civic centre. AE4 commented that the design of the overall rating scale should be verified and subjectively judged by informed users, which in this case are people with visual impairment. AE5 suggested the system should be extended to other disabilities, such as motor and hearing impairment.

7.4.1.2 Space classification

The four conformance levels (No Conformance, A, AA, and AAA) were defined in Section 6.4. The experts were asked to validate and review the definitions used in the BRS. 12 experts agreed with the definitions used in the space classification, while 1 accessibility expert disagreed and 2 building and interior design experts were neutral. Table 7.8 showed that the space classification was successfully validated with 12 experts' agreement, the mean of the experts' agreement was slightly dropping to 3.667 and was found to be statistically significantly higher than the neutral ($p = 0.027$).

Table 7.8: Expert validation – space classification

	Agree	Disagree	Neutral	Validation	Mean	p
Do you agree with the conformance to be used in the space classification?	10	3	2	Pass	3.67	0.027

A number of comments were made during the expert review. RDE2 suggested that in some cases technology can solve the problem, for example the head room can be protected by using an infrared sensor. Thus, there could be another level of Conformance named "Technology". However, RDE3 commented that the definitions should be clear and justifiable.

AE2 disagreed with the Conformance levels and suggested that using level of usability may be better than level of accessibility. For example, Conformance A is defined as "Features may not be well-designed, please use with caution"; and No Conformance means people with visual impairment need to bring friends with them. AE2 also suggested that imitating WCAG 2.0 in another way would be better, thus: Level 1: Physical, Level 2: Colour, Level 3: Sound.

In Conformance A, BIE2 disagreed that "Cannot tell" or "Not applicable" should not be provided in the Must-Have requirements since requirements at this level cannot be avoided or ignored. BDE1 pointed out that multi-level criteria could be used instead of Pass/Fail criteria.

AE3 pointed out the connection between spaces should also be measured for its accessibility. RDE1 and AE1 suggested some vertical circulations such as stair and lift are not attached to any floor but connected to all floors vertically. Thus, the measure of accessibility for stair and lift should be split from floor level.

7.4.1.3 Floor and Building classifications

The method for floor and building classifications is now addressed, with the use of averaging method discussed in Section 6.5. The experts were asked to validate and review whether this method was good enough to rate the building for overall accessibility. Most experts disagreed with the method used for floor and building classification, as shown in Table 7.9. A method for floor and building classifications was successfully validated but failed in its design as only 3 experts agreed with the method, which is reflected by the mean of 2.4, statistically significantly lower than the neutral ($p = 0.033$). A solution to this problem will be given in Section 7.5.3.

TABLE 7.9: Expert validation – floor and building classifications

	Agree	**Disagree**	**Neutral**	**Validation**	**Mean**	***p***
Do you agree with the conformance to be used in the floor and building classifications?	2	10	2	Fail	2.22	0.005

Most experts disagreed with the averaging method since it results in wrongly rating the buildings. RDE3 commented that averaging may be too coarse to use, especially for safety concerns. For example, the building may have high average score but still have spaces that have No conformance. Likewise, RDE4 commented that if some floor falls into No conformance, this means there is no accessibility provided in any space of the floor, but the overall building score is probably 2 or over if there is full accessibility provided on other floors. Because the average score only is considered, the overall score can be high, but it cannot indicate that every floor provides good accessibility for people with visual impairment.

To solve the averaging method's limitation, RIE2 and BIE4 suggested that this may be addressed by the use of overlapping scores. The method uses common scores from each floor to be an overall building rating score. However, AE5 suggested that the rating scale could be extended by using number scales (e.g. 0.5) rather than categorical scales (i.e. A, AA, and AAA) while AE1 advised that using a categorical score would be better, such as

- Score 1.00-1.49: Conformance A
- Score 1.50-1.99: Conformance A+
- Score 2.00-2.49: Conformance AA
- etc.

BIE2 suggested using a different set of Conformance levels, focusing on suitability rather than accessibility as proposed. For example,

- Conformance A - the building is good for blind people. This level focuses on the features that blind people can perceive, for example surface (touch) and hearing features.
- Conformance AA - the building is good for visually impaired people. This level extends the previous level, focusing on other features that visually impaired people can perceive.
- Conformance AAA - the building is good for both blind and visually impaired people. This level extends the previous level where specific features are added in order to make full use of buildings. For example, type of walls, type of mirrors, etc.

7.4.2 Success Criteria

The experts were asked to validate and review the success criteria for 13 types of space provided in general buildings and public spaces as follows:

1. Entrances — Section 7.4.2.1
2. Foyers — Section 7.4.2.2
3. Horizontal circulation (e.g. corridor and passageway) — Section 7.4.2.3
4. Vertical circulation - Stairs — Section 7.4.2.4
5. Vertical circulation - Ramps — Section 7.4.2.5
6. Vertical circulation - Lifts — Section 7.4.2.6
7. Sanitary - Ambulant Disable WCs — Section 7.4.2.7
8. Sanitary - Accessible Washroom — Section 7.4.2.8
9. Sanitary - Bathrooms and shower rooms — Section 7.4.2.9
10. Bedrooms — Section 7.4.2.10
11. General space (e.g. office, living room, refreshment room) — Section 7.4.2.11
12. Utility spaces (e.g. kitchen, laundry, and storage room) — Section 7.4.2.12
13. Hall and stadium (e.g. lecture room, conference room, auditorium, and stadium) — Section 7.4.2.13

7.4.2.1 Entrance

The experts were asked to validate and review all success criteria for Entrances from Conformance A, AA, and AAA, as shown in Section 6.7.1. 9 experts agreed with the success criteria for Conformance A and AAA, and 10 experts agreed on Conformance AA, while 1 accessibility expert disagreed. As shown in Table 7.10, the success criteria for entrance spaces were successfully validated at all levels of Conformance A ($p = 0.048$), AA ($p < 0.001$), and AAA ($p = 0.006$), while all means of experts' agreement were above 3.

Table 7.10: Expert validation of success criteria – entrance spaces

Entrance Space	Agree	Disagree	Neutral	Validation	Mean	p
Do you agree with the success criteria shown in Conformance A?	9	1	5	Pass	3.47	0.048
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	9	1	5	Pass	3.53	0.006

AE1 commented that the lighting matter should be in Conformance AA since some people with visual impairment can perceive the information using a white cane. AE4 mentioned a lack of pathway and floor surrounding requirements for the entrance space, and audible warning should also be installed at the entrance with signage incorporated.

BIE2 and BIE3 suggested that more specification for the mirror used on the door's adjacent wall may be required. This is because when people might bump into the entrance door, they might get injured by the encounter if the material used on the entrance breaks. BIE5 mentioned the flooring systems and ramp criteria should be developed since some buildings' entrances might have a change of level.

It was suggested by BIE5 that the entry system should be equipped with two operational buttons installed at two different heights: one for wheelchair users and another for people with visual impairment. BIE4 mentioned that all space should take the acoustic environment into account since people with visual impairment have used that noise to help them navigate.

7.4.2.2 Foyers

The experts were asked to validate and review all success criteria for Foyers from Conformance A, AA, and AAA, as shown in Section 6.7.2. 10 experts agreed with the success criteria for Conformance A, AA and AAA. As shown in Table 7.11, the success criteria for foyer spaces were successfully validated at all levels of Conformance A, AA, and AAA, while all means of experts' agreement were above 3 ($p < 0.001$).

Most of the suggestions in this space are about lighting. Building and interior design experts (BIE1, BIE2, and BIE3) advised that illumination of 500 lux should be in Conformance AAA since it is too specific and does not much affect people with visual impairment performing some activities in this area. BIE1 gave as supporting reason that

Table 7.11: Expert validation of success criteria – foyer space

Foyer Space	Agree	Disagree	Neutral	Validation	Mean	p
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

sufficient illumination used in Thailand is between 150-300 lux. Nonetheless, BIE1 mentioned that the specification used in the success criteria must comply with the design standards and guideline used in the country of the building being measured.

BIE4 mentioned again that all space should take acoustic environment into account since people with visual impairment have used that noise to help them navigate.

7.4.2.3 Horizontal circulation

The experts were asked to validate and review all sets of success criteria for horizontal circulation from Conformance A, AA, and AAA, as shown in Section 6.7.3. 10 experts agreed with the given set of criteria while 5 experts expressed Neutral opinion. As shown in Table 7.12, the success criteria for horizontal circulation spaces were successfully validated at all levels of Conformance A, AA, and AAA, while all means of experts' agreement were above 3 ($p < 0.001$).

Table 7.12: Expert validation of success criteria – horizontal circulation space

Horizontal Circulation Space	Agree	Disagree	Neutral	Validation	Mean	p
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

BIE2 and BIE3 both suggested that an illumination of 100 lux in Conformance A in all spaces could be moved to Conformance AA instead, since blind people cannot make use of light, while BIE1 gave a supporting reason that sufficient illumination used in Thailand is between 150-300 lux. However, BIE1 also mentioned that the specification used in the success criteria must comply with the design standards and guideline used in the country of the building being measured.

BIE4 advised that the acoustic item may be added since it is important to people with visual impairment when navigating. It was agreed by BIE2 and BIE3 that the acoustic could be added in Conformance AA.

However, two suggestions were made regarding a guardrail and use of colour in the horizontal circulation. First, AE4 pointed out in a wall category (or similar) that a guardrail with an appropriate height should be added for Passageways that connect to other Passageways or open-air areas, e.g. Passageways connecting buildings. Secondly, BIE5 suggested that a use of colour may be added in Conformance AAA. For example, utilising colour and borders as a navigational guide can help people with visual impairment to perform their activities.

7.4.2.4 vertical circulation – Stair

The experts were asked to validate and review all sets of success criteria for rating vertical circulation – stair spaces from Conformance A, AA, and AAA, as shown in Section 6.7.4. 10 experts agreed with the given set of criteria while 5 experts expressed a Neutral opinion. As shown in Table 7.13, the success criteria for vertical circulation – stair spaces were successfully validated at all levels of Conformance A, AA, and AAA, while all means of experts' agreement were above 3 ($p < 0.001$).

Table 7.13: Expert validation of success criteria – vertical circulation – stair space

vertical circulation – Stair Space	Agree	Disagree	Neutral	Validation	Mean	p
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

Accessibility expert AE4 mentioned an addition of specification for stair nosing. The surface on steps and stair nosing should be made from non-slippery material. A comment raised by RD5, said there should be markers on the last step on both top and bottom of a stairway. These markers will help prevent people with visual impairment from a falling hazard, since missing a step or losing body balance could potentially harm them.

Experts BIE2 and BIE3 claimed that in all spaces, the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3 above. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

7.4.2.5 vertical circulation – Ramp

The sets of success criteria used for rating vertical circulation – ramp spaces, shown in Section 6.7.5, were validated and reviewed. 9 experts agreed with the given set of criteria of Conformance A and 10 experts agreed with the rest of the criteria for Conformance AA and AAA. 1 building and interior design expert, however, disagreed with Conformance

A, while 5 experts expressed a Neutral opinion. As shown in Table 7.14, the success criteria for vertical circulation – ramp spaces were successfully validated at all levels of Conformance A ($p = 0.006$), AA ($p < 0.001$) and AAA ($p < 0.001$), while all means of experts' agreement were above 3.

TABLE 7.14: Expert validation of success criteria – vertical circulation – ramp space

vertical circulation – Ramp Space	Agree	Disagree	Neutral	Validation	Mean	p
Do you agree with the success criteria shown in Conformance A?	9	1	5	Pass	3.53	0.006
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

Two comments were raised by AE4 about ramp surface and handrails along the ramp. The first suggestion is that the ramp surface must be slip-resistant when dry, while the other suggestion is that handrails that should be securely fixed on the supportive wall, and moved to Conformance A instead of Conformance AA, since the handrails along both sides are used to prevent the tripping hazard and help with body balancing while navigating through this space.

AE5 suggested that signage and warnings should be provided for people with visual impairment when approaching the ramp. BIE5 raised the point that a gradient of 1:12 for a ramp in Conformance A is enough for any length according to the building design regulations in Thailand. Gradients of 1:15 and 1:20 could be moved to either Conformance AA or AAA, but AAA is preferred.

BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3 above. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

7.4.2.6 vertical circulation – Lift

The sets of success criteria used for rating vertical circulation – lift spaces, shown in Section 6.7.6, were validated and reviewed. 9 experts agreed on Conformance A and AAA, and 10 experts agreed on Conformance AA. However, 1 accessibility expert disagreed with Conformance A and AAA, while 5 experts expressed a Neutral opinion. As shown in Table 7.15, the success criteria for lift spaces were successfully validated at all levels of Conformance A ($p = 0.007$), AA ($p < 0.001$), and AAA ($p = 0.006$), while all means of experts' agreement were above 3.

AE4, who disagreed with the Conformance A, commented that Braille and tactile information should be provided on the lift control panel as well as audible feedbacks and

Table 7.15: Expert validation of success criteria – vertical circulation – lift space

vertical circulation – Lift Space	Agree	Disagree	Neutral	Validation	Mean	*p*
Do you agree with the success criteria shown in Conformance A?	9	1	5	Pass	3.53	0.006
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	9	1	5	Pass	3.53	0.006

warnings when the lift is arriving or closing should be in Conformance A instead of Conformance AAA. The supporting reason is that people with visual impairment are unlikely make use of lifts if no tactile information provided on the control panel, and the absence of audible feedback and warnings may result in the person being hit. BIE4 also suggested the addition of audible feedback with an appropriate use of sound. In Thailand, most lifts have no audible feedback and warnings, which makes them inaccessible to people with visual impairment.

AE5 suggested there should be signage, lines (floor signs/markings), or tactile (braille blocks) to guide people with visual impairment to the lifts. With this information, people will navigate more easily in big and complex buildings, and in public spaces.

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

7.4.2.7 Sanitary - Ambulant Disabled Water Closet

The sets of success criteria used for rating sanitary - ambulant disabled water closet spaces shown in Section 6.7.7 were validated and reviewed. 10 experts agreed on Conformance A, AA and AAA while 5 experts expressed a Neutral opinion. As shown in Table 7.16, the success criteria for horizontal circulation spaces were successfully validated at all levels of Conformance A, AA and AAA, while all means of experts' agreement are above 3 ($p < 0.001$).

Table 7.16: Expert validation of success criteria – ambulant disabled water closet space

Ambulant Disabled WC Space	Agree	Disagree	Neutral	Validation	Mean	*p*
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

No special changes in the success criteria were suggested, other than the common changes in lighting and acoustics raised by BIE2 and BIE3 who claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured, as suggested by BIE1.

7.4.2.8 Sanitary - Accessible Washroom

The sets of success criteria used for rating sanitary - accessible washroom spaces shown in Section 6.7.8 were validated and reviewed. 10 experts agreed on Conformance A, AA and AAA, while 5 experts expressed a Neutral opinion. As shown in Table 7.17, the success criteria for accessible washroom spaces were successfully validated at all levels of Conformance A, AA and AAA, while all means of experts' agreement were above 3 ($p < 0.001$).

Table 7.17: Expert validation of success criteria – accessible washroom space

Accessible Washroom Space	**Agree**	**Disagree**	**Neutral**	**Validation**	**Mean**	***p***
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

No special changes in the success criteria were suggested, except the common changes. One interesting suggestion made by AE5, was that there should be a mini-map or information describing the layout of the space, provided on the right-hand side when entering the accessible washroom. Thus, people with visual impairment would be able to familiarise themselves with this space and use with caution. However, BIE5 was most concerned about the surface in this space. The surface and tile textures used in this space must be slip-resistant in both dry and wet.

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

7.4.2.9 Sanitary - Bathroom and Shower Space

The sets of success criteria used for rating sanitary - bathroom and shower spaces shown in Section 6.7.9 were validated and reviewed. 9 experts agreed with the Conformance A and 10 experts agreed on Conformance AA and AAA. 1 building and interior design expert disagreed with Conformance A, while 5 experts expressed a Neutral opinion. As shown in Table 7.18, the success criteria for accessible washroom spaces were successfully validated at all levels of Conformance A ($p = 0.041$), AA ($p < 0.001$) and AAA ($p < 0.001$), while all means of experts' agreement were above 3.

TABLE 7.18: Expert validation of success criteria – bathroom and shower space

Bathroom and Shower Space	**Agree**	**Disagree**	**Neutral**	**Validation**	**Mean**	***p***
Do you agree with the success criteria shown in Conformance A?	9	1	5	Pass	3.47	0.048
Do you agree with the success criteria shown in Conformance AA?	9	1	5	Pass	3.53	0.006
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

Some conflicts in the success criteria were raised by AE4, who said that if BS1 is Passed (e.g. a bathtub is provided), BS2 will automatically fail because shower stall is recommended rather than the bathtub. With this success criterion, this space will acquire No conformance, otherwise the bathroom provides the shower stall or both bathtub and shower stall. However, one suggestion from BIE5 was that the bathroom should also provide clothes hooks at an appropriate height.

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

As shown in sanitary - accessible washroom in Section 7.4.2.8, AE5 suggested a mini-map or information provided on the right-hand side when entering to this space describing the layout of the space.

7.4.2.10 Bedroom

The sets of success criteria used for rating bedroom spaces shown in Section 6.7.10 were validated and reviewed. 10 experts agreed with Conformance A and AAA, while 8 experts agreed on Conformance AA. 2 experts from building and interior design area disagreed with Conformance AA. As shown Table 7.19, the success criteria for accessible washroom spaces were successfully validated at all levels of Conformance A ($p < 0.001$), AA ($p = 0.054$) and AAA ($p < 0.001$), while all means of experts' agreement were above 3.

Conformance AA was found not to be statistically significant for reasons given by the building and interior design experts. BIE4 commented that sanitary accommodation (i.e. an accessible washroom with a bathtub or shower stall) in Conformance AA should be moved to Conformance AAA instead, since it could have been provided in this space. BIE5 said the bed should be equipped with bedrails to help people with visual impairment

TABLE 7.19: Expert validation of success criteria – bedroom space

Bedroom Space	Agree	Disagree	Neutral	Validation	Mean	*p*
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	8	2	5	Pass	3.40	0.054
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

maintain their balance when getting up, in Conformance AA. With these it would also help people with motor disability.

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

As shown in sanitary - accessible washroom in Section 7.4.2.8, AE5 suggested a mini-map or information provided on the right-hand side when entering to this space describing the layout of the space.

7.4.2.11 General Space

The sets of success criteria used for rating general spaces shown in Section 6.7.11 were validated and reviewed. 10 experts agreed on the success criteria for Conformance A, AA and AAA, while 5 experts expressed a Neutral opinion. Table 7.20 showed the success criteria for general space were successfully validated at all levels of Conformance A, AA and AAA, while all means of experts' agreement were above 3 ($p < 0.001$).

TABLE 7.20: Expert validation of success criteria – general space

General Space	Agree	Disagree	Neutral	Validation	Mean	*p*
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

No changes in success criteria were suggested, except one noted by AE1. This expert said that meeting-room spaces may not be classified as general space, which means the success criteria for this space would not fit in this case.

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3.

Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

As shown in sanitary - accessible washroom in Section 7.4.2.8, AE5 suggested a mini-map or information provided on the right-hand side when entering to this space describing the layout of the space.

7.4.2.12 Utility Space

The sets of success criteria to be used for rating utility spaces shown in Section 6.7.12 were validated and reviewed. 8 experts agreed with the success criteria for Conformance A, while 2 experts from accessibility and building and interior design disagreed. However, 10 experts agreed on the success criteria for Conformance AA and AAA, while 5 experts expressed a Neutral opinion.

Table 7.21 showed the success criteria for utility spaces were successfully validated at all levels of Conformance A ($p = 0.054$), AA ($p < 0.001$) and AAA ($p < 0.001$), while all means of experts' agreement were above 3. Conformance A was found not to be statistically significant for reasons given by two experts.

TABLE 7.21: Expert validation of success criteria – utility space

Utility Space	**Agree**	**Disagree**	**Neutral**	**Validation**	**Mean**	***p***
Do you agree with the success criteria shown in Conformance A?	8	2	5	Pass	3.40	0.054
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

Two experts commented that there were two missing criteria in this space. AE4 said that there should not be changes in level such as steps or ramp. Supporting reasons are that in this type of space, especially a kitchen space, many features could potentially harm people with visual impairment if no appropriate place for equipment has been considered. BIE5 suggested that tiles used on a wall or surface should also be slip-resistant, otherwise causing the same incidents mentioned by AE4.

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

As shown in sanitary - accessible washroom in Section 7.4.2.8, AE5 suggested a mini-map or information provided on the right-hand side when entering to this space describing the layout of the space.

7.4.2.13 Hall and Stadium Spaces

The sets of success criteria used for rating hall and lecture theatre spaces shown in Section 6.7.13 were validated and reviewed. 10 experts agreed on the success criteria for Conformance A, AA and AAA, while 5 experts expressed a Neutral opinion. Table 7.22 showed the success criteria for hall and stadium spaces were successfully validated at all levels of Conformance A, AA and AAA, while all means of experts' agreement were above 3 ($p < 0.001$).

Table 7.22: Expert validation of success criteria – hall and lecture spaces

Hall and Lecture Spaces	**Agree**	**Disagree**	**Neutral**	**Validation**	**Mean**	p
Do you agree with the success criteria shown in Conformance A?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AA?	10	0	5	Pass	3.67	< 0.001
Do you agree with the success criteria shown in Conformance AAA?	10	0	5	Pass	3.67	< 0.001

No changes in success criteria were suggested, except the common ones already mentioned:

Experts BIE2 and BIE3 claimed that in all spaces the lighting and acoustic matters should be the same as mentioned in the horizontal circulation spaces in Section 7.4.2.3. Also, all specifications must comply with the design standards and guidelines used in the country of the building being measured was suggested by BIE1.

As shown in sanitary - accessible washroom in Section 7.4.2.8, AE5 suggested a mini-map or information provided on the right-hand side when entering to this space describing the layout of the space.

7.5 Discussion of Expert Validation and Review

Most parts of the BRS were successfully validated while some were not. A number of comments and amendments were suggested by the experts in research and development (RDE), accessibility (AE), and building and interior design (BIE). These findings are now discussed with justifications and solutions provided, i.e. changes to the building rating system and future work considerations.

In this section, 45 feedback items were provided by the groups of experts, of which 15 are considered as changes, and 11 are judged to be future works.

7.5.1 Building Rating System

1. AE4 suggested that the design of the rating levels (number of levels, definition of each level) should be verified and subjectively judged by informed users, i.e. people with visual impairment.

   Justification: Due to health and physical safety concerns, the study was limited to feasibility. This was done to make sure none of participants would be physically injured during this study in accordance with the risk assessment plan submitted to the University of Southampton Ethics Committee.

   Solutions: This may be done later when the exact deployment plan is given covering the health and safety concerns.

2. AE5 suggested a rating scale extended to be more precise, e.g. 0, 0.5,..., 3. Also, the BRS should be extended to cover other disabilities such as motor and hearing impairments.

   Justification: This is not the case and unnecessary at this stage. The conformance levels used in the space classification are categories. To create an explicit scale requires another experiment to determine the weights or composite indexes for all components in each space. Using this approach, a BRS can classify the building in the form of numbers or scales. However, the current approach has been validated, so there is no need for a precise scale since it is not relevant to the current version.

   In terms of extension to cover other disabilities, this is not necessary or relevant. At this stage, an approach to visual impairment is objective of this work.

   Solutions: No changes, since these are not relevant. It is worth investigating composite indexes as future work.

3. BIE3 suggested that the set of spaces used in the BRS should be separated, depending on type of building, because each building has its own set of spaces and complexity. BIE4 advised that the buildings to be measured should be the most used, e.g. shopping malls, hospital, civic centre.

   Justification: These are good suggestions, but beyond the scope of this work. The current system was designed for general building and public spaces.

   Solutions: Other types of building (e.g. sport centre) may be done as future work.

7.5.2 Space Classification

As mentioned in Section 7.4.2, the design of BRS was partially validated, whereas the floor and building classification were not validated. A number of comments and suggestions were given which are now listed.

4. RDE2 suggested that some problems in indoor navigation can be solved by the use of technology. Could another level called "technology" be added to the BRS?

   Justification: At this stage, the BRS has been validated. Adding another level will cause a disruption in the structure of the BRS, requiring further investigation. This is a good point, and can be added to success criteria as an alternative provision for some spaces.

   Solutions: This may be done as future work.

5. AE1 commented that some spaces are not based on a particular floor, e.g. vertical circulation (stair, ramp, and lift). It would be better if the vertical circulation is not based on any floor, and measured separately.

   Justification: All vertical circulation spaces connecting different floors are measured separately.

   Solutions: The BRS has been revised so that it is no longer included in each floor that it connects.

6. AE1 suggested that some success criteria are better measured with multiple levels rather than Pass/Fail.

   Justification: This is a good suggestion, but beyond the scope of this work. Using multiple levels requires further investigation with a number of focus groups such as research and development, accessibility, building and interior design, and others associated with the use of the BRS.

   Solutions: This may be done as future work.

7. AE2 commented that the conformance level could be classified by level of usability instead of level of accessibility. For example, Level A: Physical; Level AA: Colour; and Level AAA: Sound.

   Justification: The building rating scale has been validated.

   Solutions: It is not necessary at this stage; however, it is worth investigating this approach. This may be done as future work.

8. AE2 commented that the definitions used in Conformance A should be changed. For example, Conformance A: features may not be well-designed, please use with caution. Also, using a sentence of "people with visual impairment are advised not to visit the building" seems to be discriminating.

   Justification: Changes in definition have been made as underlined.

   Solutions: The BRS has been revised so that the definitions of No Conformance and Conformance A have been changed as follows:

   - No Conformance: At this level, people with visual impairment are advised not to visit unless accompanied by an assistant within the building.

- Conformance A: At this level, people with visual impairment are likely need assistance to perform some activities, otherwise perform activities with caution.

9. AE3 made a point that the connection between space (e.g. passageways and corridors) should be evaluated for accessibility.

   Justification: This remark has already been considered under "Horizontal circulation".

   Solutions: No change needed.

10. BIE2 commented that the option of "Can't tell" or "Not applicable (N/A)" must not be provided in the Must-Have requirements for all spaces since it creates complications and an inability to measure the spaces. So, the option of "Can't tell" or "N/A" must not be provided in "Must-have" items.

    Justification: This can be agreed with because of the definition of "Must-Have". The criteria in this category must be provided and pass the given specification. Thus, there is no choice for "Can't tell", "Not applicable", or "N/A" in this category.

    Solutions: The BRS has been revised so that the options "Can't tell", "Not applicable", or "N/A" are removed from Must-Have requirements.

7.5.3 Floor and Building Classifications

11. RDE3 pointed out that the averaging score approach may be too coarse to be used, especially for safety measurement. For example, the building may have high average score but still have spaces that have No conformance. Furthermore, some spaces may be more critical than others, such as main entrance or restrooms. A percentage of each building area falling within each accessibility level (0, A, AA, AAA) could be used instead of the averaging score approach.

    Justification: This comment can be agreed with. The averaging score approach can result in wrongly falling into one particular conformance which could be biased and not accurate.

    Solutions: Since the conformance level used in the BRS is categories, in this case, the majority vote is deployed as suggested, where the most conformance level acquired will be used to determine the classification.

12. BIE2 and BIE3 pointed out that the averaging score approach is not good enough. Both experts suggested another approach using a method where the floor and building classifications are determined by using overlapping scores for each space (floor classification) and floor (building classification).

    Justification: The overlapping score method is not as good as the averaging score method. Similarly, if one floor falls into No Conformance level, the building classification will correctly fall into No Conformance as well.

Solutions: Since the conformance level used in the BRS is categories, the majority vote is deployed as suggested, where the most conformance level acquired will be used to determine the classification.

13. RDE4 pointed out the limitation of the averaging score method. If a floor falls into "No conformance level", this means there is no any accessibility provided in any space of the floor. On the other hand, the overall building score is probably about 2 or over, if full accessibility is provided in other floors, because only the averaging score is considered. The overall score can be high, but it cannot indicate that every floor provides good accessibility.

    Justification: This comment can be agreed with. The averaging score approach can result in wrongly falling into one particular conformance which could be biased and not accurate.

    Solutions: Since the conformance level used in the BRS is categories, the majority vote is deployed as suggested, where the most conformance level acquired will be used to determine the classification.

7.5.4 Success Criteria

7.5.4.1 All Spaces

A number of comments were given by the expert review, which can be applied to all spaces.

14. AE1, BIE2, and BIE3 suggested that lighting may be included in Conformance AA instead of Conformance A.

    Justification: By definition of the space classification - Conformance A, the presence of any accident shall not be allowed to happen in this conformance. Thus, every essential feature (e.g. lighting) that prevents the incidents must be added.

    Solutions: Lighting must be retained in Conformance A.

15. BIE1 suggested that some specifications need to be changed to comply with the building design standards and guidelines used in the country of the building being measured. For example, in Thailand acceptance of illumination in front of a reception counter is between 150-300 lux.

    Justification: This statement can be agreed with. As this study is in an exploratory stage, the use of UK building design standards is appropriate (Health and Safety Executive, 1997; Knight, 2015; Silvester & Konstantinou, 2010). The minimum acceptance of illumination is 50-100 lux (British Standards Institution, 2010).

    Solutions: No change needed.

16. BIE4 suggested that internal acoustics of the building should be considered when designing the spaces.

    Justification: This statement can be agreed with due to the use of acoustics in navigating within buildings. It has been suggested that sound enables people with visual impairment to gain more information from the environment while navigating. For example, orientating themselves by using sound as well as using a white cane to find the direction (Design Studio Architects, 2015; Foster, Phin, 2016; Golledge, 1997; Portugali, 1996).

    Although adding acoustic matters to the BRS is appropriate, measuring the acoustics level seems difficult due to specific procedures and special tools being required. Further, there are no standards for an exact range of acoustic level that is suitable for indoor navigation by people with visual impairment. This beyond the scope of this work.

    Solutions: Acoustic matters will not be added to any conformance levels. It is worth investigating for future work.

17. AE5 advised that there should be a mini-map or information provided, describing the layout of the space people are walking in. Thus, they will be informed how the space is organised.

    Justification: This statement can be agreed with. In some countries, maps are provided and placed on the wall, on a consistent left- or right-hand side, to allow people with visual impairment to touch before going into the room and space. However, according to our field study, most people with visual impairment said that they cannot understand Braille and tactile maps. There are no recommendations for tactile maps mentioned in the building design standards and guidelines.

    Solutions: No change needed. However, it is worth investigating for future work.

7.5.4.2 Entrance Spaces

18. AE4 pointed out that there is no statement about the entrance pathway and floor surrounding the entrance. The pathway and floor surrounding should be smooth and flat, with no bumps or steps.

    Justification: This statement can be agreed with. Surface on the entrance area must be considered.

    Solutions: A requirement: "the surface on the entrance area must be smooth, flat and slip-resistant", is added to Conformance A.

19. AE4 suggested that in E.21, the accessible door must be operational at all the times, even when the revolving door is not working.

Justification: The building design standards and guidelines (British Standards Institution, 2010; Building and Construction Authority, 2013), state that the accessible door must be provided and in operation at all the times.

Solutions: No change needed.

20. AE4 suggested that a guide dog should be allowed inside the building, an addition to the "Must-Have" or the "Should Have" criterion

    Justification: This statement can be agreed. Under the Equality Act 2010 (HM Government, 2010) guide dogs and assistance dogs are allowed into all public spaces and buildings with their owners.

    Solutions: It is not relevant, thus no solution or change needed.

21. AE4 suggested E.38-39 should provide audible, signage warning, etc.

    Justification: The building design standards and guidelines (British Standards Institution, 2010) state that using audible warning feedback at the main entrance can cause confusion about the direction of opening and direction of approach.

    Solutions: No change needed.

22. AE5, BIE2, and BIE3 suggested specific information may be required. For example, what type of door handle and where is it located on the door; and what type of wall and mirror? All have claimed that these types of information are of use to people with visual impairment when accessing the building and public spaces.

    Justification: This statement can be agreed with. Some information is already provided, while some is excluded because it is too specific, e.g. tempered glass used for glass doors or walls in the passageways and corridors due to its durability and strength (hard to break), providing a safe environment.

    Increasing the specificity dilutes the BRS, since some spaces may then fall into No Conformance, causing failures in floor and building classification. Using generic specification is appropriate, as also used in the building design standards and guidelines.

    Solutions: No change needed.

23. BIE5 pointed out that flooring system and ramp criterion should be added to Conformance AA.

    Justification: Flooring system has already been added as Doormat E.22-23. However, these may not cover the flooring system. In case of a ramp, the statement can be agreed with since the ramp criterion is missing.

    Solutions:

    - A term *doormat* has been changed into *flooring system*, covering all types of flooring, doormat included.

- Ramp criterion has been added to Conformance A.

24. BIE5 suggested that operational buttons must be at two different heights, one for visually impaired people and one for wheelchair users.

    Justification: This statement can be agreed with. According to the building design standards and guidelines, an operational button is usually installed at 900-1100mm above the floor.

    Solutions: No change needed.

7.5.4.3 Foyers

25. AE5 commented that the location of reception and counter service should be clear and able to see the entrance so staff can give prompt assistance when people with disability are approaching.

    Justification: This statement can be agreed with. F.2 calls for the reception desk to be logically placed.

    Solutions: No change needed.

26. BIE2 and BIE3 suggested that an illumination of 500 lux (F.11 in Conformance AA - Foyers) could be moved into Conformance AAA.

    Justification: This statement can be agreed with, since the minimum illumination is set between 50-100 lux for navigation and 150-300 lux for workspaces. Thus, illumination of 500 lux is appropriate to be moved to Conformance AAA.

    Solutions: F.11 has been moved to Conformance AAA.

7.5.4.4 Horizontal circulation Spaces

27. AE4 suggested a new category of “Wall” (or something similar) be added. For instance, for the passageway connecting other passageways, or close to an open air area (e.g. passage connecting building), guard rails with enough height must be securely installed.

    Justification: This statement can be agreed with. However, it beyond the scope of this work as it only focuses on indoor spaces, not on space linking two buildings. This issue could be resolved with a new type of space called “inter-connection spaces”, which requires further investigation.

    Solutions: This may be done as future work.

28. BIE5 said that colour or border might be provided in interior design in Conformance AAA. For example, utilising a colour or border in corridor design increases visibility, which facilitates usability for people with visual impairment.

Justification: This statement can be agreed with. Most building design standards and guidelines usually refer this as “visual contrast” instead of “colour”.

Solutions: No change needed.

7.5.4.5 Vertical circulation - Lift Spaces

29. RDE5 commented that marks should indicate the last steps at both top and bottom of stairs.

    Justification: This statement is already included as VS.8 - detachable warning surfaces must be provided at both top and bottom of stairs.

    Solutions: No change needed.

30. AE4 advised that stairs and stair nosing should be made from non-slippery materials.

    Justification: This statement is already covered in VS.24.

    Solutions: No change needed.

7.5.4.6 Vertical circulation - Ramp Spaces

31. AE4 mentioned that the surface of ramps must be slip-resistant when dry.

    Justification: This statement can be agreed with and is already covered in VR.5.

    Solutions: No change needed.

32. AE4 said that handrails must be securely fixed to the supporting wall. Further, VR.34 - handrails are securely fixed to the supporting wall could be in Conformance A.

    Justification: This statement can be agreed with, since handrails are used to help people with visual impairment to maintain their balance while navigating ramp spaces.

    Solutions:

    - A term of “securely” has been added to VR.10.
    - VR.34 will be removed as it is already mentioned in VR.10.

33. AE5 suggested that signage and warnings when approaching a ramp should be provided.

    Justification: This statement can be agreed with. In practice, the indicators of an approaching ramp are provided by the detectable warning surfaces at top, bottom and intermediate landings.

    Solutions: Provisions of detectable warning surfaces (VR.24-26) have been added.

34. BIE5 pointed out the gradient used on the ramp. First, a gradient of 1:12 for ramp spaces in Conformance A is enough for any length of the ramp (according to the regulations in Thailand). The gradient of 1:15 and 1:20 could be moved to Conformance AA or AAA, respectively.

    Justification: This statement can be agreed with. Gradient of ramp is always involved as a safety issue. Mentioning all possible gradients in Conformance A is suitable.

    Solutions: No change needed.

7.5.4.7 Vertical circulation - Lift Spaces

35. AE4 suggested that Braille and tactile information should be provided on the lift control panels, and audible warnings must be provided when the lift arrives or the lift is closing. This means that VL.28 and VL.29 should be in Conformance A.

    Justification: This statement can be agreed with. Since Conformance A is about safety matters, moving VL.29 to Conformance A, and VL.28 to Conformance AA is more appropriate.

    Solutions:

    - VL.28 has been moved into Conformance AA.
    - VL.29 has been moved into Conformance A.

36. AE5 advised that some signage, lines (floor signs/markings), or tactile floor should be provided to guide people towards the lift.

    Justification: This statement could be agreed with. Some buildings such as coach stations, train stations, and airports, provide tactile pavement where necessary to help people with visual impairment navigate around the building. Tactile pavement is usually installed outside rather than inside the buildings, as mentioned by the building design standards and guidelines.

    Solutions: No change needed.

37. BIE4 suggested an addition to VL.21 - audible feedback should be provided with appropriate use of sound.

    Justification: This statement can be agreed with. Some lifts come with no audible feedback, for example Building 53 - Mountbatten, the University of Southampton. It is essential to consider the audible feedback with an appropriate use of sound.

    Solutions: A term of "appropriate use of audible sound" has been added to VL.21.

7.5.4.8 Ambulant Disabled Water Closet Spaces

There were no comments on missing pieces in this space.

7.5.4.9 Accessible Washroom Spaces

38. BIE5 mentioned that tile texture could be used create slip resistance on the surface.

    Justification: This statement is already mentioned in AW.11.

    Solutions: No change needed.

7.5.4.10 Bathroom and Shower Spaces

39. AE5 highlighted that BS.1 and BS.2 seem to be conflict. This space will fail when bathtub is provided.

    Justification: This statement can be agreed with. The building design standards and guidelines recommend that a bathroom for people with visual impairment should have a shower stall (BS.2) rather than a bathtub (which is good for wheelchair users). However, people with visual impairment still can use the bathtub, although it is not recommended.

    Solutions: To avoid conflict in measuring this space:

    - BS.1 is moved to Conformance AA with the statement "The accessible bathroom provides either bathtub or shower space".
    - BS.2 is moved to Conformance AAA with same reason.

40. BIE5 pointed out that a handrail must be installed on three sides of bathtub, of which the one between the bathtub and basin should be a flip-up handrail.

    Justification: This statement can be agreed with. However, all building standards and guidelines suggest that grab bars installed on two sides are enough (British Standards Institution, 2010; Building and Construction Authority, 2013), while the last side is used for seating. One vertical grab bar between bathtub and basin, and an L-shaped grab bar (or one horizontal and vertical grab bars).

    Solutions: No change needed.

7.5.4.11 Bedroom Spaces

41. BIE4 said that sanitary accommodation should be moved to level AAA since it is a "Could Have" success criteria.

    Justification: This statement can be agreed with. Sanitary accommodation, e.g. toilet or bathroom could be provided in a bedroom but not necessarily.

    Solutions: BS.12 and BS.13 have been moved into Conformance AAA.

42. 42. An interesting comment by BIE5 said that the bed might have bedside rail.

    Justification: Healey, Oliver, Milne, and Connelly (2008) presented many points for the use of bed rails. One remark concerns a falling accident, which usually occurs with people who can independently navigate since they have to climb over. An ultra-low bed is better off in this case.

    This statement would be appropriately included at this stage, but further investigation must be conducted.

    Solutions: This may be done as future work.

7.5.4.12 General Spaces

43. AE1 pointed out that a meeting room may be not classified as general space.

    Justification: Meeting rooms are usually small to medium sized space. Allocating meeting rooms to general space is appropriate at this stage.

    Solutions: No changes needed.

7.5.4.13 Utility Spaces

44. AE4 suggested that no steps or ramps must be present in this space.

    Justification: This statement can be agreed with, since steps or ramps can present tripping hazards. Within this space, accidents seems more likely to damage people with visual impairment due to the sharpness at the edges of furniture and equipment.

    Solutions: KU.3 "Surface must be smooth, flat and slip-resistant" has been added.

45. BIE5 pointed out that the type of tile used in this space is another issue for choosing kitchen tile materials. Thus, slip resistance needs to be specified as well.

    Justification: This statement can be agreed with. However, providing a type for tiles would be too specific at this stage. The use of a generic specification is better.

    Solutions: No change needed.

7.5.4.14 Hall and Stadium Spaces

There were no comments on missing pieces in this space.

7.5.5 Revision of the Building Rating System

Table 7.23 shows the revisions that have been made for validation of the BRS, following the feedback in this chapter.

Table 7.23: List of the revisions of the building rating system

Category	**Feedback**	**Action**	**Description**
Section 6.3: Conformance	8	Revised	Definitions have been revised, as follows: No Conformance: At this level, people with visual impairment are not advised to visit this space, unless assisted while inside the building. Conformance A: At this level, people with visual impairment are likely to need assistance to perform some activities, or else perform an activity with caution.
Section 6.7: Success Criteria	10	Revised	Choices used in the rating system have been revised. The criteria in "Must-have" category must be provided and pass the given specification. Thus, there is no longer a choice for "Can't tell", "Not applicable", or "N/A" in this category.
Section 6.5: Floor and Building Classifications	11-13	Removed	Average scoring approach has been removed.
		Added	A majority scoring approach has been added where the most conformance level acquired will be used to determine the classification.
Section: 6.7.1: Entrance	18	Added	The requirement of "E.5 - the surface on the entrance area must be smooth, flat and slip-resistant" has been added in Conformance A.
	23	Revised	A term of "doormat" has been changed into "flooring system" covering all types of flooring system, doormat included.
		Added	The requirement of "E.7 - No ramp is provided at the entrance door" has been added.
Section: 6.7.2: Foyers	26	Moved	R11 has been moved to Conformance AAA.
Section: 6.7.5: Vertical Circulation - Ramp	32	Revised	The term "securely" is added to VR.10.
		Removed	VR.34 has been removed as it is already mentioned in VR.10.
	33	Added	Provisions of detectable warning surfaces (VR.24-26) have been added.
Section:6.7.6: Vertical Circulation - Lift	35	Moved	VL.28 has been moved into Conformance AA. VL.29 has been moved into Conformance A.
	37	Revised	The term "appropriate use of audible sound" has been added to VL.18.
Section: 6.7.9: Bathroom and Shower	39	Moved	BS.1 has been moved to Conformance AA with the statement "The accessible bathroom provides either bathtub or shower space". BS.2 has been moved to Conformance AAA.

... Continued on next page

Category	**Feedback**	**Action**	**Description**
Section: 6.7.10: Bedroom	41	Moved	BS.12 and BS.13 have been moved into Conformance AAA.
Section: 6.7.12: Utility Space	44	Added	The requirement "KU.3 - Surface must be smooth, flat and slip-resistant" has been added.

7.6 User Evaluation

User evaluation of the BRS was carried out with three focus groups each of three experts in risk assessment to verify the usability of the system. The process involved site inspections of Building 53 (Mountbatten) at the University of Southampton. Prior to the focus groups, the experts were asked to assess the accessibility for the types of space shown below.

- Main Foyer (Wide-open area)
- Seminar Room (Large, and movable space)
- Zepler Student Laboratory (Large, and fix space)
- Office (Small space)
- WCs - Accessible washroom
- WCs - Public toilets
- Horizontal Circulation (e.g. passageways and corridors)
- Vertical Circulation - Stairs
- Vertical Circulation - Lifts

The experts were then asked to give opinions based on their experience of using the BRS. System Usability Scales (SUS) were used to judge usability, all responses on a five-point Likert scale ranging from 1 - *Strongly Disagree* to 5 - *Strongly Agree* (Bangor et al., 2009; Brooke, 2013). For more information, see Appendix H.

The results of the usability analysis are shown in (1) overview and (2) details, in Sections 7.6.1 and 7.6.2, respectively.

7.6.1 Overview Usability of Building Rating System

Table 7.24 shows that the overall usability of the BRS was rated a 72.2 SUS score, classified as *Good* in the adjective rating scale Bangor et al. (2009), while the actual SUS scores varied from 30.0 (*Awful*) to 92.5 (*Best Imaginable*). On the adjective rating scales, 4 out of the 9 experts rated the usability of the BRS at the *OK* level, while others said 2 for *Best Imaginable* and *Good*, and 1 for *Awful*. These indicators have shown that the BRS does not perform its best at this stage, and there is room for improvement, which leads to a question-by-question in-depth analysis in Section 7.6.2.

Table 7.24: SUS Scores for user evaluation of the BRS, where SUS scores are 1: *Strongly Disagree*, 2: *Disagree*, 3: *Neutral*, 4: *Agree*, and 5: *Strongly Agree*

	Risk Assessor (N = 9)								
SUS Question	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**
1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	5	4	4	4	5	4	5	5	2
2. I found the BRS unnecessarily complex.	1	1	2	2	1	2	1	1	4
3. I thought the BRS was easy to use.	5	5	4	5	5	4	4	5	2
4. I think that I would need the support of a technical person to be able to use this system.	4	4	4	3	2	1	5	4	5
5. I found the various functions in the BRS were well integrated.	4	4	4	5	4	4	4	5	3
6. I thought there was too much inconsistency in this system.	2	2	2	1	2	2	2	1	3
7. I imagine that most people would learn to use this system very quickly.	4	5	5	4	5	5	3	5	1
8. I found the BRS very awkward to use.	3	3	3	1	1	2	3	1	4
9. I felt very confident using the BRS.	4	4	5	4	5	4	3	5	3
10. I needed to learn a lot of things before I could get going with this system.	4	4	4	2	1	2	2	1	3
Sum	36	36	37	31	31	30	32	33	30
SUS Score	70.0	70.0	67.5	82.5	92.5	80.0	65.0	92.5	30.0

Min Score	30.0 (Awful)	**Adjective Rating**[1,2]	
Max Score	92.5 (Best)	90.1 - 100	Best Imaginable
Average Score	72.2 (Good)	85.5 - 90.1	Excellent
		71.4 - 85.5	Good
Acquired Adjective Ratings	Best × 2	50.9 - 71.4	Ok
	Good × 2	35.7 - 50.9	Poor
[1] Bangor et al. (2009)	Ok × 4	20.3 - 35.7	Awful
[2] Brooke (2013)	Awful × 1	0 - 20.3	Worst Imaginable

7.6.2 Detailed Usability of Building Rating System

To analyse the detailed usability of BRS, a test for difference in means of 10 SUS questions was conducted by a repeated-measures one-way ANOVA and a simple one-way ANOVA. However, in both cases, the tests could not be conducted due to insufficient information,

Table 7.25: One-Sample t-tests at 95% Confidence Interval

SUS Odd Questions	**N**	**Mean**	p
Q1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	9	4.22	0.005*
Q3. I thought the BRS was easy to use.	9	4.33	0.004*
Q5. I found the various functions in the BRS were well integrated.	9	4.11	0.001*
Q7. I imagine that most people would learn to use this system very quickly.	9	4.11	0.040*
Q9. I felt very confident using the BRS.	9	4.11	0.003*
SUS Even Questions (Reversed scales)			
Q2. I found the BRS unnecessarily complex.	9	1.67	0.004*
Q4. I think that I would need the support of a technical person to be able to use this system.	9	3.56	0.247
Q6. I thought there was too much inconsistency in this system.	9	1.89	0.001*
Q8. I found the BRS very awkward to use.	9	2.33	0.111
Q10. I needed to learn a lot of things before I could get going with this system.	9	2.56	0.312

* Significantly different from 3 at 5% level of significance

10 SUS questions (factors) but 9 records (N = 9). For this reason, checking differences in means was done by using one-sample t-tests instead.

The t-tests comprised 10 multiple comparisons reflecting the number of questions in SUS. A suitable adjustment by Bonferroni correction was required ($\alpha = 0.05/10 = 0.005$, i.e. 99.5% confidence interval) in this case. However, while the Bonferroni correction was required to use the 0.5% level of significance for testing for a difference from 3 (Neutral), SUS has its own distinct values for *average* and *good* for each question. So it is acceptable to use the 5% significance level for testing the difference between average and good, as shown in Table 7.26 for SUS odd questions and Table 7.27 for even questions (reversed scale). Details of t-tests can be found in Appendix G.4.

Table 7.25 shows that 4 out of 5 means of SUS odd questions were found to be statistically significantly higher than the 3 (Neutral) point. The exception was Q4 which was not significant, as its mean was within the 95% confidence interval. 3 out of 5 SUS even questions were significantly lower than the neutral point of 3.

Compared with the SUS benchmarks, the trends of user responses were a bit similar in the SUS odd questions, as shown in Table 7.26. Figure 7.4 shows that there were 2 means, Q1 and Q5 that were significantly higher than average scores, as their average ratings are outside their 95% confidence interval. For the SUS even questions, the results are shown in Table 7.27 and Figure 7.5, where there was a spike in Q4 indicating that the Q4 mean was significantly higher than the average and good scores.

TABLE 7.26: Actual mean score (N = 9) for odd questions in the BRS usability test against the benchmarks for average and good scores

SUS	**Mean**	**Benchmarks**[1]		**95% Confidence Interval of Mean**		**95% Confidence Interval of the Difference of 3**		
		Average	**Good**	**Lower**	**Upper**	**Lower**	**Upper**	**Center**
Q1	4.22	>= 3.39*	>= 3.80	3.48	4.97	0.48	1.97	0.75
Q3	4.33	>= 3.67	>= 4.24	3.56	5.10	0.56	2.10	0.77
Q5	4.11	>= 3.55*	>= 3.96	3.65	4.57	0.65	1.57	0.46
Q7	4.11	>= 3.71	>= 4.19	3.06	5.16	0.06	2.16	1.05
Q9	4.11	>= 3.72	>= 4.25	3.51	4.71	0.51	1.71	0.60

[1] Lewis and Sauro (2018)
* The mean in this row different from the average score at the 5% level of significance

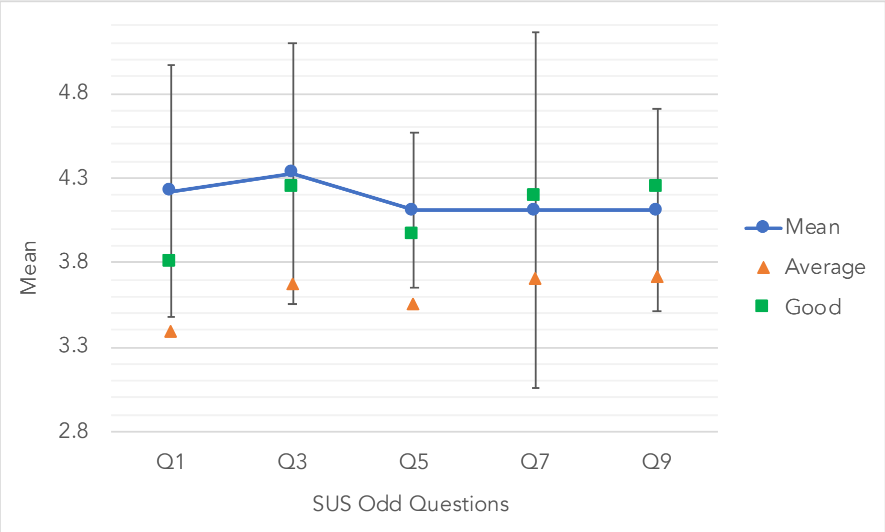


FIGURE 7.4: Profile plot for SUS Odd Questions

7.7 Discussion of User Evaluation

Tables 7.26 and 7.27, it can be seen that many means of SUS questions were not significantly higher or lower than the average and good scores given by Lewis and Sauro (2018). However, SUS is a highly robust and versatile tool for usability testing (Bangor, Kortum, & Miller, 2008), and can be applicable over a wide range of systems and types of technology, even though the sample size is small (8-12) (Tullis & Stetson, 2004). At this stage, however, it was an exploratory research with 9 participants. It is recommended that 5 is the minimum number of participants, and 15 is best as most usability problems can then be discovered (Nielsen & Landauer, 1993), so the number recruited were fine. For these reasons, statistical significance shown in both Tables 7.26 and 7.27 were ignored.

Tables 7.26 and 7.27 show that the BRS performed very well in terms of ease of use and its design/workflow, see items Q1-Q3 and Q5, whose means have achieved the good

Table 7.27: Actual mean score (N = 9) for even questions (reversed scale) in the BRS usability test against the benchmarks for average and good scores

SUS	Mean	Benchmarks[1]		95% Confidence Interval of Mean		95% Confidence Interval of the Difference of 3		
		Average	Good	Lower	Upper	Lower	Upper	Center
Q2	1.67	<= 2.44	<= 1.85	0.90	2.44	-2.10	-0.56	0.77
Q4	3.56	<= 1.85*	<= 1.51**	2.54	4.59	-0.47	1.58	1.03
Q6	1.89	<= 2.20	<= 1.77	1.43	2.35	-1.57	-0.65	0.46
Q8	2.33	<= 2.25	<= 1.66	1.47	3.19	-1.53	0.19	0.86
Q10	2.56	<= 2.09	<= 1.64	1.61	3.51	-1.39	0.51	0.95

[1] Lewis and Sauro (2018)
* The mean in this row different from the average score at the 5% level of significance
** The mean in this row different from the good score at the 5% level of significance

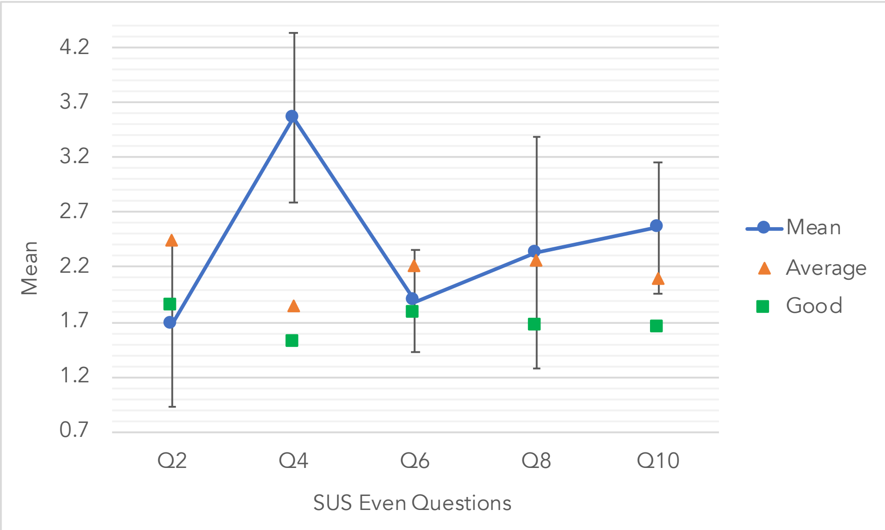


Figure 7.5: Profile plot for SUS Even Questions

score, while items Q6-Q7 achieved the average score.

On the other hand, some improvements are needed as shown by items Q4, Q8 and Q10. The findings from the three focus groups showed that the metrics/requirements used in the Success Criteria are architectural jargon which are often too technical, but are always used in the building design standards and guidelines around the world. To create a BRS for all people, some terminology might have to be changed to make it easier to understand. For this reason, the experts asked a technical person to guide them at the beginning. Based on their on-site observation, the experts could grasp using the BRS when they understood the big picture. Otherwise a user manual or training must be provided prior to use of the BRS.

7.8 Summary

The BRS was almost successfully validated, but some parts need to be reconsidered as a result of the findings in Section 7.4. For instance, the floor and building classifications originally used the average approach, which presented a significant problem in the overall rating of the building causing a biased classification in overall. All success criteria used in the space classification were successfully validated with the amendments suggested by experts in research and development, accessibility, and building and interior design. Even though all the success criteria for all spaces were successfully validated, two success criteria - bedroom spaces - Conformance AA, and utility spaces - Conformance A - were found not to be significant, which was reflected by the feedback given by the experts. Beyond the feedback, a number of suggestions were made that will be of use for modifying the BRS into a better version.

In Section 7.5, 45 feedback points were given by the same groups of experts. 15 of the feedback points resulted in changes to improve the BRS (as shown in Section 7.5.5), while 11 were considered for future work.

The BRS was created by triangulation and verifying different aspects: existing theories and frameworks, expert validation and review, and user evaluation. In the user evaluation, the BRS performed at a good level on average, and detailed feedback was given suggesting that many technical terms used are too difficult for the layman to understand, and may therefore be changed. The BRS created with a use of SRF has shown its performance, which answers the research question SRQ5.

Chapter 8

Conclusion and Future work

8.1 Conclusion

According to a report by WHO in 2014, the number of visually impaired people in the world is increasing, where visual impairment can be classified into: normal, low, moderate vision, and blind, which directly impacts their ability to navigate both inside and outside buildings. Therefore, orientation and mobility (O&M) training is necessary and is provided to people with visual impairment. The main objective of such training is to teach them how to navigate without vision, and understand and use sensory compensation during navigation with a white cane.

Navigation inside buildings by visually impaired people is challenging as it takes a long time to become familiar with spaces, especially when visiting places for the first time, the so-called *unfamiliar spaces and buildings*. Many of the difficulties experienced by visually impaired people have been studied, such as obstacles, barriers and accessibility information, which has led to more research to fill the gaps in knowledge and technology. Current indoor navigation tools may be not suitable for them as additional information such as obstacles, barriers, and accessibility, are not provided in a map used by those systems.

However, a map is fundamental for everybody for navigation, and helps people with information about locations, landmarks, and routes. For visually impaired people, maps are widely used in appropriate formats, such as tactile maps and accessible maps, which enable them to learn the environment beforehand, and help them prepare for the experience as pre-visit information. Moreover, previous studies for people with visual impairment have proved that the map has played a significant role in improving and accelerating the process of constructing a spatial representation.

These reasons led to this study on what kind of information must be provided for promoting indoor navigation by visually impaired people, and how the study can be extended. The research question adopted, with its five sub-questions, are shown below.

Research Question: *What is an appropriate framework for indoor spaces with unfamiliar features to support independent navigation in freedom and safety by people with visual impairment?*

This research question, was broken down into five sub-research questions, of which five are given here:

SRQ 1: What problems do visually impaired people encounter when moving in unfamiliar interior spaces?

SRQ 2: What information should be provided to support indoor navigation by visually impaired people when moving inside buildings with unfamiliar features?

SRQ 3: What components need to be included in a spatial representation framework to support indoor navigation by visually impaired people, and to construct an indoor map?

SRQ 4: What tools based on the framework could help architects design spaces within buildings that make it easier for visually impaired people to navigate?

SRQ 5: Can such a tool be used by assessors to measure risks in spaces navigated by visually impaired people?

To address SRQ 1 and SRQ 2, a review of relevant literature and desk-based study was conducted, reported in Chapter 2 and Appendix A. This was the first step to begin to understand navigation by visually impaired people, and the problems they face, and also gather the evidence that supports the design of the spatial representation framework (SRF) for the construction of indoor maps for them. The literature showed that sensory compensation comes into play as the main role in navigation to help them understand and become familiar with the surrounding environment. This is all used in the process of constructing a spatial representation. To improve the process of constructing this spatial representation, suitable important information must be provided beforehand to enable them to anticipate what they are going to experience. The literature identified a lack of accessibility provided for most buildings and most outdoor spaces such as public places, transportation, etc. To navigate within a building is an entirely different challenge since other factors emerge such as objects, furniture, people walking around, and noise coming from all around, which are considered barriers that disable navigation by visually impaired people. In addition, in some buildings, transition spaces such as stairs, elevators, and escalators, are not well-designed to support people with disabilities. As a result, it is important and useful if ALL the information is stored in a map that can be used to solve many of the problems identified.

In Chapter 4, an SRF was proposed by considering the problems found in the desk-based and field studies. The framework was originally designed by desk-based study, as Appendix A shows, and finalised in Section 5.4 where SRQ 3 was answered. It was validated by visually impaired and sighted people, and the results shown in Section 5.5. The SRF was presented as a conceptual framework used to support indoor navigation by people with visual impairment in places full of unfamiliar features. The framework consists of 11 components organised into five layers: *structural*, three categories of *objects* (*fixed*, *rearrangeable* and *transient objects*), *sensor*, *path*, and a *wayfinding* layer. A scaling method was defined for object classification to characterise their movability: 0-3 for fixed, 4-6 for rearrangeable, and 7-9 for transient objects.

Findings of the field study were discussed in Chapter 5, where SRQ 1 and SRQ 2 were addressed and answered. A number of problems were found in places full of unfamiliar features, as demonstrated in Section 5.4. For example, different views by visually impaired and sighted people regarding assistance and distance estimation. The use of indoor landmarks was found to be significantly useful to visually impaired people. For SRQ 3, the framework validation was performed and its results were described in Section 5.5. This showed that both visually impaired and sighted people agreed with all the proposed factors included in the SRF, except for seven factors: Wi-Fi coverage and noise (by visually impaired people), lighting, building profile, event/exhibition, weather, and the reception (by sighted people). All the proposed factors were included in the SRF, discussed in Section 5.7 and Section 5.8.

Finally, the SRF was deployed by developing an instrument called the "Building Rating System" (BRS). This is a building accessibility measurement for people with visual impairment that can be carried out manually, and in the future perhaps automatically. The system was designed bottom-up using the SRF skeleton and a number of building design standards available around the world (see Chapter 6), and later validated by three groups of five experts in the fields of research & development, accessibility, and building and interior designs. The findings and discussion are shown in Sections 7.4 and 7.5, respectively. After validation, user evaluation of the BRS was conducted and the feedback determined as *Good* using System Usability Scale (SUS), as seen in Section 7.6. At the end, the SRQ 4 and SRQ 5 are answered.

8.2 Contributions

This research has produced the following contributions.

1. The problems and challenges faced while moving inside unfamiliar interior spaces by people with visual impairment has been confirmed, as well as the strategies to overcome those challenges, which has resulted in a list of information required to enact those strategies.

2. The validated spatial representation framework (SRF) for indoor navigation by people with visual impairment can be used to solve some problems of indoor navigation found in the review of literature and the field study in Section 5.4, Chapter 5.

3. The validated building rating system is an instrument for building accessibility measurement for people with visual impairment. This system enables architects and risk assessors to identify deficiencies and weaknesses in the built environment and includes:

   3.1 Building accessibility classification: three levels of standardisation (Conformance A, AA, and AAA) plus NO conformance level, used to classify levels of accessibility provided in building (top level), floors (mid level) and spaces (bottom level).

   3.2 Success Criteria: a set of requirements for 13 types of spaces have been developed and validated for building accessibility classification.

8.3 Future Work

Once the SRF was established, many applications and extensions could be built on it, as shown in Section 4.2.1 (Chapter 4) and Figure A.3 (Appendix A).

8.3.1 Spatial Representation Framework

The SRF was designed for people with visual impairment. Extending the SRF to other disabilities (e.g. physical, hearing and mental), and also autonomous system and robotics (e.g. guide dog robot, indoor autonomous vehicles in airports) is important to allow access for all.

8.3.2 Data Models for Spatial Representation

To extend the SRF to other applications is really interesting. Developing the SRF into data models (SRD), which visualise spaces and buildings in 3D geography, can result in huge benefits and contributions to the indoor-based technology industries, as shown in Table 4.1.

The SRD should be designed as a machine-readable open data format, which is freely available to everyone. An example SRD is given in Appendix I. Using SRD with integrated sensor information, the applications and systems can 'know' the information of the spaces and buildings, which can potentially result in breakthrough development from:

- Context awareness
- Interactive accessible map
- Indoor navigation system for disabled people
- Self-driving vehicles. autonomous systems and robotics

8.3.3 Building Rating System

The building rating system was introduced so that the feedback coming out of the system can recommend omissions in an inclusive built environment for people with visual impairment. Extending the system to support all other disabilities is worth doing as it will provide access for all. Thus, SRF will be revised to support other disabilities as follows.

- **Physical disability**. The common characteristics of physical disability usually refer to physical functioning such as mobility, dexterity, or stamina. Designing spaces and buildings ignoring physical disability concerns would cause them difficulties when navigating some spaces due to the physical challenges. For example, for people with wheelchair if a ramp or stair lift is not provided when there is a change in floor height.
- **Hearing impairment**. People who are hard of hearing may have difficulties when navigating unfamiliar spaces and buildings such as airports and train stations. Moving in these spaces can be frustrating for people with hearing impairment, and even mild hearing loss, since they cannot hear important messages or the messages are drowned out by ambient noise. It is essential to be able to receive such information while navigating spaces.
- **Autism Spectrum Disorder**. Autistic people often have difficulties in reading, recognising, and understanding, when interacting with objects and people. Autistic people have experienced over- or under-sensitivity to all perceptions such as sounds, touch, sight, olfaction. For example, background sounds or white noise are unbearably loud or distracting to these people. This can cause anxiety or even physical pain. Thus, it is necessary to include these requirements in the BRS.

In terms of improving the BRS, some feedback is also worth investigating, as shown in Section 7.5.

- **Use of multiple scales of measurement for success criteria**. Previous research has often used multiple levels in measuring accessibility in spaces and buildings, but none of them use it on the success criteria. The BRS has used the binary Pass/Fail as its simple design, with which it is easy to perform accessibility measurement. However, the BRS was formerly designed with multiple scales (Fail/Partial Pass/Full Pass) which is more accurate for accessibility measurement. Thus, changing a binary scale to a 3-level scale is worth investigating.

- **Alternative space classification**. The BRS was designed with the space classification using category scales, considering safety in Conformance A, and then accessibility in Conformance AA and AAA. Investigating other approaches might make BRS more efficient.

- **Alternative methods for floor and building classification**. The averaging approach was used in the BRS with conversion of category data to interval scales. However, the scales may not be equal interval, which needs to be tested. The results arising from this test will make the floor and building classification more accurate and more easily interpreted in a report on recommendations or in a possible building accessibility certificate.

- **Success criteria for other types of building**. The BRS was introduced with accessibility measurement for general spaces and buildings. Other types of buildings could be explored, such as hospitals and sports centres, whose architectures and layouts are specifically designed for their purposes.

As building legislation around the world gradually introduces equality to society, every building must comply, e.g. housing and accommodation for disabled people. This system can be extended as plugins integrated into the computer-aided design software, e.g. AutoCad, to check the design meets the needs of disabled people.

Appendix A

Desk-based Study

The advantages and disadvantages of what was found relating to the navigation by visually impaired people people has been discussed. In this chapter, a framework for the design of a map data representation of indoor spaces will be developed taking into account the components required.

A.1 Problems and Challenges

The literature was reviewed in various fields related to blind behaviour, navigation, assistive technology, and INS. Problems were identified by observation, interview and scenario-based experiment. Many solutions have been applied to solve the problems using a wide range of technology and algorithms built into a variety of devices and systems, both low-tech devices (white cane, guide dog, and sighted people) and high-tech devices (wearable computing, smart cane, and indoor positioning system). Table A.1 summarises the problems that visually impaired people experience, solutions that have been applied, and also shows that an accessible map can solve all these problems.

For this reason, it is important to develop a map that can store essential information that can be used to help visually impaired people navigate independently. Furthermore, Table 2.3 also shows that no map on the market or in the literature has been proposed or developed for visually impaired people who require a map that integrates further features for accessibility and disabilities such as hazards, objects (ground, body and head level).

A.2 Spatial Representation Framework

By the review of the literature, this research aims to solve some of the problems and also provide basic principles to solve residual problems. We conjecture that visually impaired

Table A.1: Problems and Challenges found by visually impaired people

Topics	**Problem**	**Solutions**	**References**
Unfamiliar places	Difficulties in navigating inside the unfamiliar places which are usually large, complex, wide-open, full of crowd and noise, and lack accessibility information. Guide dog may not be allowed in some buildings, especially intensive care unit at the hospital.	Sighted guide, Guide dog, Accessible map	Guide Dogs Australia (2016); The Guide Dogs for the Blind Association (UK) (2013); Williams et al. (2014, 2013)
Accessibility Information	Difficulties in navigating inside buildings which lack accessibility information such as tactile pavement, information regarding stairs, escalator, dropoffs, room number & name, etc. which are not usually provided.	Sighted guide, Accessible map	Williams et al. (2013); Zeng (2015)
Map for the Blind people	Information provided in a map, both commercial and public service, is limited and not enough for people with visual impairment. To provide more confidence in navigation, objects and accessibility information should be integrated into the map.	*Proposed Framework*	Table 2.3, Apple (2016); Google (2016); T. H. Kolbe et al. (2005); J. Lee et al. (2014); Li and Lee (2013); Miao et al. (2011); OpenStreetMap (2016); Ryu et al. (2014)
Indoor Navigation System	No matter what indoor positioning techniques have been used in the indoor navigation system, the map is the main part of the navigation, which is usually proprietary and lacks information required by the blind.	*Proposed Framework*	Table 2.3, Indoo.rs (2015); Wifarer (2016)
Obstacle Detection and Avoidance	Difficulties in detecting and dodging obstacles installed or placed in the environment during navigation.	Echolocation, Ultrasound	Table 2.1, Brogaard and Marlow (2015); Finkel (2012); Williams et al. (2014)
Unpredictable Obstacles	Difficulties in detecting or receiving information regarding unpredictable objects such as crowd, noise, etc.	Sensor: Camera	Williams et al. (2013)

people people can independently navigate inside buildings if they have a map with sufficient information and detail about the buildings. This research proposes a framework of map data representation for indoor navigation that will be of use in constructing maps of these buildings. To construct the map, a framework is developed as a form of a multiple-layered model consisting of seven layers, extending the three layers of IndoorGML (J. Lee et al., 2014) by a further four covering the parameters of disability.

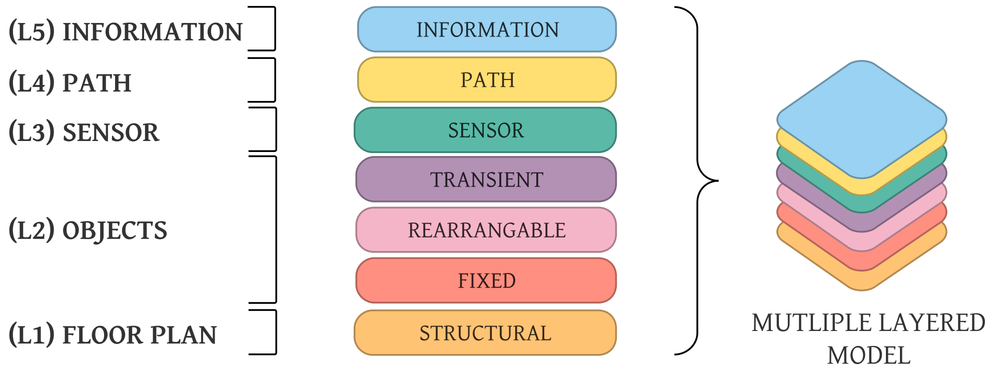


FIGURE A.1: Conceptual Framework for Indoor Map Representation adapted from IndoorGML (J. Lee et al., 2014).

Figure A.1 shows the conceptual framework, adding to the layers of IndoorGML intended for autonomous systems such as self-driving vehicles and robots that can detect their surrounding environments, as used by airports, hospitals, warehouses and large buildings. For example, at the airport, a self-driving electric vehicle for physically-challenged people who are not comfortable with a long walk; shelf-picking or item-finding autonomous systems at Amazon's warehouse (Knight, 2015), which is usually complicated and extensive. For these reasons, it is more costly to the business to run these operations manually. However, the framework has not been developed only for autonomous systems, but also for visually impaired people people since these lack vision in the same way as the autonomous system.

The framework is split into seven layers consisting of three lower layers from IndoorGML, with four layers placed on top covering disability for promoting indoor navigation by visually impaired people people. The four new layers are divided into major elements: objects and information, which will be discussed in Sections A.2.2 and A.2.3, respectively.

Each of the layers represents a different purpose and are defined as follows.

1. **Structural** The bottommost layer represents the floor plan showing relationships between rooms, spaces and entrances for all floors in the building in 3D including physical dimensions, size, and type of wall. It consists of two sub-layers, space (state) and connectivity (transition), that determine how rooms are connected with each other via transition links. This layer is compulsory as a main component of the indoor map. The floor plan is formed of a general indoor map inside the building without any internal information, also known as interior[26] design information. This layer will potentially solve the problems of visiting unfamiliar places, accessible map and indoor navigation.

[26]The term interior will be used to mean internal information representing objects installed, placed, or appearing inside the building.

2. **Fixed Objects** This layer contains information about objects that are fixed, installed, attached to the building as defined for furniture, doors, stairs, lifts or objects that are permanently installed. It also encompasses some barriers such as drop-offs, curbs, and construction areas or building renovations which will take a long time to be completed. This layer is responsible for many of the challenges of providing free mobility, warning information about critical areas, landmarks, so on. To classify the object, a scaling method will be discussed in Section A.2.2.

3. **Rearrangeable Objects** This layer contains information about objects that can be rearranged by someone. The layer is designed for objects like table, chairs, waste bins and other items that remain in their position for a medium to long time depending on a movability factor. This layer is responsible for random objects as obstacle detection and avoidance. To classify the object, a scaling method will be discussed in Section A.2.2.

4. **Transient Objects** This new layer contains information about objects that last for a short period of time like people or weather changes. This layer will be used for measuring indoor traffic, detecting people, calculating an appropriate route for visually impaired people people and the autonomous systems. To classify the object, a scaling method will be discussed in Section A.2.2.

5. **Sensor** A special object that possess abilities of detecting events and/or sending out information to the spaces for specific purposes, for example: lighting, smoke detector, Wi-Fi, RFID, closed-circuit television (CCTV), camera, door switch sensor, etc. This layer allows sensors to be placed on the indoor map. At some point of this layer, it will be used as part of the indoor positioning system. As a result, this layer is mostly responsible for many applications and extensions such as indoor localisation and navigation, obstacle detection, security and surveillance.

6. **Path** An important layer that contains information about the walkable area (e.g. hallways) and restriction area (e.g. emergency exit), enabling people with visual impairment to know which area and path are approved for walking, depending on situations. This component can be used as part of the route planning process for indoor navigation systems, and construction of accessible maps.

7. **Information** The topmost layer provides essential and useful information regarding indoor navigation, e.g. context and spatial awareness, provided to people and autonomous systems. This layer will be of use that providing information for navigation to support wayfinding when people and autonomous systems are navigating unfamiliar buildings, for example, room number and name, a description of the exhibitions in the museum, or healthcare information in the hospital. In this layer, information will be classified, discussed in Section A.2.3.

A.2.1 Reference Model

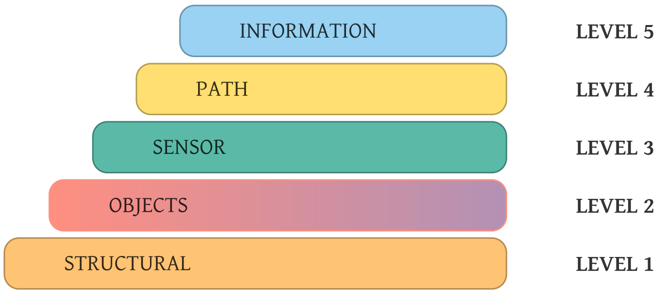


FIGURE A.2: Reference Model of Spatial Representation Architecture

From Figure A.1 and its definitions, it can be seen that this framework can be arranged as a reference model, in which indoor spatial information is represented by a collection of data and relationships mapping between layers, as shown in Figure A.2. To design a map data representation, the topographic data must be the bottommost layer as it is essential information. Information is assumed to be the topmost layer since it acts as complementary information for people and autonomous systems. Object classification combines as the second (level 2) layer, which represents the information about the objects installed and placed in the building that promotes their navigation in the same way as the sensor layer (level 3) does. The sensor layer was originally designed for an indoor positioning system, but is also used to provide information that will be utilised for other purposes such as network planning and design, lighting, security and surveillance, and even indoor localisation and navigation when cooperating with the navigation layer (level 4) that provides a walkable path in the building.

Table A.2 gives an example of how each layer comes into play with the other layers to support future development. First, the bottommost layer (L1) is responsible for the construction of the floor plan of all floors in the building, also known as the general indoor map. Including object classification (L2), however, the floor plan is given interior information which will be used and responsible for spatial awareness. In sensor layer (L3), enhanced with the sensor information, the applications can be extended, for example, Camera: object detection and avoidance, and security and surveillance, Wi-Fi: indoor positioning system, network planning, map insight, and RFID: indoor navigation and access control. In the navigation layer (L4), a navigable path is provided to satisfy the indoor navigation system feature used in general by people and autonomous systems and robots. With information (L5) included in the map data representation, the map will be of use for people with disabilities as complementary information along during their navigation inside buildings such museums, hospitals, and airports, which is potentially designed for context awareness. Further, it provides free mobility information to people with disabilities so that they can understand what they are going to experience.

This clearly shows that the problems cannot be solved with just one layer. Multiple layers will, therefore, be used to solve the problems, as shown in Table A.3, because

TABLE A.2: Bottom up design of the framework and its potential applications

Level	Description	Potential Applications
L5 - Information	Building profile, wayfinding, exhibition, event, external information	Indoor Navigation for People with Disabilities, Accessible Map (interactive), Context Awareness
L4 - Navigation	Navigable paths	Indoor Navigation for Autonomous Systems and Robots, Indoor Route Planning
L3 - Sensor	Camera, Wi-Fi, RFID, others	Indoor Positioning System, Network Planning, Security and Surveillance, Map Insight, Obstacle Detection and Avoidance, Access Control
L2 - Object	Fixed, rearrangeable, and transient objects	Floor Plan with Interior, Spatial awareness, Accessible Map (standard)
L1 - Topo-graphic	Relationships between rooms, spaces, entrances	Floor Plan (a general indoor map)

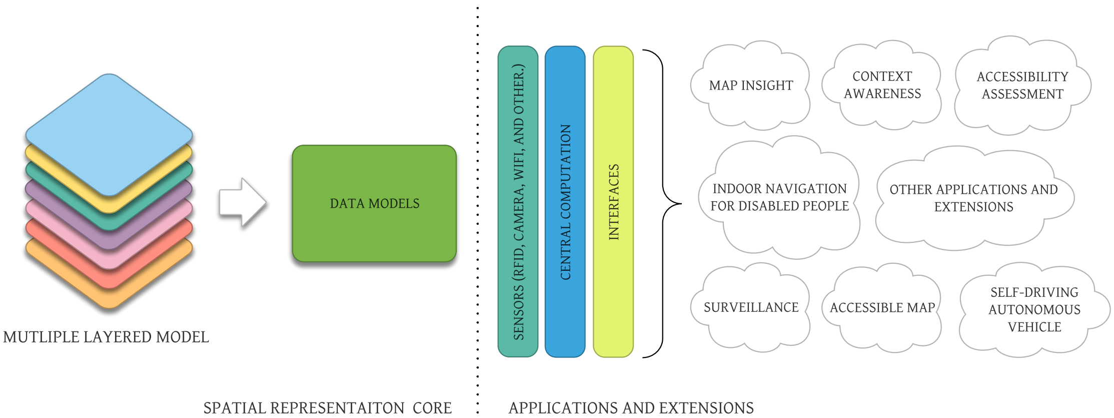


FIGURE A.3: Conceptual Framework for Indoor Map Representation adapted from IndoorGML (J. Lee et al., 2014).

when all of the layers are compiled together, the building is logically visualized as a 3D geography providing all the information needed by visually impaired people people. Furthermore, the map data representation is created in a machine-readable open data format which is freely available to everyone for future use. By integrating the sensors into the system, this approach can be extended to other applications and extensions, as Figure A.3 shows. This general concept could be used by: people with disability for indoor navigation, for security and surveillance, as an accessible map, to provide context awareness, users insight[27], and also used by autonomous systems in buildings such as

[27]users insight is a location analytics providing the information about users behavior such as where they go, what customers look for, and how long they stay in a certain area. This information is potentially useful for all kind of applications and businesses.

airports, museums, hospitals, universities.

TABLE A.3: Multiple layers used in different use case scenarios

Problems and Challenges	**Topographic**	**Sensors**	**Navigation**	**Fixed Objects**	**Rearrangeable Objects**	**Transient Objects**	**Accessibility Information**
Unfamiliar Places	✓		✓	✓	✓	✓	✓
Accessibility Information	✓			✓	✓		✓
Map for Blind people	✓		✓	✓	✓		✓
Indoor Localisation and Navigation	✓	✓	✓				
Obstacle Detection and Avoidance		✓		✓	✓	✓	
Unpredictable Obstacles		✓				✓	✓

A.2.2 Objects Classification

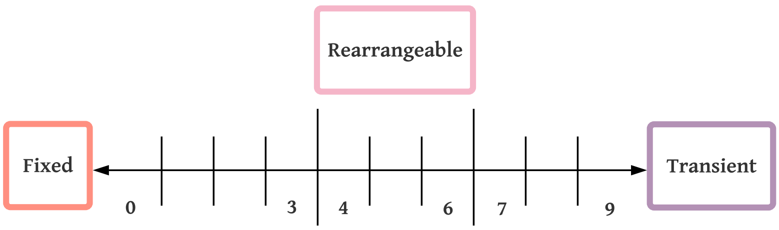


FIGURE A.4: Objects classification.

Layer 2 needs special attention. In Figure A.4 objects are classified into *fixed*, *rearrangeable*, and *transient*, that are each used in different ways for promoting navigation by visually impaired and blind people. Note that all types of object would be allowed to have a movable attribute.

Object The representation of a physical object that can be anything that has a surface and is touchable. The objects can be split into three types based on their movability factor: fixed object, rearrangeable object, and transient object.

Transition Object An object with moving ability that moves by itself without any external force. It provides the capacity to transfer objects from one state to another state. For example, an escalator or moving staircase, is a transport device driven by an electric motor for carrying people from one floor to another floor, in the way same as an elevator or travelator.

The movability of objects (obj_m) inside buildings will be scaled in a range from 0 (fixed) to 9 (transient), shown in Table A.4. Consequently, the objects will be defined as follows.

Table A.4: Classification of Objects: Scaling Definitions and examples

Types	**Scale**	**Definitions**	**Examples**
Fixed Objects	0	Permanently part of the building, cannot be changed	Stair, Sidewalk, Pavement Drop-off, Sloped floor, Kerb, Hole in the ground
	1	Installed in the building, impossible or hard to uninstall	Elevator, Escalator, Travelator, Fence
	2	Installed in the building, can be removable	Floor-mounted furniture, Wall-mounted furniture, Built-in furniture, Bathroom equipment (basin, shower bowl, toilet, urinal)
	3	Temporarily installed in the building, with time limit	Construction area, Building renovation, Events
Rearrangeable Objects	4	Large object that is difficult to reposition due to a physical appearance	Refrigerator, freezer (Family sized)
	5	Medium object that is sometime difficult to reposition	Table, Chair, Freezer, Small refrigerator, Personal Computer, Workstation, Office plant
	6	Small object that is easy to reposition or detachable	Litter bin, Rug, Portable Equipment, Fire extinguisher
Transient Objects	7	Unintentional or accidental objects	Wet floor, Litters
	8	Objects created by schedules	Cleaning area
	9	Self-moving objects	People, Pet Robots, Autonomous System

Fixed Object A predictable object permanently installed or attached inside the building at any height (ground, body, or head level), such as floor-mounted types of furniture, wall-mounted types of furniture, stairs, elevators, escalators, travelator, and railing.

Rearrangeable Object A random object placed in the building that can be rearranged by someone (not by itself) like a table, chair, refrigerator, freezer, computer and workstation, office plant, and waste bin.

Transient Object A random object that always moves around in a given area, for example, people, crowd, weather changes (sensory information like sunlight and rain), robots, and autonomous systems.

A.2.3 Information Classification

In this layer, information will be divided into six sub-categories as shown in Figure A.5, and integrated into map data representation that enables people and autonomous systems to receive essential information about the building which promotes both indoor navigation and safety awareness.

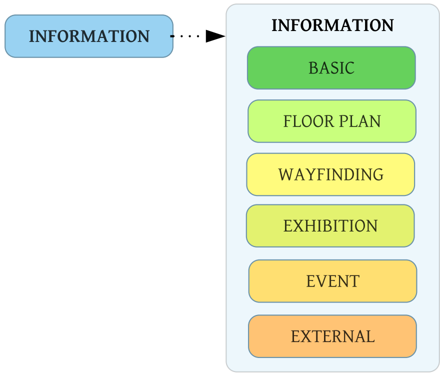


FIGURE A.5: Sub categories for information classification

Basic General information about the building provided to visitors such as the building's profile, type (organisation, university, hospital, and museum), pre-visit information, open hours, front desk information, and FAQ. Related Layers: *None.*

Floor plan This information describes details of the floors in buildings such as room (number, name, and type) and area (common, hallway, living, and kitchen). Related Layers: *Topographic.*

Wayfinding Essential information used for promoting indoor navigation such as pavement information, transition space information (e.g. stairs: steps, width, height, where is handrail), transition spaces' status (e.g. door is open, Elevator is on 4th floor, Escalator/Travelator is active), signage and intersection and corner markers. Related Layers: *Navigation, Fixed Objects, Rearrangeable Objects, Topographic, Sensors.*

Exhibition This information describes objects placed in the building provided by museums, hospitals, offices or universities, in various media such as captions, posters, announcements, and leaflets. For example, Museum: Object 462, "Mona Lisa", "a portrait of a woman by Leonardo da Vinci". Related Layers: *Fixed Objects, Rearrangeable Objects.*

Event Information describe the events held in the building to inform people: What is the event about? Where is the event held in the building, and its layout? Which companies are participating in this event including information about the companies, products, and promotion, that potentially impact the business aspect. Related Layers: *Fixed Objects, Rearrangeable Objects, Topographic.*

External External information that impacts visually impaired and blind people travelling inside the building, such as light goes through windows, noise from rain, noise from construction outside the building, or even car horn when the traffic is jammed. However, this information will be provided by third-party services (e.g. weather forecast) or sensors (noise measurement sensor and cameras). Related Layers: *Transient Objects, Sensors.*

A.3 Summary

Considering the problems detailed in Table A.1, a framework was developed in Section A.2. For an indoor map representation, 7 layers were constructed consisting of objects and information. By cooperation between each of the layers, a 3D building can be rendered and will be used in some applications such as indoor navigation, surveillance, museum exhibits. However, the ultimate goal of this model is to provide a standard for indoor maps, including the terms for disability, in both human and machine readable format, freely available to everyone to use or develop further.

To make our contributions clear, this approach is compared with the study of IndoorGML (J. Lee et al., 2014), shown in Table A.5.

TABLE A.5: A comparison of feature between IndoorGML and proposed model

	Features	**(J. Lee et al., 2014)**	**Proposed Framework**
IndoorGML Core	2D Supported	✓	✓
	3D Supported	✓	✓
	Floor Plan	✓	✓
	Sensors	✓	✓
Indoor Navigation	Navigable Paths	✓	✓
Objects	Fixed Objects		✓
	Rearrangeable Objects		✓
	Transient Objects		✓
	Free Mobility		✓
	Critical and Hazard Zones		✓
	Obstacle (Ground Level)		✓
	Obstacle (Body Level)		✓
	Obstacle (Head Level)		✓
Information	Accessibility Information		✓
	Essential Information		✓

Appendix B

Spatial Representation Framework - Questionnaire for Visually Impaired People

This chapter shows the questionnaires that were used in the preliminary study where participants were visually impaired people recruited in United Kingdom and Thailand. The questionnaires were split into two version (English and Thai) used in the interviews with participants who are British (Section C.1) and Thai (Section C.2), respectively.

B.1 English version

Participant Information Sheet

Study Title: A study of indoor navigation behaviour by visually impaired and blind people.

Investigator: Watthanasak Jeamwatthanachai
Ethics number: ERGO/FEPS/23512

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
This research is trying to help visually impaired and blind people to have a confident to navigate independently inside buildings with safety awareness. To help them, this study proposes a data representation of buildings which will be used towards the construction of indoor navigation systems. Consequently, this study is first to identify what important factors, obstacles, and useful information needed by visually impaired and blind people.

Why have I been chosen?
At this stage, this study is trying to collect information about behaviour of indoor navigation by visually impaired and blind people. Thus, visually impaired and blind people including staff, who work closely with these people, are invited to participate in this study.

What will happen to me if I take part?
If you are visually impaired or blind, you will be interviewed about indoor navigation behaviour inside buildings, which consists of five sections and will take 30-40 minutes to complete.

If you are staff, you will fill out a given questionnaire which will take no more than 25 minutes. The questionnaire is comprised of five sections regarding behaviour of indoor navigation by visually impaired and blind people.

Are there any benefits in my taking part?
By taking part, you have the opportunity to help us development the technology to help visually impaired and blind people to have freedom and confidence in navigating inside buildings by themselves.

Are there any risks involved?
There is no any risk involved for participants completing the questionnaires and interviews.

Will my participation be confidential?
The name of the participants will not be taken and participation will be kept anonymous. All data will be safe in a protected computer. All will be destroyed once the research is completed.

What happens if I change my mind?
You have the right to withdraw from doing the questionnaire or interview at any time.

What happens if something goes wrong?
If you have any concern or complaint with this study, please contacts Watthanasak Jeamwatthanachai at wj1g14@ecs.soton.ac.uk

Where can I get more information?

If you would like to get more information about this study, please feel free to contact Watthanasak Jeamwatthanachai at wj1g14@ecs.soton.ac.uk

Interview

Study Title: Helping visually impaired and blind people to independently navigate unfamiliar spaces

Investigator: Watthanasak Jeamwatthanachai
Ethics number: ERGO/FEPS/23512

Invitation

Thank you for reading this. I would like to invite you to take part in my research study by completing this questionnaire. It is entirely up to you whether you participate but your responses would be valued. You have been identified as a potential participant by your expertise, experience and knowledge in the area.

My study is trying to help visually impaired and blind people to have the freedom and confidence to independently navigate unfamiliar spaces inside buildings.

The questionnaire is anonymous and your confidentiality is assured:

- Completed questionnaires will be scanned to create a single PDF file.
- This single PDF file will not be duplicated - only one copy will be created.
- This PDF file will be stored on a password protected computer at the University of Southampton.
- This PDF file will be destroyed 1 year after the completion of my PhD study.
- The original questionnaire sheets (paper transcripts) will be stored in a locked filing cabinet at the University of Southampton.
- The original questionnaire sheets (paper transcripts) will be destroyed 1 year after the completion of my PhD study.

If you have any questions, please contact the investigator (Watthanasak Jeamwatthanachai, PhD researcher) and my supervisors.

Yours Sincerely,

Watthanasak Jeamwatthanachai	Investigator, PhD researcher	wj1g14@ecs.soton.ac.uk
Prof Gary Wills	Primary Supervisor	gbw@ecs.soton.ac.uk
Prof Mike Wald	Secondary Supervisor	mw@ecs.soton.ac.uk

Instruction:

This questionnaire will take approximately 1.30 - 2 hours to finish.

Questions can be answered in 3 ways:

- Boxes: Insert an X mark in the appropriate box e.g. ☑
- Letters: circle the appropriate letter e.g. (a.) important
- Spaces: Write the answer in the space provided e.g. [2 years]

This study aims to help visually impaired and blind people to have the freedom and confidence to independently navigate unfamiliar spaces inside buildings.

In ALL cases, the questions refer ONLY to unfamiliar spaces inside buildings.

The questions do NOT refer to: Familiar spaces (regardless of whether these familiar spaces are inside or outside) Outdoor spaces (regardless of whether these outdoor spaces are familiar or unfamiliar)

Section 1 Basic information

1. What is your gender?
   a. Male
   b. Female

2. Please specify your age range?
   a. 18-29 years old (Young adult)
   b. 30-49 years old (Middle-aged adult)
   c. 50-64 years old (Older adult)
   d. 65+ years old (Elder)
   e. Prefer not to say

3. Which of the following describes your sight?
   a. I am blind, BUT I had sight before. When did you lose it? ____________ years old
   b. I was born blind
   c. I am visually impaired. Please check all that apply
      - [ ] I can see LIGHTS
      - [ ] I can see SHADOWS
      - [ ] I can see COLORS
      - [ ] I can see MOVEMENT
   d. Other, please specify ______________________________

Section 2 Behavior and Indoor Navigation

4. Did you attend a mobility training course, e.g. orientation and mobility?

   a. Yes

   b. No

5. Which assistance do you use when you navigate inside buildings by yourself? How often do you use the assistance for your daily routines?

   - White Cane

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never , please give a reason: ______________________

   - Guide Dog

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never , please give a reason: ______________________

   - Sighted Guide

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never , please give a reason: ______________________

   - Tactile Map

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never , please give a reason: ______________________

   - Other: ______________________________________

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week

- ☐ Once a week
- ☐ Once a month
- ☐ Occasionally
- ☐ Never , please give a reason: ____________________

6. How do you estimate the distance while navigating inside buildings by yourself?

   a. By foot steps

   b. By length unit, e.g. feet or meter

   c. By time, e.g. 5 seconds

   d. Other, please specify ____________________

Section 3 Unfamiliar Spaces

Definition: Unfamiliar spaces are places that visually impaired and blind people rarely visit or have not learnt to navigate by themselves. Examples of unfamiliar spaces could include the university, hospital, museum, department store or airport.

7. How often do you navigate by yourself inside unfamiliar spaces, e.g. university, hospital, department store, museum, and airport?

    - University

      Frequency: ☐ Everyday
      ☐ Few times a week
      ☐ Once a week
      ☐ Once a month
      ☐ Occasionally
      ☐ Never

      Please give a reason: ______________________________

    - Hospital

      Frequency: ☐ Everyday
      ☐ Few times a week
      ☐ Once a week
      ☐ Once a month
      ☐ Occasionally
      ☐ Never

      Please give a reason: ______________________________

    - Department Store

      Frequency: ☐ Everyday
      ☐ Few times a week
      ☐ Once a week
      ☐ Once a month
      ☐ Occasionally
      ☐ Never

      Please give a reason: ______________________________

    - Museum

      Frequency: ☐ Everyday
      ☐ Few times a week
      ☐ Once a week
      ☐ Once a month
      ☐ Occasionally
      ☐ Never

      Please give a reason: ______________________________

- Airport

  Frequency:
  - ☐ Everyday
  - ☐ Few times a week
  - ☐ Once a week
  - ☐ Once a month
  - ☐ Occasionally
  - ☐ Never

  Please give a reason: ______________________________

- Other: ______________________________

  Frequency:
  - ☐ Everyday
  - ☐ Few times a week
  - ☐ Once a week
  - ☐ Once a month
  - ☐ Occasionally
  - ☐ Never

  Please give a reason: ______________________________

8. What is the level of difficulty to navigate the following unfamiliar spaces?

- University

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ______________________________

- Hospital

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ______________________________

- Department Store

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ______________________________

- Museum

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ______________________________

- Airport

  Level of Difficulty: ☐ Easy
  ☐ Moderate
  ☐ Hard

  Please give a reason: ____________________

- Other: ____________________

  Level of Difficulty: ☐ Easy
  ☐ Moderate
  ☐ Hard

  Please give a reason: ____________________

9. Do you have confidence to navigate inside buildings by yourself through the following unfamiliar spaces?

   - Wide open spaces without any landmarks

     Level of Difficulty: ☐ Yes
     ☐ No
     ☐ Not sure

     Please give a reason: ____________________

   - Hallway

     Level of Difficulty: ☐ Yes
     ☐ No
     ☐ Not sure

     Please give a reason: ____________________

   - Room (e.g. office)

     Level of Difficulty: ☐ Yes
     ☐ No
     ☐ Not sure

     Please give a reason: ____________________

   - Large room (e.g. auditorium, conference room, movie theatre, and exhibition)

     Level of Difficulty: ☐ Yes
     ☐ No
     ☐ Not sure

     Please give a reason: ____________________

10. Inside unfamiliar spaces inside buildings, how do you know where you are?

11. Inside unfamilar spaces inside buildings, how do you reach your destination?

12. How can you find your orientation or the direction you are heading to? Orientation means knowing which direction you are heading to, and where landmarks are located.

13. What landmarks are you looking for in order to learn or to help you to navigate by yourself through unfamiliar spaces?

14. Have you ever asked anybody (e.g. reception and local people) for directions or instructions to reach the destination?

    a. Yes, they have
    b. No, they have not

15. Have you ever found any directions or instructions from local people has been confusing or ambiguous?

    a. Yes
    b. No

    If Yes, Please give example

Section 4 Obstacles and Hazards

16. Have you experienced any problems or challenges while navigating by yourself inside buildings? For example, ground/body/head-level obstacles, noise, silent, or light.

    a. Yes, please give example ____________________

    b. No

17. By navigating inside buildings by yourself, have you ever experienced hitting or being hit by the following obstacles?

    - Ground-Level Obstacles e.g. Curb, drop-off, sloped floor, hole

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________________

    - Body-Level Obstacles e.g. Furniture, wall-mounted equipment

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________________

    - Head-Level Obstacles e.g. Stairs and hanging objects

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________________

    - Noise Obstacles e.g. Too much noise in the area

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________________

- Silence Obstacles e.g. Too silent in the area

  Frequency: ☐ Always
  ☐ Often
  ☐ Sometimes
  ☐ Rare
  ☐ Never

  Please give a reason: ____________________

- Light Obstacles e.g. Too much lighting

  Frequency: ☐ Always
  ☐ Often
  ☐ Sometimes
  ☐ Rare
  ☐ Never

  Please give a reason: ____________________

- Moving Obstacles e.g. People, pet, trolley

  Frequency: ☐ Always
  ☐ Often
  ☐ Sometimes
  ☐ Rare
  ☐ Never

  Please give a reason: ____________________

- Other: ____________________

  Frequency: ☐ Always
  ☐ Often
  ☐ Sometimes
  ☐ Rare
  ☐ Never

  Please give a reason: ____________________

18. What obstacles can you detect by your assistance (e.g. white cane, guide dog, tactile map)? Please select all that apply.

    ☐ Objects on the floor
    ☐ Edges and holes
    ☐ Other, please specify ____________________

19. What obstacles are you not able to detect by your assistance (e.g. white cane, guide dog, tactile map)? Please select all that apply.

    ☐ Slippery and sloped surfaces
    ☐ Objects above waist (body and head level obstacles)
    ☐ Other, please specify ____________________

20. While navigating inside buildings, how do you sense or know any dangers in your way? Please select all that apply.

    - [ ] Using assistance (cane, guide dog, sighted guide, or tactile map)
    - [ ] Using hearing sense
    - [ ] Using odor sense
    - [ ] Other, please specify ______

21. Have you ever found that using stairs, escalators, or elevators is difficult and dangerous? For example, the handrail is difficult to find or installed at a level too high or too low. Another example is that the stair width is too wide and non-standard.

    a. Yes, please give example ______
    b. No
    c. Not sure

Section 5 Accessibility and Essential Information

22. While navigating inside buildings, is any accessibility information available to you? For example, tactile maps, tactile pavements, Braille, audio or haptic feedback?

    a. Yes

    b. No

    If Yes, Please give example

23. Do you know that there is a tactile map available in some buildings for visually impaired and blind people which provides you with information about the buildings and spaces such as rooms, corridors, and landmark that help you to walk by yourself?

    a. Yes

    b. No

24. Have you used a tactile map to help you find directions to your destination?

    a. Yes IF YES, GO TO QUESTION 23

    b. No IF NO, GO TO QUESTION 25

25. Did the tactile map take you to your destination?

    a. Always

    b. Sometimes, why ____________________

    c. Never, why ____________________

26. What is the most important information you look for while using a tactile map in order to reach your destination?

27. To help you navigate by yourself inside buildings with safety awareness, how can you rate the following information in terms of importance to you while you are navigating?

Information	**Very Important**	**Important**	**Somewhat Important**	**Not Very Important**	**Not at all Important**	**No Opinion**
Building profile (e.g. opening hours)	☐	☐	☐	☐	☐	☐
Floor Plan (e.g. rooms and layout)	☐	☐	☐	☐	☐	☐
Floor Number	☐	☐	☐	☐	☐	☐
Room Number	☐	☐	☐	☐	☐	☐
Toilet and Bathroom	☐	☐	☐	☐	☐	☐
Entrance and Exit	☐	☐	☐	☐	☐	☐
Door	☐	☐	☐	☐	☐	☐
Emergency Exit	☐	☐	☐	☐	☐	☐
Lighting	☐	☐	☐	☐	☐	☐
Wi-Fi Coverage	☐	☐	☐	☐	☐	☐
Walkable Path	☐	☐	☐	☐	☐	☐
Tactile Pavement	☐	☐	☐	☐	☐	☐
Stairs	☐	☐	☐	☐	☐	☐
Steps, Drop-off, and Curb	☐	☐	☐	☐	☐	☐
Elevator	☐	☐	☐	☐	☐	☐
Escalator	☐	☐	☐	☐	☐	☐
Event and Exhibition	☐	☐	☐	☐	☐	☐
Furniture	☐	☐	☐	☐	☐	☐
Dangerous Areas	☐	☐	☐	☐	☐	☐
People are walking	☐	☐	☐	☐	☐	☐
Weather	☐	☐	☐	☐	☐	☐
Reception	☐	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐	☐

28. 28. How important is it to you to know where landmarks are located while navigating inside buildings by yourself?

    a. Very important
    b. Important
    c. Somewhat important
    d. Not at all important
    e. No Opinion

29. While navigating inside buildings by yourself, which of the following are important to you in order to learn and remember the buildings? Please select all that apply.

    - [ ] Landmarks (e.g. escalators, elevators, pillars, office plants, and statues)
    - [ ] Sound and noise
    - [ ] Floor texture
    - [ ] Smell
    - [ ] Other, please give example ____________________

B.2 Thai version

เอกสารข้อมูลสำหรับผู้เข้าร่วมงานวิจัย (Participant Information Sheet)

โครงการวิจัย: การศึกษาพฤติกรรมของผู้บกพร่องทางสายตาและคนตาบอดเดินทางภายอาคารสถาน (A study of indoor navigation behavior by visually impaired and blind people)

ชื่อนักวิจัย: วัฒนศักดิ์ เจียมวัฒนชัย

Ethics number: ERGO/FEPS/23512

โปรดอ่านข้อมูลนี้อย่างถี่ถ้วนก่อนตัดสินใจเข้าร่วมในการวิจัยนี้ หากคุณยินดีที่จะเข้าร่วมกรุณาลงนามในแบบฟอร์มแสดงความยินยอมเข้าร่วมงานวิจัย

รายละเอียดของโครงการวิจัย

งานวิจัยนี้เสนอวิธีการจัดเก็บข้อมูลของอาคารเพื่อนำไปใช้ในการสร้างแผนที่สำหรับระบบนำทางภายในอาคารและเทคโน-โลยีอื่น ที่เกี่ยวข้องเพื่อช่วยให้ผู้ที่มีความบกพร่องทางสายตาและคนตาบอดนั้นสามารถมีอิสระภาพในการเดินทางภายในอาคารโดยไม่ได้รับบาดเจ็บ

เหตุผลที่ผู้เข้าร่วมวิจัยได้รับเชิญ

ขณะนี้การดำเนินงานวิจัยอยู่ในขั้นการประเมินพฤติกรรมการเดินภายในอาคารของผู้มีความ บกพร่องทางสายตาและคนพิการ เพื่อให้ได้ข้อมูลที่ได้มีความชัดเจนและประโยชน์สูงสุด ดังนั้นข้อมูลที่ได้จากผู้ที่มีความบกพร่องทางสายตาและคนพิการนั้นถือว่ามีความสำคัญอย่างมากและรวมถึงข้อมูลจากเจ้าหน้าที่ที่ดูแลคนเหล่านี้ซึ่งจะให้อีกมุมมองหนึ่ง ซึ้งข้อมูลทั้งหมดที่กล่าวมานั้นมีความสำคัญและเป็นประโยชน์ต่องานวิจัยนี้เป็นอย่างมาก

สิ่งที่ผู้เข้าร่วมวิจัยต้องปฏิบัติ

๑. อ่านเอกสารชี้แจงผู้เข้าร่วมโครงการวิจัยนี้โดยละเอียดและทำเครื่องหมายถูก (✓) ในเอกสารยินยอมเข้าร่วมวิจัยไว้เป็นหลักฐาน

๒. ในกรณีผู้เข้าร่วมเป็นผู้มีความรู้พร่องทางสายตาและคนตาบอด ผู้เข้าร่วมจะให้สัมภาษณ์เกี่ยวกับพฤติกรรมการเดินภายในอาคารสถาน ปัญหาที่ประสบในขณะที่เดินอยู่ภายในอาคาร และข้อมูลสำคัญที่มีความจำเป็นและเป็นประโยชน์เพื่อช่วยห้ามารถเดินภายในอาคารได้อย่างอิสระและปลอดภัย ซึ่งในการสัมภาษณ์นี้จะใช้ระยะเวลา 30-40 นาที

๓. ในกรณีผู้เข้าร่วมไม่ใช่ผู้มีความพร่องทางสายตาหรือคนตาบอด ผู้เข้าร่วมจะต้องกรอกแบบสอบถามเกี่ยวกับพฤติ-กรรมการเดินภายในอาคารสถานของ ผู้ที่มีความปกพร่องทางสายตาและคนตาบอด ซึ่งจะใช้ระยะเวลา20-25 นาที

วิธีตอบรับการเข้าร่วมวิจัยด้วยความสมัครใจ

การทำเครื่องหมายถูก (✓) ในเอกสารยินยอมเข้าร่วมวิจัยแสดงถึงการตอบรับการเข้าร่วมวิจัยด้วยความสมัครใจ ในกรณีผู้เข้าร่วมเป็นผู้มีความรู้พร่องทางสายตาและคนตาบอด การยินยอมและตอบรับการเข้าร่วมนั้นจะถูกบันทึกด้วยเสียงและทำเครื่องหมายถูกโดยผู้ทำการสัมภาษณ์ ทั้งนี้ผู้เข้าร่วมวิจัยมีสิทธิในการปฏิเสธการเข้าร่วมวิจัยโดยไม่ส่งผลกระทบใดๆ กับวิถีชีวิตและมีสิทธิ์ถอนตัวออกจากโครงการวิจัยได้ทุกเวลาโดยไม่ต้องแจ้งให้ผู้วิจัยทราบล่วงหน้า

ประโยชน์ที่จะได้รับสำหรับผู้เข้าร่วมวิจัยและส่วนรวม

ผลของการศึกษาวิจัยนี้จะสะท้อนให้เห็นถึงพฤติกรรมการเดินภายในอาคารสถานที่ ของผู้มีความบกพร่องทางสายตาและคนตาบอด การเดินภายในอาคารสถานที่ ปัญหาที่พบเจอและรวมถึงข้อมูลที่มีความสำคัญและเป็นประโยชน์ต่อผู้คนเหล่านี้ ซึ่งข้อมูลเหล่านี้สามารถนำไปใช้ในการพัฒนาต่อยอดให้บริการด้านต่างๆ ที่มีประโยชน์ต่อผู้ที่มีความบกพร่องทางสายตาและคนตาบอด

ความเสี่ยงที่อาจจะเกิดขึ้นเมื่อเข้าร่วมวิจัย

การกรอกแบบสอบถามและการสัมภาษณ์ความคิดเห็นไม่ก่อให้เกิดความเสี่ยงอันตรายใดๆแก่ผู้เข้าร่วมวิจัย

การจัดเก็บและประมวลผลข้อมูล

คำตอบของผู้เข้าร่วมวิจัยจะถือเป็นความลับและไม่มีการเก็บข้อมูลชื่อของผู้เข้าร่วมวิจัยโดยข้อมูลส่วนตัวของผู้เข้าร่วม วิจัยจะถูกเก็บรักษาไว้ไม่เปิดเผยต่อสาธารณะเป็นรายบุคคลแต่จะรายงานผลการวิจัยในข้อมูลส่วนรวมและข้อมูลทั้งหมดจะถูกบันทึกในเครื่องคอมพิวเตอร์ที่มีระบบรักษาความปลอดภัยอย่างดี

กรณีมีปัญหาหรือข้อสงสัย

หากผู้เข้าร่วมวิจัยมีปัญหาหรือข้อสงสัยเกี่ยวกับงานวิจัยสามารถติดต่อผู้วิจัย นายวัฒนศักดิ์ เจียมวัฒนชัย ทางอีเมล์ wj1g14@ecs.soton.ac.uk

แบบสอบถาม

โครงการวิจัย: การศึกษาพฤติกรรมของผู้บกพร่องทางสายตาและคนตาบอดเดินทางภายอาคารสถาน (A study of indoor navigation behavior by visually impaired and blind people)

ชื่อนักวิจัย: วัฒนศักดิ์ เจียมวัฒนชัย
Ethics number: ERGO/FEPS/23512

ขอเชิญชวนเข้าร่วมงานวิจัย

งานวิจัยนี้เกี่ยวกับการศึกษาวิจัยพฤติกรรมของผู้มีความบกพร่องทางสายตาและคนตาบอดขณะเดินภายในอาคารด้วยตัวเอง แบบสอบถามฉบับนี้ถูกสร้างขึ้นการเก็บข้อมูลทางด้านพฤติกรรมของผู้มีความบกพร่องทางสายตาและคนตาบอดขณะเดินภายในอาคารด้วยตัวเอง การเก็บข้อมูลครั้งนี้จะประกอบไปด้วยกลุ่มตัวอย่างทั้งสิ้น สองกลุ่ม กลุ่มที่ 1 ผู้พิการทางสายตาและคนตาบอด และ กลุ่มที่ 2 เจ้าหน้าที่ที่ดูแลผู้พิการทางสายตาและคนตาบอดหรือกลุ่มคนที่ทำงานใกล้ชิดกับผู้พิการทางสายตาและคนตาบอด ในการตอบแบบสอบถามฉบับนี้จะใช้ระยะเวลา 15-20 นาที

ความคิดเห็นของคุณจะถูกเก็บเป็นความลับไม่มีการเปิดเผยชื่อผู้เข้าร่วมและเพื่อให้เป็นไปตามมาตรฐานการปกป้องข้อมูล

- แบบสอบถามจะถูกแสกนเก็บในรูปแบบเอกสารอิเล็กทรอนิกส์ (PDF) และไม่มีการทำสำเนา
- แบบสอบถามจะถูกจัดเก็บในตู้เอกสารที่ใช้กุญแจในการเข้าถึง ณ มหาวิทยาลัยเซาท์แฮมป์ตัน
- เอกสารอิเล็กทรอนิกส์จะถูกจัดเก็บในเครื่องคอมพิวเตอร์ที่มีการใช้รหัสผ่านในการเข้าถึงข้อมูล ณ มหาวิทยาลัยเซาท์แฮมป์ตัน
- แบบสอบถามและเอกสารอิเล็กทรอนิกส์จะถูกทำลายภายใน 1 ปีหลังงานวิจัยนี้สำเร็จเสร็จสิ้น

หากผู้เข้าร่วมวิจัยมีปัญหาหรือข้อสงสัยเกี่ยวกับงานวิจัยสามารถติดต่อผู้วิจัย นายวัฒนศักดิ์ เจียมวัฒนชัย ทางอีเมล์ wj1g14@ecs.soton.ac.uk

ขอบพระคุณที่เข้าร่วมงานวิจัย,

วัฒนศักดิ์ เจียมวัฒนชัย	นักวิจัย	wj1g14@ecs.soton.ac.uk
Prof Gary Wills	ที่ปรึกษา	gbw@ecs.soton.ac.uk
Prof Mike Wald	ที่ปรึกษา	mw@ecs.soton.ac.uk

คำแนะนำ:

แบบสอบถามฉบับนี้จะใช้ระยะเวลา 1.30-2 ชั่วโมง

ชุดคำถามในแบบสอบถามฉบับนี้สามารถตอบได้ 3 วิธี ดังต่อไปนี้:

- ติ๊กเครื่องหมายถูก (✓) ลงในช่องสี่เหลี่ยม ตัวอย่าง ☑
- วงกลมตัวเลือกที่ตรงตามที่ต้องการ ตัวอย่าง (a.) important
- เขียนคำอธิบายลงในช่องว่าที่เตรียมไว้ให้ ตัวอย่าง [2 years]

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อช่วยคนพิการทางสายตาและคนตาบอดให้มีอิสระและความมั่นใจในการเดินในพื้นที่ที่ไม่คุ้นเคยภายในตัวอาคารและสถานที่ต่างๆ

นิยาม: พื้นที่ที่ไม่คุ้น: พื้นที่ภายในอาคารและสถานที่ต่างๆที่คนพิการทางสายตาและคนตาบอดไม่มีความคุ้นเคย/ไม่สมารถคาดเดาสภาพแวดล้อมภายในได้

นิยามที่ไม่มีการกล่าวถึงในงานวิจัย: ช่องว่างที่คุ้นเคย (ไม่ว่าช่องว่างที่คุ้นเคยเหล่านี้จะอยู่ด้านในหรือด้านนอก) พื้นที่กลางแจ้ง (ไม่ว่าพื้นที่กลางแจ้งเหล่านี้จะคุ้นเคยหรือไม่คุ้นเคยก็ตาม)

ส่วนที่ ๑ ข้อมูลทั่วไป

๑. โปรดระบุเพศของคุณ?

ก. ชาย

ข. หญิง

๒. โปรดระบุช่วงอายุของท่าน?

ก. 18-29 ปี

ข. 30-49 ปี

ค. 50-64 ปี

ง. 65+ ปี

จ. ไม่ระบุ

๓. ข้อใดต่อไปนี้อธิบายความสามารถทางสายตาของคุณ?

ก. ตาบอดแต่สูญเสียความสามารถในการมองเห็นเมื่ออายุ ____________ ปี

ข. ตาบอดตั้งแต่กำเนิด

ค. มีความบกพร่องทางสายตา (โปรดระบุความความสามารถทางสายตา)

- ☐ แต่สามารถมองเห็น<u>แสง</u>
- ☐ แต่สามารถมองเห็น<u>เงา</u>
- ☐ แต่สามารถมองเห็น<u>สี</u>
- ☐ แต่สามารถมองเห็น<u>การเคลื่อนไวของวัตถุ</u>

ง. Other, please specify ____

ส่วนที่ ๒ พฤติกรรมและการเดินภายในอาคาร

๔. คุณเคยผ่านการฝึกอบรมทักษะการทำความคุ้นเคยกับสภาพแวดล้อมและการเคลื่อนไหว (Orientation & Mobility , O&M) หรือไม่?

ก. เคย

ข. ไม่เคย

๕. คุณใช้ตัวช่วยเหล่านี้สำหรับทำกิจวัตรประจำวันสม่ำเสมอเท่าใด?

- ไม้เท้าขาว (White Cane)

ความถี่:
- ☐ ทุกวัน
- ☐ หลายครั้ง/สัปดาห์
- ☐ 1 ครั้ง/สัปดาห์
- ☐ 1 ครั้ง/เดือน
- ☐ บางโอกาส
- ☐ ไม่เคย , โปรดระบุเหตุผล: ____________________

- สุนัขนำทาง (Guide Dog)

ความถี่:
- ☐ ทุกวัน
- ☐ หลายครั้ง/สัปดาห์
- ☐ 1 ครั้ง/สัปดาห์
- ☐ 1 ครั้ง/เดือน
- ☐ บางโอกาส
- ☐ ไม่เคย , โปรดระบุเหตุผล: ____________________

- คนนำทาง (Sighted Guide)

ความถี่:
- ☐ ทุกวัน
- ☐ หลายครั้ง/สัปดาห์
- ☐ 1 ครั้ง/สัปดาห์
- ☐ 1 ครั้ง/เดือน
- ☐ บางโอกาส
- ☐ ไม่เคย , โปรดระบุเหตุผล: ____________________

- แผนที่คนตาบอด (Tactile Map)

ความถี่:
- ☐ ทุกวัน
- ☐ หลายครั้ง/สัปดาห์
- ☐ 1 ครั้ง/สัปดาห์
- ☐ 1 ครั้ง/เดือน
- ☐ บางโอกาส
- ☐ ไม่เคย , โปรดระบุเหตุผล: ______________________

- อื่นๆ: ______________________

ความถี่:
- ☐ ทุกวัน
- ☐ หลายครั้ง/สัปดาห์
- ☐ 1 ครั้ง/สัปดาห์
- ☐ 1 ครั้ง/เดือน
- ☐ บางโอกาส
- ☐ ไม่เคย , โปรดระบุเหตุผล: ______________________

๖. ในกรณีที่คุณเดินภายในอาคารด้วยตัวคุณเอง คุณใช้วิธีใดในการคำนวนระยะทาง?

ก. โดยใช้การนับจำนวนการก้าวเท้า (foot steps)

ข. ด้วยระยะทาง เช่น ฟุต (feet) หรือ เมตร (meter)

ค. โดยการจับเวลา เช่น 5 วินาที

ง. อื่นๆ โปรดระบุ ______________________

ส่วนที่ ๓ สถานที่ไม่คุ้นเคย

นิยาม: สถานที่ที่ไม่คุ้นเคย คือ สถานที่ที่คุณไม่ได้ไปเป็นประจำ (Rarely visit) หรืออาคารสถานที่ที่คุณยังไม่เคยรู้จำ ในกรณีการที่ต้องเดินทางด้วยตัวเอง เช่นการเดินทางไปมหาวิทยาลัย โรงพยาบาล พิพิธภัณฑ์ ห้างสรรพสินค้า และสนามบิน

๗. บ่อยครั้งไหมที่คุณต้องเดินด้วยตัวเองภายในอาคารสถานที่ที่ไม่คุ้นเคย เช่น มหาวิทยาลัย โรงพยาบาล พิพิธภัณฑ์ ห้างสรรพสินค้า และสนามบิน?

- มหาวิทยาลัย

  ความถี่:
  - ☐ ทุกวัน
  - ☐ หลายครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/เดือน
  - ☐ บางโอกาส
  - ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- โรงพยาบาล

  ความถี่:
  - ☐ ทุกวัน
  - ☐ หลายครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/เดือน
  - ☐ บางโอกาส
  - ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- ห้างสรรพสินค้า

  ความถี่:
  - ☐ ทุกวัน
  - ☐ หลายครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/เดือน
  - ☐ บางโอกาส

☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- พิพิธภัณฑ์

ความถี่: ☐ ทุกวัน
☐ หลายครั้ง/สัปดาห์
☐ 1 ครั้ง/สัปดาห์
☐ 1 ครั้ง/เดือน
☐ บางโอกาส
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- สนามบิน

ความถี่: ☐ ทุกวัน
☐ หลายครั้ง/สัปดาห์
☐ 1 ครั้ง/สัปดาห์
☐ 1 ครั้ง/เดือน
☐ บางโอกาส
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- อื่นๆ: ____________________

ความถี่: ☐ ทุกวัน
☐ หลายครั้ง/สัปดาห์
☐ 1 ครั้ง/สัปดาห์
☐ 1 ครั้ง/เดือน
☐ บางโอกาส
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

๘. จงระบุระดับความยากง่ายในการเดินทางภายในอาคารสถานที่ที่ไม่คุ้นเคยต่อไปนี้

- มหาวิทยาลัย

ระดับความยาก: ☐ ง่าย

☐ ปานกลาง

☐ ยาก

โปรดระบุเหตุผล: ____________________

- โรงพยาบาล

ระดับความยาก: ☐ ง่าย

☐ ปานกลาง

☐ ยาก

โปรดระบุเหตุผล: ____________________

- ห้างสรรพสินค้า

ระดับความยาก: ☐ ง่าย

☐ ปานกลาง

☐ ยาก

โปรดระบุเหตุผล: ____________________

- พิพิธภัณฑ์

ระดับความยาก: ☐ ง่าย

☐ ปานกลาง

☐ ยาก

โปรดระบุเหตุผล: ____________________

- สนามบิน

ระดับความยาก: ☐ ง่าย

☐ ปานกลาง

☐ ยาก

โปรดระบุเหตุผล: ____________________

- อื่นๆ: ______________________

ระดับความยาก: ☐ ง่าย
☐ ปานกลาง
☐ ยาก

โปรดระบุเหตุผล: ______________________

๙. คุณมีความมั่นใจในการเดินด้วยตัวเอง ในสถานที่ที่ไม่คุ้นเคยต่อไปนี้หรือไม่?

- พื้นที่เปิด โล่งกว้างไม่มีจุดสังเกต (landmarks)

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

- ห้องโถง (Hallway)

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

- ห้องที่มีขนาดเล็ก เช่น ออฟฟิต

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

- ห้องที่มีขนาดใหญ่ (เช่นหอประชุม, ห้องประชุม, โรงภาพยนตร์และพื้นที่แสดงนิทรรศการ)

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

๑๐. คุณจะทำอย่างไรเพื่อให้รู้ได้ว่าคุณอยู่ตรงไหนของอาคาร ในกรณีที่คุณอยู่ในอาคาร สถานที่ที่ไม่คุ้นเคย?

๑๑. ในอาคารสถานที่ที่คุณไม่คุ้นเคย คุณจะทำอย่างไรเพื่อให้สามารถเดินไปยังปลายทางที่คุณต้องการ?

๑๒. ในขณะเดินด้วยตัวเองในสถานที่ที่ไม่คุ้นเคย คุณมีวิธีในการค้นหาทิศ (direction or orientation) ตรงหน้าคุณได้อย่างไร.

๑๓. ในขณะเดินด้วยตัวเองในสถานที่ที่คุณไม่คุ้นเคย คุณใช้จุดสังเกต (landmark) อะไรเพื่อช่วยให้คุณสามารถเดินภายในอาคารได้ด้วยตัวคุณเอง?

๑๔. คุณเคยสอบถามคนในพื้นที่ (เช่น เจ้าหน้าที่ แผนกต้อนรับ) หรือไม่เพื่อหาทิศทางหรือวิธีการเพื่อให้สามารถเดินไปยังปลายทางที่คุณต้องการได้หรือไม่?

ก. เคย

ข. ไม่เคย

๑๕. คุณเคยได้รับข้อมูลที่สับสน (confusing) หรือ ไม่ชัดเจน (ambiguous) ในการสอบถามข้อมูลจากคนในพื้นที่หรือไม่

ก. เคย, กรุณายกตัวอย่าง ______________________________

ข. ไม่เคย

ส่วนที่ ๔ สิ่งกีดขวางและพื้นที่อันตราย

๑๖. คุณเคยประสบปัญหาใดๆ ในขณะที่เดินภายในอาคารด้วยตัวเองหรือไม่ เช่น สิ่งกีดขวางระดับพื้น สิ่งกีดขวางระดับร่างกาย สิ่งกีดขวางระดับหัว พื้นที่ที่มีเสียงดังเกินไปหรือเงียบเกิน หรือพื้นที่ที่มีแสงสว่างมากเกินไป?

ก. เคย, กรุณายกตัวอย่าง ____________________

ข. ไม่เคย

๑๗. ในขณะที่เดินภายในอาคารด้วยตัวเอง คุณเคยประสบปัญหาเดินชนหรือถูกชนโดยสิ่งกีดขวางต่อไปนี้หรือไม่?

- สิ่งกีดขวางระดับพื้น เช่น ขอบพื้น หลุม พื้นเอียง ทางราดชัน

  ความถี่:
  ☐ ทุกครั้ง
  ☐ บ่อยครั้ง
  ☐ บางครั้ง
  ☐ น้อยครั้ง
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- สิ่งกีดขวางระดับร่างกาย เช่น เฟอร์นิเจอร์ อุปกรณ์ติดตามผนัง

  ความถี่:
  ☐ ทุกครั้ง
  ☐ บ่อยครั้ง
  ☐ บางครั้ง
  ☐ น้อยครั้ง
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- สิ่งกีดขวางระดับหัว เช่น บันได ป้ายแขวน

  ความถี่:
  ☐ ทุกครั้ง
  ☐ บ่อยครั้ง
  ☐ บางครั้ง
  ☐ น้อยครั้ง
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- พื้นที่ที่มีเสียงรบกวน

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- พื้นที่เงียบเกินไป

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- พื้นที่ที่มีแสงสว่างมากเกินไป

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- สิ่งกีดขวางที่เดินได้ เช่น คน สัตว์ รถเข็น

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- อื่นๆ โปรดระบุ: ____________________

  ความถี่:
  - ☐ ทุกครั้ง
  - ☐ บ่อยครั้ง
  - ☐ บางครั้ง
  - ☐ น้อยครั้ง
  - ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

๑๘. สิ่งกีดขวางอะไรบ้างที่คุณสามารถตรวจหาได้โดยใช้ตัวช่วยทั่วไป เช่น ไม้เท้าขาว (White cane) สุนัขนำทาง (Guide dog) แผนที่คนตาบอด (tactile map)?

- ☐ สิ่งของที่วางบนพื้น
- ☐ ขอบพื้นและหลุม
- ☐ อื่นๆ โปรดระบุ ____________________

๑๙. สิ่งกีดขวางอะไรบ้างที่คุณ<u>ไม่สามารถตรวจหา</u>ได้โดยใช้ตัวช่วยทั่วไป เช่น ไม้เท้าขาว (White cane) สุนัขนำทาง (Guide dog) แผนที่คนตาบอด (tactile map)?

- ☐ พื้นเอียงและลื่น
- ☐ สิ่งของในดับเอวขึ้นไป เช่น สิ่งกีดขวางระดับร่างกาย และ สิ่งกีดขวางระดับหัว
- ☐ อื่นๆ โปรดระบุ ____________________

๒๐. ในขณะที่เดินภายในอาคารด้วยตัวเอง คุณมีวิธีหรือตัวช่วยให้ในการรับรู้ได้อย่างไรว่ามีสิ่งอันตรายกีดขวางทางเดินของคุณ

- ☐ ใช้ตัวช่วยทั่วไป เช่น ไม้เท้าขาว (White cane) สุนัขนำทาง (Guide dog) แผนที่คนตาบอด (tactile map)
- ☐ ใช้การได้ยิน (hearing sense)
- ☐ ใช้การดมกลิ่น (odor sense)
- ☐ อื่นๆ โปรดระบุ ____________________

๒๑. คุณเคยประสบปัญหากับการใช้งานบันได บันไดเลื่อนหรือลิฟต์นั้นมีความยากการอันตรายในการใช้งาน เช่น ราวสำหรับมือจับของขั้นบันไดถูกติดตั้งไว้สูงหรือต่ำเกินไป หรือความกว้างของบันไดไม่ได้มาตรฐาน เช่น กว้างเกินไป

ก. เคย, กรุณายกตัวอย่าง ____________________

ข. ไม่เคย

ค. ไม่แน่ใจ

ส่วนที่ ๕ การเข้าถึงข้อมูล (Accessibility)

๒๒. ในขณะที่เดินภายในอาคารด้วยตัวเอง มีข้อมูลอะไรบ้างที่คุณสามารถนำมาใช้เพื่อให้สามารถเดินภายในอาคารได้ด้วยตัวเอง เช่น แผนที่สำหรับคนตาบอด (tactile map), ทางเท้าสำหรับคนตาบอด (tactile pavement), อักษรเบรลล์ (Braille) เสียงและการสัมผัส (audio and haptic feedback)?

ก. มี

ข. ไม่มี

ถ้ามี, โปรดยกตัวอย่าง

๒๓. คุณรู้หรือไม่ว่าในบางอาคารแผนที่สำหรับคนตาบอด (tactile map) ได้ถูกติดตั้งไว้เพื่อบอกรายละเอียดของอาคาร เช่น ห้อง (room) ระเบียง (corridor) จุดสังเกต (landmark) ที่จะช่วยให้คุณสามารถเดินได้ด้วยตัวเอง?

ก. รู้

ข. ไม่รู้

๒๔. แผนที่คนตาบอดนั้นได้พาคุณไปถึงเป้าหมายปลายทางหรือไม่?

ก. เคย ถ้า เคย ไปข้อที่ 25

ข. ไม่เคย ถ้า ไม่เคย ข้ามไปข้อที่ 27

๒๕. แผนที่คนตาบอดนั้นได้พาคุณไปถึงเป้าหมายปลายทางหรือไม่?

ก. ทุกครั้ง

ข. บางครั้ง, เพราะ ______

ค. ไม่เคย, เพราะ ______

๒๖. ในขณะที่ใช้งานแผนที่คนตาบอด (tactile map) คุณคิดว่าอะไรคือข้อมูลที่สำคัญที่ช่วยให้คุณสามารถเดินไปยังปลายทางที่ต้องการได้?

๒๗. เพื่อทำให้คุณสามารถเดินภายในอาคารได้ด้วยตัวเองและตระหนักถึงความปลอดภัย คุณคิดว่าข้อมูลต่อไปนี้มีความสำคัญมากน้อยเท่าไหร่ในขณะที่คุณเดินอยู่ภายในอาคาร?

ประเภทของข้อมูล	สำคัญมาก	สำคัญ	บางส่วนสำคัญ	ไม่ค่อยสำคัญ	ไม่สำคัญ	ไม่มีความคิดเห็น
ข้อมูลอาคาร เช่น เวลาเปิด-ปิด	☐	☐	☐	☐	☐	☐
แผนผังอาคาร (e.g. rooms and layout)	☐	☐	☐	☐	☐	☐
เลขชั้น	☐	☐	☐	☐	☐	☐
เลขห้อง	☐	☐	☐	☐	☐	☐
ห้องน้ำ	☐	☐	☐	☐	☐	☐
ทางเข้าและทางออก	☐	☐	☐	☐	☐	☐
ประตู	☐	☐	☐	☐	☐	☐
ทางออกฉุกเฉิน	☐	☐	☐	☐	☐	☐
แสงสว่าง	☐	☐	☐	☐	☐	☐
พื้นที่ของ Wi-FI	☐	☐	☐	☐	☐	☐
ทางเดิน	☐	☐	☐	☐	☐	☐
ทางเท้าสำหรับคนตาบอด	☐	☐	☐	☐	☐	☐
บันได	☐	☐	☐	☐	☐	☐
ทางขึ้น ทางลาดชัน และขอบพื้น	☐	☐	☐	☐	☐	☐
ลิฟต์	☐	☐	☐	☐	☐	☐
บันไดเลื่อน	☐	☐	☐	☐	☐	☐
พื้นกิจกรรมและการแสดงนิทรรศการ	☐	☐	☐	☐	☐	☐
เฟอร์นิเจอร์	☐	☐	☐	☐	☐	☐
พื้นที่อันตราย	☐	☐	☐	☐	☐	☐
ผู้คนกำลังเดิน	☐	☐	☐	☐	☐	☐
สภาพอากาศ	☐	☐	☐	☐	☐	☐
แผนกต้อนรับ	☐	☐	☐	☐	☐	☐
เสียงรบกวน	☐	☐	☐	☐	☐	☐

๒๘. ในขณะที่เดินอยู่ภายในอาคารด้วยตัวเอง คุณคิดว่ามีความสำคัญมากหรือน้อยสำหรับคุณอย่างไรถ้าคุณสามารถระบุตำแหน่งของจุดสังเกต (landmark) ภายในอาคาร?

ก. สำคัญมาก

ข. สำคัญ

ค. บางส่วนสำคัญ

ง. ไม่สำคัญ

จ. ไม่มีความคิดเห็น

๒๙. ในขณะที่เดินอยู่ภายในอาคารด้วยตัวเอง คุณคิดสิ่งใดบ้างต่อไปนี้มีความสำคัญกับคุณเพื่อการเรียนรู้และจดจำพื้นที่เพื่อที่คุณสามารถเดินภายในอาคารได้ด้วยตัวเอง?

- ☐ จุดสังเกต (landmark) เช่น บันไดเลื่อน ลิฟต์ เสา ต้นไม้ หรือรูปปั้น
- ☐ เสียงรบกวน
- ☐ ลักษณะของพื้น
- ☐ กลิ่น
- ☐ อื่นๆ, โปรดระบุ ____________________

Appendix C

Spatial Representation Framework - Questionnaire for Normal Sighted People

This chapter shows the questionnaires that were used in the preliminary study where participants were normal sighted people recruited in United Kingdom and Thailand. The questionnaires were split into two version (English and Thai) used in the survey with participants who are British (Section B.1) and Thai (Section B.2), respectively.

C.1 English version

Participant Information Sheet

Study Title: A study of indoor navigation behaviour by visually impaired and blind people.

Investigator: Watthanasak Jeamwatthanachai
Ethics number: ERGO/FEPS/23512

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
This research is trying to help visually impaired and blind people to have a confident to navigate independently inside buildings with safety awareness. To help them, this study proposes a data representation of buildings which will be used towards the construction of indoor navigation systems. Consequently, this study is first to identify what important factors, obstacles, and useful information needed by visually impaired and blind people.

Why have I been chosen?
At this stage, this study is trying to collect information about behaviour of indoor navigation by visually impaired and blind people. Thus, visually impaired and blind people including staff, who work closely with these people, are invited to participate in this study.

What will happen to me if I take part?
If you are visually impaired or blind, you will be interviewed about indoor navigation behaviour inside buildings, which consists of five sections and will take 30-40 minutes to complete.

If you are staff, you will fill out a given questionnaire which will take no more than 25 minutes. The questionnaire is comprised of five sections regarding behaviour of indoor navigation by visually impaired and blind people.

Are there any benefits in my taking part?
By taking part, you have the opportunity to help us development the technology to help visually impaired and blind people to have freedom and confidence in navigating inside buildings by themselves.

Are there any risks involved?
There is no any risk involved for participants completing the questionnaires and interviews.

Will my participation be confidential?
The name of the participants will not be taken and participation will be kept anonymous. All data will be safe in a protected computer. All will be destroyed once the research is completed.

What happens if I change my mind?
You have the right to withdraw from doing the questionnaire or interview at any time.

What happens if something goes wrong?
If you have any concern or complaint with this study, please contacts Watthanasak Jeamwatthanachai at wj1g14@ecs.soton.ac.uk

Where can I get more information?

If you would like to get more information about this study, please feel free to contact Watthanasak Jeamwatthanachai at wj1g14@ecs.soton.ac.uk

Questionnaire

Study Title: Helping visually impaired and blind people to independently navigate unfamiliar spaces

Investigator: Watthanasak Jeamwatthanachai
Ethics number: ERGO/FEPS/23512

Invitation

Thank you for reading this. I would like to invite you to take part in my research study by completing this questionnaire. It is entirely up to you whether you participate but your responses would be valued. You have been identified as a potential participant by your expertise, experience and knowledge in the area.

My study is trying to help visually impaired and blind people to have the freedom and confidence to independently navigate unfamiliar spaces inside buildings.

The questionnaire is anonymous and your confidentiality is assured:

- Completed questionnaires will be scanned to create a single PDF file.
- This single PDF file will not be duplicated - only one copy will be created.
- This PDF file will be stored on a password protected computer at the University of Southampton.
- This PDF file will be destroyed 1 year after the completion of my PhD study.
- The original questionnaire sheets (paper transcripts) will be stored in a locked filing cabinet at the University of Southampton.
- The original questionnaire sheets (paper transcripts) will be destroyed 1 year after the completion of my PhD study.

If you have any questions, please contact the investigator (Watthanasak Jeamwatthanachai, PhD researcher) and my supervisors.

Yours Sincerely,

Watthanasak Jeamwatthanachai	Investigator, PhD researcher	wj1g14@ecs.soton.ac.uk
Prof Gary Wills	Primary Supervisor	gbw@ecs.soton.ac.uk
Prof Mike Wald	Secondary Supervisor	mw@ecs.soton.ac.uk

Instruction:

This questionnaire will take approximately 1.30 - 2 hours to finish.

Questions can be answered in 3 ways:

- Boxes: Insert an X mark in the appropriate box e.g. ☑
- Letters: circle the appropriate letter e.g. (a.) important
- Spaces: Write the answer in the space provided e.g. [2 years]

This study aims to help visually impaired and blind people to have the freedom and confidence to independently navigate unfamiliar spaces inside buildings.

In ALL cases, the questions refer ONLY to unfamiliar spaces inside buildings.

The questions do NOT refer to: Familiar spaces (regardless of whether these familiar spaces are inside or outside) Outdoor spaces (regardless of whether these outdoor spaces are familiar or unfamiliar)

Section 1 Basic information

1. How long have you been working closely with visually impaired and blind people?

    ____________________ years (approximately)

Section 2 Behavior and Indoor Navigation

2. Is a mobility training course (e.g. orientation and mobility) important to visually impaired and blind people?

    a. Important

    b. Important, but not necessary

    c. Not important

3. Which assistance do visually impaired and blind people use when they navigate inside buildings by themselves? How often do they use this assistance?

    - White Cane

      Frequency:
      - ☐ Everyday
      - ☐ Few times a week
      - ☐ Once a week
      - ☐ Once a month
      - ☐ Occasionally
      - ☐ Never , please give a reason: ____________________

    - Guide Dog

      Frequency:
      - ☐ Everyday
      - ☐ Few times a week
      - ☐ Once a week
      - ☐ Once a month
      - ☐ Occasionally
      - ☐ Never , please give a reason: ____________________

    - Sighted Guide

      Frequency:
      - ☐ Everyday
      - ☐ Few times a week
      - ☐ Once a week
      - ☐ Once a month
      - ☐ Occasionally
      - ☐ Never , please give a reason: ____________________

    - Tactile Map

      Frequency:
      - ☐ Everyday
      - ☐ Few times a week
      - ☐ Once a week
      - ☐ Once a month
      - ☐ Occasionally
      - ☐ Never , please give a reason: ____________________

- Other: ____________________

  Frequency:
  - ☐ Everyday
  - ☐ Few times a week
  - ☐ Once a week
  - ☐ Once a month
  - ☐ Occasionally
  - ☐ Never , please give a reason: ____________________

4. How do visually impaired and blind people estimate the distance while navigating inside buildings by themselves?

   a. By foot steps

   b. By length unit, e.g. feet or meter

   c. By time, e.g. 5 seconds

   d. Other, please specify ____________________

Section 3 Unfamiliar Spaces

Definition: Unfamiliar spaces are places that visually impaired and blind people rarely visit or have not learnt to navigate by themselves. Examples of unfamiliar spaces could include the university, hospital, museum, department store or airport.

5. How often do visually impaired and blind people navigate by themselves inside unfamiliar spaces, e.g. university, hospital, department store, museum, and airport?

   - University

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never

     Please give a reason: ______________________

   - Hospital

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never

     Please give a reason: ______________________

   - Department Store

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never

     Please give a reason: ______________________

   - Museum

     Frequency:
     - ☐ Everyday
     - ☐ Few times a week
     - ☐ Once a week
     - ☐ Once a month
     - ☐ Occasionally
     - ☐ Never

     Please give a reason: ______________________

- Airport

  Frequency:
  - ☐ Everyday
  - ☐ Few times a week
  - ☐ Once a week
  - ☐ Once a month
  - ☐ Occasionally
  - ☐ Never

  Please give a reason: ____________________

- Other: ____________________

  Frequency:
  - ☐ Everyday
  - ☐ Few times a week
  - ☐ Once a week
  - ☐ Once a month
  - ☐ Occasionally
  - ☐ Never

  Please give a reason: ____________________

6. While navigating inside buildings by visually impaired and blind people, what is the level of difficulty to navigate the following unfamiliar buildings?

- University

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ____________________

- Hospital

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ____________________

- Department Store

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ____________________

- Museum

  Level of Difficulty:
  - ☐ Easy
  - ☐ Moderate
  - ☐ Hard

  Please give a reason: ____________________

- Airport

  Level of Difficulty: ☐ Easy
  ☐ Moderate
  ☐ Hard

  Please give a reason: ____________________

- Other: ____________________

  Level of Difficulty: ☐ Easy
  ☐ Moderate
  ☐ Hard

  Please give a reason: ____________________

7. Do visually impaired and blind people have confidence to navigate by themselves through the following unfamiliar spaces inside buildings?

- Wide open spaces without any landmarks

  Level of Difficulty: ☐ Yes
  ☐ No
  ☐ Not sure

  Please give a reason: ____________________

- Hallway

  Level of Difficulty: ☐ Yes
  ☐ No
  ☐ Not sure

  Please give a reason: ____________________

- Room (e.g. office)

  Level of Difficulty: ☐ Yes
  ☐ No
  ☐ Not sure

  Please give a reason: ____________________

- Large room (e.g. auditorium, conference room, movie theatre, and exhibition)

  Level of Difficulty: ☐ Yes
  ☐ No
  ☐ Not sure

  Please give a reason: ____________________

8. In unfamiliar spaces inside buildings, how do visually impaired and blind people know where they are?

9. In unfamiliar spaces inside buildings, how do visually impaired and blind people reach their destination?

10. How do visually impaired and blind people find their orientation or the direction they are heading to? Orientation means knowing which direction you are heading to, and where landmarks are located.

11. What landmarks are visually impaired and blind people looking for in order to help them to navigate by themselves through unfamiliar spaces?

12. Have visually impaired and blind people ever asked anybody (e.g. reception and local people) for directions or instructions to reach the destination?

    a. Yes, they have

    b. No, they have not

13. Have visually impaired and blind people ever found that directions or instructions from local people have been confusing or ambiguous?

    a. Yes

    b. No

    If Yes, Please give example

Section 4 Obstacles and Hazards

14. Have visually impaired and blind people experienced any problems or challenges while navigating inside buildings? For example, ground/body/head-level obstacles, noise, silent, or light.

    a. Yes, please give example ____________

    b. No

15. When navigating unfamiliar spaces inside buildings, do visually impaired and blind people experience a collision by the following obstacles?

    - Ground-Level Obstacles e.g. Curb, drop-off, sloped floor, hole

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________

    - Body-Level Obstacles e.g. Furniture, wall-mounted equipment

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________

    - Head-Level Obstacles e.g. Stairs and hanging objects

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________

    - Noise Obstacles e.g. Too much noise in the area

      Frequency: ☐ Always
      ☐ Often
      ☐ Sometimes
      ☐ Rare
      ☐ Never

      Please give a reason: ____________

- Silence Obstacles e.g. Too silent in the area

  Frequency:
  - ☐ Always
  - ☐ Often
  - ☐ Sometimes
  - ☐ Rare
  - ☐ Never

  Please give a reason: ____________________

- Light Obstacles e.g. Too much lighting

  Frequency:
  - ☐ Always
  - ☐ Often
  - ☐ Sometimes
  - ☐ Rare
  - ☐ Never

  Please give a reason: ____________________

- Moving Obstacles e.g. People, pet, trolley

  Frequency:
  - ☐ Always
  - ☐ Often
  - ☐ Sometimes
  - ☐ Rare
  - ☐ Never

  Please give a reason: ____________________

- Other: ____________________

  Frequency:
  - ☐ Always
  - ☐ Often
  - ☐ Sometimes
  - ☐ Rare
  - ☐ Never

  Please give a reason: ____________________

16. What obstacles can they detect by their assistance (e.g. white cane, guide dog, tactile map)? Please select all that apply.

    - ☐ Objects on the floor
    - ☐ Edges and holes
    - ☐ Other, please specify ____________________

17. What obstacles are they not able to detect by their assistance (e.g. white cane, guide dog, tactile map)? Please select all that apply.

    - ☐ Slippery and sloped surfaces
    - ☐ Objects above waist (body and head level obstacles)
    - ☐ Other, please specify ____________________

18. While navigating inside buildings by visually impaired and blind people, how do they perceive any dangers in their way? Please select all that apply.

    - ☐ Using assistance (cane, guide dog, sighted guide, or tactile map)
    - ☐ Using hearing sense
    - ☐ Using odor sense
    - ☐ Other, please specify ____________________

19. Have they ever found that using stairs, escalators, or elevators is difficult and dangerous? For example, the handrail is difficult to find or installed at a level too high or too low. Another example is that the stair width is too wide and non-standard.

    a. Yes, please give example ____________________
    b. No
    c. Not sure

Section 5 Accessibility and Essential Information

20. While navigating inside buildings, is any accessibility information available to visually impaired and blind people? For example, tactile maps, tactile pavements, Braille, audio or haptic feedback?

    a. Yes
    b. No

    If Yes, Please give example

21. Do you know that there is a tactile map available in some buildings for visually impaired and blind people which provides you with information about the buildings and spaces such as rooms, corridors, and landmark that help them to walk independently?

    a. Yes
    b. No

22. Have they ever used a tactile map to help you find directions to your destination?

    a. Yes IF YES, GO TO QUESTION 23
    b. No IF NO, GO TO QUESTION 25

23. Did the tactile map take them to their destination?

    a. Always
    b. Sometimes, why ____________________
    c. Never, why ____________________

24. What is the most important information they look for while using a tactile map in order to reach their destination?

25. Different kinds of information may be helpful to visually impaired and blind people to help them navigate independently inside buildings with safety awareness. How would you rate the importance of the following information in terms of safety awareness for visually impaired and blind people while they are navigating inside?

Information	**Very Important**	**Important**	**Somewhat Important**	**Not Very Important**	**Not at all Important**	**No Opinion**
Building profile (e.g. opening hours)	☐	☐	☐	☐	☐	☐
Floor Plan (e.g. rooms and layout)	☐	☐	☐	☐	☐	☐
Floor Number	☐	☐	☐	☐	☐	☐
Room Number	☐	☐	☐	☐	☐	☐
Toilet and Bathroom	☐	☐	☐	☐	☐	☐
Entrance and Exit	☐	☐	☐	☐	☐	☐
Door	☐	☐	☐	☐	☐	☐
Emergency Exit	☐	☐	☐	☐	☐	☐
Lighting	☐	☐	☐	☐	☐	☐
Wi-Fi Coverage	☐	☐	☐	☐	☐	☐
Walkable Path	☐	☐	☐	☐	☐	☐
Tactile Pavement	☐	☐	☐	☐	☐	☐
Stairs	☐	☐	☐	☐	☐	☐
Steps, Drop-off, and Curb	☐	☐	☐	☐	☐	☐
Elevator	☐	☐	☐	☐	☐	☐
Escalator	☐	☐	☐	☐	☐	☐
Event and Exhibition	☐	☐	☐	☐	☐	☐
Furniture	☐	☐	☐	☐	☐	☐
Dangerous Areas	☐	☐	☐	☐	☐	☐
People are walking	☐	☐	☐	☐	☐	☐
Weather	☐	☐	☐	☐	☐	☐
Reception	☐	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐	☐

26. How important is it to visually impaired and blind people to know where landmarks are located while navigating inside buildings by themselves?

    a. Very important
    b. Important
    c. Somewhat important
    d. Not at all important
    e. No Opinion

27. While navigating inside buildings by visually impaired and blind people, which of the following are important to them in order to learn and remember layouts and environments inside the buildings? Please select all that apply.

    - [ ] Landmarks (e.g. escalators, elevators, pillars, office plants, and statues)
    - [ ] Sound and noise
    - [ ] Floor texture
    - [ ] Smell
    - [ ] Other, please give example ______________________________

C.2 Thai version

เอกสารข้อมูลสำหรับผู้เข้าร่วมงานวิจัย (Participant Information Sheet)

โครงการวิจัย: การศึกษาพฤติกรรมของผู้บกพร่องทางสายตาและคนตาบอดเดินทางภายอาคารสถาน (A study of indoor navigation behavior by visually impaired and blind people)

ชื่อนักวิจัย: วัฒนศักดิ์ เจียมวัฒนชัย

Ethics number: ERGO/FEPS/23512

โปรดอ่านข้อมูลนี้อย่างถี่ถ้วนก่อนตัดสินใจเข้าร่วมในการวิจัยนี้ หากคุณยินดีที่จะเข้าร่วมกรุณาลงนามในแบบฟอร์มแสดงความยินยอมเข้าร่วมงานวิจัย

รายละเอียดของโครงการวิจัย

งานวิจัยนี้เสนอวิธีการจัดเก็บข้อมูลของอาคารเพื่อนำไปใช้ในการสร้างแผนที่สำหรับระบบนำทางภายในอาคารและเทคโน-โลยีอื่น ที่เกี่ยวข้องเพื่อช่วยให้ผู้ที่มีความบกพร่องทางสายตาและคนตาบอดนั้นสามารถมีอิสระภาพในการเดินทางภายในอาคารโดยไม่ได้รับบาดเจ็บ

เหตุผลที่ผู้เข้าร่วมวิจัยได้รับเชิญ

ขณะนี้การดำเนินงานวิจัยอยู่ในขั้นการประเมินพฤติกรรมการเดินภายในอาคารของผู้มีความ บกพร่องทางสายตาและคนพิการ เพื่อให้ได้ข้อมูลที่ได้มีความชัดเจนและประโยชน์สูงสุด ดังนั้นข้อมูลที่ได้จากผู้ที่มีความบกพร่องทางสายตาและคนพิการนั้นถือว่ามีความสำคัญอย่างมากและรวมถึงข้อมูลจากเจ้าหน้าที่ที่ดูแลคนเหล่านี้ซึ่งจะให้อีกมุมมองหนึ่ง ซึ้งข้อมูลทั้งหมดที่กล่าวมานั้นมีความสำคัญและเป็นประโยชน์ต่องานวิจัยนี้เป็นอย่างมาก

สิ่งที่ผู้เข้าร่วมวิจัยต้องปฏิบัติ

๑. อ่านเอกสารชี้แจงผู้เข้าร่วมโครงการวิจัยนี้โดยละเอียดและทำเครื่องหมายถูก (✓) ในเอกสารยินยอมเข้าร่วมวิจัยไว้เป็นหลักฐาน

๒. ในกรณีผู้เข้าร่วมเป็นผู้มีความรู้พร่องทางสายตาและคนตาบอด ผู้เข้าร่วมจะให้สัมภาษณ์เกี่ยวกับพฤติกรรมการเดินภายในอาคารสถาน ปัญหาที่ประสบในขณะที่เดินอยู่ภายในอาคาร และข้อมูลสำคัญที่มีความจำเป็นและเป็นประโยชน์เพื่อช่วยห้ามารถเดินภายในอาคารได้อย่างอิสระและปลอดภัย ซึ่งในการสัมภาษณ์นี้จะใช้ระยะเวลา 30-40 นาที

๓. ในกรณีผู้เข้าร่วมไม่ใช่ผู้มีความพร่องทางสายตาหรือคนตาบอด ผู้เข้าร่วมจะต้องกรอกแบบสอบถามเกี่ยวกับพฤติ-กรรมการเดินภายในอาคารสถานของ ผู้ที่มีความปกพร่องทางสายตาและคนตาบอด ซึ่งจะใช้ระยะเวลา20-25 นาที

วิธีตอบรับการเข้าร่วมวิจัยด้วยความสมัครใจ

การทำเครื่องหมายถูก (✓) ในเอกสารยินยอมเข้าร่วมวิจัยแสดงถึงการตอบรับการเข้าร่วมวิจัยด้วยความสมัครใจ ในกรณีผู้เข้าร่วมเป็นผู้มีความรู้พร่องทางสายตาและคนตาบอด การยินยอมและตอบรับการเข้าร่วมนั้นจะถูกบันทึกด้วยเสียงและทำเครื่องหมายถูกโดยผู้ทำการสัมภาษณ์ ทั้งนี้ผู้เข้าร่วมวิจัยมีสิทธิในการปฏิเสธการเข้าร่วมวิจัยโดยไม่ส่งผลกระทบใดๆ กับวิถีชีวิตและมีสิทธิ์ถอนตัวออกจากโครงการวิจัยได้ทุกเวลาโดยไม่ต้องแจ้งให้ผู้วิจัยทราบล่วงหน้า

ประโยชน์ที่จะได้รับสำหรับผู้เข้าร่วมวิจัยและส่วนรวม

ผลของการศึกษาวิจัยนี้จะสะท้อนให้เห็นถึงพฤติกรรมการเดินภายในอาคารสถานที่ ของผู้มีความบกพร่องทางสายตาและคนตาบอด การเดินภายในอาคารสถานที่ ปัญหาที่พบเจอและรวมถึงข้อมูลที่มีความสำคัญและเป็นประโยชน์ต่อผู้คนเหล่านี้ ซึ่งข้อมูลเหล่านี้สามารถนำไปใช้ในการพัฒนาต่อยอดให้บริการด้านต่างๆ ที่มีประโยชน์ต่อผู้ที่มีความบกพร่องทางสายตาและคนตาบอด

ความเสี่ยงที่อาจจะเกิดขึ้นเมื่อเข้าร่วมวิจัย

การกรอกแบบสอบถามและการสัมภาษณ์ความคิดเห็นไม่ก่อให้เกิดความเสี่ยงอันตรายใดๆแก่ผู้เข้าร่วมวิจัย

การจัดเก็บและประมวลผลข้อมูล

คำตอบของผู้เข้าร่วมวิจัยจะถือเป็นความลับและไม่มีการเก็บข้อมูลชื่อของผู้เข้าร่วมวิจัยโดยข้อมูลส่วนตัวของผู้เข้าร่วม วิจัยจะถูกเก็บรักษาไว้ไม่เปิดเผยต่อสาธารณะเป็นรายบุคคลแต่จะรายงานผลการวิจัยในข้อมูลส่วนรวมและข้อมูลทั้งหมดจะถูกบันทึกในเครื่องคอมพิวเตอร์ที่มีระบบรักษาความปลอดภัยอย่างดี

กรณีมีปัญหาหรือข้อสงสัย

หากผู้เข้าร่วมวิจัยมีปัญหาหรือข้อสงสัยเกี่ยวกับงานวิจัยสามารถติดต่อผู้วิจัย นายวัฒนศักดิ์ เจียมวัฒนชัย ทางอีเมล์ wj1g14@ecs.soton.ac.uk

แบบสอบถาม

โครงการวิจัย: การศึกษาพฤติกรรมของผู้บกพร่องทางสายตาและคนตาบอดเดินทางภายอาคารสถาน (A study of indoor navigation behavior by visually impaired and blind people)

ชื่อนักวิจัย: วัฒนศักดิ์ เจียมวัฒนชัย
Ethics number: ERGO/FEPS/23512

ขอเชิญชวนเข้าร่วมงานวิจัย

งานวิจัยนี้เกี่ยวกับการศึกษาวิจัยพฤติกรรมของผู้มีความบกพร่องทางสายตาและคนตาบอดขณะเดินภายในอาคารด้วยตัวเอง แบบสอบถามฉบับนี้ถูกสร้างขึ้นการเก็บข้อมูลทางด้านพฤติกรรมของผู้มีความบกพร่องทางสายตาและคนตาบอดขณะเดินภายในอาคารด้วยตัวเอง การเก็บข้อมูลครั้งนี้จะประกอบไปด้วยกลุ่มตัวอย่างทั้งสิ้น สองกลุ่ม กลุ่มที่ 1 ผู้พิการทางสายตาและคนตาบอด และ กลุ่มที่ 2 เจ้าหน้าที่ที่ดูแลผู้พิการทางสายตาและคนตาบอดหรือกลุ่มคนที่ทำงานใกล้ชิดกับผู้พิการทางสายตาและคนตาบอด ในการตอบแบบสอบถามฉบับนี้จะใช้ระยะเวลา 15-20 นาที

ความคิดเห็นของคุณจะถูกเก็บเป็นความลับไม่มีการเปิดเผยชื่อผู้เข้าร่วมและเพื่อให้เป็นไปตามมาตรฐานการปกป้องข้อมูล

- แบบสอบถามจะถูกแสกนเก็บในรูปแบบเอกสารอิเล็กทรอนิกส์ (PDF) และไม่มีการทำสำเนา
- แบบสอบถามจะถูกจัดเก็บในตู้เอกสารที่ใช้กุญแจในการเข้าถึง ณ มหาวิทยาลัยเซาท์แฮมป์ตัน
- เอกสารอิเล็กทรอนิกส์จะถูกจัดเก็บในเครื่องคอมพิวเตอร์ที่มีการใช้รหัสผ่านในการเข้าถึงข้อมูล ณ มหาวิทยาลัยเซาท์แฮมป์ตัน
- แบบสอบถามและเอกสารอิเล็กทรอนิกส์จะถูกทำลายภายใน 1 ปีหลังงานวิจัยนี้สำเร็จเสร็จสิ้น

หากผู้เข้าร่วมวิจัยมีปัญหาหรือข้อสงสัยเกี่ยวกับงานวิจัยสามารถติดต่อผู้วิจัย นายวัฒนศักดิ์ เจียมวัฒนชัย ทางอีเมล์ wj1g14@ecs.soton.ac.uk

ขอบพระคุณที่เข้าร่วมงานวิจัย,

วัฒนศักดิ์ เจียมวัฒนชัย	นักวิจัย	wj1g14@ecs.soton.ac.uk
Prof Gary Wills	ที่ปรึกษา	gbw@ecs.soton.ac.uk
Prof Mike Wald	ที่ปรึกษา	mw@ecs.soton.ac.uk

คำแนะนำ:

แบบสอบถามฉบับนี้จะใช้ระยะเวลา 1.30-2 ชั่วโมง

ชุดคำถามในแบบสอบถามฉบับนี้สามารถตอบได้ 3 วิธี ดังต่อไปนี้:

- ติ๊กเครื่องหมายถูก (✓) ลงในช่องสี่เหลี่ยม ตัวอย่าง ☑
- วงกลมตัวเลือกที่ตรงตามที่ต้องการ ตัวอย่าง (a.) important
- เขียนคำอธิบายลงในช่องว่าที่เตรียมไว้ให้ ตัวอย่าง [2 years]

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อช่วยคนพิการทางสายตาและคนตาบอดให้มีอิสระและความมั่นใจในการเดินในพื้นที่ที่ไม่คุ้นเคยภายในตัวอาคารและสถานที่ต่างๆ

นิยาม: พื้นที่ที่ไม่คุ้น: พื้นที่ภายในอาคารและสถานที่ต่างๆที่คนพิการทางสายตาและคนตาบอดไม่มีความคุ้นเคย/ไม่สมารถคาดเดาสภาพแวดล้อมภายในได้

นิยามที่ไม่มีการกล่าวถึงในงานวิจัย: ช่องว่างที่คุ้นเคย (ไม่ว่าช่องว่างที่คุ้นเคยเหล่านี้จะอยู่ด้านในหรือด้านนอก) พื้นที่กลางแจ้ง (ไม่ว่าพื้นที่กลางแจ้งเหล่านี้จะคุ้นเคยหรือไม่คุ้นเคยก็ตาม)

ส่วนที่ ๑ ข้อมูลทั่วไป

๑. คุณทำงานทางด้านนี้มาเป็นระยะเวลากี่ปี?

____________________ ปี (โดยประมาณ)

ส่วนที่ ๒ พฤติกรรมและการเดินภายในอาคาร

๒. การฝึกอบรมทักษะการทำความคุ้นเคยกับสภาพแวดล้อมและการเคลื่อนไหว (Orientation & Mobility , O&M) มีความสำคัญต่อผู้มีความบกพร่องทางสายตาและคนตาบอดหรือไม่?

ก. สำคัญ

ข. สำคัญแต่ไม่จำเป็น

ค. ไม่สำคัญ

๓. ผู้มีความบกพร่องทางสายตาและคนตาบอดตัวช่วยเหล่านี้สำหรับทำกิจวัตรประจำวันสม่ำเสมอเท่าใด?

- ไม้เท้าขาว (White Cane)

  ความถี่:
  - ☐ ทุกวัน
  - ☐ หลายครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/เดือน
  - ☐ บางโอกาส
  - ☐ ไม่เคย , โปรดระบุเหตุผล: ____________________

- สุนัขนำทาง (Guide Dog)

  ความถี่:
  - ☐ ทุกวัน
  - ☐ หลายครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/เดือน
  - ☐ บางโอกาส
  - ☐ ไม่เคย , โปรดระบุเหตุผล: ____________________

- คนนำทาง (Sighted Guide)

  ความถี่:
  - ☐ ทุกวัน
  - ☐ หลายครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/สัปดาห์
  - ☐ 1 ครั้ง/เดือน
  - ☐ บางโอกาส

- [ ] ไม่เคย , โปรดระบุเหตุผล: ______________________________

- แผนที่คนตาบอด (Tactile Map)

ความถี่:
- [ ] ทุกวัน
- [ ] หลายครั้ง/สัปดาห์
- [ ] 1 ครั้ง/สัปดาห์
- [ ] 1 ครั้ง/เดือน
- [ ] บางโอกาส
- [ ] ไม่เคย , โปรดระบุเหตุผล: ______________________________

- อื่นๆ: ______________________________

ความถี่:
- [ ] ทุกวัน
- [ ] หลายครั้ง/สัปดาห์
- [ ] 1 ครั้ง/สัปดาห์
- [ ] 1 ครั้ง/เดือน
- [ ] บางโอกาส
- [ ] ไม่เคย , โปรดระบุเหตุผล: ______________________________

๔. ในกรณีที่ผู้มีความบกพร่องทางสายตาและคนตาบอดเดินภายในอาคารด้วยตนเอง เขาใช้วิธีใดในการคำนวนระยะทาง?

ก. โดยใช้การนับจำนวนการก้าวเท้า (foot steps)

ข. ด้วยระยะทาง เช่น ฟุต (feet) หรือ เมตร (meter)

ค. โดยการจับเวลา เช่น 5 วินาที

ง. อื่นๆ โปรดระบุ ______________________________

ส่วนที่ ๓ สถานที่ไม่คุ้นเคย

นิยาม: สถานที่ที่ไม่คุ้นเคย คือ สถานที่ที่คุณไม่ได้ไปเป็นประจำ (Rarely visit) หรืออาคารสถานที่ที่คุณยังไม่เคยรู้จำ ในกรณีการที่ต้องเดินทางด้วยตัวเอง เช่นการเดินทางไปมหาวิทยาลัย โรงพยาบาล พิพิธภัณฑ์ ห้างสรรพสินค้า และสนามบิน

๕. บ่อยครั้งไหมที่ผู้มีความบกพร่องทางสายตาและคนตาบอดต้องเดินด้วยตนเองภายในอาคารสถานที่ที่ไม่คุ้นเคย เช่น มหาวิทยาลัย โรงพยาบาล พิพิธภัณฑ์ ห้างสรรพสินค้า และสนามบิน?

- มหาวิทยาลัย

  ความถี่: ☐ ทุกวัน
  ☐ หลายครั้ง/สัปดาห์
  ☐ 1 ครั้ง/สัปดาห์
  ☐ 1 ครั้ง/เดือน
  ☐ บางโอกาส
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- โรงพยาบาล

  ความถี่: ☐ ทุกวัน
  ☐ หลายครั้ง/สัปดาห์
  ☐ 1 ครั้ง/สัปดาห์
  ☐ 1 ครั้ง/เดือน
  ☐ บางโอกาส
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- ห้างสรรพสินค้า

  ความถี่: ☐ ทุกวัน
  ☐ หลายครั้ง/สัปดาห์
  ☐ 1 ครั้ง/สัปดาห์
  ☐ 1 ครั้ง/เดือน
  ☐ บางโอกาส

☐ ไม่เคย

โปรดระบุเหตุผล: ____________________

- พิพิธภัณฑ์

ความถี่: ☐ ทุกวัน
☐ หลายครั้ง/สัปดาห์
☐ 1 ครั้ง/สัปดาห์
☐ 1 ครั้ง/เดือน
☐ บางโอกาส
☐ ไม่เคย

โปรดระบุเหตุผล: ____________________

- สนามบิน

ความถี่: ☐ ทุกวัน
☐ หลายครั้ง/สัปดาห์
☐ 1 ครั้ง/สัปดาห์
☐ 1 ครั้ง/เดือน
☐ บางโอกาส
☐ ไม่เคย

โปรดระบุเหตุผล: ____________________

- อื่นๆ: ____________________

ความถี่: ☐ ทุกวัน
☐ หลายครั้ง/สัปดาห์
☐ 1 ครั้ง/สัปดาห์
☐ 1 ครั้ง/เดือน
☐ บางโอกาส
☐ ไม่เคย

โปรดระบุเหตุผล: ____________________

๖. ในมุมมองของคุณ คุณคิดว่าระดับความยากง่ายในการเดินทางภายในอาคาร สถานที่ที่ไม่คุ้นเคยต่อไปนี้อย่างไร

- มหาวิทยาลัย

  ระดับความยาก: ☐ ง่าย
  ☐ ปานกลาง
  ☐ ยาก

  โปรดระบุเหตุผล: ____________________

- โรงพยาบาล

  ระดับความยาก: ☐ ง่าย
  ☐ ปานกลาง
  ☐ ยาก

  โปรดระบุเหตุผล: ____________________

- ห้างสรรพสินค้า

  ระดับความยาก: ☐ ง่าย
  ☐ ปานกลาง
  ☐ ยาก

  โปรดระบุเหตุผล: ____________________

- พิพิธภัณฑ์

  ระดับความยาก: ☐ ง่าย
  ☐ ปานกลาง
  ☐ ยาก

  โปรดระบุเหตุผล: ____________________

- สนามบิน

  ระดับความยาก: ☐ ง่าย
  ☐ ปานกลาง
  ☐ ยาก

  โปรดระบุเหตุผล: ____________________

- อื่นๆ: ______________________

ระดับความยาก: ☐ ง่าย
☐ ปานกลาง
☐ ยาก

โปรดระบุเหตุผล: ______________________

๗. ในมุมมองของคุณ คุณคิดว่าผู้มีความบกพร่องทางสายตาและคนตาบอดมีความมั่นใจในการเดินด้วยตนเอง ในสถานที่ที่ไม่คุ้นเคยต่อไปนี้หรือไม่?

- พื้นที่เปิด โล่งกว้างไม่มีจุดสังเกต (landmarks)

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

- ห้องโถ่ง (Hallway)

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

- ห้องที่มีขนาดเล็ก เช่น ออฟฟิต

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

- ห้องที่มีขนาดใหญ่ (เช่นหอประชุม, ห้องประชุม, โรงภาพยนตร์และพื้นที่แสดงนิทรรศการ)

ระดับความยาก: ☐ มั่นใจ
☐ ไม่มั่นใจ
☐ ไม่แน่ใจ

โปรดระบุเหตุผล: ______________________

๘. ผู้มีความบกพร่องทางสายตาและคนตาบอดจะทำอย่างไรเพื่อให้รู้ได้ว่าเขาอยู่ตรงไหนของอาคาร ในกรณีที่เขาอยู่ในอาคาร สถานที่ที่ไม่คุ้นเคย?

๙. ในอาคารสถานที่ที่ไม่คุ้นเคย ผู้มีความบกพร่องทางสายตาและคนตาบอดจะทำอย่างไรเพื่อให้สามารถเดินไปยังปลายทางที่เขาต้องการ?

๑๐. ในขณะเดินด้วยตนเองในสถานที่ที่ไม่คุ้นเคย ผู้มีความบกพร่องทางสายตาและคนตาบอดมีวิธีในการค้นหาทิศ (direction or orientation) ตรงหน้าของเขาได้อย่างไร.

๑๑. ในขณะเดินด้วยตนเองในสถานที่ที่คุณไม่คุ้นเคย ผู้มีความบกพร่องทางสายตาและคนตาบอดใช้จุดสังเกต (landmark) อะไรเพื่อช่วยให้เขาสามารถเดินภายในอาคารได้ด้วยตนเอง?

๑๒. ผู้มีความบกพร่องทางสายตาและคนตาบอดเคยสอบถามคนในพื้นที่ (เช่น เจ้าหน้าที่ แผนกต้อนรับ) หรือไม่เพื่อหาทิศทางหรือวิธีการเพื่อให้สามารถเดินไปยังปลายทางที่คุณต้องการได้หรือไม่?

ก. เคย

ข. ไม่เคย

๑๓. ผู้มีความบกพร่องทางสายตาและคนตาบอดเคยได้รับข้อมูลที่สับสน (confusing) หรือ ไม่ชัดเจน (ambiguous) ในการสอบถามข้อมูลจากคนในพื้นที่หรือไม่

ก. เคย, กรุณายกตัวอย่าง ____________________

ข. ไม่เคย

ส่วนที่ ๔ สิ่งกีดขวางและพื้นที่อันตราย

๑๔. ผู้มีความบกพร่องทางสายตาและคนตาบอดเคยประสบปัญหาใดๆ ในขณะที่เดินภายในอาคารด้วยตนเองหรือไม่ เช่น สิ่งกีดขวางระดับพื้น สิ่งกีดขวางระดับร่างกาย สิ่งกีดขวางระดับหัว พื้นที่ที่มีเสียงดังเกินไปหรือเงียบเกิน หรือพื้นที่ที่มีแสงสว่างมากเกินไป?

ก. เคย, กรุณายกตัวอย่าง ____________________

ข. ไม่เคย

๑๕. ในขณะที่เดินภายในอาคารด้วยตนเอง ผู้มีความบกพร่องทางสายตาและคนตาบอดเคยประสบปัญหาเดินชนหรือถูกชนโดยสิ่งกีดขวางต่อไปนี้หรือไม่?

- สิ่งกีดขวางระดับพื้น เช่น ขอบพื้น หลุม พื้นเอียง ทางราดชัน

  ความถี่: ☐ ทุกครั้ง
  ☐ บ่อยครั้ง
  ☐ บางครั้ง
  ☐ น้อยครั้ง
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- สิ่งกีดขวางระดับร่างกาย เช่น เฟอร์นิเจอร์ อุปกรณ์ติดตามผนัง

  ความถี่: ☐ ทุกครั้ง
  ☐ บ่อยครั้ง
  ☐ บางครั้ง
  ☐ น้อยครั้ง
  ☐ ไม่เคย

  โปรดระบุเหตุผล: ____________________

- สิ่งกีดขวางระดับหัว เช่น บันได ป้ายแขวน

  ความถี่: ☐ ทุกครั้ง
  ☐ บ่อยครั้ง
  ☐ บางครั้ง
  ☐ น้อยครั้ง

☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- พื้นที่ที่มีเสียงรบกวน

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- พื้นที่เงียบเกินไป

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- พื้นที่ที่มีแสงสว่างมากเกินไป

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________________

- สิ่งกีดขวางที่เดินได้ เช่น คน สัตว์ รถเข็น

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง

☐ ไม่เคย

โปรดระบุเหตุผล: ______________________

- อื่นๆ โปรดระบุ: ______________________

ความถี่: ☐ ทุกครั้ง
☐ บ่อยครั้ง
☐ บางครั้ง
☐ น้อยครั้ง
☐ ไม่เคย

โปรดระบุเหตุผล: ______________________

๑๖. สิ่งกีดขวางอะไรบ้างที่ผู้มีความบกพร่องทางสายตาและคนตาบอดสามารถตรวจหาได้โดยใช้ตัวช่วยทั่วไป เช่น ไม้เท้าขาว (White cane) สุนัขนำทาง (Guide dog) แผนที่คนตาบอด (tactile map)?

☐ สิ่งของที่วางบนพื้น
☐ ขอบพื้นและหลุม
☐ อื่นๆ โปรดระบุ ______________________

๑๗. สิ่งกีดขวางอะไรบ้างที่ผู้มีความบกพร่องทางสายตาและคนตาบอด<u>ไม่สามารถตรวจหา</u>ได้โดยใช้ตัวช่วยทั่วไป เช่น ไม้เท้าขาว (White cane) สุนัขนำทาง (Guide dog) แผนที่คนตาบอด (tactile map)?

☐ พื้นเอียงและลื่น
☐ สิ่งของในดับเอวขึ้นไป เช่น สิ่งกีดขวางระดับร่างกาย และ สิ่งกีดขวางระดับหัว
☐ อื่นๆ โปรดระบุ ______________________

๑๘. ในขณะที่เดินภายในอาคารด้วยตนเอง ผู้มีความบกพร่องทางสายตาและคนตาบอดมีวิธีหรือตัวช่วยให้ในการรับรู้ได้อย่างไรว่ามีสิ่งอันตรายกีดขวางทางเดินของคุณ

☐ ใช้ตัวช่วยทั่วไป เช่น ไม้เท้าขาว (White cane) สุนัขนำทาง (Guide dog) แผนที่คนตาบอด (tactile map)
☐ ใช้การได้ยิน (hearing sense)
☐ ใช้การดมกลิ่น (odor sense)
☐ อื่นๆ โปรดระบุ ______________________

๑๙. ผู้มีความบกพร่องทางสายตาและคนตาบอดเคยประสบปัญหากับการใช้งานบันได บันไดเลื่อนหรือลิฟต์นั้นมีความยากการอันตรายในการใช้งาน เช่น ราวสำหรับมือจับของขั้นบันไดถูกติดตั้งไว้สูงหรือต่ำเกินไป หรือความกว้างของบันไดไม่ได้มาตรฐาน เช่น กว้างเกินไป

ก. เคย, กรุณายกตัวอย่าง ____________________

ข. ไม่เคย

ค. ไม่แน่ใจ

ส่วนที่ ๕ การเข้าถึงข้อมูล (Accessibility)

๒๐. ในขณะที่เดินภายในอาคารด้วยตนเอง มีข้อมูลอะไรบ้างที่ผู้มีความบกพร่องทางสายตาและคนตาบอดสามารถนำมาใช้เพื่อให้สามารถเดินภายในอาคารได้ด้วยตัวเอง เช่น แผนที่สำหรับคนตาบอด (tactile map), ทางเท้าสำหรับคนตาบอด (tactile pavement), อักษรเบรลล์ (Braille) เสียงและการสัมผัส (audio and haptic feedback)?

ก. มี

ข. ไม่มี

ถ้ามี, โปรดยกตัวอย่าง

๒๑. คุณคิดว่าผู้มีความบกพร่องทางสายตาและคนตาบอดรู้หรือไม่ว่าในบางอาคารแผนที่สำหรับคนตาบอด (tactile map) ได้ถูกติดตั้งไว้เพื่อบอกรายละเอียดของอาคาร เช่น ห้อง (room) ระเบียง (corridor) จุดสังเกต (landmark) ที่จะช่วยให้เขาสามารถเดินได้ด้วยตนเอง?

ก. รู้

ข. ไม่รู้

๒๒. ผู้มีความบกพร่องทางสายตาและคนตาบอดเคยใช้แผนที่สำหรับคนตาบอดหรือไม่ เพื่อช่วยให้คุณเดินไปยังปลายทางที่ต้องการได้?

ก. เคย ถ้า เคย ไปข้อที่ 25

ข. ไม่เคย ถ้า ไม่เคย ข้ามไปข้อที่ 27

๒๓. แผนที่คนตาบอดนั้นได้พาผู้มีความบกพร่องทางสายตาและคนตาบอดไปถึงเป้าหมายปลายทางหรือไม่?

ก. ทุกครั้ง

ข. บางครั้ง, เพราะ ____________________

ค. ไม่เคย, เพราะ ____________________

๒๔. ในขณะที่ใช้งานแผนที่คนตาบอด (tactile map) คุณคิดว่าอะไรคือข้อมูลที่สำคัญที่ช่วยให้ผู้มีความบกพร่องทางสายตาและคนตาบอดสามารถเดินไปยังปลายทางที่ต้องการได้?

๒๕. เพื่อทำให้ผู้มีความบกพร่องทางสายตาและคนตาบอดสามารถเดินภายในอาคารได้ด้วยตนเองและตระหนักถึงความปลอดภัย คุณคิดว่าข้อมูลต่อไปนี้มีความสำคัญมากน้อยเท่าไหร่ในขณะที่ผู้มีความบกพร่องทางสายตาและคนตาบอดเดินอยู่ภายในอาคาร?

ประเภทของข้อมูล	**สำคัญมาก**	**สำคัญ**	**บางส่วน สำคัญ**	**ไม่ค่อยสำคัญ**	**ไม่สำคัญ**	**ไม่มีความคิดเห็น**
ข้อมูลอาคาร เช่น เวลาเปิด-ปิด	☐	☐	☐	☐	☐	☐
แผนผังอาคาร (e.g. rooms and layout)	☐	☐	☐	☐	☐	☐
เลขชั้น	☐	☐	☐	☐	☐	☐
เลขห้อง	☐	☐	☐	☐	☐	☐
ห้องน้ำ	☐	☐	☐	☐	☐	☐
ทางเข้าและทางออก	☐	☐	☐	☐	☐	☐
ประตู	☐	☐	☐	☐	☐	☐
ทางออกฉุกเฉิน	☐	☐	☐	☐	☐	☐
แสงสว่าง	☐	☐	☐	☐	☐	☐
พื้นที่ของ Wi-FI	☐	☐	☐	☐	☐	☐
ทางเดิน	☐	☐	☐	☐	☐	☐
ทางเท้าสำหรับคนตาบอด	☐	☐	☐	☐	☐	☐
บันได	☐	☐	☐	☐	☐	☐
ทางขึ้น ทางลาดชัน และขอบพื้น	☐	☐	☐	☐	☐	☐
ลิฟต์	☐	☐	☐	☐	☐	☐
บันไดเลื่อน	☐	☐	☐	☐	☐	☐
พื้นกิจกรรมและการแสดงนิทรรศการ	☐	☐	☐	☐	☐	☐
เฟอร์นิเจอร์	☐	☐	☐	☐	☐	☐
พื้นที่อันตราย	☐	☐	☐	☐	☐	☐
ผู้คนกำลังเดิน	☐	☐	☐	☐	☐	☐
สภาพอากาศ	☐	☐	☐	☐	☐	☐
แผนกต้อนรับ	☐	☐	☐	☐	☐	☐
เสียงรบกวน	☐	☐	☐	☐	☐	☐

๒๖. ในขณะที่เดินอยู่ภายในอาคารด้วยตัวเอง คุณคิดว่ามีความสำคัญมากหรือน้อยสำหรับผู้มีความบกพร่องทางสายตาและคนตาบอดอย่างไรถ้าเขาสามารถระบุตำแหน่งของจุดสังเกต (landmark) ภายในอาคาร?

ก. สำคัญมาก

ข. สำคัญ

ค. บางส่วนสำคัญ

ง. ไม่สำคัญ

จ. ไม่มีความคิดเห็น

๒๗. ในขณะที่เดินอยู่ภายในอาคารด้วยตนเอง คุณคิดสิ่งใดบ้างต่อไปนี้มีความสำคัญกับผู้มีความบกพร่องทางสายตาและคนตาบอดเพื่อการเรียนรู้และจดจำพื้นที่ เพื่อที่เขาสามารถเดินภายในอาคารได้ด้วยตนเอง?

☐ จุดสังเกต (landmark) เช่น บันไดเลื่อน ลิฟต์ เสา ต้นไม้ หรือรูปปั้น

☐ เสียงรบกวน

☐ ลักษณะของพื้น

☐ กลิ่น

☐ อื่นๆ, โปรดระบุ ____________________

Appendix D

Spatial Representation Framework - Statistical tests

This appendix details the results of statistical tests were done in SPSS for providing further information discussed in Chapter 5 as follow:

- Section D.1 tested whether degree of visual impairments or condition of participants affected their responses.
- Section D.2 - D.8 performed chi-square tests of independence for the indoor navigation survey.
  - Section D.2: Survey of Assistance Usage
  - Section D.3: Survey of Distance Estimation
  - Section D.4: Survey of Wayfinding
  - Section D.5: Survey of Asking of Assistance
  - Section D.6: Survey of Difficulty in Spaces
  - Section D.7: Survey of Confidence in Spaces
  - Section D.8: Survey of Hazards in Spaces
- Section D.9 performed repeated-measures one-way ANOVA for the SRF framework validation with suitably adjusted p-values by Sidak correction.
- Section D.10 tested whether there were statistically significant differences between groups of visually impaired participants and sighted participants.
- Section D.11 showed results of the reliability test SRF framework validation.

D.1 MANOVA: Difference in perspectives affected participants' responses

D.1.1 Congenital blindness vs. Adventitious blindness

TABLE D.1: CB vs. AB: Between-Subjects Factors

		Value Label	N
Groups	1	Congenitally	10
	2	Adventitiously	20

TABLE D.2: CB vs. AB: Descriptive Statistics

	Condition	Mean	Std. Deviation	N
Building Profile	Congenitally	3.30	1.49	10
	Adventitiously	3.90	0.97	20
	Total	3.70	1.18	30
Floor Layout	Congenitally	3.90	1.20	10
	Adventitiously	3.55	1.23	20
	Total	3.67	1.21	30
Floor Number	Congenitally	4.40	0.52	10
	Adventitiously	3.95	1.15	20
	Total	4.10	1.00	30
Room Number	Congenitally	4.50	0.53	10
	Adventitiously	4.00	0.97	20
	Total	4.17	0.87	30
Toilet and Bathroom	Congenitally	4.70	0.48	10
	Adventitiously	4.10	0.55	20
	Total	4.30	0.60	30
Entrance and Exit	Congenitally	4.50	0.53	10
	Adventitiously	4.35	0.49	20
	Total	4.40	0.50	30
Door	Congenitally	4.70	0.48	10
	Adventitiously	4.60	0.50	20
	Total	4.63	0.49	30

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	Condition	**Mean**	**Std. Deviation**	**N**
Emergency Exit	Congenitally	4.10	0.74	10
	Adventitiously	4.15	0.75	20
	Total	4.13	0.73	30
Lighting	Congenitally	3.90	0.88	10
	Adventitiously	3.50	1.36	20
	Total	3.63	1.22	30
WiFi Coverage	Congenitally	3.70	1.06	10
	Adventitiously	2.80	1.47	20
	Total	3.10	1.40	30
Walkable Path	Congenitally	4.00	0.82	10
	Adventitiously	4.30	0.57	20
	Total	4.20	0.66	30
Tactile Pavement	Congenitally	4.00	0.94	10
	Adventitiously	3.90	1.25	20
	Total	3.93	1.14	30
Stairs	Congenitally	4.30	0.48	10
	Adventitiously	4.20	0.89	20
	Total	4.23	0.77	30
Steps, Dropoff, Curb	Congenitally	4.10	0.57	10
	Adventitiously	4.25	0.55	20
	Total	4.20	0.55	30
Elevator	Congenitally	4.20	0.42	10
	Adventitiously	4.15	0.59	20
	Total	4.17	0.53	30
Escalator	Congenitally	4.10	0.57	10
	Adventitiously	3.95	0.83	20
	Total	4.00	0.74	30
Event and Exhibition	Congenitally	3.80	0.79	10
	Adventitiously	3.75	0.72	20
	Total	3.77	0.73	30
Furniture	Congenitally	4.40	0.52	10
	Adventitiously	3.95	0.89	20

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	Condition	Mean	Std. Deviation	N
	Total	4.10	0.80	30
Dangerous area	Congenitally	4.50	0.53	10
	Adventitiously	4.05	0.95	20
	Total	4.20	0.85	30
People	Congenitally	4.30	0.48	10
	Adventitiously	3.85	1.04	20
	Total	4.00	0.91	30
Weather	Congenitally	4.00	0.94	10
	Adventitiously	3.50	1.28	20
	Total	3.67	1.18	30
Reception	Congenitally	3.70	1.16	10
	Adventitiously	3.95	0.95	20
	Total	3.87	1.01	30
Noise	Congenitally	2.80	1.69	10
	Adventitiously	3.35	1.31	20
	Total	3.17	1.44	30
White cane	Congenitally	2.50	1.90	10
	Adventitiously	2.55	1.79	20
	Total	2.53	1.80	30
Guide dog	Congenitally	0.60	1.58	10
	Adventitiously	0.15	0.49	20
	Total	0.30	0.99	30
Sighted Guide	Congenitally	3.40	1.78	10
	Adventitiously	3.75	1.71	20
	Total	3.63	1.71	30
Tactile map	Congenitally	0.10	0.32	10
	Adventitiously	0.25	0.72	20
	Total	0.20	0.61	30
Distance estimation	Congenitally	2.50	1.35	10
	Adventitiously	2.50	1.67	20
	Total	2.50	1.55	30
Freq: University	Congenitally	0.90	1.29	10

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	Condition	Mean	Std. Deviation	N
	Adventitiously	0.90	1.17	20
	Total	0.90	1.19	30
Freq: Hospital	Congenitally	1.10	1.10	10
	Adventitiously	1.00	0.80	20
	Total	1.03	0.89	30
Freq: Department Store	Congenitally	1.60	1.51	10
	Adventitiously	1.95	1.15	20
	Total	1.83	1.26	30
Freq: Museum	Congenitally	0.60	0.52	10
	Adventitiously	1.30	1.08	20
	Total	1.07	0.98	30
Freq: Airport	Congenitally	0.50	0.53	10
	Adventitiously	1.05	0.83	20
	Total	0.87	0.78	30
Difficulty: University	Congenitally	2.70	0.68	10
	Adventitiously	2.40	0.68	20
	Total	2.50	0.68	30
Difficulty: Hospital	Congenitally	2.70	0.48	10
	Adventitiously	2.65	0.59	20
	Total	2.67	0.55	30
Difficulty: Department Store	Congenitally	2.70	0.48	10
	Adventitiously	2.40	0.75	20
	Total	2.50	0.68	30
Difficulty: Museum	Congenitally	2.80	0.42	10
	Adventitiously	2.55	0.69	20
	Total	2.63	0.62	30
Difficulty: Airport	Congenitally	2.80	0.42	10
	Adventitiously	2.55	0.69	20
	Total	2.63	0.62	30
Confidence: Wide open	Congenitally	0.00	0.00	10
	Adventitiously	0.50	0.89	20
	Total	0.33	0.76	30

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	Condition	Mean	Std. Deviation	N
Confidence: Hallway	Congenitally	0.40	0.84	10
	Adventitiously	0.70	0.98	20
	Total	0.60	0.93	30
Confidence: Room	Congenitally	0.60	0.97	10
	Adventitiously	1.20	1.01	20
	Total	1.00	1.02	30
Confidence: Large room	Congenitally	0.00	0.00	10
	Adventitiously	0.40	0.82	20
	Total	0.27	0.69	30
Help: Ask for direction	Congenitally	0.90	0.32	10
	Adventitiously	0.85	0.37	20
	Total	0.87	0.35	30
Help: Information confusing	Congenitally	0.60	0.52	10
	Adventitiously	0.55	0.51	20
	Total	0.57	0.50	30
Hazards: Ground Obstacles	Congenitally	2.00	1.33	10
	Adventitiously	2.10	1.07	20
	Total	2.07	1.14	30
Hazards: Body Obstacles	Congenitally	2.10	1.37	10
	Adventitiously	2.30	1.13	20
	Total	2.23	1.19	30
Hazards: Head Obstacles	Congenitally	1.90	1.52	10
	Adventitiously	1.95	1.19	20
	Total	1.93	1.29	30
Hazards: Noise	Congenitally	2.20	1.03	10
	Adventitiously	1.80	1.32	20
	Total	1.93	1.23	30
Hazards: Silence	Congenitally	1.60	1.27	10
	Adventitiously	1.10	1.21	20
	Total	1.27	1.23	30
Hazards: Light	Congenitally	1.60	1.27	10
	Adventitiously	1.45	1.32	20

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	Condition	Mean	Std. Deviation	N
	Total	1.50	1.28	30
Hazards: Moving Obstacles	Congenitally	1.90	1.45	10
	Adventitiously	2.60	1.19	20
	Total	2.37	1.30	30

Table D.3: CB vs. AB: Multivariate Test

Effect		Value	F	Hypothesis df	Error df	*p*
Intercept	Pillai's Trace	1.00	42.84	28.00	1.00	0.120
	Wilks' Lambda	0.00	42.84	28.00	1.00	0.120
	Hotelling's Trace	1199.47	42.84	28.00	1.00	0.120
	Roy's Largest Root	1199.47	42.84	28.00	1.00	0.120
CB vs. AB	Pillai's Trace	0.96	0.93	28.00	1.00	0.692
	Wilks' Lambda	0.04	0.93	28.00	1.00	0.692
	Hotelling's Trace	25.95	0.93	28.00	1.00	0.692
	Roy's Largest Root	25.95	0.93	28.00	1.00	0.692

Table D.4: CB vs. AB: Tests of Between-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	*p*
Corrected Model	Building Profile	2.40[a]	1	2.40	1.77	0.194
	Floor Layout	0.82[b]	1	0.82	0.55	0.466
	Floor Number	1.35[c]	1	1.35	1.38	0.250
	Room Number	1.67[d]	1	1.67	2.28	0.143
	Toilet and Bathroom	2.40[e]	1	2.40	8.51	0.007
	Entrance and Exit	0.15[f]	1	0.15	0.60	0.447
	Door	0.07[g]	1	0.07	0.27	0.607
	Emergency Exit	0.02[h]	1	0.02	0.03	0.863
	Lighting	1.07[i]	1	1.07	0.71	0.406
	WiFi Coverage	5.40[j]	1	5.40	2.95	0.097
	Walkable Path	0.60[k]	1	0.60	1.38	0.250
	Tactile Pavement	0.07[l]	1	0.07	0.05	0.826
	Stairs	0.07[m]	1	0.07	0.11	0.745

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Steps, Dropoff, Curb	0.15^{n}	1	0.15	0.49	0.492
	Elevator	0.02^{o}	1	0.02	0.06	0.813
	Escalator	0.15^{p}	1	0.15	0.26	0.611
	Event and Exhibition	0.02^{q}	1	0.02	0.03	0.863
	Furniture	1.35^{r}	1	1.35	2.18	0.151
	Dangerous area	1.35^{s}	1	1.35	1.94	0.174
	People	1.35^{t}	1	1.35	1.67	0.207
	Weather	1.67^{u}	1	1.67	1.20	0.283
	Reception	0.42^{v}	1	0.42	0.40	0.531
	Noise	2.02^{w}	1	2.02	0.97	0.333
	White cane	0.02^{x}	1	0.02	0.00	0.944
	Guide dog	1.35^{y}	1	1.35	1.40	0.246
	Sighted Guide	0.82^{z}	1	0.82	0.27	0.606
	Tactile map	0.15^{aa}	1	0.15	0.39	0.535
	Distance estimation	0.00^{ab}	1	0.00	0.00	1.000
	Freq: University	0.00^{ab}	1	0.00	0.00	1.000
	Freq: Hospital	0.07^{ac}	1	0.07	0.08	0.777
	Freq: Department Store	0.82^{ad}	1	0.82	0.50	0.484
	Freq: Museum	3.27^{ae}	1	3.27	3.72	0.064
	Freq: Airport	2.02^{af}	1	2.02	3.65	0.066
	Difficulty: University	0.60^{ag}	1	0.60	1.30	0.263
	Difficulty: Hospital	0.02^{ah}	1	0.02	0.05	0.818
	Difficulty: Department Store	0.60^{ai}	1	0.60	1.30	0.263
	Difficulty: Museum	0.42^{aj}	1	0.42	1.11	0.302
	Difficulty: Airport	0.42^{aj}	1	0.42	1.11	0.302
	Confidence: Wide open	1.67^{ak}	1	1.67	3.11	0.089
	Confidence: Hallway	0.60^{al}	1	0.60	0.68	0.416
	Confidence: Room	2.40^{am}	1	2.40	2.43	0.130
	Confidence: Large room	1.07^{an}	1	1.07	2.33	0.138
	Help: Ask for direction	0.02^{ao}	1	0.02	0.14	0.716
	Help: Information confusing	0.02^{ap}	1	0.02	0.06	0.803
	Hazards: Ground Obstacles	0.07^{aq}	1	0.07	0.05	0.826
	Hazards: Body Obstacles	0.27^{ar}	1	0.27	0.18	0.673

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Hazards: Head Obstacles	0.02^{as}	1	0.02	0.01	0.922
	Hazards: Noise	1.07^{at}	1	1.07	0.70	0.411
	Hazards: Silence	1.67^{au}	1	1.67	1.11	0.302
	Hazards: Light	0.15^{av}	1	0.15	0.09	0.768
	Hazards: Moving Obstacles	3.27^{aw}	1	3.27	2.00	0.168
Intercept	Building Profile	345.60	1	345.60	255.32	< 0.001
	Floor Layout	370.02	1	370.02	247.56	< 0.001
	Floor Number	464.82	1	464.82	475.86	< 0.001
	Room Number	481.67	1	481.67	657.89	< 0.001
	Toilet and Bathroom	516.27	1	516.27	1829.81	< 0.001
	Entrance and Exit	522.15	1	522.15	2073.79	< 0.001
	Door	576.60	1	576.60	2339.83	< 0.001
	Emergency Exit	453.75	1	453.75	822.33	< 0.001
	Lighting	365.07	1	365.07	243.96	< 0.001
	WiFi Coverage	281.67	1	281.67	153.74	< 0.001
	Walkable Path	459.27	1	459.27	1054.05	< 0.001
	Tactile Pavement	416.07	1	416.07	308.20	< 0.001
	Stairs	481.67	1	481.67	779.58	< 0.001
	Steps, Dropoff, Curb	464.82	1	464.82	1504.61	< 0.001
	Elevator	464.82	1	464.82	1596.92	< 0.001
	Escalator	432.02	1	432.02	763.18	< 0.001
	Event and Exhibition	380.02	1	380.02	693.19	< 0.001
	Furniture	464.82	1	464.82	750.14	< 0.001
	Dangerous area	487.35	1	487.35	701.58	< 0.001
	People	442.82	1	442.82	547.41	< 0.001
	Weather	375.00	1	375.00	269.23	< 0.001
	Reception	390.15	1	390.15	376.05	< 0.001
	Noise	252.15	1	252.15	121.41	< 0.001
	White cane	170.02	1	170.02	50.94	< 0.001
	Guide dog	3.75	1	3.75	3.90	0.058
	Sighted Guide	340.82	1	340.82	113.40	< 0.001
	Tactile map	0.82	1	0.82	2.15	0.154
	Distance estimation	166.67	1	166.67	67.15	< 0.001

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Freq: University	21.60	1	21.60	14.86	0.001
	Freq: Hospital	29.40	1	29.40	35.95	< 0.001
	Freq: Department Store	84.02	1	84.02	51.87	< 0.001
	Freq: Museum	24.07	1	24.07	27.39	< 0.001
	Freq: Airport	16.02	1	16.02	29.03	< 0.001
	Difficulty: University	173.40	1	173.40	376.37	< 0.001
	Difficulty: Hospital	190.82	1	190.82	617.67	< 0.001
	Difficulty: Department Store	173.40	1	173.40	376.37	< 0.001
	Difficulty: Museum	190.82	1	190.82	506.43	< 0.001
	Difficulty: Airport	190.82	1	190.82	506.43	< 0.001
	Confidence: Wide open	1.67	1	1.67	3.11	0.089
	Confidence: Hallway	8.07	1	8.07	9.18	0.005
	Confidence: Room	21.60	1	21.60	21.91	< 0.001
	Confidence: Large room	1.07	1	1.07	2.33	0.138
	Help: Ask for direction	20.42	1	20.42	165.70	< 0.001
	Help: Information confusing	8.82	1	8.82	33.59	< 0.001
	Hazards: Ground Obstacles	112.07	1	112.07	83.01	< 0.001
	Hazards: Body Obstacles	129.07	1	129.07	87.93	< 0.001
	Hazards: Head Obstacles	98.82	1	98.82	57.82	< 0.001
	Hazards: Noise	106.67	1	106.67	69.78	< 0.001
	Hazards: Silence	48.60	1	48.60	32.25	< 0.001
	Hazards: Light	62.02	1	62.02	36.67	< 0.001
	Hazards: Moving Obstacles	135.00	1	135.00	82.71	< 0.001
Visual Condition	Building Profile	2.40	1	2.40	1.77	0.194
	Floor Layout	0.82	1	0.82	0.55	0.466
	Floor Number	1.35	1	1.35	1.38	0.250
	Room Number	1.67	1	1.67	2.28	0.143
	Toilet and Bathroom	2.40	1	2.40	8.51	0.007
	Entrance and Exit	0.15	1	0.15	0.60	0.447
	Door	0.07	1	0.07	0.27	0.607
	Emergency Exit	0.02	1	0.02	0.03	0.863
	Lighting	1.07	1	1.07	0.71	0.406
	WiFi Coverage	5.40	1	5.40	2.95	0.097
	Walkable Path	0.60	1	0.60	1.38	0.250
	Tactile Pavement	0.07	1	0.07	0.05	0.826
	Stairs	0.07	1	0.07	0.11	0.745
	Steps, Dropoff, Curb	0.15	1	0.15	0.49	0.492

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Elevator	0.02	1	0.02	0.06	0.813
	Escalator	0.15	1	0.15	0.26	0.611
	Event and Exhibition	0.02	1	0.02	0.03	0.863
	Furniture	1.35	1	1.35	2.18	0.151
	Dangerous area	1.35	1	1.35	1.94	0.174
	People	1.35	1	1.35	1.67	0.207
	Weather	1.67	1	1.67	1.20	0.283
	Reception	0.42	1	0.42	0.40	0.531
	Noise	2.02	1	2.02	0.97	0.333
	White cane	0.02	1	0.02	0.00	0.944
	Guide dog	1.35	1	1.35	1.40	0.246
	Sighted Guide	0.82	1	0.82	0.27	0.606
	Tactile map	0.15	1	0.15	0.39	0.535
	Distance estimation	0.00	1	0.00	0.00	1.000
	Freq: University	0.00	1	0.00	0.00	1.000
	Freq: Hospital	0.07	1	0.07	0.08	0.777
	Freq: Department Store	0.82	1	0.82	0.50	0.484
	Freq: Museum	3.27	1	3.27	3.72	0.064
	Freq: Airport	2.02	1	2.02	3.65	0.066
	Difficulty: University	0.60	1	0.60	1.30	0.263
	Difficulty: Hospital	0.02	1	0.02	0.05	0.818
	Difficulty: Department Store	0.60	1	0.60	1.30	0.263
	Difficulty: Museum	0.42	1	0.42	1.11	0.302
	Difficulty: Airport	0.42	1	0.42	1.11	0.302
	Confidence: Wide open	1.67	1	1.67	3.11	0.089
	Confidence: Hallway	0.60	1	0.60	0.68	0.416
	Confidence: Room	2.40	1	2.40	2.43	0.130
	Confidence: Large room	1.07	1	1.07	2.33	0.138
	Help: Ask for direction	0.02	1	0.02	0.14	0.716
	Help: Information confusing	0.02	1	0.02	0.06	0.803
	Hazards: Ground Obstacles	0.07	1	0.07	0.05	0.826
	Hazards: Body Obstacles	0.27	1	0.27	0.18	0.673
	Hazards: Head Obstacles	0.02	1	0.02	0.01	0.922
	Hazards: Noise	1.07	1	1.07	0.70	0.411
	Hazards: Silence	1.67	1	1.67	1.11	0.302
	Hazards: Light	0.15	1	0.15	0.09	0.768
	Hazards: Moving Obstacles	3.27	1	3.27	2.00	0.168
Error	Building Profile	37.90	28	1.35		
	Floor Layout	41.85	28	1.49		
	Floor Number	27.35	28	0.98		
	Room Number	20.50	28	0.73		
	Toilet and Bathroom	7.90	28	0.28		
	Entrance and Exit	7.05	28	0.25		
	Door	6.90	28	0.25		
	Emergency Exit	15.45	28	0.55		
	Lighting	41.90	28	1.50		

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Source		Type III Sum of Squares	df	Mean Square	F	p
	WiFi Coverage	51.30	28	1.83		
	Walkable Path	12.20	28	0.44		
	Tactile Pavement	37.80	28	1.35		
	Stairs	17.30	28	0.62		
	Steps, Dropoff, Curb	8.65	28	0.31		
	Elevator	8.15	28	0.29		
	Escalator	15.85	28	0.57		
	Event and Exhibition	15.35	28	0.55		
	Furniture	17.35	28	0.62		
	Dangerous area	19.45	28	0.69		
	People	22.65	28	0.81		
	Weather	39.00	28	1.39		
	Reception	29.05	28	1.04		
	Noise	58.15	28	2.08		
	White cane	93.45	28	3.34		
	Guide dog	26.95	28	0.96		
	Sighted Guide	84.15	28	3.01		
	Tactile map	10.65	28	0.38		
	Distance estimation	69.50	28	2.48		
	Freq: University	40.70	28	1.45		
	Freq: Hospital	22.90	28	0.82		
	Freq: Department Store	45.35	28	1.62		
	Freq: Museum	24.60	28	0.88		
	Freq: Airport	15.45	28	0.55		
	Difficulty: University	12.90	28	0.46		
	Difficulty: Hospital	8.65	28	0.31		
	Difficulty: Department Store	12.90	28	0.46		
	Difficulty: Museum	10.55	28	0.38		
	Difficulty: Airport	10.55	28	0.38		
	Confidence: Wide open	15.00	28	0.54		
	Confidence: Hallway	24.60	28	0.88		
	Confidence: Room	27.60	28	0.99		
	Confidence: Large room	12.80	28	0.46		
	Help: Ask for direction	3.45	28	0.12		
	Help: Information confusing	7.35	28	0.26		
	Hazards: Ground Obstacles	37.80	28	1.35		
	Hazards: Body Obstacles	41.10	28	1.47		
	Hazards: Head Obstacles	47.85	28	1.71		
	Hazards: Noise	42.80	28	1.53		
	Hazards: Silence	42.20	28	1.51		
	Hazards: Light	47.35	28	1.69		
	Hazards: Moving Obstacles	45.70	28	1.63		
Total	Building Profile	451.00	30			
	Floor Layout	446.00	30			
	Floor Number	533.00	30			
	Room Number	543.00	30			

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Toilet and Bathroom	565.00	30			
	Entrance and Exit	588.00	30			
	Door	651.00	30			
	Emergency Exit	528.00	30			
	Lighting	439.00	30			
	WiFi Coverage	345.00	30			
	Walkable Path	542.00	30			
	Tactile Pavement	502.00	30			
	Stairs	555.00	30			
	Steps, Dropoff, Curb	538.00	30			
	Elevator	529.00	30			
	Escalator	496.00	30			
	Event and Exhibition	441.00	30			
	Furniture	523.00	30			
	Dangerous area	550.00	30			
	People	504.00	30			
	Weather	444.00	30			
	Reception	478.00	30			
	Noise	361.00	30			
	White cane	286.00	30			
	Guide dog	31.00	30			
	Sighted Guide	481.00	30			
	Tactile map	12.00	30			
	Distance estimation	257.00	30			
	Freq: University	65.00	30			
	Freq: Hospital	55.00	30			
	Freq: Department Store	147.00	30			
	Freq: Museum	62.00	30			
	Freq: Airport	40.00	30			
	Difficulty: University	201.00	30			
	Difficulty: Hospital	222.00	30			
	Difficulty: Department Store	201.00	30			
	Difficulty: Museum	219.00	30			
	Difficulty: Airport	219.00	30			
	Confidence: Wide open	20.00	30			
	Confidence: Hallway	36.00	30			
	Confidence: Room	60.00	30			
	Confidence: Large room	16.00	30			
	Help: Ask for direction	26.00	30			
	Help: Information confusing	17.00	30			
	Hazards: Ground Obstacles	166.00	30			
	Hazards: Body Obstacles	191.00	30			
	Hazards: Head Obstacles	160.00	30			
	Hazards: Noise	156.00	30			
	Hazards: Silence	92.00	30			
	Hazards: Light	115.00	30			

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Hazards: Moving Obstacles	217.00	30			
Corrected Total	Building Profile	40.30	29			
	Floor Layout	42.67	29			
	Floor Number	28.70	29			
	Room Number	22.17	29			
	Toilet and Bathroom	10.30	29			
	Entrance and Exit	7.20	29			
	Door	6.97	29			
	Emergency Exit	15.47	29			
	Lighting	42.97	29			
	WiFi Coverage	56.70	29			
	Walkable Path	12.80	29			
	Tactile Pavement	37.87	29			
	Stairs	17.37	29			
	Steps, Dropoff, Curb	8.80	29			
	Elevator	8.17	29			
	Escalator	16.00	29			
	Event and Exhibition	15.37	29			
	Furniture	18.70	29			
	Dangerous area	20.80	29			
	People	24.00	29			
	Weather	40.67	29			
	Reception	29.47	29			
	Noise	60.17	29			
	White cane	93.47	29			
	Guide dog	28.30	29			
	Sighted Guide	84.97	29			
	Tactile map	10.80	29			
	Distance estimation	69.50	29			
	Freq: University	40.70	29			
	Freq: Hospital	22.97	29			
	Freq: Department Store	46.17	29			
	Freq: Museum	27.87	29			
	Freq: Airport	17.47	29			
	Difficulty: University	13.50	29			
	Difficulty: Hospital	8.67	29			
	Difficulty: Department Store	13.50	29			
	Difficulty: Museum	10.97	29			
	Difficulty: Airport	10.97	29			
	Confidence: Wide open	16.67	29			
	Confidence: Hallway	25.20	29			
	Confidence: Room	30.00	29			
	Confidence: Large room	13.87	29			
	Help: Ask for direction	3.47	29			
	Help: Information confusing	7.37	29			
	Hazards: Ground Obstacles	37.87	29			

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Hazards: Body Obstacles	41.37	29			
	Hazards: Head Obstacles	47.87	29			
	Hazards: Noise	43.87	29			
	Hazards: Silence	43.87	29			
	Hazards: Light	47.50	29			
	Hazards: Moving Obstacles	48.97	29			

[a] R Squared = 0.06 (Adjusted R Squared = 0.03)
[b] R Squared = 0.02 (Adjusted R Squared = -0.02)
[c] R Squared = 0.05 (Adjusted R Squared = 0.01)
[d] R Squared = 0.08 (Adjusted R Squared = 0.04)
[e] R Squared = 0.23 (Adjusted R Squared = 0.21)
[f] R Squared = 0.02 (Adjusted R Squared = -0.01)
[g] R Squared = 0.01 (Adjusted R Squared = -0.03)
[h] R Squared = 0.00 (Adjusted R Squared = -0.04)
[i] R Squared = 0.03 (Adjusted R Squared = -0.01)
[j] R Squared = 0.10 (Adjusted R Squared = 0.06)
[k] R Squared = 0.05 (Adjusted R Squared = 0.01)
[l] R Squared = 0.00 (Adjusted R Squared = -0.03)
[m] R Squared = 0.00 (Adjusted R Squared = -0.03)
[n] R Squared = 0.02 (Adjusted R Squared = -0.02)
[o] R Squared = 0.00 (Adjusted R Squared = -0.03)
[p] R Squared = 0.01 (Adjusted R Squared = -0.03)
[q] R Squared = 0.00 (Adjusted R Squared = -0.04)
[r] R Squared = 0.07 (Adjusted R Squared = 0.04)
[s] R Squared = 0.07 (Adjusted R Squared = 0.03)
[t] R Squared = 0.06 (Adjusted R Squared = 0.02)
[u] R Squared = 0.04 (Adjusted R Squared = 0.01)
[v] R Squared = 0.01 (Adjusted R Squared = -0.02)
[w] R Squared = 0.03 (Adjusted R Squared = 0.00)
[x] R Squared = 0.00 (Adjusted R Squared = -0.04)
[y] R Squared = 0.05 (Adjusted R Squared = 0.01)
[z] R Squared = 0.01 (Adjusted R Squared = -0.03)
[aa] R Squared = 0.01 (Adjusted R Squared = -0.02)
[ab] R Squared = 0.00 (Adjusted R Squared = -0.04)
[ac] R Squared = 0.00 (Adjusted R Squared = -0.03)
[ad] R Squared = 0.02 (Adjusted R Squared = -0.02)
[ae] R Squared = 0.12 (Adjusted R Squared = 0.09)
[af] R Squared = 0.12 (Adjusted R Squared = 0.08)
[ag] R Squared = 0.04 (Adjusted R Squared = 0.01)
[ah] R Squared = 0.00 (Adjusted R Squared = -0.03)
[ai] R Squared = 0.04 (Adjusted R Squared = 0.01)
[aj] R Squared = 0.04 (Adjusted R Squared = 0.00)
[ak] R Squared = 0.10 (Adjusted R Squared = 0.07)
[al] R Squared = 0.02 (Adjusted R Squared = -0.01)
[am] R Squared = 0.08 (Adjusted R Squared = 0.05)
[an] R Squared = 0.08 (Adjusted R Squared = 0.04)
[ao] R Squared = 0.01 (Adjusted R Squared = -0.03)
[ap] R Squared = 0.00 (Adjusted R Squared = -0.03)
[aq] R Squared = 0.00 (Adjusted R Squared = -0.03)
[ar] R Squared = 0.01 (Adjusted R Squared = -0.03)
[as] R Squared = 0.00 (Adjusted R Squared = -0.04)
[at] R Squared = 0.02 (Adjusted R Squared = -0.01)
[au] R Squared = 0.04 (Adjusted R Squared = 0.00)
[av] R Squared = 0.00 (Adjusted R Squared = -0.03)
[aw] R Squared = 0.07 (Adjusted R Squared = 0.03)

D.1.2 Severely sighted impairment vs. Partially sighted impairment

Table D.5: SS vs. PS: Between-Subjects Factors

		Value Label	N
Groups	1	Severely sighted impairment	23
	2	Partially sighted impairment	7

Table D.6: SS vs. PS: Descriptive Statistics

	Condition	Mean	Std. Deviation	N
Building Profile	Severely sighted impairment	3.70	1.19	23
	Partially sighted impairment	3.71	1.25	7
	Total	3.70	1.18	30
Floor Layout	Severely sighted impairment	3.70	1.22	23
	Partially sighted impairment	3.57	1.27	7
	Total	3.67	1.21	30
Floor Number	Severely sighted impairment	4.13	0.87	23
	Partially sighted impairment	4.00	1.41	7
	Total	4.10	1.00	30
Room Number	Severely sighted impairment	4.09	0.90	23
	Partially sighted impairment	4.43	0.79	7
	Total	4.17	0.87	30
Toilet and Bathroom	Severely sighted impairment	4.43	0.59	23
	Partially sighted impairment	3.86	0.38	7
	Total	4.30	0.60	30
Entrance and Exit	Severely sighted impairment	4.30	0.47	23
	Partially sighted impairment	4.71	0.49	7
	Total	4.40	0.50	30
Door	Severely sighted impairment	4.61	0.50	23
	Partially sighted impairment	4.71	0.49	7
	Total	4.63	0.49	30
Emergency Exit	Severely sighted impairment	4.00	0.74	23
	Partially sighted impairment	4.57	0.54	7
	Total	4.13	0.73	30

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	Condition	**Mean**	**Std. Deviation**	**N**
Lighting	Severely sighted impairment	3.48	1.31	23
	Partially sighted impairment	4.14	0.69	7
	Total	3.63	1.22	30
WiFi Coverage	Severely sighted impairment	3.13	1.42	23
	Partially sighted impairment	3.00	1.41	7
	Total	3.10	1.40	30
Walkable Path	Severely sighted impairment	4.09	0.67	23
	Partially sighted impairment	4.57	0.54	7
	Total	4.20	0.66	30
Tactile Pavement	Severely sighted impairment	4.00	1.00	23
	Partially sighted impairment	3.71	1.60	7
	Total	3.93	1.14	30
Stairs	Severely sighted impairment	4.26	0.45	23
	Partially sighted impairment	4.14	1.46	7
	Total	4.23	0.77	30
Steps, Dropoff, Curb	Severely sighted impairment	4.13	0.55	23
	Partially sighted impairment	4.43	0.54	7
	Total	4.20	0.55	30
Elevator	Severely sighted impairment	4.17	0.49	23
	Partially sighted impairment	4.14	0.69	7
	Total	4.17	0.53	30
Escalator	Severely sighted impairment	4.04	0.48	23
	Partially sighted impairment	3.86	1.35	7
	Total	4.00	0.74	30
Event and Exhibition	Severely sighted impairment	3.61	0.66	23
	Partially sighted impairment	4.29	0.76	7
	Total	3.77	0.73	30
Furniture	Severely sighted impairment	4.17	0.58	23
	Partially sighted impairment	3.86	1.35	7
	Total	4.10	0.80	30
Dangerous area	Severely sighted impairment	4.13	0.92	23
	Partially sighted impairment	4.43	0.54	7

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	Condition	Mean	Std. Deviation	N
	Total	4.20	0.85	30
People	Severely sighted impairment	3.96	0.93	23
	Partially sighted impairment	4.14	0.90	7
	Total	4.00	0.91	30
Weather	Severely sighted impairment	3.78	1.20	23
	Partially sighted impairment	3.29	1.11	7
	Total	3.67	1.18	30
Reception	Severely sighted impairment	3.87	1.10	23
	Partially sighted impairment	3.86	0.69	7
	Total	3.87	1.01	30
Noise	Severely sighted impairment	3.22	1.48	23
	Partially sighted impairment	3.00	1.41	7
	Total	3.17	1.44	30
White cane	Severely sighted impairment	2.87	1.74	23
	Partially sighted impairment	1.43	1.62	7
	Total	2.53	1.80	30
Guide dog	Severely sighted impairment	0.35	1.11	23
	Partially sighted impairment	0.14	0.38	7
	Total	0.30	0.99	30
Sighted Guide	Severely sighted impairment	4.00	1.31	23
	Partially sighted impairment	2.43	2.37	7
	Total	3.63	1.71	30
Tactile map	Severely sighted impairment	0.22	0.67	23
	Partially sighted impairment	0.14	0.38	7
	Total	0.20	0.61	30
Distance estimation	Severely sighted impairment	2.35	1.58	23
	Partially sighted impairment	3.00	1.41	7
	Total	2.50	1.55	30
Freq: University	Severely sighted impairment	0.96	1.22	23
	Partially sighted impairment	0.71	1.11	7
	Total	0.90	1.19	30
Freq: Hospital	Severely sighted impairment	0.87	0.82	23

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	Condition	Mean	Std. Deviation	N
	Partially sighted impairment	1.57	0.98	7
	Total	1.03	0.89	30
Freq: Department Store	Severely sighted impairment	1.70	1.33	23
	Partially sighted impairment	2.29	0.95	7
	Total	1.83	1.26	30
Freq: Museum	Severely sighted impairment	0.91	0.95	23
	Partially sighted impairment	1.57	0.98	7
	Total	1.07	0.98	30
Freq: Airport	Severely sighted impairment	0.87	0.82	23
	Partially sighted impairment	0.86	0.69	7
	Total	0.87	0.78	30
Difficulty: University	Severely sighted impairment	2.52	0.67	23
	Partially sighted impairment	2.43	0.79	7
	Total	2.50	0.68	30
Difficulty: Hospital	Severely sighted impairment	2.74	0.45	23
	Partially sighted impairment	2.43	0.79	7
	Total	2.67	0.55	30
Difficulty: Department Store	Severely sighted impairment	2.61	0.58	23
	Partially sighted impairment	2.14	0.90	7
	Total	2.50	0.68	30
Difficulty: Museum	Severely sighted impairment	2.70	0.56	23
	Partially sighted impairment	2.43	0.79	7
	Total	2.63	0.62	30
Difficulty: Airport	Severely sighted impairment	2.74	0.54	23
	Partially sighted impairment	2.29	0.76	7
	Total	2.63	0.62	30
Confidence: Wide open	Severely sighted impairment	0.17	0.58	23
	Partially sighted impairment	0.86	1.07	7
	Total	0.33	0.76	30
Confidence: Hallway	Severely sighted impairment	0.52	0.90	23
	Partially sighted impairment	0.86	1.07	7
	Total	0.60	0.93	30

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	Condition	Mean	Std. Deviation	N
Confidence: Room	Severely sighted impairment	0.87	1.01	23
	Partially sighted impairment	1.43	0.98	7
	Total	1.00	1.02	30
Confidence: Large room	Severely sighted impairment	0.17	0.58	23
	Partially sighted impairment	0.57	0.98	7
	Total	0.27	0.69	30
Help: Ask for direction	Severely sighted impairment	0.91	0.29	23
	Partially sighted impairment	0.71	0.49	7
	Total	0.87	0.35	30
Help: Information confusing	Severely sighted impairment	0.61	0.50	23
	Partially sighted impairment	0.43	0.54	7
	Total	0.57	0.50	30
Hazards: Gound Obstacles	Severely sighted impairment	2.17	1.07	23
	Partially sighted impairment	1.71	1.38	7
	Total	2.07	1.14	30
Hazards: Body Obstacles	Severely sighted impairment	2.35	1.11	23
	Partially sighted impairment	1.86	1.46	7
	Total	2.23	1.19	30
Hazards: Head Obstacles	Severely sighted impairment	1.87	1.33	23
	Partially sighted impairment	2.14	1.22	7
	Total	1.93	1.29	30
Hazards: Noise	Severely sighted impairment	2.09	1.13	23
	Partially sighted impairment	1.43	1.51	7
	Total	1.93	1.23	30
Hazards: Silence	Severely sighted impairment	1.30	1.22	23
	Partially sighted impairment	1.14	1.35	7
	Total	1.27	1.23	30
Hazards: Light	Severely sighted impairment	1.39	1.20	23
	Partially sighted impairment	1.86	1.57	7
	Total	1.50	1.28	30
Hazards: Moving Obstacles	Severely sighted impairment	2.43	1.24	23
	Partially sighted impairment	2.14	1.57	7

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Condition	Mean	Std. Deviation	N
Total	2.37	1.30	30

Table D.7: SS vs. PS: Multivariate Test

Effect		Value	F	Hypothesis df	Error df	p
Intercept	Pillai's Trace	1.00	92.87	28.00	1.00	0.082
	Wilks' Lambda	0.00	92.87	28.00	1.00	0.082
	Hotelling's Trace	2600.33	92.87	28.00	1.00	0.082
	Roy's Largest Root	2600.33	92.87	28.00	1.00	0.082
SS vs. PS	Pillai's Trace	0.98	1.98	28.00	1	0.517
	Wilks' Lambda	0.02	1.98	28.00	1	0.517
	Hotelling's Trace	55.38	1.98	28.00	1	0.517
	Roy's Largest Root	55.38	1.98	28.00	1	0.517

Table D.8: SS vs. PS: Tests of Between-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	*p*
Corrected Model	Building Profile	0.00[a]	1.00	0.00	0.00	0.972
	Floor Layout	0.08[b]	1.00	0.08	0.05	0.817
	Floor Number	0.09[c]	1.00	0.09	0.09	0.767
	Room Number	0.63[d]	1.00	0.63	0.81	0.375
	Toilet and Bathroom	1.79[e]	1.00	1.79	5.89	0.022
	Entrance and Exit	0.90[f]	1.00	0.90	4.01	0.055
	Door	0.06[g]	1.00	0.06	0.24	0.626
	Emergency Exit	1.75[h]	1.00	1.75	3.58	0.069
	Lighting	2.37[i]	1.00	2.37	1.63	0.212
	WiFi Coverage	0.09[j]	1.00	0.09	0.05	0.833
	Walkable Path	1.26[k]	1.00	1.26	3.06	0.091
	Tactile Pavement	0.44[l]	1.00	0.44	0.33	0.572
	Stairs	0.07[m]	1.00	0.07	0.12	0.731
	Steps, Dropoff, Curb	0.48[n]	1.00	0.48	1.60	0.216
	Elevator	0.01[o]	1.00	0.01	0.02	0.895
	Escalator	0.19[p]	1.00	0.19	0.33	0.57
	Event and Exhibition	2.46[q]	1.00	2.46	5.34	0.028
	Furniture	0.54[r]	1.00	0.54	0.83	0.37
	Dangerous area	0.48[s]	1.00	0.48	0.66	0.424
	People	0.19[t]	1.00	0.19	0.22	0.643
	Weather	1.33[u]	1.00	1.33	0.94	0.34
	Reception	0.00[v]	1.00	0.00	0.00	0.978
	Noise	0.25[w]	1.00	0.25	0.12	0.733

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	White cane	11.14^{x}	1.00	11.14	3.79	0.062
	Guide dog	0.23^{y}	1.00	0.23	0.22	0.639
	Sighted Guide	13.25^{z}	1.00	13.25	5.17	0.031
	Tactile map	0.03^{aa}	1.00	0.03	0.08	0.783
	Distance estimation	2.28^{ab}	1.00	2.28	0.95	0.338
	Freq: University	0.31^{ac}	1.00	0.31	0.22	0.644
	Freq: Hospital	2.64^{ad}	1.00	2.64	3.64	0.067
	Freq: Department Store	1.87^{ae}	1.00	1.87	1.18	0.286
	Freq: Museum	2.33^{af}	1.00	2.33	2.55	0.121
	Freq: Airport	0.00^{ag}	1.00	0.00	0.00	0.971
	Difficulty: University	0.05^{ah}	1.00	0.05	0.10	0.758
	Difficulty: Hospital	0.52^{ai}	1.00	0.52	1.78	0.193
	Difficulty: Department Store	1.16^{aj}	1.00	1.16	2.64	0.115
	Difficulty: Museum	0.38^{ak}	1.00	0.38	1.01	0.323
	Difficulty: Airport	1.10^{al}	1.00	1.10	3.13	0.088
	Confidence: Wide open	2.51^{am}	1.00	2.51	4.95	0.034
	Confidence: Hallway	0.60^{an}	1.00	0.60	0.69	0.414
	Confidence: Room	1.68^{ao}	1.00	1.68	1.66	0.208
	Confidence: Large room	0.85^{ap}	1.00	0.85	1.82	0.188
	Help: Ask for direction	0.21^{ap}	1.00	0.21	1.82	0.188
	Help: Information confusing	0.17^{aq}	1.00	0.17	0.68	0.417
	Hazards: Ground Obstacles	1.13^{ar}	1.00	1.13	0.86	0.361
	Hazards: Body Obstacles	1.29^{as}	1.00	1.29	0.90	0.35
	Hazards: Head Obstacles	0.40^{at}	1.00	0.40	0.24	0.631
	Hazards: Noise	2.33^{au}	1.00	2.33	1.57	0.221
	Hazards: Silence	0.14^{av}	1.00	0.14	0.09	0.767
	Hazards: Light	1.16^{aw}	1.00	1.16	0.70	0.409
	Hazards: Moving Obstacles	0.46^{ax}	1.00	0.46	0.26	0.611
Intercept	Building Profile	294.67	1.00	294.67	204.74	< 0.001
	Floor Layout	283.42	1.00	283.42	186.35	< 0.001
	Floor Number	354.76	1.00	354.76	347.21	< 0.001
	Room Number	389.16	1.00	389.16	505.86	< 0.001
	Toilet and Bathroom	368.99	1.00	368.99	1214.17	< 0.001
	Entrance and Exit	436.50	1.00	436.50	1940.58	< 0.001
	Door	466.46	1.00	466.46	1891.01	< 0.001
	Emergency Exit	394.29	1.00	394.29	805.00	< 0.001
	Lighting	311.70	1.00	311.70	214.99	< 0.001
	WiFi Coverage	201.69	1.00	201.69	99.76	< 0.001
	Walkable Path	402.33	1.00	402.33	976.15	< 0.001
	Tactile Pavement	319.37	1.00	319.37	238.92	< 0.001
	Stairs	379.01	1.00	379.01	613.71	< 0.001
	Steps, Dropoff, Curb	393.14	1.00	393.14	1322.61	< 0.001
	Elevator	371.21	1.00	371.21	1273.51	< 0.001
	Escalator	334.99	1.00	334.99	593.13	< 0.001
	Event and Exhibition	334.46	1.00	334.46	725.58	< 0.001
	Furniture	346.14	1.00	346.14	533.65	< 0.001

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Dangerous area	393.14	1.00	393.14	541.65	< 0.001
	People	352.05	1.00	352.05	413.94	< 0.001
	Weather	268.13	1.00	268.13	190.83	< 0.001
	Reception	320.40	1.00	320.40	304.46	< 0.001
	Noise	207.45	1.00	207.45	96.95	< 0.001
	White cane	99.14	1.00	99.14	33.72	< 0.001
	Guide dog	1.29	1.00	1.29	1.29	0.266
	Sighted Guide	221.79	1.00	221.79	86.59	< 0.001
	Tactile map	0.70	1.00	0.70	1.81	0.189
	Distance estimation	153.48	1.00	153.48	63.93	< 0.001
	Freq: University	14.98	1.00	14.98	10.39	0.003
	Freq: Hospital	31.98	1.00	31.98	44.06	< 0.001
	Freq: Department Store	85.07	1.00	85.07	53.77	< 0.001
	Freq: Museum	33.13	1.00	33.13	36.32	< 0.001
	Freq: Airport	16.00	1.00	16.00	25.65	< 0.001
	Difficulty: University	131.51	1.00	131.51	273.71	< 0.001
	Difficulty: Hospital	143.32	1.00	143.32	492.44	< 0.001
	Difficulty: Department Store	121.16	1.00	121.16	275.03	< 0.001
	Difficulty: Museum	140.92	1.00	140.92	372.80	< 0.001
	Difficulty: Airport	135.50	1.00	135.50	384.67	< 0.001
	Confidence: Wide open	5.71	1.00	5.71	11.28	0.002
	Confidence: Hallway	10.20	1.00	10.20	11.62	0.002
	Confidence: Room	28.34	1.00	28.34	28.02	< 0.001
	Confidence: Large room	2.98	1.00	2.98	6.41	0.017
	Help: Ask for direction	14.21	1.00	14.21	122.27	< 0.001
	Help: Information confusing	5.77	1.00	5.77	22.48	< 0.001
	Hazards: Ground Obstacles	81.13	1.00	81.13	61.84	< 0.001
	Hazards: Body Obstacles	94.89	1.00	94.89	66.30	< 0.001
	Hazards: Head Obstacles	86.40	1.00	86.40	50.97	< 0.001
	Hazards: Noise	66.33	1.00	66.33	44.71	< 0.001
	Hazards: Silence	32.14	1.00	32.14	20.58	< 0.001
	Hazards: Light	56.63	1.00	56.63	34.22	< 0.001
	Hazards: Moving Obstacles	112.46	1.00	112.46	64.91	< 0.001
Visual Condition	Building Profile	0.00	1.00	0.00	0.00	0.972
	Floor Layout	0.08	1.00	0.08	0.05	0.817
	Floor Number	0.09	1.00	0.09	0.09	0.767
	Room Number	0.63	1.00	0.63	0.81	0.375
	Toilet and Bathroom	1.79	1.00	1.79	5.89	0.022
	Entrance and Exit	0.90	1.00	0.90	4.01	0.055
	Door	0.06	1.00	0.06	0.24	0.626
	Emergency Exit	1.75	1.00	1.75	3.58	0.069
	Lighting	2.37	1.00	2.37	1.63	0.212
	WiFi Coverage	0.09	1.00	0.09	0.05	0.833
	Walkable Path	1.26	1.00	1.26	3.06	0.091
	Tactile Pavement	0.44	1.00	0.44	0.33	0.572
	Stairs	0.07	1.00	0.07	0.12	0.731

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Steps, Dropoff, Curb	0.48	1.00	0.48	1.60	0.216
	Elevator	0.01	1.00	0.01	0.02	0.895
	Escalator	0.19	1.00	0.19	0.33	0.57
	Event and Exhibition	2.46	1.00	2.46	5.34	0.028
	Furniture	0.54	1.00	0.54	0.83	0.37
	Dangerous area	0.48	1.00	0.48	0.66	0.424
	People	0.19	1.00	0.19	0.22	0.643
	Weather	1.33	1.00	1.33	0.94	0.34
	Reception	0.00	1.00	0.00	0.00	0.978
	Noise	0.25	1.00	0.25	0.12	0.733
	White cane	11.14	1.00	11.14	3.79	0.062
	Guide dog	0.23	1.00	0.23	0.22	0.639
	Sighted Guide	13.25	1.00	13.25	5.17	0.031
	Tactile map	0.03	1.00	0.03	0.08	0.783
	Distance estimation	2.28	1.00	2.28	0.95	0.338
	Freq: University	0.31	1.00	0.31	0.22	0.644
	Freq: Hospital	2.64	1.00	2.64	3.64	0.067
	Freq: Department Store	1.87	1.00	1.87	1.18	0.286
	Freq: Museum	2.33	1.00	2.33	2.55	0.121
	Freq: Airport	0.00	1.00	0.00	0.00	0.971
	Difficulty: University	0.05	1.00	0.05	0.10	0.758
	Difficulty: Hospital	0.52	1.00	0.52	1.78	0.193
	Difficulty: Department Store	1.16	1.00	1.16	2.64	0.115
	Difficulty: Museum	0.38	1.00	0.38	1.01	0.323
	Difficulty: Airport	1.10	1.00	1.10	3.13	0.088
	Confidence: Wide open	2.51	1.00	2.51	4.95	0.034
	Confidence: Hallway	0.60	1.00	0.60	0.69	0.414
	Confidence: Room	1.68	1.00	1.68	1.66	0.208
	Confidence: Large room	0.85	1.00	0.85	1.82	0.188
	Help: Ask for direction	0.21	1.00	0.21	1.82	0.188
	Help: Information confusing	0.17	1.00	0.17	0.68	0.417
	Hazards: Ground Obstacles	1.13	1.00	1.13	0.86	0.361
	Hazards: Body Obstacles	1.29	1.00	1.29	0.90	0.35
	Hazards: Head Obstacles	0.40	1.00	0.40	0.24	0.631
	Hazards: Noise	2.33	1.00	2.33	1.57	0.221
	Hazards: Silence	0.14	1.00	0.14	0.09	0.767
	Hazards: Light	1.16	1.00	1.16	0.70	0.409
	Hazards: Moving Obstacles	0.46	1.00	0.46	0.26	0.611
Error	Building Profile	40.30	28.00	1.44		
	Floor Layout	42.58	28.00	1.52		
	Floor Number	28.61	28.00	1.02		
	Room Number	21.54	28.00	0.77		
	Toilet and Bathroom	8.51	28.00	0.30		
	Entrance and Exit	6.30	28.00	0.22		
	Door	6.91	28.00	0.25		
	Emergency Exit	13.71	28.00	0.49		

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Lighting	40.60	28.00	1.45		
	WiFi Coverage	56.61	28.00	2.02		
	Walkable Path	11.54	28.00	0.41		
	Tactile Pavement	37.43	28.00	1.34		
	Stairs	17.29	28.00	0.62		
	Steps, Dropoff, Curb	8.32	28.00	0.30		
	Elevator	8.16	28.00	0.29		
	Escalator	15.81	28.00	0.56		
	Event and Exhibition	12.91	28.00	0.46		
	Furniture	18.16	28.00	0.65		
	Dangerous area	20.32	28.00	0.73		
	People	23.81	28.00	0.85		
	Weather	39.34	28.00	1.41		
	Reception	29.47	28.00	1.05		
	Noise	59.91	28.00	2.14		
	White cane	82.32	28.00	2.94		
	Guide dog	28.07	28.00	1.00		
	Sighted Guide	71.71	28.00	2.56		
	Tactile map	10.77	28.00	0.38		
	Distance estimation	67.22	28.00	2.40		
	Freq: University	40.39	28.00	1.44		
	Freq: Hospital	20.32	28.00	0.73		
	Freq: Department Store	44.30	28.00	1.58		
	Freq: Museum	25.54	28.00	0.91		
	Freq: Airport	17.47	28.00	0.62		
	Difficulty: University	13.45	28.00	0.48		
	Difficulty: Hospital	8.15	28.00	0.29		
	Difficulty: Department Store	12.34	28.00	0.44		
	Difficulty: Museum	10.58	28.00	0.38		
	Difficulty: Airport	9.86	28.00	0.35		
	Confidence: Wide open	14.16	28.00	0.51		
	Confidence: Hallway	24.60	28.00	0.88		
	Confidence: Room	28.32	28.00	1.01		
	Confidence: Large room	13.02	28.00	0.46		
	Help: Ask for direction	3.25	28.00	0.12		
	Help: Information confusing	7.19	28.00	0.26		
	Hazards: Ground Obstacles	36.73	28.00	1.31		
	Hazards: Body Obstacles	40.07	28.00	1.43		
	Hazards: Head Obstacles	47.47	28.00	1.70		
	Hazards: Noise	41.54	28.00	1.48		
	Hazards: Silence	43.73	28.00	1.56		
	Hazards: Light	46.34	28.00	1.65		
	Hazards: Moving Obstacles	48.51	28.00	1.73		
Total	Building Profile	451.00	30.00			
	Floor Layout	446.00	30.00			
	Floor Number	533.00	30.00			

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Room Number	543.00	30.00			
	Toilet and Bathroom	565.00	30.00			
	Entrance and Exit	588.00	30.00			
	Door	651.00	30.00			
	Emergency Exit	528.00	30.00			
	Lighting	439.00	30.00			
	WiFi Coverage	345.00	30.00			
	Walkable Path	542.00	30.00			
	Tactile Pavement	502.00	30.00			
	Stairs	555.00	30.00			
	Steps, Dropoff, Curb	538.00	30.00			
	Elevator	529.00	30.00			
	Escalator	496.00	30.00			
	Event and Exhibition	441.00	30.00			
	Furniture	523.00	30.00			
	Dangerous area	550.00	30.00			
	People	504.00	30.00			
	Weather	444.00	30.00			
	Reception	478.00	30.00			
	Noise	361.00	30.00			
	White cane	286.00	30.00			
	Guide dog	31.00	30.00			
	Sighted Guide	481.00	30.00			
	Tactile map	12.00	30.00			
	Distance estimation	257.00	30.00			
	Freq: University	65.00	30.00			
	Freq: Hospital	55.00	30.00			
	Freq: Department Store	147.00	30.00			
	Freq: Museum	62.00	30.00			
	Freq: Airport	40.00	30.00			
	Difficulty: University	201.00	30.00			
	Difficulty: Hospital	222.00	30.00			
	Difficulty: Department Store	201.00	30.00			
	Difficulty: Museum	219.00	30.00			
	Difficulty: Airport	219.00	30.00			
	Confidence: Wide open	20.00	30.00			
	Confidence: Hallway	36.00	30.00			
	Confidence: Room	60.00	30.00			
	Confidence: Large room	16.00	30.00			
	Help: Ask for direction	26.00	30.00			
	Help: Information confusing	17.00	30.00			
	Hazards: Ground Obstacles	166.00	30.00			
	Hazards: Body Obstacles	191.00	30.00			
	Hazards: Head Obstacles	160.00	30.00			
	Hazards: Noise	156.00	30.00			
	Hazards: Silence	92.00	30.00			
	Hazards: Light	115.00	30.00			

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Hazards: Moving Obstacles	217.00	30.00			
Corrected Total	Building Profile	40.30	29.00			
	Floor Layout	42.67	29.00			
	Floor Number	28.70	29.00			
	Room Number	22.17	29.00			
	Toilet and Bathroom	10.30	29.00			
	Entrance and Exit	7.20	29.00			
	Door	6.97	29.00			
	Emergency Exit	15.47	29.00			
	Lighting	42.97	29.00			
	WiFi Coverage	56.70	29.00			
	Walkable Path	12.80	29.00			
	Tactile Pavement	37.87	29.00			
	Stairs	17.37	29.00			
	Steps, Dropoff, Curb	8.80	29.00			
	Elevator	8.17	29.00			
	Escalator	16.00	29.00			
	Event and Exhibition	15.37	29.00			
	Furniture	18.70	29.00			
	Dangerous area	20.80	29.00			
	People	24.00	29.00			
	Weather	40.67	29.00			
	Reception	29.47	29.00			
	Noise	60.17	29.00			
	White cane	93.47	29.00			
	Guide dog	28.30	29.00			
	Sighted Guide	84.97	29.00			
	Tactile map	10.80	29.00			
	Distance estimation	69.50	29.00			
	Freq: University	40.70	29.00			
	Freq: Hospital	22.97	29.00			
	Freq: Department Store	46.17	29.00			
	Freq: Museum	27.87	29.00			
	Freq: Airport	17.47	29.00			
	Difficulty: University	13.50	29.00			
	Difficulty: Hospital	8.67	29.00			
	Difficulty: Department Store	13.50	29.00			
	Difficulty: Museum	10.97	29.00			
	Difficulty: Airport	10.97	29.00			
	Confidence: Wide open	16.67	29.00			
	Confidence: Hallway	25.20	29.00			
	Confidence: Room	30.00	29.00			
	Confidence: Large room	13.87	29.00			
	Help: Ask for direction	3.47	29.00			
	Help: Information confusing	7.37	29.00			
	Hazards: Ground Obstacles	37.87	29.00			

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Hazards: Body Obstacles	41.37	29.00			
	Hazards: Head Obstacles	47.87	29.00			
	Hazards: Noise	43.87	29.00			
	Hazards: Silence	43.87	29.00			
	Hazards: Light	47.50	29.00			
	Hazards: Moving Obstacles	48.97	29.00			

[a] R Squared = 0.00 (Adjusted R Squared = -0.04)
[b] R Squared = 0.00 (Adjusted R Squared = -0.03)
[c] R Squared = 0.00 (Adjusted R Squared = -0.03)
[d] R Squared = 0.03 (Adjusted R Squared = -0.01)
[e] R Squared = 0.17 (Adjusted R Squared = 0.14)
[f] R Squared = 0.13 (Adjusted R Squared = 0.09)
[g] R Squared = 0.01 (Adjusted R Squared = -0.03)
[h] R Squared = 0.11 (Adjusted R Squared = 0.08)
[i] R Squared = 0.06 (Adjusted R Squared = 0.02)
[j] R Squared = 0.00 (Adjusted R Squared = -0.03)
[k] R Squared = 0.10 (Adjusted R Squared = 0.07)
[l] R Squared = 0.01 (Adjusted R Squared = -0.02)
[m] R Squared = 0.00 (Adjusted R Squared = -0.03)
[n] R Squared = 0.05 (Adjusted R Squared = 0.02)
[o] R Squared = 0.00 (Adjusted R Squared = -0.04)
[p] R Squared = 0.01 (Adjusted R Squared = -0.02)
[q] R Squared = 0.16 (Adjusted R Squared = 0.13)
[r] R Squared = 0.03 (Adjusted R Squared = -0.01)
[s] R Squared = 0.02 (Adjusted R Squared = -0.01)
[t] R Squared = 0.01 (Adjusted R Squared = -0.03)
[u] R Squared = 0.03 (Adjusted R Squared = 0.00)
[v] R Squared = 0.00 (Adjusted R Squared = -0.04)
[w] R Squared = 0.00 (Adjusted R Squared = -0.03)
[x] R Squared = 0.12 (Adjusted R Squared = 0.09)
[y] R Squared = 0.01 (Adjusted R Squared = -0.03)
[z] R Squared = 0.16 (Adjusted R Squared = 0.13)
[aa] R Squared = 0.00 (Adjusted R Squared = -0.03)
[ab] R Squared = 0.03 (Adjusted R Squared = 0.00)
[ac] R Squared = 0.01 (Adjusted R Squared = -0.03)
[ad] R Squared = 0.12 (Adjusted R Squared = 0.08)
[ae] R Squared = 0.04 (Adjusted R Squared = 0.01)
[af] R Squared = 0.08 (Adjusted R Squared = 0.05)
[ag] R Squared = 0.00 (Adjusted R Squared = -0.04)
[ah] R Squared = 0.00 (Adjusted R Squared = -0.03)
[ai] R Squared = 0.06 (Adjusted R Squared = 0.03)
[aj] R Squared = 0.09 (Adjusted R Squared = 0.05)
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[at] R Squared = 0.01 (Adjusted R Squared = -0.03)
[au] R Squared = 0.05 (Adjusted R Squared = 0.02)
[av] R Squared = 0.00 (Adjusted R Squared = -0.03)
[aw] R Squared = 0.03 (Adjusted R Squared = -0.01)
[ax] R Squared = 0.01 (Adjusted R Squared = -0.03)

D.1.3 O&M Instructors and care-givers (OMC) vs. Accessibility experts (AC)

TABLE D.9: OMC vs. ACC: Between-Subjects Factors

		Value Label	N
Groups	1	O&M instructors and care-givers	7
	2	Accessibility experts	8

TABLE D.10: OMC vs. ACC: Descriptive Statistics

	Expert	Mean	Std. Deviation	N
Building Profile	O&M instructors and care-givers	4.71	0.49	7
	Accessibility experts	3.25	1.04	8
	Total	3.93	1.10	15
Floor Layout	O&M instructors and care-givers	4.43	0.79	7
	Accessibility experts	4.13	0.64	8
	Total	4.27	0.70	15
Floor Number	O&M instructors and care-givers	4.57	0.54	7
	Accessibility experts	4.75	0.46	8
	Total	4.67	0.49	15
Room Number	O&M instructors and care-givers	4.57	0.79	7
	Accessibility experts	4.75	0.46	8
	Total	4.67	0.62	15
Toilet and Bathroom	O&M instructors and care-givers	4.71	0.49	7
	Accessibility experts	4.25	0.89	8
	Total	4.47	0.74	15
Entrance and Exit	O&M instructors and care-givers	4.71	0.49	7
	Accessibility experts	4.75	0.46	8
	Total	4.73	0.46	15
Door	O&M instructors and care-givers	4.86	0.38	7
	Accessibility experts	4.38	0.74	8
	Total	4.60	0.63	15
Emergency Exit	O&M instructors and care-givers	5.00	0.00	7

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	Expert	**Mean**	**Std. Deviation**	**N**
	Accessibility experts	4.25	0.71	8
	Total	4.60	0.63	15
Lighting	O&M instructors and care-givers	3.00	1.53	7
	Accessibility experts	2.25	1.49	8
	Total	2.60	1.50	15
WiFi Coverage	O&M instructors and care-givers	4.14	0.90	7
	Accessibility experts	2.13	0.99	8
	Total	3.07	1.39	15
Walkable Path	O&M instructors and care-givers	4.14	1.46	7
	Accessibility experts	4.13	0.64	8
	Total	4.13	1.06	15
Tactile Pavement	O&M instructors and care-givers	4.57	0.54	7
	Accessibility experts	4.63	0.52	8
	Total	4.60	0.51	15
Stairs	O&M instructors and care-givers	4.43	0.54	7
	Accessibility experts	4.25	0.71	8
	Total	4.33	0.62	15
Steps, Dropoff, Curb	O&M instructors and care-givers	4.57	0.54	7
	Accessibility experts	4.50	0.54	8
	Total	4.53	0.52	15
Elevator	O&M instructors and care-givers	4.43	0.54	7
	Accessibility experts	4.13	0.64	8
	Total	4.27	0.59	15
Escalator	O&M instructors and care-givers	4.29	0.76	7
	Accessibility experts	3.88	0.64	8
	Total	4.07	0.70	15
Event and Exhibition	O&M instructors and care-givers	3.86	1.07	7
	Accessibility experts	3.13	0.35	8
	Total	3.47	0.83	15
Furniture	O&M instructors and care-givers	4.14	0.69	7
	Accessibility experts	3.75	0.46	8

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	Expert	Mean	Std. Deviation	N
	Total	3.93	0.59	15
Dangerous area	O&M instructors and care-givers	4.71	0.49	7
	Accessibility experts	4.50	0.76	8
	Total	4.60	0.63	15
People	O&M instructors and care-givers	4.00	1.00	7
	Accessibility experts	3.38	0.74	8
	Total	3.67	0.90	15
Weather	O&M instructors and care-givers	3.29	1.25	7
	Accessibility experts	2.63	1.06	8
	Total	2.93	1.16	15
Reception	O&M instructors and care-givers	4.00	1.53	7
	Accessibility experts	3.63	1.30	8
	Total	3.80	1.37	15
Noise	O&M instructors and care-givers	4.43	0.79	7
	Accessibility experts	3.75	1.04	8
	Total	4.07	0.96	15
White cane	O&M instructors and care-givers	3.57	1.90	7
	Accessibility experts	4.75	0.46	8
	Total	4.20	1.42	15
Guide dog	O&M instructors and care-givers	0.57	0.54	7
	Accessibility experts	1.13	1.89	8
	Total	0.87	1.41	15
Sighted Guide	O&M instructors and care-givers	2.57	1.62	7
	Accessibility experts	3.88	1.55	8
	Total	3.27	1.67	15
Tactile map	O&M instructors and care-givers	0.86	0.38	7
	Accessibility experts	0.88	1.36	8
	Total	0.87	0.99	15
Distance estimation	O&M instructors and care-givers	2.71	1.60	7
	Accessibility experts	2.25	1.49	8
	Total	2.47	1.51	15

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	Expert	**Mean**	**Std. Deviation**	**N**
Freq: University	O&M instructors and care-givers	1.43	1.13	7
	Accessibility experts	3.25	2.19	8
	Total	2.40	1.96	15
Freq: Hospital	O&M instructors and care-givers	1.43	1.13	7
	Accessibility experts	1.25	0.46	8
	Total	1.33	0.82	15
Freq: Department Store	O&M instructors and care-givers	1.57	1.13	7
	Accessibility experts	2.38	1.06	8
	Total	2.00	1.13	15
Freq: Museum	O&M instructors and care-givers	1.43	1.13	7
	Accessibility experts	1.13	0.35	8
	Total	1.27	0.80	15
Freq: Airport	O&M instructors and care-givers	1.43	1.13	7
	Accessibility experts	0.88	0.35	8
	Total	1.13	0.83	15
Difficulty: University	O&M instructors and care-givers	2.14	0.69	7
	Accessibility experts	2.25	0.46	8
	Total	2.20	0.56	15
Difficulty: Hospital	O&M instructors and care-givers	2.86	0.38	7
	Accessibility experts	2.63	0.52	8
	Total	2.73	0.46	15
Difficulty: Department Store	O&M instructors and care-givers	1.86	0.69	7
	Accessibility experts	2.50	0.54	8
	Total	2.20	0.68	15
Difficulty: Museum	O&M instructors and care-givers	2.43	0.79	7
	Accessibility experts	2.50	0.54	8
	Total	2.47	0.64	15
Difficulty: Airport	O&M instructors and care-givers	1.86	0.69	7
	Accessibility experts	2.38	0.52	8
	Total	2.13	0.64	15
Confidence: Wide open	O&M instructors and care-givers	0.57	0.98	7

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	Expert	**Mean**	**Std. Deviation**	**N**
	Accessibility experts	0.00	0.00	8
	Total	0.27	0.70	15
Confidence: Hallway	O&M instructors and care-givers	0.86	1.07	7
	Accessibility experts	0.75	1.04	8
	Total	0.80	1.01	15
Confidence: Room	O&M instructors and care-givers	1.29	0.95	7
	Accessibility experts	1.25	0.89	8
	Total	1.27	0.88	15
Confidence: Large room	O&M instructors and care-givers	0.57	0.98	7
	Accessibility experts	0.25	0.46	8
	Total	0.40	0.74	15
Help: Ask for direction	O&M instructors and care-givers	1.00	0.00	7
	Accessibility experts	1.00	0.00	8
	Total	1.00	0.00	15
Help: Information confusing	O&M instructors and care-givers	0.43	0.54	7
	Accessibility experts	1.00	0.00	8
	Total	0.73	0.46	15
Hazards: Gound Obstacles	O&M instructors and care-givers	2.14	1.07	7
	Accessibility experts	2.38	0.52	8
	Total	2.27	0.80	15
Hazards: Body Obstacles	O&M instructors and care-givers	2.00	1.00	7
	Accessibility experts	2.50	0.76	8
	Total	2.27	0.88	15
Hazards: Head Obstacles	O&M instructors and care-givers	1.71	1.11	7
	Accessibility experts	2.25	0.89	8
	Total	2.00	1.00	15
Hazards: Noise	O&M instructors and care-givers	2.43	1.27	7
	Accessibility experts	2.75	1.39	8
	Total	2.60	1.30	15
Hazards: Silence	O&M instructors and care-givers	1.57	1.27	7
	Accessibility experts	1.00	0.93	8

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	Expert	Mean	Std. Deviation	N
	Total	1.27	1.10	15
Hazards: Light	O&M instructors and care-givers	1.71	1.38	7
	Accessibility experts	1.25	1.17	8
	Total	1.47	1.25	15
Hazards: Moving Obstacles	O&M instructors and care-givers	2.43	0.79	7
	Accessibility experts	2.75	1.04	8
	Total	2.60	0.91	15

Table D.11: OMC vs. ACC: Multivariate Test

Effect		Value	F	Hypothesis df	Error df	p
Intercept	Pillai's Trace	1.00	4414.87	13.00	1.00	0.012
	Wilks' Lambda	1.00	4414.87	13.00	1.00	0.012
	Hotelling's Trace	57393.35	4414.87	13.00	1.00	0.012
	Roy's Largest Root	57393.35	4414.87	13.00	1.00	0.012
OMC vs. AC	Pillai's Trace	0.99	9.31	13.00	1.00	0.252
	Wilks' Lambda	0.01	9.31	13.00	1.00	0.252
	Hotelling's Trace	121.07	9.31	13.00	1.00	0.252
	Roy's Largest Root	121.07	9.31	13.00	1.00	0.252

Table D.12: OMC vs. ACC: Tests of Between-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	*p*
Corrected Model	Building Profile	8.00^a	1.00	8.00	11.65	0.005
	Floor Layout	0.34^b	1.00	0.34	0.68	0.425
	Floor Number	0.12^c	1.00	0.12	0.48	0.500
	Room Number	0.12^d	1.00	0.12	0.30	0.595
	Toilet and Bathroom	0.80^e	1.00	0.80	1.51	0.241
	Entrance and Exit	0.00^f	1.00	0.00	0.02	0.887
	Door	0.87^g	1.00	0.87	2.38	0.147
	Emergency Exit	2.10^h	1.00	2.10	7.80	0.015
	Lighting	2.10^i	1.00	2.10	0.93	0.354
	WiFi Coverage	15.20^j	1.00	15.20	16.84	0.001
	Walkable Path	0.00^k	1.00	0.00	0.00	0.975
	Tactile Pavement	0.01^l	1.00	0.01	0.04	0.847
	Stairs	0.12^d	1.00	0.12	0.30	0.595
	Steps, Dropoff, Curb	0.02^m	1.00	0.02	0.07	0.800
	Elevator	0.34^n	1.00	0.34	0.97	0.342

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Escalator	0.63^{o}	1.00	0.63	1.30	0.275
	Event and Exhibition	2.00^{p}	1.00	2.00	3.36	0.090
	Furniture	0.58^{q}	1.00	0.58	1.72	0.212
	Dangerous area	0.17^{r}	1.00	0.17	0.41	0.533
	People	1.46^{s}	1.00	1.46	1.92	0.189
	Weather	1.63^{t}	1.00	1.63	1.22	0.289
	Reception	0.53^{u}	1.00	0.53	0.26	0.616
	Noise	1.72^{v}	1.00	1.72	1.99	0.182
	White cane	5.19^{w}	1.00	5.19	2.90	0.112
	Guide dog	1.14^{x}	1.00	1.14	0.56	0.468
	Sighted Guide	6.34^{y}	1.00	6.34	2.53	0.136
	Tactile map	0.00^{z}	1.00	0.00	0.00	0.974
	Distance estimation	0.80^{aa}	1.00	0.80	0.34	0.571
	Freq: University	12.39^{ab}	1.00	12.39	3.91	0.070
	Freq: Hospital	0.12^{ac}	1.00	0.12	0.17	0.689
	Freq: Department Store	2.41^{ad}	1.00	2.41	2.01	0.180
	Freq: Museum	0.34^{ae}	1.00	0.34	0.52	0.483
	Freq: Airport	1.14^{af}	1.00	1.14	1.73	0.211
	Difficulty: University	0.04^{ag}	1.00	0.04	0.13	0.726
	Difficulty: Hospital	0.20^{ah}	1.00	0.20	0.96	0.346
	Difficulty: Department Store	1.54^{ai}	1.00	1.54	4.13	0.063
	Difficulty: Museum	0.02^{aj}	1.00	0.02	0.04	0.838
	Difficulty: Airport	1.00^{ak}	1.00	1.00	2.75	0.121
	Confidence: Wide open	1.22^{al}	1.00	1.22	2.77	0.120
	Confidence: Hallway	0.04^{am}	1.00	0.04	0.04	0.847
	Confidence: Room	0.00^{an}	1.00	0.00	0.01	0.941
	Confidence: Large room	0.39^{ao}	1.00	0.39	0.70	0.420
	Help: Ask for direction	0.00^{ap}	1.00	0.00	0.00	0.000
	Help: Information confusing	1.22^{aq}	1.00	1.22	9.24	0.009
	Hazards: Gound Obstacles	0.20^{ar}	1.00	0.20	0.30	0.593
	Hazards: Body Obstacles	0.93^{as}	1.00	0.93	1.21	0.291
	Hazards: Head Obstacles	1.07^{at}	1.00	1.07	1.08	0.318
	Hazards: Noise	0.39^{au}	1.00	0.39	0.22	0.650
	Hazards: Silence	1.22^{av}	1.00	1.22	1.01	0.334
	Hazards: Light	0.80^{aw}	1.00	0.80	0.50	0.492
	Hazards: Moving Obstacles	0.39^{ax}	1.00	0.39	0.45	0.515
Intercept	Building Profile	236.80	1.00	236.80	344.79	0.000
	Floor Layout	273.14	1.00	273.14	538.89	0.000
	Floor Number	324.39	1.00	324.39	1311.96	0.000
	Room Number	324.39	1.00	324.39	808.74	0.000
	Toilet and Bathroom	300.00	1.00	300.00	562.90	0.000
	Entrance and Exit	334.40	1.00	334.40	1484.43	0.000
	Door	318.20	1.00	318.20	874.15	0.000
	Emergency Exit	319.43	1.00	319.43	1186.47	0.000
	Lighting	102.90	1.00	102.90	45.35	0.000
	WiFi Coverage	146.67	1.00	146.67	162.52	0.000

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Walkable Path	255.20	1.00	255.20	210.88	0.000
	Tactile Pavement	315.74	1.00	315.74	1143.59	0.000
	Stairs	281.19	1.00	281.19	701.04	0.000
	Steps, Dropoff, Curb	307.22	1.00	307.22	1075.27	0.000
	Elevator	273.14	1.00	273.14	773.73	0.000
	Escalator	248.63	1.00	248.63	512.75	0.000
	Event and Exhibition	182.00	1.00	182.00	306.00	0.000
	Furniture	232.58	1.00	232.58	693.92	0.000
	Dangerous area	316.97	1.00	316.97	759.06	0.000
	People	203.06	1.00	203.06	267.32	0.000
	Weather	130.43	1.00	130.43	97.99	0.000
	Reception	217.06	1.00	217.06	109.05	0.000
	Noise	249.72	1.00	249.72	289.48	0.000
	White cane	258.52	1.00	258.52	144.77	0.000
	Guide dog	10.74	1.00	10.74	5.25	0.039
	Sighted Guide	155.14	1.00	155.14	61.89	0.000
	Tactile map	11.20	1.00	11.20	10.60	0.006
	Distance estimation	92.00	1.00	92.00	38.67	0.000
	Freq: University	81.72	1.00	81.72	25.78	0.000
	Freq: Hospital	26.79	1.00	26.79	37.79	0.000
	Freq: Department Store	58.14	1.00	58.14	48.49	0.000
	Freq: Museum	24.34	1.00	24.34	36.85	0.000
	Freq: Airport	19.81	1.00	19.81	29.98	0.000
	Difficulty: University	72.04	1.00	72.04	214.95	0.000
	Difficulty: Hospital	112.20	1.00	112.20	533.87	0.000
	Difficulty: Department Store	70.88	1.00	70.88	189.70	0.000
	Difficulty: Museum	90.69	1.00	90.69	206.31	0.000
	Difficulty: Airport	66.87	1.00	66.87	183.70	0.000
	Confidence: Wide open	1.22	1.00	1.22	2.77	0.120
	Confidence: Hallway	9.64	1.00	9.64	8.73	0.011
	Confidence: Room	24.00	1.00	24.00	28.55	0.000
	Confidence: Large room	2.52	1.00	2.52	4.54	0.053
	Help: Ask for direction	14.93	1.00	14.93	0.00	0.000
	Help: Information confusing	7.62	1.00	7.62	57.78	0.000
	Hazards: Gound Obstacles	76.20	1.00	76.20	113.44	0.000
	Hazards: Body Obstacles	75.60	1.00	75.60	98.28	0.000
	Hazards: Head Obstacles	58.67	1.00	58.67	59.00	0.000
	Hazards: Noise	100.12	1.00	100.12	56.07	0.000
	Hazards: Silence	24.69	1.00	24.69	20.42	0.001
	Hazards: Light	32.80	1.00	32.80	20.38	0.001
	Hazards: Moving Obstacles	100.12	1.00	100.12	116.06	0.000
Experts	Building Profile	8.00	1.00	8.00	11.65	0.005
	Floor Layout	0.34	1.00	0.34	0.68	0.425
	Floor Number	0.12	1.00	0.12	0.48	0.500
	Room Number	0.12	1.00	0.12	0.30	0.595
	Toilet and Bathroom	0.80	1.00	0.80	1.51	0.241

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Entrance and Exit	0.00	1.00	0.00	0.02	0.887
	Door	0.87	1.00	0.87	2.38	0.147
	Emergency Exit	2.10	1.00	2.10	7.80	0.015
	Lighting	2.10	1.00	2.10	0.93	0.354
	WiFi Coverage	15.20	1.00	15.20	16.84	0.001
	Walkable Path	0.00	1.00	0.00	0.00	0.975
	Tactile Pavement	0.01	1.00	0.01	0.04	0.847
	Stairs	0.12	1.00	0.12	0.30	0.595
	Steps, Dropoff, Curb	0.02	1.00	0.02	0.07	0.800
	Elevator	0.34	1.00	0.34	0.97	0.342
	Escalator	0.63	1.00	0.63	1.30	0.275
	Event and Exhibition	2.00	1.00	2.00	3.36	0.090
	Furniture	0.58	1.00	0.58	1.72	0.212
	Dangerous area	0.17	1.00	0.17	0.41	0.533
	People	1.46	1.00	1.46	1.92	0.189
	Weather	1.63	1.00	1.63	1.22	0.289
	Reception	0.52	1.00	0.52	0.26	0.616
	Noise	1.72	1.00	1.72	1.99	0.182
	White cane	5.19	1.00	5.19	2.90	0.112
	Guide dog	1.14	1.00	1.14	0.56	0.468
	Sighted Guide	6.34	1.00	6.34	2.53	0.136
	Tactile map	0.00	1.00	0.00	0.00	0.974
	Distance estimation	0.80	1.00	0.80	0.34	0.571
	Freq: University	12.39	1.00	12.39	3.91	0.070
	Freq: Hospital	0.12	1.00	0.12	0.17	0.689
	Freq: Department Store	2.41	1.00	2.41	2.01	0.180
	Freq: Museum	0.34	1.00	0.34	0.52	0.483
	Freq: Airport	1.14	1.00	1.14	1.73	0.211
	Difficulty: University	0.04	1.00	0.04	0.13	0.726
	Difficulty: Hospital	0.20	1.00	0.20	0.96	0.346
	Difficulty: Department Store	1.54	1.00	1.54	4.13	0.063
	Difficulty: Museum	0.02	1.00	0.02	0.04	0.838
	Difficulty: Airport	1.00	1.00	1.00	2.75	0.121
	Confidence: Wide open	1.22	1.00	1.22	2.77	0.120
	Confidence: Hallway	0.04	1.00	0.04	0.04	0.847
	Confidence: Room	0.00	1.00	0.00	0.01	0.941
	Confidence: Large room	0.39	1.00	0.39	0.70	0.420
	Help: Ask for direction	0.00	1.00	0.00	0.00	0.000
	Help: Information confusing	1.22	1.00	1.22	9.24	0.009
	Hazards: Gound Obstacles	0.20	1.00	0.20	0.30	0.593
	Hazards: Body Obstacles	0.93	1.00	0.93	1.21	0.291
	Hazards: Head Obstacles	1.07	1.00	1.07	1.08	0.318
	Hazards: Noise	0.39	1.00	0.39	0.22	0.650
	Hazards: Silence	1.22	1.00	1.22	1.01	0.334
	Hazards: Light	0.80	1.00	0.80	0.50	0.492
	Hazards: Moving Obstacles	0.39	1.00	0.39	0.45	0.515

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Error	Building Profile	8.93	13.00	0.69		
	Floor Layout	6.59	13.00	0.51		
	Floor Number	3.21	13.00	0.25		
	Room Number	5.21	13.00	0.40		
	Toilet and Bathroom	6.93	13.00	0.53		
	Entrance and Exit	2.93	13.00	0.23		
	Door	4.73	13.00	0.36		
	Emergency Exit	3.50	13.00	0.27		
	Lighting	29.50	13.00	2.27		
	WiFi Coverage	11.73	13.00	0.90		
	Walkable Path	15.73	13.00	1.21		
	Tactile Pavement	3.59	13.00	0.28		
	Stairs	5.21	13.00	0.40		
	Steps, Dropoff, Curb	3.71	13.00	0.29		
	Elevator	4.59	13.00	0.35		
	Escalator	6.30	13.00	0.48		
	Event and Exhibition	7.73	13.00	0.59		
	Furniture	4.36	13.00	0.34		
	Dangerous area	5.43	13.00	0.42		
	People	9.88	13.00	0.76		
	Weather	17.30	13.00	1.33		
	Reception	25.87	13.00	1.99		
	Noise	11.21	13.00	0.86		
	White cane	23.21	13.00	1.79		
	Guide dog	26.59	13.00	2.05		
	Sighted Guide	32.59	13.00	2.51		
	Tactile map	13.73	13.00	1.06		
	Distance estimation	30.93	13.00	2.38		
	Freq: University	41.21	13.00	3.17		
	Freq: Hospital	9.21	13.00	0.71		
	Freq: Department Store	15.59	13.00	1.20		
	Freq: Museum	8.59	13.00	0.66		
	Freq: Airport	8.59	13.00	0.66		
	Difficulty: University	4.36	13.00	0.34		
	Difficulty: Hospital	2.73	13.00	0.21		
	Difficulty: Department Store	4.86	13.00	0.37		
	Difficulty: Museum	5.71	13.00	0.44		
	Difficulty: Airport	4.73	13.00	0.36		
	Confidence: Wide open	5.71	13.00	0.44		
	Confidence: Hallway	14.36	13.00	1.10		
	Confidence: Room	10.93	13.00	0.84		
	Confidence: Large room	7.21	13.00	0.55		
	Help: Ask for direction	0.00	13.00	0.00		
	Help: Information confusing	1.71	13.00	0.13		
	Hazards: Gound Obstacles	8.73	13.00	0.67		
	Hazards: Body Obstacles	10.00	13.00	0.77		

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Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Hazards: Head Obstacles	12.93	13.00	0.99		
	Hazards: Noise	23.21	13.00	1.79		
	Hazards: Silence	15.71	13.00	1.21		
	Hazards: Light	20.93	13.00	1.61		
	Hazards: Moving Obstacles	11.21	13.00	0.86		
Total	Building Profile	249.00	15.00			
	Floor Layout	280.00	15.00			
	Floor Number	330.00	15.00			
	Room Number	332.00	15.00			
	Toilet and Bathroom	307.00	15.00			
	Entrance and Exit	339.00	15.00			
	Door	323.00	15.00			
	Emergency Exit	323.00	15.00			
	Lighting	133.00	15.00			
	WiFi Coverage	168.00	15.00			
	Walkable Path	272.00	15.00			
	Tactile Pavement	321.00	15.00			
	Stairs	287.00	15.00			
	Steps, Dropoff, Curb	312.00	15.00			
	Elevator	278.00	15.00			
	Escalator	255.00	15.00			
	Event and Exhibition	190.00	15.00			
	Furniture	237.00	15.00			
	Dangerous area	323.00	15.00			
	People	213.00	15.00			
	Weather	148.00	15.00			
	Reception	243.00	15.00			
	Noise	261.00	15.00			
	White cane	293.00	15.00			
	Guide dog	39.00	15.00			
	Sighted Guide	199.00	15.00			
	Tactile map	25.00	15.00			
	Distance estimation	123.00	15.00			
	Freq: University	140.00	15.00			
	Freq: Hospital	36.00	15.00			
	Freq: Department Store	78.00	15.00			
	Freq: Museum	33.00	15.00			
	Freq: Airport	29.00	15.00			
	Difficulty: University	77.00	15.00			
	Difficulty: Hospital	115.00	15.00			
	Difficulty: Department Store	79.00	15.00			
	Difficulty: Museum	97.00	15.00			
	Difficulty: Airport	74.00	15.00			
	Confidence: Wide open	8.00	15.00			
	Confidence: Hallway	24.00	15.00			
	Confidence: Room	35.00	15.00			

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Confidence: Large room	10.00	15.00			
	Help: Ask for direction	15.00	15.00			
	Help: Information confusing	11.00	15.00			
	Hazards: Gound Obstacles	86.00	15.00			
	Hazards: Body Obstacles	88.00	15.00			
	Hazards: Head Obstacles	74.00	15.00			
	Hazards: Noise	125.00	15.00			
	Hazards: Silence	41.00	15.00			
	Hazards: Light	54.00	15.00			
	Hazards: Moving Obstacles	113.00	15.00			
Corrected Total	Building Profile	16.93	14.00			
	Floor Layout	6.93	14.00			
	Floor Number	3.33	14.00			
	Room Number	5.33	14.00			
	Toilet and Bathroom	7.73	14.00			
	Entrance and Exit	2.93	14.00			
	Door	5.60	14.00			
	Emergency Exit	5.60	14.00			
	Lighting	31.60	14.00			
	WiFi Coverage	26.93	14.00			
	Walkable Path	15.73	14.00			
	Tactile Pavement	3.60	14.00			
	Stairs	5.33	14.00			
	Steps, Dropoff, Curb	3.73	14.00			
	Elevator	4.93	14.00			
	Escalator	6.93	14.00			
	Event and Exhibition	9.73	14.00			
	Furniture	4.93	14.00			
	Dangerous area	5.60	14.00			
	People	11.33	14.00			
	Weather	18.93	14.00			
	Reception	26.40	14.00			
	Noise	12.93	14.00			
	White cane	28.40	14.00			
	Guide dog	27.73	14.00			
	Sighted Guide	38.93	14.00			
	Tactile map	13.73	14.00			
	Distance estimation	31.73	14.00			
	Freq: University	53.60	14.00			
	Freq: Hospital	9.33	14.00			
	Freq: Department Store	18.00	14.00			
	Freq: Museum	8.93	14.00			
	Freq: Airport	9.73	14.00			
	Difficulty: University	4.40	14.00			
	Difficulty: Hospital	2.93	14.00			
	Difficulty: Department Store	6.40	14.00			

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Source		Type III Sum of Squares	df	Mean Square	F	*p*
	Difficulty: Museum	5.73	14.00			
	Difficulty: Airport	5.73	14.00			
	Confidence: Wide open	6.93	14.00			
	Confidence: Hallway	14.40	14.00			
	Confidence: Room	10.93	14.00			
	Confidence: Large room	7.60	14.00			
	Help: Ask for direction	0.00	14.00			
	Help: Information confusing	2.93	14.00			
	Hazards: Gound Obstacles	8.93	14.00			
	Hazards: Body Obstacles	10.93	14.00			
	Hazards: Head Obstacles	14.00	14.00			
	Hazards: Noise	23.60	14.00			
	Hazards: Silence	16.93	14.00			
	Hazards: Light	21.73	14.00			
	Hazards: Moving Obstacles	11.60	14.00			

[a] R Squared = 0.47 (Adjusted R Squared = 0.43)
[b] R Squared = 0.05 (Adjusted R Squared = -0.02)
[c] R Squared = 0.04 (Adjusted R Squared = -0.04)
[d] R Squared = 0.02 (Adjusted R Squared = -0.05)
[e] R Squared = 0.10 (Adjusted R Squared = 0.04)
[f] R Squared = 0.00 (Adjusted R Squared = -0.08)
[g] R Squared = 0.16 (Adjusted R Squared = 0.09)
[h] R Squared = 0.38 (Adjusted R Squared = 0.33)
[i] R Squared = 0.07 (Adjusted R Squared = -0.01)
[j] R Squared = 0.56 (Adjusted R Squared = 0.53)
[k] R Squared = 0.00 (Adjusted R Squared = -0.08)
[l] R Squared = 0.00 (Adjusted R Squared = -0.07)
[m] R Squared = 0.00 (Adjusted R Squared = -0.07)
[n] R Squared = 0.07 (Adjusted R Squared = 0.00)
[o] R Squared = 0.09 (Adjusted R Squared = 0.02)
[p] R Squared = 0.21 (Adjusted R Squared = 0.14)
[q] R Squared = 0.12 (Adjusted R Squared = 0.05)
[r] R Squared = 0.03 (Adjusted R Squared = -0.04)
[s] R Squared = 0.13 (Adjusted R Squared = 0.06)
[t] R Squared = 0.09 (Adjusted R Squared = 0.02)
[u] R Squared = 0.02 (Adjusted R Squared = -0.06)
[v] R Squared = 0.13 (Adjusted R Squared = 0.07)
[w] R Squared = 0.18 (Adjusted R Squared = 0.12)
[x] R Squared = 0.04 (Adjusted R Squared = -0.03)
[y] R Squared = 0.16 (Adjusted R Squared = 0.10)
[z] R Squared = 0.00 (Adjusted R Squared = -0.08)
[aa] R Squared = 0.03 (Adjusted R Squared = -0.05)
[ab] R Squared = 0.23 (Adjusted R Squared = 0.17)
[ac] R Squared = 0.01 (Adjusted R Squared = -0.06)
[ad] R Squared = 0.13 (Adjusted R Squared = 0.07)
[ae] R Squared = 0.04 (Adjusted R Squared = -0.04)
[af] R Squared = 0.12 (Adjusted R Squared = 0.05)
[ag] R Squared = 0.01 (Adjusted R Squared = -0.07)
[ah] R Squared = 0.07 (Adjusted R Squared = 0.00)
[ai] R Squared = 0.24 (Adjusted R Squared = 0.18)
[aj] R Squared = 0.00 (Adjusted R Squared = -0.07)
[ak] R Squared = 0.18 (Adjusted R Squared = 0.11)
[al] R Squared = 0.18 (Adjusted R Squared = 0.11)
[am] R Squared = 0.00 (Adjusted R Squared = -0.07)
[an] R Squared = 0.00 (Adjusted R Squared = -0.08)
[ao] R Squared = 0.05 (Adjusted R Squared = -0.02)
[ap] R Squared = 0.00 (Adjusted R Squared = 0.00)
[aq] R Squared = 0.42 (Adjusted R Squared = 0.37)
[ar] R Squared = 0.02 (Adjusted R Squared = -0.05)
[as] R Squared = 0.09 (Adjusted R Squared = 0.015)
[at] R Squared = 0.08 (Adjusted R Squared = 0.005)
[au] R Squared = 0.02 (Adjusted R Squared = -0.06)
[av] R Squared = 0.07 (Adjusted R Squared = 0.00)
[aw] R Squared = 0.04 (Adjusted R Squared = -0.04)
[ax] R Squared = 0.03 (Adjusted R Squared = -0.04)

D.2 Chi-square: Assistances Survey

Table D.13: Assistances Survey: Case Processing Summary

	Valid		Missing		Total	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * White cane	45	100.00%	0	0.0%	45	100.00%
Groups * Guide dog	45	100.00%	0	0.0%	45	100.00%
Groups * Sighted Guide	45	100.00%	0	0.0%	45	100.00%
Groups * Tactile map	45	100.00%	0	0.0%	45	100.00%

D.2.1 White cane

Table D.14: White cane - Crosstab

		NEV	**OCC**	**OAM**	**OAW**	**FAW**	**EVD**	**Total**
Visually Impaired	Count	4^a	9^a	1^a	4^a	7^a	5^a	30
	% within Groups	13.3%	30.0%	3.3%	13.3%	23.3%	16.7%	100.0%
Sighted	Count	0^a	2^a	0^a	1^a	2^a	10^a	15
	% within Groups	0.0%	13.3%	0.0%	6.7%	13.3%	66.7%	100.0%
Total	Count	4	11	1	5	9	15	45
	% within Groups	8.9%	24.4%	2.2%	11.1%	20.0%	33.3%	100.0%

[*] Each subscript letter denotes a subset of White cane categories whose column proportions do not differ significantly from each other at the 0.05 level.
NEV Never
OCC Occasionally
OAM Once a month
OAW Once a week
FAW Few a week
EVD Every day

Table D.15: White cane - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	12.04^a	5	0.034
Likelihood Ratio	13.22	5	0.021
Linear-by-Linear Association	8.17	1	0.004
N of Valid Cases	45		

[a] 8 cells (66.7%) have expected count less than 5. The minimum expected count is 0.33.

D.2.2 Guide dog

TABLE D.16: Guide dog - Crosstab

		NEV	**OCC**	**OAM**	**OAW**	**EVD**	**Total**
Visually Impaired	Count	26^a	2^a	1^a	0^a	1^a	30
	% within Groups	86.7%	6.7%	3.3%	0.0%	3.3%	100.0%
Sighted	Count	8^a	5^a	0^a	1^a	1^a	15
	% within Groups	53.3%	33.3%	0.0%	6.7%	6.7%	100.0%
Total	Count	34	7	1	1	2	45
	% within Groups	75.6%	15.6%	2.2%	2.2%	4.4%	100.0%

[*] Each subscript letter denotes a subset of Guide dog categories whose column proportions do not differ significantly from each other at the 0.05 level.
NEV Never
OCC Occasionally
OAM Once a month
OAW Once a week
FAW Few a week
EVD Every day

TABLE D.17: Guide dog - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	8.79^a	4	0.067
Likelihood Ratio	9.04	4	0.060
Linear-by-Linear Association	2.39	1	0.123
N of Valid Cases	45		

[a] 8 cells (80.0%) have expected count less than 5. The minimum expected count is 0.33.

D.2.3 Sighted guide

Table D.18: Sighted guide - Crosstab

		NEV	**OCC**	**OAM**	**OAW**	**FAW**	**EVD**	**Total**
Visually Impaired	Count	3^a	3^a	0^a	2^a	10^a	12^a	30
	% within Groups	10.0%	10.0%	0.0%	6.7%	33.3%	40.0%	100.0%
Sighted	Count	0^a	4^a	1^a	2^a	3^a	5^a	15
	% within Groups	0.0%	26.7%	6.7%	13.3%	20.0%	33.3%	100.0%
Total	Count	3	7	1	4	13	17	45
	% within Groups	6.7%	15.6%	2.2%	8.9%	28.9%	37.8%	100.0%

[*] Each subscript letter denotes a subset of Tactile map categories whose column proportions do not differ significantly from each other at the 0.05 level.

NEV Never
OCC Occasionally
OAM Once a month
OAW Once a week
FAW Few a week
EVD Every day

Table D.19: Sighted guide - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	6.52^a	5	0.259
Likelihood Ratio	7.54	5	0.184
Linear-by-Linear Association	0.47	1	0.492
N of Valid Cases	45		

[a] 9 cells (75.0%) have expected count less than 5. The minimum expected count is 0.33.

D.2.4 Tactile map

Table D.20: Tactile map - Crosstab

		NEV	**OCC**	**OAM**	**OAW**	**FAW**	**EVD**	**Total**
Visually Impaired	Count	26^a	3b	1a, b	0a, b	30		
	% within Groups	86.7%	10.0%	3.3%	0.0%	100.0%		
Sighted	Count	5^a	9b	0a, b	1a, b	15		
	% within Groups	33.3%	60.0%	0.0%	6.7%	100.0%		
Total	Count	31	12	1	1	45		
	% within Groups	68.9%	26.7%	2.2%	2.2%	100.0%		

[*] Each subscript letter denotes a subset of Sighted guide categories whose column proportions do not differ significantly from each other at the 0.05 level.

NEV Never
OCC Occasionally
OAM Once a month
OAW Once a week
FAW Few a week
EVD Every day

Table D.21: Tactile map - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	16.00^a	3	0.001
Likelihood Ratio	16.40	3	0.001
Linear-by-Linear Association	6.75	1	0.009
N of Valid Cases	45		

[a] 5 cells (62.5%) have expected count less than 5. The minimum expected count is 0.33.

D.3 Chi-square: Distance Estimation Survey

Table D.22: Distance Estimation Survey: Case Processing Summary

	Valid		Missing		Total	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * Distance Estimation	45	100.00%	0	0.0%	45	100.00%

Table D.23: Distance Estimation - Crosstab

		Can't estimate	**Footsteps**	**Length units**	**Time**	**Others**	**Total**
Visually Impaired	Count	3^a	9^a	1^a	4^a	13^a	30
	% within Groups	10.0%	30.0%	3.3%	13.3%	43.3%	100.0%
Sighted	Count	0^a	7^a	1^a	0^a	7^a	15
	% within Groups	0.0%	46.7%	6.7%	0.0%	46.7%	100.0%
Total	Count	3	16	2	4	20	45
	% within Groups	6.7%	35.6%	4.4%	8.9%	44.4%	100.0%

[*] Each subscript letter denotes a subset of Distance Estimation categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.24: Distance Estimation - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	4.56^a	4	0.336
Likelihood Ratio	6.69	4	0.153
Linear-by-Linear Association	0.00	1	0.945
N of Valid Cases	45		

[a] 6 cells (60.0%) have expected count less than 5. The minimum expected count is 0.67.

D.4 Chi-square: Wayfinding Survey

Table D.25: Wayfinding Survey: Case Processing Summary

	Valid		**Missing**		**Total**	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * Find Location	45	100.00%	0	0.0%	45	100.00%
Groups * Find Way to Destination	45	100.00%	0	0.0%	45	100.00%
Groups * Find Orientation	45	100.00%	0	0.0%	45	100.00%

D.4.1 Find Location

Table D.26: Find Location - Crosstab

		Sighted People	**Landmark**	**Floor Texture**	**Environ-ment**	**Other**	**Mixed method**	**Total**
Visually Impaired	Count	11^a	9^a	3^a	1^a	1^a	5^a	30
	% within Groups	36.7%	30.0%	10.0%	3.3%	3.3%	16.7%	100.0%
Sighted	Count	6^a	4^a	0^a	0^a	0^a	5^a	15
	% within Groups	40.0%	26.7%	0.0%	0.0%	0.0%	33.3%	100.0%
Total	Count	17	13	3	1	1	10	45
	% within Groups	37.8%	28.9%	6.7%	2.2%	2.2%	22.2%	100.0%

[*] Each subscript letter denotes a subset of Wayfinding: Find Location categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.27: Find Location - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	3.82^a	5	0.576
Likelihood Ratio	5.30	5	0.380
Linear-by-Linear Association	0.44	1	0.508
N of Valid Cases	45		

[a] 8 cells (66.7%) have expected count less than 5. The minimum expected count is 0.33.

D.4.2 Find Way to Destination

Table D.28: Find Way to Destination - Crosstab

		Sighted People	**Landmark**	**Floor Texture**	**Mixed method**	**Total**
Visually Impaired	Count	21^a	3^a	4^a	2^a	30
	% within Groups	70.0%	10.0%	13.3%	6.7%	100.0%
Sighted	Count	8^a	0^a	1^a	6^a	15
	% within Groups	53.3%	0.0%	6.7%	40.0%	100.0%
Total	Count	29	3	5	8	45
	% within Groups	64.4%	6.7%	11.1%	17.8%	100.0%

[*] Each subscript letter denotes a subset of Wayfinding: Find Way to Destination categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.29: Find Way to Destination - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	8.58^a	3	0.035
Likelihood Ratio	9.12	3	0.028
Linear-by-Linear Association	6.01	1	0.014
N of Valid Cases	45		

[a] 5 cells (62.5%) have expected count less than 5. The minimum expected count is 1.00.

D.4.3 Find Orientation

Table D.30: Find Orientation - Crosstab

		Sighted People	Landmark	Floor Texture	Environ-ment	Sense & Feeling	Other	Mixed method	Total
Visually Impaired	Count	12^a	8^a	0^a	4^a	1^a	1^a	4^a	30
	% within Groups	40.0%	26.7%	0.0%	13.3%	3.3%	3.3%	13.3%	100.0%
Sighted	Count	3^a	2^a	1^a	2^a	0^a	1^a	6^a	15
	% within Groups	20.0%	13.3%	6.7%	13.3%	0.0%	6.7%	40.0%	100.0%
Total	Count	15	10	1	6	1	2	10	45
	% within Groups	33.3%	22.2%	2.2%	13.3%	2.2%	4.4%	22.2%	100.0%

[*] Each subscript letter denotes a subset of Wayfinding: Find Orientation categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.31: Find Orientation - Chi-Square Tests

	Value	df	p
Pearson Chi-Square	7.95^a	6	0.242
Likelihood Ratio	8.40	6	0.211
Linear-by-Linear Association	4.63	1	0.031
N of Valid Cases	45		

[a] 10 cells (71.4%) have expected count less than 5. The minimum expected count is 0.33.

D.5 Chi-square: Asking for Assistance Survey

Table D.32: Asking for Assistance Survey: Case Processing Summary

	Valid		Missing		Total	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * Ask for Direction	45	100.00%	0	0.0%	45	100.00%
Groups * Confusing Information	45	100.00%	0	0.0%	45	100.00%

D.5.1 Ask for Assistance

Table D.33: Ask for Direction - Crosstab

		No	**Yes**	**Total**
Visually Impaired	Count	4^a	26^a	30
	% within Groups	13.3%	86.7%	100.0%
Sighted	Count	0^a	15^a	15
	% within Groups	0.0%	100.0%	100.0%
Total	Count	4	41	45
	% within Groups	8.9%	91.1%	100.0%

[*] Each subscript letter denotes a subset of Help: Ask for Direction categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.34: Ask for Direction - Chi-Square Tests

	Value	**df**	***p***	**Exact *p* (2-sided)**	**Exact *p* (1-sided)**
Pearson Chi-Square	2.20^a	1	0.138		
Continuity Correction[b]	0.86	1	0.354		
Likelihood Ratio	3.44	1	0.064		
Fisher's Exact Test				0.285	0.184
Linear-by-Linear Association	2.15	1	0.143		
N of Valid Cases	45				

[a] 2 cells (50.0%) have expected count less than 5. The minimum expected count is 1.33.
[b] Computed only for a 2x2 table

D.5.2 Confusing Information

TABLE D.35: Confusing Information - Crosstab

		No	**Yes**	**Total**
Visually Impaired	Count	13^a	17^a	30
	% within Groups	43.3%	56.7%	100.0%
Sighted	Count	4^a	11^a	15
	% within Groups	26.7%	73.3%	100.0%
Total	Count	17	28	45
	% within Groups	37.8%	62.2%	100.0%

[*] Each subscript letter denotes a subset of Help: Confusing Information categories whose column proportions do not differ significantly from each other at the 0.05 level.

TABLE D.36: Confusing Information - Chi-Square Tests

	Value	**df**	***p***	**Exact *p* (2-sided)**	**Exact *p* (1-sided)**
Pearson Chi-Square	1.18^a	1	0.277		
Continuity Correction[b]	0.58	1	0.447		
Likelihood Ratio	1.22	1	0.270		
Fisher's Exact Test				0.341	0.225
Linear-by-Linear Association	1.16	1	0.282		
N of Valid Cases	45				

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.67.
[b] Computed only for a 2x2 table

D.6 Chi-square: Difficulty in Spaces Survey

Table D.37: Difficulty in Spaces Survey: Case Processing Summary

	Valid		Missing		Total	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * Difficult in University	45	100.00%	0	0.0%	45	100.00%
Groups * Difficult in Hospital	45	100.00%	0	0.0%	45	100.00%
Groups * Difficult in Department Store	45	100.00%	0	0.0%	45	100.00%
Groups * Difficult in Museum	45	100.00%	0	0.0%	45	100.00%
Groups * Difficult in Airport	45	100.00%	0	0.0%	45	100.00%

D.6.1 University

Table D.38: University - Crosstab

		Easy	**Medium**	**Hard**	**Total**
Visually Impaired	Count	3^a	9^a	18^a	30
	% within Groups	10.0%	30.0%	60.0%	100.0%
Sighted	Count	1^a	10^a	4^a	15
	% within Groups	6.7%	66.7%	26.7%	100.0%
Total	Count	4	19	22	45
	% within Groups	8.9%	42.2%	48.9%	100.0%

[*] Each subscript letter denotes a subset of Difficulty: University categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.39: University - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	5.58^a	2	0.061
Likelihood Ratio	5.64	2	0.060
Linear-by-Linear Association	2.11	1	0.147
N of Valid Cases	45		

[a] 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.33.

D.6.2 Hospital

Table D.40: Hospital - Crosstab

		Easy	**Medium**	**Hard**	**Total**
Visually Impaired	Count	1^a	8^a	21^a	30
	% within Groups	3.3%	26.7%	70.0%	100.0%
Sighted	Count	0^a	4^a	11^a	15
	% within Groups	0.0%	26.7%	73.3%	100.0%
Total	Count	1	12	32	45
	% within Groups	2.2%	26.7%	71.1%	100.0%

[*] Each subscript letter denotes a subset of Difficulty: Hospital categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.41: Hospital - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	0.52^a	2	0.773
Likelihood Ratio	0.83	2	0.662
Linear-by-Linear Association	0.17	1	0.682
N of Valid Cases	45		

[a] 3 cells (50.0%) have expected count less than 5. The minimum expected count is 0.33.

D.6.3 Department Store

Table D.42: Department Store - Crosstab

		Easy	Medium	Hard	Total
Visually Impaired	Count	3^a	9^a	18^a	30
	% within Groups	10.0%	30.0%	60.0%	100.0%
Sighted	Count	2^a	8^a	5^a	15
	% within Groups	13.3%	53.3%	33.3%	100.0%
Total	Count	5	17	23	45
	% within Groups	11.1%	37.8%	51.1%	100.0%

* Each subscript letter denotes a subset of Difficulty: Department Store categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.43: Department Store - Chi-Square Tests

	Value	df	p
Pearson Chi-Square	2.93^a	2	0.231
Likelihood Ratio	2.96	2	0.227
Linear-by-Linear Association	1.90	1	0.168
N of Valid Cases	45		

[a] 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.67.

D.6.4 Museum

Table D.44: Museum - Crosstab

		Easy	**Medium**	**Hard**	**Total**
Visually Impaired	Count	2^a	7^a	21^a	30
	% within Groups	6.7%	23.3%	70.0%	100.0%
Sighted	Count	1^a	6^a	8^a	15
	% within Groups	6.7%	40.0%	53.3%	100.0%
Total	Count	3	13	29	45
	% within Groups	6.7%	28.9%	64.4%	100.0%

[*] Each subscript letter denotes a subset of Difficulty: Museum categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.45: Museum - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	1.39^a	2	0.498
Likelihood Ratio	1.36	2	0.507
Linear-by-Linear Association	0.72	1	0.396
N of Valid Cases	45		

[a] 3 cells (50.0%) have expected count less than 5. The minimum expected count is 1.00.

D.6.5 Airport

Table D.46: Airport - Crosstab

		Easy	**Medium**	**Hard**	**Total**
Visually Impaired	Count	$2^{a,b}$	7^{b}	21^{a}	30
	% within Groups	6.7%	23.3%	70.0%	100.0%
Sighted	Count	$2^{a,b}$	9^{b}	4^{a}	15
	% within Groups	13.3%	60.0%	26.7%	100.0%
Total	Count	4	16	25	45
	% within Groups	8.9%	35.6%	55.6%	100.0%

* Each subscript letter denotes a subset of Difficulty: Airport categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.47: Airport - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	7.66^{a}	2	0.022
Likelihood Ratio	7.83	2	0.020
Linear-by-Linear Association	5.73	1	0.017
N of Valid Cases	45		

[a] 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.33.

D.7 Chi-square: Confidence in Spaces Survey

TABLE D.48: Confidence in Spaces Survey: Case Processing Summary

	Valid		Missing		Total	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * Confidence in Wide open	45	100.00%	0	0.0%	45	100.00%
Groups * Confidence in Hallway	45	100.00%	0	0.0%	45	100.00%
Groups * Confidence in Room	45	100.00%	0	0.0%	45	100.00%
Groups * Confidence in Large room	45	100.00%	0	0.0%	45	100.00%

D.7.1 Wide-open Area

TABLE D.49: Wide-open Area - Crosstab

		No	**Yes**	**Total**
Visually Impaired	Count	25^a	5^a	30
	% within Groups	83.3%	16.7%	100.0%
Sighted	Count	13^a	2^a	15
	% within Groups	86.7%	13.3%	100.0%
Total	Count	38	7	45
	% within Groups	84.4%	15.6%	100.0%

[*] Each subscript letter denotes a subset of Confidence: Wide-open categories whose column proportions do not differ significantly from each other at the 0.05 level.

TABLE D.50: Wide-open Area - Chi-Square Tests

	Value	**df**	***p***	**Exact *p* (2-sided)**	**Exact *p* (1-sided)**
Pearson Chi-Square	0.08^a	1	0.771		
Continuity Correction[b]	0.00	1	1.000		
Likelihood Ratio	0.09	1	0.769		
Fisher's Exact Test				1.000	0.571
Linear-by-Linear Association	0.08	1	0.774		
N of Valid Cases	45				

[a] 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.33.
[b] Computed only for a 2x2 table

D.7.2 Hallway

Table D.51: Hallway - Crosstab

		No	Yes	Total
Visually Impaired	Count	21^a	9^a	30
	% within Groups	70.0%	30.0%	100.0%
Sighted	Count	9^a	6^a	15
	% within Groups	60.0%	40.0%	100.0%
Total	Count	30	15	45
	% within Groups	66.7%	33.3%	100.0%

* Each subscript letter denotes a subset of Confidence: Hallway categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.52: Hallway - Chi-Square Tests

	Value	df	p	Exact p (2-sided)	Exact p (1-sided)
Pearson Chi-Square	0.45^a	1	0.502		
Continuity Correction[b]	0.11	1	0.737		
Likelihood Ratio	0.44	1	0.505		
Fisher's Exact Test				0.522	0.365
Linear-by-Linear Association	0.44	1	0.507		
N of Valid Cases	45				

[a] 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.00.
[b] Computed only for a 2x2 table

D.7.3 Room

Table D.53: Room - Crosstab

		No	**Not sure, depending$^+$**	**Yes**	**Total**
Visually Impaired	Count	15^a	0^b	$15^{a,b}$	30
	% within Groups	50.0%	0.0%	50.0%	100.0%
Sighted	Count	4^a	3^b	$8^{a,b}$	15
	% within Groups	26.7%	20.0%	53.3%	100.0%
Total	Count	19	3	23	45
	% within Groups	42.2%	6.7%	51.1%	100.0%

* Each subscript letter denotes a subset of Confidence: Room categories whose column proportions do not differ significantly from each other at the 0.05 level.

\+ Depending on environment surrounding participants.

Table D.54: Room - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	7.31^a	2	0.026
Likelihood Ratio	8.01	2	0.018
Linear-by-Linear Association	0.75	1	0.386
N of Valid Cases	45		

[a] 2 cells (33.3%) have expected count less than 5. The minimum expected count is 1.00.

D.7.4 Large Room

Table D.55: Large Room - Crosstab

		No	Not sure, depending+	Yes	Total
Visually Impaired	Count	26^a	0^a	4^a	30
	% within Groups	86.7%	0.0%	13.3%	100.0%
Sighted	Count	11^a	2^a	2^a	15
	% within Groups	73.3%	13.3%	13.3%	100.0%
Total	Count	37	2	6	45
	% within Groups	82.2%	4.4%	13.3%	100.0%

[*] Each subscript letter denotes a subset of Confidence: Large Room categories whose column proportions do not differ significantly from each other at the 0.05 level.

[+] Depending on environment surrounding participants.

Table D.56: Large Room - Chi-Square Tests

	Value	df	*p*
Pearson Chi-Square	4.22^a	2	0.121
Likelihood Ratio	4.61	2	0.100
Linear-by-Linear Association	0.36	1	0.548
N of Valid Cases	45		

[a] 4 cells (66.7%) have expected count less than 5. The minimum expected count is 0.67.

D.8 Chi-square: Hazards in Spaces Survey

Table D.57: Hazards in Spaces Survey: Case Processing Summary

	Valid		Missing		Total	
	N	**Percent**	**N**	**Percent**	**N**	**Percent**
Groups * Ground Obstacles	45	100.00%	0	0.0%	45	100.00%
Groups * Body Obstacles	45	100.00%	0	0.0%	45	100.00%
Groups * Head Obstacles	45	100.00%	0	0.0%	45	100.00%
Groups * Noise	45	100.00%	0	0.0%	45	100.00%
Groups * Silence	45	100.00%	0	0.0%	45	100.00%
Groups * Light	45	100.00%	0	0.0%	45	100.00%
Groups * Moving Obstacles	45	100.00%	0	0.0%	45	100.00%

D.8.1 Ground Obstacle

Table D.58: Ground Obstacle - Crosstab

		Never	**Rare**	**Sometimes**	**Often**	**Always**	**Total**
Visually Impaired	Count	4^a	4^a	10^a	10^a	2^a	30
	% within Groups	13.3%	13.3%	33.3%	33.3%	6.7%	100.0%
Sighted	Count	1^a	0^a	8^a	6^a	0^a	15
	% within Groups	6.7%	0.0%	53.3%	40.0%	0.0%	100.0%
Total	Count	5	4	18	16	2	45
	% within Groups	11.1%	8.9%	40.0%	35.6%	4.4%	100.0%

[*] Each subscript letter denotes a subset of Hazards: Ground Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.59: Ground Obstacle - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	4.52^a	4	0.340
Likelihood Ratio	6.38	4	0.172
Linear-by-Linear Association	0.37	1	0.541
N of Valid Cases	45		

[a] 6 cells (60.0%) have expected count less than 5. The minimum expected count is 0.67.

D.8.2 Body Obstacle

Table D.60: Body Obstacle - Crosstab

		Never	**Rare**	**Sometimes**	**Often**	**Always**	**Total**
Visually Impaired	Count	4^a	3^a	8^a	12^a	3^a	30
	% within Groups	13.3%	10.0%	26.7%	40.0%	10.0%	100.0%
Sighted	Count	1^a	1^a	6^a	7^a	0^a	15
	% within Groups	6.7%	6.7%	40.0%	46.7%	0.0%	100.0%
Total	Count	5	4	14	19	3	45
	% within Groups	11.1%	8.9%	31.1%	42.2%	6.7%	100.0%

* Each subscript letter denotes a subset of Hazards: Body Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.61: Body Obstacle - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	2.70^a	4	0.609
Likelihood Ratio	3.65	4	0.455
Linear-by-Linear Association	0.01	1	0.923
N of Valid Cases	45		

[a] 7 cells (70.0%) have expected count less than 5. The minimum expected count is 1.00.

D.8.3 Head Obstacle

Table D.62: Head Obstacle - Crosstab

		Never	**Rare**	**Sometimes**	**Often**	**Always**	**Total**
Visually Impaired	Count	6^a	5^a	6^a	11^a	2^a	30
	% within Groups	20.0%	16.7%	20.0%	36.7%	6.7%	100.0%
Sighted	Count	1^a	4^a	4^a	6^a	0^a	15
	% within Groups	6.7%	26.7%	26.7%	40.0%	0.0%	100.0%
Total	Count	7	9	10	17	2	45
	% within Groups	15.6%	20.0%	22.2%	37.8%	4.4%	100.0%

[*] Each subscript letter denotes a subset of Hazards: Head Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.63: Head Obstacle - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	2.87^a	4	0.579
Likelihood Ratio	3.64	4	0.456
Linear-by-Linear Association	0.03	1	0.859
N of Valid Cases	45		

[a] 6 cells (60.0%) have expected count less than 5. The minimum expected count is 0.67.

D.8.4 Noise

TABLE D.64: Noise - Crosstab

		Never	Rare	Sometimes	Often	Always	Total
Visually Impaired	Count	7^a	2^a	7^a	14^a	0^a	30
	% within Groups	23.3%	6.7%	23.3%	46.7%	0.0%	100.0%
Sighted	Count	2^a	0^a	4^a	5^a	4^a	15
	% within Groups	13.3%	0.0%	26.7%	33.3%	26.7%	100.0%
Total	Count	9	2	11	19	4	45
	% within Groups	20.0%	4.4%	24.4%	42.2%	8.9%	100.0%

[*] Each subscript letter denotes a subset of Hazards: Noise categories whose column proportions do not differ significantly from each other at the 0.05 level.

TABLE D.65: Noise - Chi-Square Tests

	Value	df	p
Pearson Chi-Square	9.97^a	4	0.041
Likelihood Ratio	11.43	4	0.022
Linear-by-Linear Association	2.72	1	0.099
N of Valid Cases	45		

[a] 6 cells (60.0%) have expected count less than 5. The minimum expected count is 0.67.

D.8.5 Silence

Table D.66: Silence - Crosstab

		Never	**Rare**	**Sometimes**	**Often**	**Total**
Visually Impaired	Count	12^a	5^a	6^a	7^a	30
	% within Groups	40.0%	16.7%	20.0%	23.3%	100.0%
Sighted	Count	5^a	3^a	5^a	2^a	15
	% within Groups	33.3%	20.0%	33.3%	13.3%	100.0%
Total	Count	17	8	11	9	45
	% within Groups	37.8%	17.8%	24.4%	20.0%	100.0%

[*] Each subscript letter denotes a subset of Hazards: Silence categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.67: Silence - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	1.41^a	3	0.704
Likelihood Ratio	1.41	3	0.703
Linear-by-Linear Association	0.00	1	1.000
N of Valid Cases	45		

[a] 3 cells (37.5%) have expected count less than 5. The minimum expected count is 2.67.

D.8.6 Light

Table D.68: Light - Crosstab

		Never	Rare	Sometimes	Often	Always	Total
Visually Impaired	Count	10^a	4^a	8^a	7^a	1^a	30
	% within Groups	33.3%	13.3%	26.7%	23.3%	3.3%	100.0%
Sighted	Count	5^a	2^a	4^a	4^a	0^a	15
	% within Groups	33.3%	13.3%	26.7%	26.7%	0.0%	100.0%
Total	Count	15	6	12	11	1	45
	% within Groups	33.3%	13.3%	26.7%	24.4%	2.2%	100.0%

[*] Each subscript letter denotes a subset of Hazards: Light categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.69: Light - Chi-Square Tests

	Value	df	*p*
Pearson Chi-Square	0.55^a	4	0.969
Likelihood Ratio	0.86	4	0.931
Linear-by-Linear Association	0.01	1	0.933
N of Valid Cases	45		

[a] 6 cells (60.0%) have expected count less than 5. The minimum expected count is 0.33.

D.8.7 Moving Obstacle

Table D.70: Moving Obstacle - Crosstab

		Never	**Rare**	**Sometimes**	**Often**	**Always**	**Total**
Visually Impaired	Count	4^a	3^a	7^a	10^a	6^a	30
	% within Groups	13.3%	10.0%	23.3%	33.3%	20.0%	100.0%
Sighted	Count	0^a	2^a	4^a	7^a	2^a	15
	% within Groups	0.0%	13.3%	26.7%	46.7%	13.3%	100.0%
Total	Count	4	5	11	17	8	45
	% within Groups	8.9%	11.1%	24.4%	37.8%	17.8%	100.0%

[*] Each subscript letter denotes a subset of Hazards: Moving Obstacle categories whose column proportions do not differ significantly from each other at the 0.05 level.

Table D.71: Moving Obstacle - Chi-Square Tests

	Value	**df**	***p***
Pearson Chi-Square	2.87^a	4	0.580
Likelihood Ratio	4.10	4	0.392
Linear-by-Linear Association	0.39	1	0.531
N of Valid Cases	45		

[a] 6 cells (60.0%) have expected count less than 5. The minimum expected count is 1.33.

D.9 Repeated Measures One-way ANOVA on SRF Components

Table D.72: SRF Components: Within-Subjects Factors

SRF	Dependent Variable	SRF	Dependent Variable
1	Building Profile	13	Stairs
2	Floor Layout	14	Steps, Dropoff, Curb
3	Floor Number	15	Elevator
4	Room Number	16	Escalator
5	Toilet and Bathroom	17	Event and Exhibition
6	Entrance and Exit	18	Furniture
7	Door	19	Dangerous Area
8	Emergency Exit	20	People
9	Lighting	21	Weather
10	WiFi Coverage	22	Reception
11	Walkable Path	23	Noise
12	Tactile Pavement		

Table D.73: SRF Components: Descriptive Statistics

SRF	Mean	Std. Deviation	N
Building Profile	3.78	1.15	45
Floor Layout	3.87	1.10	45
Floor Number	4.29	0.89	45
Room Number	4.33	0.83	45
Toilet and Bathroom	4.36	0.65	45
Entrance and Exit	4.51	0.51	45
Door	4.62	0.53	45
Emergency Exit	4.29	0.73	45
Lighting	3.29	1.39	45
WiFi Coverage	3.09	1.38	45
Walkable Path	4.18	0.81	45
Tactile Pavement	4.16	1.02	45
Stairs	4.27	0.72	45
Steps, Dropoff, Curb	4.31	0.56	45
Elevator	4.20	0.55	45
Escalator	4.02	0.72	45
Event and Exhibition	3.67	0.77	45
Furniture	4.04	0.74	45
Dangerous Area	4.33	0.80	45
People	3.89	0.91	45
Weather	3.42	1.22	45
Reception	3.84	1.13	45
Noise	3.47	1.36	45

Table D.74: SRF Components: Estimate

SRF	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Building Profile	3.78	0.17	3.43	4.12
Floor Layout	3.87	0.16	3.54	4.20
Floor Number	4.29	0.13	4.02	4.56
Room Number	4.33	0.12	4.09	4.58
Toilet and Bathroom	4.36	0.10	4.16	4.55
Entrance and Exit	4.51	0.08	4.36	4.66
Door	4.62	0.08	4.46	4.78
Emergency Exit	4.29	0.11	4.07	4.51
Lighting	3.29	0.21	2.87	3.71
WiFi Coverage	3.09	0.21	2.68	3.50
Walkable Path	4.18	0.12	3.94	4.42
Tactile Pavement	4.16	0.15	3.85	4.46
Stairs	4.27	0.11	4.05	4.48
Steps, Dropoff, Curb	4.31	0.08	4.14	4.48
Elevator	4.20	0.08	4.04	4.37
Escalator	4.02	0.11	3.81	4.24
Event and Exhibition	3.67	0.12	3.44	3.90
Furniture	4.04	0.11	3.82	4.27
Dangerous Area	4.33	0.12	4.09	4.57
People	3.89	0.14	3.62	4.16
Weather	3.42	0.18	3.06	3.79
Reception	3.84	0.17	3.51	4.18
Noise	3.47	0.20	3.06	3.88

Table D.75: SRF Components: Multivariate tests[a]

Effect		Value	F	Hypothesis df	Error df	p
SRF	Pillai's Trace	0.83	5.20[b]	22	23	< 0.001
	Wilks' Lambda	0.17	5.20[b]	22	23	< 0.001
	Hotelling's Trace	4.98	5.20[b]	22	23	< 0.001
	Roy's Largest Root	4.98	5.20[b]	22	23	< 0.001

[a] Design: Intercept Within Subjects Design: SRF
[b] Exact statistic

Table D.76: SRF Components: Mauchly's Test of Sphericity[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	p	Epsilonb		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
SRF	0.00	527.28	252	< 0.001	0.46	0.61	0.05

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
[a] Design: Intercept Within Subjects Design: SRFComponent
[b] May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table D.77: SRF Components: Tests of Within-Subjects Effects

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***	**Partial Eta Squared**
SRF	Sphericity Assumed	161.86	22.00	7.36	10.35	<0.001	0.19
	Greenhouse-Geisser	161.86	10.10	16.03	10.35	<0.002	0.19
	Huynh-Feldt	161.86	13.35	12.13	10.35	<0.003	0.19
	Lower-bound	161.86	1.00	161.86	10.35	0.002	0.19
Error(SRF)	Sphericity Assumed	688.32	968.00	0.71			
	Greenhouse-Geisser	688.32	444.40	1.55			
	Huynh-Feldt	688.32	587.32	1.17			
	Lower-bound	688.32	44.00	15.64			

Table D.78: SRF Components: Tests of Within-Subjects Contrasts

Source	**SRFComponent**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***	**Partial Eta Squared**
SRF	Level 1 vs. Level 2	0.36	1	0.36	0.16	0.694	0.004
	Level 2 vs. Level 3	8.02	1	8.02	9.06	0.004	0.171
	Level 3 vs. Level 4	0.09	1	0.09	0.20	0.660	0.004
	Level 4 vs. Level 5	0.02	1	0.02	0.03	0.864	0.001
	Level 5 vs. Level 6	1.09	1	1.09	2.00	0.164	0.044
	Level 6 vs. Level 7	0.56	1	0.56	1.69	0.200	0.037
	Level 7 vs. Level 8	5.00	1	5.00	7.86	0.008	0.152
	Level 8 vs. Level 9	45.00	1	45.00	22.00	<0.001	0.333
	Level 9 vs. Level 10	1.80	1	1.80	0.60	0.445	0.013
	Level 10 vs. Level 11	53.36	1	53.36	24.55	<0.001	0.358
	Level 11 vs. Level 12	0.02	1	0.02	0.02	0.895	0.000
	Level 12 vs. Level 13	0.56	1	0.56	0.67	0.417	0.015
	Level 13 vs. Level 14	0.09	1	0.09	0.25	0.623	0.006
	Level 14 vs. Level 15	0.56	1	0.56	1.69	0.200	0.037
	Level 15 vs. Level 16	1.42	1	1.42	4.29	0.044	0.089
	Level 16 vs. Level 17	5.69	1	5.69	7.75	0.008	0.150
	Level 17 vs. Level 18	6.42	1	6.42	8.17	0.006	0.157
	Level 18 vs. Level 19	3.76	1	3.76	3.82	0.057	0.080

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Source	SRFComponent	Type III Sum of Squares	df	Mean Square	F	*p*	Partial Eta Squared
	Level 19 vs. Level 20	8.89	1	8.89	10.54	0.002	0.193
	Level 20 vs. Level 21	9.80	1	9.80	10.47	0.002	0.192
	Level 21 vs. Level 22	8.02	1	8.02	6.42	0.015	0.127
	Level 22 vs. Level 23	6.42	1	6.42	2.56	0.117	0.055
Error (SRF)	Level 1 vs. Level 2	99.64	44	2.27			
	Level 2 vs. Level 3	38.98	44	0.89			
	Level 3 vs. Level 4	19.91	44	0.45			
	Level 4 vs. Level 5	32.98	44	0.75			
	Level 5 vs. Level 6	23.91	44	0.54			
	Level 6 vs. Level 7	14.44	44	0.33			
	Level 7 vs. Level 8	28.00	44	0.64			
	Level 8 vs. Level 9	90.00	44	2.05			
	Level 9 vs. Level 10	133.20	44	3.03			
	Level 10 vs. Level 11	95.64	44	2.17			
	Level 11 vs. Level 12	54.98	44	1.25			
	Level 12 vs. Level 13	36.44	44	0.83			
	Level 13 vs. Level 14	15.91	44	0.36			
	Level 14 vs. Level 15	14.44	44	0.33			
	Level 15 vs. Level 16	14.58	44	0.33			
	Level 16 vs. Level 17	32.31	44	0.73			
	Level 17 vs. Level 18	34.58	44	0.79			
	Level 18 vs. Level 19	43.24	44	0.98			
	Level 19 vs. Level 20	37.11	44	0.84			
	Level 20 vs. Level 21	41.20	44	0.94			
	Level 21 vs. Level 22	54.98	44	1.25			
	Level 22 vs. Level 23	110.58	44	2.51			

Table D.79: SRF Components: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	723.48	1	723.48	3942.10	< 0.001	0.99
Error	8.08	44	0.18			

Table D.80: SRF Components: Estimated Marginal Means: Estimates

SRF	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Building Profile	3.78	0.17	3.43	4.12
Floor Layout	3.87	0.16	3.54	4.20
Floor Number	4.29	0.13	4.02	4.56
Room Number	4.33	0.12	4.09	4.58
Toilet and Bathroom	4.36	0.10	4.16	4.55
Entrance and Exit	4.51	0.08	4.36	4.66
Door	4.62	0.08	4.46	4.78
Emergency Exit	4.29	0.11	4.07	4.51
Lighting	3.29	0.21	2.87	3.71
WiFi Coverage	3.09	0.21	2.68	3.50
Walkable Path	4.18	0.12	3.94	4.42
Tactile Pavement	4.16	0.15	3.85	4.46
Stairs	4.27	0.11	4.05	4.48
Steps, Dropoff, Curb	4.31	0.08	4.14	4.48
Elevator	4.20	0.08	4.04	4.37
Escalator	4.02	0.11	3.81	4.24
Event and Exhibition	3.67	0.12	3.44	3.90
Furniture	4.04	0.11	3.82	4.27
Dangerous Area	4.33	0.12	4.09	4.57
People	3.89	0.14	3.62	4.16
Weather	3.42	0.18	3.06	3.79
Reception	3.84	0.17	3.51	4.18
Noise	3.47	0.20	3.06	3.88

Table D.81: SRF Components: Estimated Marginal Means: Pairwise Comparisons with 95% Confidence Interval (CI) for Difference

SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference^b	
					Lower Bound	Upper Bound
Building Profile	Floor Layout	-0.09	0.22	1.000	-1.00	0.82
	Floor Number	-0.51	0.21	0.985	-1.34	0.32
	Room Number	-0.56	0.20	0.911	-1.39	0.27
	Toilet and Bathroom	-0.58	0.17	0.346	-1.28	0.12
	Entrance and Exit	-0.73*	0.16	0.013	-1.40	-0.07
	Door	-0.84*	0.16	0.001	-1.47	-0.21
	Emergency Exit	-0.51	0.20	0.964	-1.31	0.29
	Lighting	0.49	0.27	1.000	-0.62	1.60
	WiFi Coverage	0.69	0.26	0.921	-0.35	1.73
	Walkable Path	-0.40	0.20	1.000	-1.22	0.42
	Tactile Pave	-0.38	0.23	1.000	-1.29	0.54
	Stairs	-0.49	0.18	0.921	-1.22	0.25
	Steps, Dropoff, Curb	-0.53	0.17	0.536	-1.22	0.16

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Elevator	-0.42	0.17	0.986	-1.11	0.27
	Escalator	-0.24	0.19	1.000	-1.03	0.54
	Event and Exhibition	0.11	0.20	1.000	-0.70	0.92
	Furniture	-0.27	0.18	1.000	-1.01	0.48
	Dangerous Area	-0.56	0.18	0.657	-1.30	0.19
	People	-0.11	0.21	1.000	-0.96	0.74
	Weather	0.36	0.24	1.000	-0.63	1.34
	Reception	-0.07	0.22	1.000	-0.97	0.84
	Noise	0.31	0.21	1.000	-0.53	1.15
Floor Layout	Building Profile	0.09	0.22	1.000	-0.82	1.00
	Floor Number	-0.42	0.14	0.666	-0.99	0.15
	Room Number	-0.47	0.17	0.918	-1.17	0.23
	Toilet and Bathroom	-0.49	0.18	0.921	-1.22	0.25
	Entrance and Exit	-0.64	0.16	0.065	-1.30	0.01
	Door	-0.76*	0.17	0.021	-1.46	-0.05
	Emergency Exit	-0.42	0.19	1.000	-1.21	0.37
	Lighting	0.58	0.26	0.999	-0.46	1.61
	WiFi Coverage	0.78	0.25	0.564	-0.24	1.79
	Walkable Path	-0.31	0.22	1.000	-1.18	0.56
	Tactile Pave	-0.29	0.22	1.000	-1.20	0.62
	Stairs	-0.40	0.18	1.000	-1.14	0.34
	Steps, Dropoff, Curb	-0.44	0.16	0.910	-1.11	0.22
	Elevator	-0.33	0.18	1.000	-1.06	0.40
	Escalator	-0.16	0.20	1.000	-0.95	0.64
	Event and Exhibition	0.20	0.18	1.000	-0.55	0.95
	Furniture	-0.18	0.17	1.000	-0.87	0.52
	Dangerous Area	-0.47	0.18	0.969	-1.20	0.27
	People	-0.02	0.18	1.000	-0.76	0.71
	Weather	0.44	0.21	1.000	-0.40	1.28
	Reception	0.02	0.21	1.000	-0.84	0.88
	Noise	0.40	0.24	1.000	-0.56	1.36
Floor Number	Building Profile	0.51	0.21	0.985	-0.32	1.34
	Floor Layout	0.42	0.14	0.666	-0.15	0.99
	Room Number	-0.04	0.10	1.000	-0.45	0.36
	Toilet and Bathroom	-0.07	0.14	1.000	-0.62	0.49
	Entrance and Exit	-0.22	0.13	1.000	-0.74	0.29
	Door	-0.33	0.13	0.988	-0.88	0.21

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference^b	
					Lower Bound	Upper Bound
	Emergency Exit	0.00	0.15	1.000	-0.60	0.60
	Lighting	1.00*	0.22	0.015	0.09	1.91
	WiFi Coverage	1.20*	0.23	0.001	0.27	2.13
	Walkable Path	0.11	0.18	1.000	-0.62	0.84
	Tactile Pave	0.13	0.19	1.000	-0.66	0.92
	Stairs	0.02	0.16	1.000	-0.63	0.67
	Steps, Dropoff, Curb	-0.02	0.14	1.000	-0.59	0.55
	Elevator	0.09	0.15	1.000	-0.50	0.68
	Escalator	0.27	0.16	1.000	-0.37	0.90
	Event and Exhibition	0.62*	0.15	0.038	0.01	1.23
	Furniture	0.24	0.15	1.000	-0.36	0.85
	Dangerous Area	-0.04	0.15	1.000	-0.66	0.57
	People	0.40	0.17	0.997	-0.29	1.09
	Weather	0.87*	0.21	0.040	0.02	1.72
	Reception	0.44	0.16	0.910	-0.22	1.11
	Noise	0.82	0.24	0.293	-0.15	1.80
Room Number	Building Profile	0.56	0.20	0.911	-0.27	1.39
	Floor Layout	0.47	0.17	0.918	-0.23	1.17
	Floor Number	0.04	0.10	1.000	-0.36	0.45
	Toilet and Bathroom	-0.02	0.13	1.000	-0.55	0.50
	Entrance and Exit	-0.18	0.12	1.000	-0.65	0.29
	Door	-0.29	0.14	1.000	-0.84	0.27
	Emergency Exit	0.04	0.15	1.000	-0.55	0.63
	Lighting	1.04*	0.23	0.009	0.12	1.96
	WiFi Coverage	1.24*	0.22	< 0.001	0.34	2.15
	Walkable Path	0.16	0.16	1.000	-0.49	0.80
	Tactile Pave	0.18	0.18	1.000	-0.55	0.91
	Stairs	0.07	0.14	1.000	-0.52	0.65
	Steps, Dropoff, Curb	0.02	0.14	1.000	-0.53	0.58
	Elevator	0.13	0.14	1.000	-0.42	0.69
	Escalator	0.31	0.15	1.000	-0.28	0.90
	Event and Exhibition	0.67*	0.15	0.019	0.05	1.28
	Furniture	0.29	0.14	1.000	-0.27	0.84
	Dangerous Area	0.00	0.14	1.000	-0.56	0.56
	People	0.44	0.17	0.935	-0.23	1.12
	Weather	0.91*	0.21	0.015	0.08	1.74
	Reception	0.49	0.17	0.833	-0.21	1.19

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Noise	0.87	0.23	0.144	-0.09	1.82
Toilet and Bathroom	Building Profile	0.58	0.17	0.346	-0.12	1.28
	Floor Layout	0.49	0.18	0.921	-0.25	1.22
	Floor Number	0.07	0.14	1.000	-0.49	0.62
	Room Number	0.02	0.13	1.000	-0.50	0.55
	Entrance and Exit	-0.16	0.11	1.000	-0.60	0.29
	Door	-0.27	0.12	0.999	-0.74	0.20
	Emergency Exit	0.07	0.15	1.000	-0.53	0.66
	Lighting	1.07*	0.23	0.006	0.15	1.98
	WiFi Coverage	1.27*	0.20	< 0.001	0.45	2.09
	Walkable Path	0.18	0.15	1.000	-0.44	0.80
	Tactile Pave	0.20	0.16	1.000	-0.45	0.85
	Stairs	0.09	0.14	1.000	-0.47	0.65
	Steps, Dropoff, Curb	0.04	0.12	1.000	-0.45	0.54
	Elevator	0.16	0.11	1.000	-0.27	0.58
	Escalator	0.33	0.14	0.995	-0.23	0.89
	Event and Exhibition	0.69*	0.14	0.004	0.12	1.26
	Furniture	0.31	0.13	0.998	-0.23	0.85
	Dangerous Area	0.02	0.14	1.000	-0.53	0.58
	People	0.47	0.14	0.303	-0.09	1.02
	Weather	0.93*	0.17	0.001	0.23	1.63
	Reception	0.51	0.15	0.265	-0.09	1.11
	Noise	0.89*	0.21	0.036	0.02	1.76
Entrance and Exit	Building Profile	0.73*	0.16	0.013	0.07	1.40
	Floor Layout	0.64	0.16	0.065	-0.01	1.30
	Floor Number	0.22	0.13	1.000	-0.29	0.74
	Room Number	0.18	0.12	1.000	-0.29	0.65
	Toilet and Bathroom	0.16	0.11	1.000	-0.29	0.60
	Door	-0.11	0.09	1.000	-0.46	0.24
	Emergency Exit	0.22	0.12	1.000	-0.26	0.70
	Lighting	1.22*	0.22	< 0.001	0.34	2.10
	WiFi Coverage	1.42*	0.22	< 0.001	0.53	2.32
	Walkable Path	0.33	0.12	0.851	-0.15	0.82
	Tactile Pave	0.36	0.17	1.000	-0.32	1.03
	Stairs	0.24	0.12	1.000	-0.24	0.73
	Steps, Dropoff, Curb	0.20	0.09	0.999	-0.16	0.56
	Elevator	0.31	0.10	0.551	-0.09	0.71

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b] Lower Bound	95% CI for Difference[b] Upper Bound
	Escalator	0.49	0.13	0.081	-0.02	1.00
	Event and Exhibition	0.84*	0.12	< 0.001	0.35	1.34
	Furniture	0.47	0.13	0.182	-0.06	0.99
	Dangerous Area	0.18	0.11	1.000	-0.26	0.61
	People	0.622*	0.14	0.010	0.07	1.17
	Weather	1.09*	0.19	< 0.001	0.31	1.87
	Reception	0.67	0.17	0.053	0.00	1.34
	Noise	1.04*	0.20	0.001	0.25	1.84
Door	Building Profile	0.84*	0.16	0.001	0.21	1.47
	Floor Layout	0.76*	0.17	0.021	0.05	1.46
	Floor Number	0.33	0.13	0.988	-0.21	0.88
	Room Number	0.29	0.14	1.000	-0.27	0.84
	Toilet and Bathroom	0.27	0.12	0.999	-0.20	0.74
	Entrance and Exit	0.11	0.09	1.000	-0.24	0.46
	Emergency Exit	0.33	0.12	0.851	-0.15	0.82
	Lighting	1.33*	0.20	< 0.001	0.51	2.16
	WiFi Coverage	1.53*	0.22	< 0.001	0.64	2.42
	Walkable Path	0.44	0.14	0.433	-0.11	1.00
	Tactile Pave	0.47	0.17	0.891	-0.22	1.16
	Stairs	0.36	0.12	0.794	-0.15	0.86
	Steps, Dropoff, Curb	0.31	0.09	0.239	-0.05	0.67
	Elevator	0.42	0.11	0.075	-0.01	0.86
	Escalator	0.60*	0.12	0.005	0.09	1.11
	Event and Exhibition	0.96*	0.12	< 0.001	0.47	1.44
	Furniture	0.58*	0.13	0.013	0.05	1.10
	Dangerous Area	0.29	0.11	0.972	-0.17	0.75
	People	0.73*	0.12	< 0.001	0.23	1.24
	Weather	1.20*	0.18	< 0.001	0.46	1.94
	Reception	0.78*	0.16	0.006	0.11	1.45
	Noise	1.156*	0.21	< 0.001	0.31	2.00
Emergency Exit	Building Profile	0.51	0.20	0.964	-0.29	1.31
	Floor Layout	0.42	0.19	1.000	-0.37	1.21
	Floor Number	0.00	0.15	1.000	-0.60	0.60
	Room Number	-0.04	0.15	1.000	-0.63	0.55
	Toilet and Bathroom	-0.07	0.15	1.000	-0.66	0.53
	Entrance and Exit	-0.22	0.12	1.000	-0.70	0.26
	Door	-0.33	0.12	0.851	-0.82	0.15

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Lighting	1.00*	0.21	0.007	0.14	1.86
	WiFi Coverage	1.20*	0.20	$<$ 0.001	0.38	2.02
	Walkable Path	0.11	0.15	1.000	-0.48	0.70
	Tactile Pave	0.13	0.17	1.000	-0.57	0.83
	Stairs	0.02	0.14	1.000	-0.53	0.58
	Steps, Dropoff, Curb	-0.02	0.12	1.000	-0.51	0.47
	Elevator	0.09	0.12	1.000	-0.39	0.57
	Escalator	0.27	0.12	1.000	-0.24	0.77
	Event and Exhibition	0.62*	0.13	0.006	0.09	1.16
	Furniture	0.24	0.15	1.000	-0.36	0.85
	Dangerous Area	-0.04	0.15	1.000	-0.66	0.57
	People	0.40	0.18	1.000	-0.32	1.12
	Weather	0.87	0.23	0.107	-0.06	1.79
	Reception	0.44	0.19	0.999	-0.34	1.23
	Noise	0.82	0.24	0.293	-0.15	1.80
Lighting	Building Profile	-0.49	0.27	1.000	-1.60	0.62
	Floor Layout	-0.58	0.26	0.999	-1.61	0.46
	Floor Number	-1.00*	0.22	0.015	-1.91	-0.09
	Room Number	-1.04*	0.23	0.009	-1.96	-0.12
	Toilet and Bathroom	-1.07*	0.23	0.006	-1.98	-0.15
	Entrance and Exit	-1.22*	0.22	$<$ 0.001	-2.10	-0.34
	Door	-1.33*	0.20	$<$ 0.001	-2.16	-0.51
	Emergency Exit	-1.00*	0.21	0.007	-1.86	-0.14
	WiFi Coverage	0.20	0.26	1.000	-0.85	1.25
	Walkable Path	-0.89*	0.21	0.023	-1.73	-0.05
	Tactile Pave	-0.87	0.26	0.331	-1.91	0.18
	Stairs	-0.98*	0.22	0.014	-1.87	-0.09
	Steps, Dropoff, Curb	-1.02*	0.21	0.005	-1.89	-0.15
	Elevator	-0.91*	0.22	0.043	-1.81	-0.01
	Escalator	-0.73	0.21	0.262	-1.59	0.13
	Event and Exhibition	-0.38	0.18	1.000	-1.11	0.35
	Furniture	-0.76	0.21	0.195	-1.61	0.10
	Dangerous Area	-1.04*	0.25	0.028	-2.04	-0.05
	People	-0.60	0.20	0.628	-1.40	0.20
	Weather	-0.13	0.23	1.000	-1.07	0.80
	Reception	-0.56	0.22	0.971	-1.43	0.32

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference^b	
					Lower Bound	Upper Bound
	Noise	-0.18	0.30	1.000	-1.41	1.05
WiFi Coverage	Building Profile	-0.69	0.26	0.921	-1.73	0.35
	Floor Layout	-0.78	0.25	0.564	-1.79	0.24
	Floor Number	-1.20*	0.23	0.001	-2.13	-0.27
	Room Number	-1.24*	0.22	< 0.001	-2.15	-0.34
	Toilet and Bathroom	-1.27*	0.20	< 0.001	-2.09	-0.45
	Entrance and Exit	-1.42*	0.22	< 0.001	-2.32	-0.53
	Door	-1.53*	0.22	< 0.001	-2.42	-0.64
	Emergency Exit	-1.20*	0.20	< 0.001	-2.02	-0.38
	Lighting	-0.20	0.26	1.000	-1.25	0.85
	Walkable Path	-1.09*	0.22	0.003	-1.98	-0.20
	Tactile Pave	-1.07*	0.24	0.017	-2.05	-0.08
	Stairs	-1.18*	0.23	0.002	-2.12	-0.24
	Steps, Dropoff, Curb	-1.22*	0.24	0.002	-2.19	-0.26
	Elevator	-1.11*	0.22	0.002	-1.99	-0.24
	Escalator	-0.93*	0.23	0.044	-1.86	-0.01
	Event and Exhibition	-0.58	0.21	0.862	-1.42	0.26
	Furniture	-0.96*	0.22	0.027	-1.87	-0.05
	Dangerous Area	-1.24*	0.24	0.001	-2.21	-0.28
	People	-0.80	0.22	0.197	-1.71	0.11
	Weather	-0.33	0.25	1.000	-1.35	0.68
	Reception	-0.76	0.23	0.420	-1.69	0.18
	Noise	-0.38	0.31	1.000	-1.64	0.88
Walkable Path	Building Profile	0.40	0.20	1.000	-0.42	1.22
	Floor Layout	0.31	0.22	1.000	-0.56	1.18
	Floor Number	-0.11	0.18	1.000	-0.84	0.62
	Room Number	-0.16	0.16	1.000	-0.80	0.49
	Toilet and Bathroom	-0.18	0.15	1.000	-0.80	0.44
	Entrance and Exit	-0.33	0.12	0.851	-0.82	0.15
	Door	-0.44	0.14	0.433	-1.00	0.11
	Emergency Exit	-0.11	0.15	1.000	-0.70	0.48
	Lighting	0.89*	0.21	0.023	0.05	1.73
	WiFi Coverage	1.09*	0.22	0.003	0.20	1.98
	Tactile Pave	0.02	0.17	1.000	-0.65	0.70
	Stairs	-0.09	0.13	1.000	-0.63	0.45
	Steps, Dropoff, Curb	-0.13	0.13	1.000	-0.67	0.41
	Elevator	-0.02	0.12	1.000	-0.50	0.45

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b] Lower Bound	95% CI for Difference[b] Upper Bound
	Escalator	0.16	0.14	1.000	-0.42	0.73
	Event and Exhibition	0.51	0.13	0.069	-0.01	1.04
	Furniture	0.13	0.15	1.000	-0.48	0.75
	Dangerous Area	-0.16	0.17	1.000	-0.82	0.51
	People	0.29	0.15	1.000	-0.32	0.90
	Weather	0.76	0.20	0.106	-0.05	1.56
	Reception	0.33	0.18	1.000	-0.38	1.05
	Noise	0.71	0.23	0.560	-0.21	1.64
Tactile Pave	Building Profile	0.38	0.23	1.000	-0.54	1.29
	Floor Layout	0.29	0.22	1.000	-0.62	1.20
	Floor Number	-0.13	0.19	1.000	-0.92	0.66
	Room Number	-0.18	0.18	1.000	-0.91	0.55
	Toilet and Bathroom	-0.20	0.16	1.000	-0.85	0.45
	Entrance and Exit	-0.36	0.17	1.000	-1.03	0.32
	Door	-0.47	0.17	0.891	-1.16	0.22
	Emergency Exit	-0.13	0.17	1.000	-0.83	0.57
	Lighting	0.87	0.26	0.331	-0.18	1.91
	WiFi Coverage	1.07*	0.24	0.017	0.08	2.05
	Walkable Path	-0.02	0.17	1.000	-0.70	0.65
	Stairs	-0.11	0.14	1.000	-0.66	0.44
	Steps, Dropoff, Curb	-0.16	0.16	1.000	-0.80	0.49
	Elevator	-0.04	0.15	1.000	-0.65	0.56
	Escalator	0.13	0.14	1.000	-0.45	0.72
	Event and Exhibition	0.49	0.19	0.955	-0.27	1.25
	Furniture	0.11	0.17	1.000	-0.56	0.78
	Dangerous Area	-0.18	0.16	1.000	-0.83	0.47
	People	0.27	0.17	1.000	-0.41	0.94
	Weather	0.73	0.19	0.114	-0.05	1.52
	Reception	0.31	0.20	1.000	-0.51	1.13
	Noise	0.69	0.20	0.252	-0.11	1.49
Stairs	Building Profile	0.49	0.18	0.921	-0.25	1.22
	Floor Layout	0.40	0.18	1.000	-0.34	1.14
	Floor Number	-0.02	0.16	1.000	-0.67	0.63
	Room Number	-0.07	0.14	1.000	-0.65	0.52
	Toilet and Bathroom	-0.09	0.14	1.000	-0.65	0.47
	Entrance and Exit	-0.24	0.12	1.000	-0.73	0.24
	Door	-0.36	0.12	0.794	-0.86	0.15

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b] Lower Bound	Upper Bound
	Emergency Exit	-0.02	0.14	1.000	-0.58	0.53
	Lighting	0.98*	0.22	0.014	0.09	1.87
	WiFi Coverage	1.18*	0.23	0.002	0.24	2.12
	Walkable Path	0.09	0.13	1.000	-0.45	0.63
	Tactile Pave	0.11	0.14	1.000	-0.44	0.66
	Steps, Dropoff, Curb	-0.04	0.09	1.000	-0.41	0.32
	Elevator	0.07	0.09	1.000	-0.28	0.42
	Escalator	0.24	0.09	0.793	-0.10	0.59
	Event and Exhibition	0.60*	0.13	0.011	0.06	1.14
	Furniture	0.22	0.08	0.935	-0.12	0.56
	Dangerous Area	-0.07	0.13	1.000	-0.60	0.47
	People	0.38	0.15	0.967	-0.22	0.97
	Weather	0.84*	0.21	0.043	0.01	1.68
	Reception	0.42	0.20	1.000	-0.39	1.23
	Noise	0.80*	0.19	0.043	0.01	1.59
Steps, Dropoff, Curb	Building Profile	0.53	0.17	0.536	-0.16	1.22
	Floor Layout	0.44	0.16	0.910	-0.22	1.11
	Floor Number	0.02	0.14	1.000	-0.55	0.59
	Room Number	-0.02	0.14	1.000	-0.58	0.53
	Toilet and Bathroom	-0.04	0.12	1.000	-0.54	0.45
	Entrance and Exit	-0.20	0.09	0.999	-0.56	0.16
	Door	-0.31	0.09	0.239	-0.67	0.05
	Emergency Exit	0.02	0.12	1.000	-0.47	0.51
	Lighting	1.02*	0.21	0.005	0.15	1.89
	WiFi Coverage	1.22*	0.24	0.002	0.26	2.19
	Walkable Path	0.13	0.13	1.000	-0.41	0.67
	Tactile Pave	0.16	0.16	1.000	-0.49	0.80
	Stairs	0.04	0.09	1.000	-0.32	0.41
	Elevator	0.11	0.09	1.000	-0.24	0.46
	Escalator	0.29	0.11	0.972	-0.17	0.75
	Event and Exhibition	0.64*	0.12	0.001	0.14	1.15
	Furniture	0.27	0.11	0.996	-0.19	0.72
	Dangerous Area	-0.02	0.11	1.000	-0.48	0.43
	People	0.42	0.14	0.585	-0.13	0.98
	Weather	0.89*	0.20	0.020	0.06	1.72
	Reception	0.47	0.18	0.969	-0.27	1.20

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SRF (I)	**SRF (J)**	**Mean Difference (I-J)**	**Std. Error**	p^b	**95% CI for Difference^b**	
					Lower Bound	**Upper Bound**
	Noise	0.84*	0.19	0.019	0.06	1.63
Elevator	Building Profile	0.42	0.17	0.986	-0.27	1.11
	Floor Layout	0.33	0.18	1.000	-0.40	1.06
	Floor Number	-0.09	0.15	1.000	-0.68	0.50
	Room Number	-0.13	0.14	1.000	-0.69	0.42
	Toilet and Bathroom	-0.16	0.11	1.000	-0.58	0.27
	Entrance and Exit	-0.31	0.10	0.551	-0.71	0.09
	Door	-0.42	0.11	0.075	-0.86	0.01
	Emergency Exit	-0.09	0.12	1.000	-0.57	0.39
	Lighting	0.91*	0.22	0.043	0.01	1.81
	WiFi Coverage	1.11*	0.22	0.002	0.24	1.99
	Walkable Path	0.02	0.12	1.000	-0.45	0.50
	Tactile Pave	0.04	0.15	1.000	-0.56	0.65
	Stairs	-0.07	0.09	1.000	-0.42	0.28
	Steps, Dropoff, Curb	-0.11	0.09	1.000	-0.46	0.24
	Escalator	0.18	0.09	1.000	-0.17	0.53
	Event and Exhibition	0.53*	0.12	0.017	0.04	1.03
	Furniture	0.16	0.10	1.000	-0.23	0.54
	Dangerous Area	-0.13	0.13	1.000	-0.66	0.39
	People	0.31	0.14	0.999	-0.25	0.87
	Weather	0.78	0.20	0.063	-0.02	1.57
	Reception	0.36	0.18	1.000	-0.36	1.07
	Noise	0.73	0.21	0.237	-0.12	1.58
Escalator	Building Profile	0.24	0.19	1.000	-0.54	1.03
	Floor Layout	0.16	0.20	1.000	-0.64	0.95
	Floor Number	-0.27	0.16	1.000	-0.90	0.37
	Room Number	-0.31	0.15	1.000	-0.90	0.28
	Toilet and Bathroom	-0.33	0.14	0.995	-0.89	0.23
	Entrance and Exit	-0.49	0.13	0.081	-1.00	0.02
	Door	-0.60*	0.12	0.005	-1.11	-0.09
	Emergency Exit	-0.27	0.12	1.000	-0.77	0.24
	Lighting	0.73	0.21	0.262	-0.13	1.59
	WiFi Coverage	0.93*	0.23	0.044	0.01	1.86
	Walkable Path	-0.16	0.14	1.000	-0.73	0.42
	Tactile Pave	-0.13	0.14	1.000	-0.72	0.45
	Stairs	-0.24	0.09	0.793	-0.59	0.10
	Steps, Dropoff, Curb	-0.29	0.11	0.972	-0.75	0.17

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Elevator	-0.18	0.09	1.000	-0.53	0.17
	Event and Exhibition	0.36	0.13	0.866	-0.16	0.87
	Furniture	-0.02	0.09	1.000	-0.37	0.33
	Dangerous Area	-0.31	0.15	1.000	-0.90	0.28
	People	0.13	0.15	1.000	-0.48	0.75
	Weather	0.60	0.20	0.628	-0.20	1.40
	Reception	0.18	0.18	1.000	-0.55	0.91
	Noise	0.56	0.19	0.812	-0.23	1.34
Event and Exhibition	Building Profile	-0.11	0.20	1.000	-0.92	0.70
	Floor Layout	-0.20	0.18	1.000	-0.95	0.55
	Floor Number	-0.62*	0.15	0.038	-1.23	-0.01
	Room Number	-0.67*	0.15	0.019	-1.28	-0.05
	Toilet and Bathroom	-0.69*	0.14	0.004	-1.26	-0.12
	Entrance and Exit	-0.84*	0.12	< 0.001	-1.34	-0.35
	Door	-0.96*	0.12	< 0.001	-1.44	-0.47
	Emergency Exit	-0.62*	0.13	0.006	-1.16	-0.09
	Lighting	0.38	0.18	1.000	-0.35	1.11
	WiFi Coverage	0.58	0.21	0.862	-0.26	1.42
	Walkable Path	-0.51	0.13	0.069	-1.04	0.01
	Tactile Pave	-0.49	0.19	0.955	-1.25	0.27
	Stairs	-0.60*	0.13	0.011	-1.14	-0.06
	Steps, Dropoff, Curb	-0.64*	0.12	0.001	-1.15	-0.14
	Elevator	-0.53*	0.12	0.017	-1.03	-0.04
	Escalator	-0.36	0.13	0.866	-0.87	0.16
	Furniture	-0.38	0.13	0.807	-0.91	0.16
	Dangerous Area	-0.67*	0.16	0.042	-1.32	-0.01
	People	-0.22	0.14	1.000	-0.80	0.35
	Weather	0.24	0.18	1.000	-0.50	0.99
	Reception	-0.18	0.17	1.000	-0.85	0.50
	Noise	0.20	0.23	1.000	-0.75	1.15
Furniture	Building Profile	0.27	0.18	1.000	-0.48	1.01
	Floor Layout	0.18	0.17	1.000	-0.52	0.87
	Floor Number	-0.24	0.15	1.000	-0.85	0.36
	Room Number	-0.29	0.14	1.000	-0.84	0.27
	Toilet and Bathroom	-0.31	0.13	0.998	-0.85	0.23
	Entrance and Exit	-0.47	0.13	0.182	-0.99	0.06
	Door	-0.58*	0.13	0.013	-1.10	-0.05

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Emergency Exit	-0.24	0.15	1.000	-0.85	0.36
	Lighting	0.76	0.21	0.195	-0.10	1.61
	WiFi Coverage	0.96*	0.22	0.027	0.05	1.87
	Walkable Path	-0.13	0.15	1.000	-0.75	0.48
	Tactile Pave	-0.11	0.17	1.000	-0.78	0.56
	Stairs	-0.22	0.08	0.935	-0.56	0.12
	Steps, Dropoff, Curb	-0.27	0.11	0.996	-0.72	0.19
	Elevator	-0.16	0.10	1.000	-0.54	0.23
	Escalator	0.02	0.09	1.000	-0.33	0.37
	Event and Exhibition	0.38	0.13	0.807	-0.16	0.91
	Dangerous Area	-0.29	0.15	1.000	-0.89	0.31
	People	0.16	0.15	1.000	-0.45	0.76
	Weather	0.62	0.19	0.349	-0.13	1.38
	Reception	0.20	0.20	1.000	-0.60	1.00
	Noise	0.58	0.20	0.836	-0.25	1.41
Dangerous Area	Building Profile	0.56	0.18	0.657	-0.19	1.30
	Floor Layout	0.47	0.18	0.969	-0.27	1.20
	Floor Number	0.04	0.15	1.000	-0.57	0.66
	Room Number	0.00	0.14	1.000	-0.56	0.56
	Toilet and Bathroom	-0.02	0.14	1.000	-0.58	0.53
	Entrance and Exit	-0.18	0.11	1.000	-0.61	0.26
	Door	-0.29	0.11	0.972	-0.75	0.17
	Emergency Exit	0.04	0.15	1.000	-0.57	0.66
	Lighting	1.04*	0.25	0.028	0.05	2.04
	WiFi Coverage	1.24*	0.24	0.001	0.28	2.21
	Walkable Path	0.16	0.17	1.000	-0.51	0.82
	Tactile Pave	0.18	0.16	1.000	-0.47	0.83
	Stairs	0.07	0.13	1.000	-0.47	0.60
	Steps, Dropoff, Curb	0.02	0.11	1.000	-0.43	0.48
	Elevator	0.13	0.13	1.000	-0.39	0.66
	Escalator	0.31	0.15	1.000	-0.28	0.90
	Event and Exhibition	0.67*	0.16	0.042	0.01	1.32
	Furniture	0.29	0.15	1.000	-0.31	0.89
	People	0.44	0.14	0.433	-0.11	1.00
	Weather	0.91*	0.21	0.018	0.07	1.75
	Reception	0.49	0.20	0.991	-0.32	1.30

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Noise	0.87*	0.18	0.005	0.13	1.60
People	Building Profile	0.11	0.21	1.000	-0.74	0.96
	Floor Layout	0.02	0.18	1.000	-0.71	0.76
	Floor Number	-0.40	0.17	0.997	-1.09	0.29
	Room Number	-0.44	0.17	0.935	-1.12	0.23
	Toilet and Bathroom	-0.47	0.14	0.303	-1.02	0.09
	Entrance and Exit	-0.62*	0.14	0.010	-1.17	-0.07
	Door	-0.73*	0.12	< 0.001	-1.24	-0.23
	Emergency Exit	-0.40	0.18	1.000	-1.12	0.32
	Lighting	0.60	0.20	0.628	-0.20	1.40
	WiFi Coverage	0.80	0.22	0.197	-0.11	1.71
	Walkable Path	-0.29	0.15	1.000	-0.90	0.32
	Tactile Pave	-0.27	0.17	1.000	-0.94	0.41
	Stairs	-0.38	0.15	0.967	-0.97	0.22
	Steps, Dropoff, Curb	-0.42	0.14	0.585	-0.98	0.13
	Elevator	-0.31	0.14	0.999	-0.87	0.25
	Escalator	-0.13	0.15	1.000	-0.75	0.48
	Event and Exhibition	0.22	0.14	1.000	-0.35	0.80
	Furniture	-0.16	0.15	1.000	-0.76	0.45
	Dangerous Area	-0.44	0.14	0.433	-1.00	0.11
	Weather	0.47	0.14	0.443	-0.12	1.05
	Reception	0.04	0.17	1.000	-0.65	0.74
	Noise	0.42	0.23	1.000	-0.49	1.34
Weather	Building Profile	-0.36	0.24	1.000	-1.34	0.63
	Floor Layout	-0.44	0.21	1.000	-1.28	0.40
	Floor Number	-0.87*	0.21	0.040	-1.72	-0.02
	Room Number	-0.91*	0.21	0.015	-1.74	-0.08
	Toilet and Bathroom	-0.93*	0.17	0.001	-1.63	-0.23
	Entrance and Exit	-1.09*	0.19	< 0.001	-1.87	-0.31
	Door	-1.20*	0.18	< 0.001	-1.94	-0.46
	Emergency Exit	-0.87	0.23	0.107	-1.79	0.06
	Lighting	0.13	0.23	1.000	-0.80	1.07
	WiFi Coverage	0.33	0.25	1.000	-0.68	1.35
	Walkable Path	-0.76	0.20	0.106	-1.56	0.05
	Tactile Pave	-0.73	0.19	0.114	-1.52	0.05
	Stairs	-0.84*	0.21	0.043	-1.68	-0.01
	Steps, Dropoff, Curb	-0.89*	0.20	0.020	-1.72	-0.06

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	Elevator	-0.78	0.20	0.063	-1.57	0.02
	Escalator	-0.60	0.20	0.628	-1.40	0.20
	Event and Exhibition	-0.24	0.18	1.000	-0.99	0.50
	Furniture	-0.62	0.19	0.349	-1.38	0.13
	Dangerous Area	-0.91*	0.21	0.018	-1.75	-0.07
	People	-0.47	0.14	0.443	-1.05	0.12
	Reception	-0.42	0.17	0.978	-1.10	0.25
	Noise	-0.04	0.25	1.000	-1.04	0.95
Reception	Building Profile	0.07	0.22	1.000	-0.84	0.97
	Floor Layout	-0.02	0.21	1.000	-0.88	0.84
	Floor Number	-0.44	0.16	0.910	-1.11	0.22
	Room Number	-0.49	0.17	0.833	-1.19	0.21
	Toilet and Bathroom	-0.51	0.15	0.265	-1.11	0.09
	Entrance and Exit	-0.67	0.17	0.053	-1.34	0.00
	Door	-0.78*	0.16	0.006	-1.45	-0.11
	Emergency Exit	-0.44	0.19	0.999	-1.23	0.34
	Lighting	0.56	0.22	0.971	-0.32	1.43
	WiFi Coverage	0.76	0.23	0.420	-0.18	1.69
	Walkable Path	-0.33	0.18	1.000	-1.05	0.38
	Tactile Pave	-0.31	0.20	1.000	-1.13	0.51
	Stairs	-0.42	0.20	1.000	-1.23	0.39
	Steps, Dropoff, Curb	-0.47	0.18	0.969	-1.20	0.27
	Elevator	-0.36	0.18	1.000	-1.07	0.36
	Escalator	-0.18	0.18	1.000	-0.91	0.55
	Event and Exhibition	0.18	0.17	1.000	-0.50	0.85
	Furniture	-0.20	0.20	1.000	-1.00	0.60
	Dangerous Area	-0.49	0.20	0.991	-1.30	0.32
	People	-0.04	0.17	1.000	-0.74	0.65
	Weather	0.42	0.17	0.978	-0.25	1.10
	Noise	0.38	0.24	1.000	-0.58	1.34
Noise	Building Profile	-0.31	0.21	1.000	-1.15	0.53
	Floor Layout	-0.40	0.24	1.000	-1.36	0.56
	Floor Number	-0.82	0.24	0.293	-1.80	0.15
	Room Number	-0.87	0.23	0.144	-1.82	0.09
	Toilet and Bathroom	-0.89*	0.21	0.036	-1.76	-0.02
	Entrance and Exit	-1.04*	0.20	0.001	-1.84	-0.25
	Door	-1.16*	0.21	< 0.001	-2.00	-0.31

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SRF (I)	SRF (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference^b	
					Lower Bound	Upper Bound
	Emergency Exit	-0.82	0.24	0.293	-1.80	0.15
	Lighting	0.18	0.30	1.000	-1.05	1.41
	WiFi Coverage	0.38	0.31	1.000	-0.88	1.64
	Walkable Path	-0.71	0.23	0.560	-1.64	0.21
	Tactile Pave	-0.69	0.20	0.252	-1.49	0.11
	Stairs	-0.80*	0.19	0.043	-1.59	-0.01
	Steps, Dropoff, Curb	-0.84*	0.19	0.019	-1.63	-0.06
	Elevator	-0.73	0.21	0.237	-1.58	0.12
	Escalator	-0.56	0.19	0.812	-1.34	0.23
	Event and Exhibition	-0.20	0.23	1.000	-1.15	0.75
	Furniture	-0.58	0.20	0.836	-1.41	0.25
	Dangerous Area	-0.87*	0.18	0.005	-1.60	-0.13
	People	-0.42	0.23	1.000	-1.34	0.49
	Weather	0.04	0.25	1.000	-0.95	1.04
	Reception	-0.38	0.24	1.000	-1.34	0.58

Based on estimated marginal means
* The mean difference is significant at the adjustment for multiple comparisons
[b] Adjustment for multiple comparisons: Sidak

Table D.82: SRF Components: Estimated Marginal Means: Multivariate tests

	Value	F	Hypothesis df	Error df	p	Partial Eta Squared
Pillai's trace	0.833	5.202[a]	22	23	< 0.001	0.833
Wilks' lambda	0.167	5.202[a]	22	23	< 0.001	0.833
Hotelling's trace	4.976	5.202[a]	22	23	< 0.001	0.833
Roy's largest root	4.976	5.202[a]	22	23	< 0.001	0.833

Each F tests the multivariate effect of SRF. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
[a] Exact statistic

D.10 Two-way ANOVA on SRF Components

In this section, SRF individuals (23 components) were tested via two-way ANOVA in order to check whether there were differences between groups: visually impaired people and sighted people.

TABLE D.83: Two-way ANOVA on SRF Components: Between-Subjects Factors

		N
Groups	Visually impaired people	30
	Sighted people	15

D.10.1 Building Profile

Table D.84: Building Profile: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.54[a]	1	0.54	0.41	0.526
Intercept	582.68	1	582.68	437.77	< 0.001
Groups	0.54	1	0.54	0.41	0.526
Error	57.23	43	1.33		
Total	700.00	45			
Corrected Total	57.78	44			

[a] R Squared = 0.01 (Adjusted R Squared = -0.01)

Table D.85: Building Profile: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.70	0.21	3.28	4.13
2	3.93	0.30	3.33	4.53

Table D.86: Building Profile: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.23	0.37	0.526	-0.97	0.502
2	1	0.23	0.37	0.526	-0.50	0.969

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.87: Building Profile: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	.54	1	.54	.41	.526
Error	57.233	43	1.33		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.2 Floor Layout

TABLE D.88: Floor Layout: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Corrected Model	3.60[a]	1	3.60	3.12	0.084
Intercept	629.38	1	629.38	545.63	< 0.001
Groups	3.60	1	3.60	3.12	0.084
Error	49.60	43	1.15		
Total	726.00	45			
Corrected Total	53.20	44			

[a] R Squared = 0.07 (Adjusted R Squared = 0.05)

TABLE D.89: Floor Layout: Estimates

Groups	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	3.67	0.20	3.27	4.06
2	4.27	0.28	3.71	4.83

TABLE D.90: Floor Layout: Pairwise Comparisons

Groups (I)	**Groups (J)**	**Mean Difference (I - J)**	**Std. Error**	p^a	**95% Confidence Interval for Difference**[a]	
					Lower Bound	**Upper Bound**
1	2	-0.60	0.34	0.84	-1.29	0.09
2	1	0.60	0.34	0.84	-0.09	1.29

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

TABLE D.91: Floor Layout: Univariate Tests

	Sum of Squares	**df**	**Mean Square**	**F**	p
Contrast	3.60	1	3.60	3.12	0.084
Error	49.60	43	1.15		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.3 Floor Number

Table D.92: Floor Number: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	3.21[a]	1	3.21	4.31	0.44
Intercept	768.54	1	768.54	1031.66	< 0.001
Groups	3.21	1	3.21	4.31	0.44
Error	32.03	43	0.75		
Total	863.00	45			
Corrected Total	35.24	44			

[a] R Squared = 0.09 (Adjusted R Squared = 0.07)

Table D.93: Floor Number: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.10	0.16	3.78	4.42
2	4.67	0.22	4.22	5.12

Table D.94: Floor Number: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.57*	0.27	0.04	-1.12	-0.02
2	1	0.57*	0.27	0.04	0.02	1.12

Based on estimated marginal means
* The mean difference is significant at the 0
[a] Adjustment for multiple comparisons: Sidak.

Table D.95: Floor Number: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	3.21	1	3.21	4.31	0.044
Error	32.03	43	.75		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.4 Room Number

TABLE D.96: Room Number: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Corrected Model	2.50[a]	1	2.50	3.91	0.054
Intercept	780.28	1	780.28	1220.07	< 0.001
Groups	2.50	1	2.50	3.91	0.054
Error	27.50	43	0.64		
Total	875.00	45			
Corrected Total	30.00	44			

[a] R Squared = 0.08 (Adjusted R Squared = 0.06)

TABLE D.97: Room Number: Estimates

Groups	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	4.17	0.15	3.87	4.46
2	4.67	0.21	4.25	5.08

TABLE D.98: Room Number: Pairwise Comparisons

Groups (I)	**Groups (J)**	**Mean Difference (I - J)**	**Std. Error**	p^a	**95% Confidence Interval for Difference**[a]	
					Lower Bound	**Upper Bound**
1	2	-0.50	0.25	0.054	-1.01	0.01
2	1	0.50	0.25	0.054	-0.01	1.01

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

TABLE D.99: Room Number: Univariate Tests

	Sum of Squares	**df**	**Mean Square**	**F**	p
Contrast	2.50	1.00	2.50	3.91	0.054
Error	27.50	43.00	0.64		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.5 Toilet and Bathroom

Table D.100: Toilet and Bathroom: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.28[a]	1	0.28	0.66	0.420
Intercept	768.54	1	768.54	1832.57	< 0.001
Groups	0.28	1	0.28	0.66	0.420
Error	18.03	43	0.42		
Total	872.00	45			
Corrected Total	18.31	44			

[a] R Squared = 0.02 (Adjusted R Squared = -0.01)

Table D.101: Toilet and Bathroom: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.30	0.12	4.06	4.54
2	4.47	0.17	4.13	4.80

Table D.102: Toilet and Bathroom: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.17	0.20	0.420	-0.58	0.25
2	1	0.17	0.20	0.420	-0.25	0.58

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.103: Toilet and Bathroom: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.28	1	0.28	0.66	0.420
Error	18.03	43	0.42		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.6 Entrance and Exit

Table D.104: Entrance and Exit: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	1.11[a]	1	1.11	4.71	0.035
Intercept	834.18	1	834.18	3539.77	0.000
Groups	1.11	1	1.11	4.71	0.035
Error	10.13	43	0.24		
Total	927.00	45			
Corrected Total	11.24	44			

[a] R Squared = 0.10 (Adjusted R Squared = -0.08)

Table D.105: Entrance and Exit: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.40	0.09	4.22	4.58
2	4.73	0.13	4.48	4.99

Table D.106: Entrance and Exit: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.33*	0.15	0.035	-0.64	-0.02
2	1	0.33*	0.15	0.035	0.02	0.64

Based on estimated marginal means
* The mean difference is significant at the 0
[a] Adjustment for multiple comparisons: Sidak.

Table D.107: Entrance and Exit: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	1.11	1	1.11	4.71	0.035
Error	10.13	43	0.24		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.7 Door

Table D.108: Door: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.01[a]	1	0.01	0.04	0.846
Intercept	852.54	1	852.54	2917.19	0.000
Groups	0.01	1	0.01	0.04	0.846
Error	12.57	43	0.29		
Total	974.00	45			
Corrected Total	12.58	44			

[a] R Squared = 0.00 (Adjusted R Squared = -0.02)

Table D.109: Door: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.63	0.10	4.43	4.83
2	4.60	0.14	4.32	4.88

Table D.110: Door: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.03	0.17	0.846	-0.31	0.38
2	1	-0.03	0.17	0.846	-0.38	0.31

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.111: Door: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.01	1	0.01	0.04	0.846
Error	12.57	43	0.29		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.8 Emergency Exit

Table D.112: Emergency Exit: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Corrected Model	2.18[a]	1	2.18	4.45	0.041
Intercept	762.71	1	762.71	1556.80	0.000
Groups	2.18	1	2.18	4.45	0.041
Error	21.07	43	0.49		
Total	851.00	45			
Corrected Total	23.24	44			

[a] R Squared = 0.09 (Adjusted R Squared = 0.07)

Table D.113: Emergency Exit: Estimates

Groups	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	4.13	0.13	3.88	4.39
2	4.60	0.18	4.24	4.96

Table D.114: Emergency Exit: Pairwise Comparisons

Groups (I)	**Groups (J)**	**Mean Difference (I - J)**	**Std. Error**	p^a	**95% Confidence Interval for Difference[a]**	
					Lower Bound	**Upper Bound**
1	2	-0.47*	0.22	0.041	-0.91	-0.02
2	1	0.47*	0.22	0.041	0.02	0.91

Based on estimated marginal means
* The mean difference is significant at the 0
[a] Adjustment for multiple comparisons: Sidak.

Table D.115: Emergency Exit: Univariate Tests

	Sum of Squares	**df**	**Mean Square**	**F**	***p***
Contrast	2.18	1	2.18	4.45	0.041
Error	21.07	43	0.49		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.9 Lighting

Table D.116: Lighting: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10.68[a]	1	10.68	6.16	0.017
Intercept	388.54	1	388.54	224.06	0.000
Groups	10.68	1	10.68	6.16	0.017
Error	74.57	43	1.73		
Total	572.00	45			
Corrected Total	85.24	44			

[a] R Squared = 0.13 (Adjusted R Squared = 0.11)

Table D.117: Lighting: Estimates

Groups	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	3.63	0.24	3.15	4.12
2	2.60	0.34	1.91	3.29

Table D.118: Lighting: Pairwise Comparisons

Groups (I)	**Groups (J)**	**Mean Difference (I - J)**	**Std. Error**	***p*[a]**	**95% Confidence Interval for Difference[a]**	
					Lower Bound	**Upper Bound**
1	2	1.03*	0.42	0.017	0.19	1.87
2	1	-1.03*	0.42	0.017	-1.87	-0.19

Based on estimated marginal means
* The mean difference is significant at the 0
[a] Adjustment for multiple comparisons: Sidak.

Table D.119: Lighting: Univariate Tests

	Sum of Squares	**df**	**Mean Square**	**F**	***p***
Contrast	10.68	1	10.68	6.16	0.017
Error	74.57	43	1.73		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.10 Wifi Coverage

Table D.120: Wifi Coverage: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.01[a]	1	0.01	0.01	0.940
Intercept	380.28	1	380.28	195.52	0.000
Groups	0.01	1	0.01	0.01	0.940
Error	83.63	43	1.94		
Total	513.00	45			
Corrected Total	83.64	44			

[a] R Squared = 0.00 (Adjusted R Squared = -0.02)

Table D.121: Wifi Coverage: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.10	0.25	2.59	3.61
2	3.07	0.36	2.34	3.79

Table D.122: Wifi Coverage: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.03	0.44	0.940	-0.86	0.92
2	1	-0.03	0.44	0.940	-0.92	0.86

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.123: Wifi Coverage: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.01	1	0.01	0.01	0.940
Error	83.63	43	1.94		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.11 Walkable Path

Table D.124: Walkable Path: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.04[a]	1	0.04	0.07	0.797
Intercept	694.44	1	694.44	1046.53	0.000
Groups	0.04	1	0.04	0.07	0.797
Error	28.53	43	0.66		
Total	814.00	45			
Corrected Total	28.58	44			

[a] R Squared = 0.00 (Adjusted R Squared = -0.02)

Table D.125: Walkable Path: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.20	0.15	3.90	4.50
2	4.13	0.21	3.71	4.56

Table D.126: Walkable Path: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.07	0.26	0.797	-0.45	0.59
2	1	-0.07	0.26	0.797	-0.59	0.45

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.127: Walkable Path: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.04	1	0.04	0.07	0.797
Error	28.53	43	0.66		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.12 Tactile Pavement

Table D.128: Tactile Pavement: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	4.44[a]	1	4.44	4.61	0.037
Intercept	728.18	1	728.18	755.10	0.000
Groups	4.44	1	4.44	4.61	0.037
Error	41.47	43	0.96		
Total	823.00	45			
Corrected Total	45.91	44			

[a] R Squared = 0.10 (Adjusted R Squared = 0.08)

Table D.129: Tactile Pavement: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.93	0.18	3.57	4.29
2	4.60	0.25	4.09	5.11

Table D.130: Tactile Pavement: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.67*	0.31	0.037	-1.29	-0.04
2	1	0.67*	0.31	0.037	0.04	1.29

Based on estimated marginal means
* The mean difference is significant at the 0
[a] Adjustment for multiple comparisons: Sidak.

Table D.131: Tactile Pavement: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	4.44	1	4.44	4.61	0.037
Error	41.47	43	0.96		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.13 Stairs

Table D.132: Stairs: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.10[a]	1	0.10	0.19	0.666
Intercept	733.88	1	733.88	1390.16	0.000
Groups	0.10	1	0.10	0.19	0.666
Error	22.70	43	0.53		
Total	842.00	45			
Corrected Total	22.80	44			

[a] R Squared = 0.00 (Adjusted R Squared = -0.02)

Table D.133: Stairs: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.23	0.13	3.97	4.50
2	4.33	0.19	3.96	4.71

Table D.134: Stairs: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.10	0.23	0.666	-0.56	0.36
2	1	0.10	0.23	0.666	-0.36	0.56

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.135: Stairs: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.10	1	0.10	0.19	0.666
Error	22.70	43	0.53		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.14 Steps, Dropoffs and Curbs

Table D.136: Steps, Dropoff and Curbs: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Corrected Model	1.11^a	1	1.11	3.81	0.057
Intercept	762.71	1	762.71	2616.75	< 0.001
Groups	1.11	1	1.11	3.81	0.057
Error	12.53	43	0.29		
Total	850.00	45			
Corrected Total	13.64	44			

[a] R Squared = 0.08 (Adjusted R Squared = 0.06)

Table D.137: Steps, Dropoff and Curbs: Estimates

Groups	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	4.20	0.10	4.00	4.40
2	4.53	0.14	4.25	4.81

Table D.138: Steps, Dropoff and Curbs: Pairwise Comparisons

Groups (I)	**Groups (J)**	**Mean Difference (I - J)**	**Std. Error**	p^a	**95% Confidence Interval for Difference**[a]	
					Lower Bound	**Upper Bound**
1	2	-0.33	0.17	0.057	-0.68	0.01
2	1	0.33	0.17	0.057	-0.01	

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.139: Steps, Dropoff and Curbs: Univariate Tests

	Sum of Squares	**df**	**Mean Square**	**F**	p
Contrast	1.11	1	1.11	3.81	0.057
Error	12.53	43	0.29		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.15 Elevator

Table D.140: Elevator: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.10[a]	1	0.10	0.33	0.570
Intercept	711.21	1	711.21	2334.51	< 0.001
Groups	0.10	1	0.10	0.33	0.570
Error	13.10	43	0.30		
Total	807.00	45			
Corrected Total	13.20	44			

[a] R Squared = 0.01 (Adjusted R Squared = -0.02)

Table D.141: Elevator: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.17	0.10	3.96	4.37
2	4.27	0.14	3.98	4.55

Table D.142: Elevator: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.10	0.17	0.570	-0.45	0.25
2	1	0.10	0.17	0.570	-0.25	0.45

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.143: Elevator: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.10	1	0.10	0.33	0.570
Error	13.10	43	0.30		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.16 Escalator

Table D.144: Escalator: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.04[a]	1	0.04	0.08	0.774
Intercept	650.71	1	650.71	1220.08	< 0.001
Groups	0.04	1	0.04	0.08	0.774
Error	22.93	43	0.53		
Total	751.00	45			
Corrected Total	22.98	44			

[a] R Squared = 0.00 (Adjusted R Squared = -0.02)

Table D.145: Escalator: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.00	0.13	3.73	4.27
2	4.07	0.19	3.69	4.45

Table D.146: Escalator: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.07	0.23	0.774	-0.53	0.40
2	1	0.07	0.23	0.774	-0.40	0.53

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.147: Escalator: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.04	1	0.04	0.08	0.774
Error	22.93	43	0.53		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.17 Event and Exhibition

Table D.148: Event and Exhibition: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.90[a]	1	0.90	1.54	0.221
Intercept	523.21	1	523.21	896.34	< 0.001
Groups	0.90	1	0.90	1.54	0.221
Error	25.10	43	0.58		
Total	631.00	45			
Corrected Total	26.00	44			

[a] R Squared = 0.04 (Adjusted R Squared = 0.01)

Table D.149: Event and Exhibition: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.77	0.14	3.49	4.05
2	3.47	0.20	3.07	3.86

Table D.150: Event and Exhibition: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.30	0.24	0.221	-0.19	0.79
2	1	-0.30	0.24	0.221	-0.79	0.19

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.151: Event and Exhibition: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.90	1	0.90	1.54	0.221
Error	25.10	43	0.58		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.18 Furniture

Table D.152: Furniture: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.28[a]	1	0.28	0.51	0.481
Intercept	645.34	1	645.34	1174.18	< 0.001
Groups	0.28	1	0.28	0.51	0.481
Error	23.63	43	0.55		
Total	760.00	45			
Corrected Total	23.91	44			

[a] R Squared = 0.01 (Adjusted R Squared = -0.01)

Table D.153: Furniture: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.10	0.14	3.83	4.37
2	3.93	0.19	3.55	4.32

Table D.154: Furniture: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.17	0.23	0.481	-0.31	0.64
2	1	-0.17	0.23	0.481	-0.64	0.31

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.155: Furniture: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.28	1	0.28	0.51	0.481
Error	23.63	43	0.55		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.19 Dangerous Area

Table D.156: Dangerous Area: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	1.60[a]	1	1.60	2.61	0.114
Intercept	774.40	1	774.40	1261.33	< 0.001
Groups	1.60	1	1.60	2.61	0.114
Error	26.40	43	0.61		
Total	873.00	45			
Corrected Total	28.00	44			

[a] R Squared = 0.06 (Adjusted R Squared = 0.04)

Table D.157: Dangerous Area: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.20	0.14	3.91	4.49
2	4.60	0.20	4.19	5.01

Table D.158: Dangerous Area: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.40	0.25	0.114	-0.90	0.10
2	1	0.40	0.25	0.114	-0.10	0.90

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.159: Dangerous Area: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	1.60	1	1.60	2.61	0.114
Error	26.40	43	0.61		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.20 People

Table D.160: People: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	1.11^a	1	1.11	1.35	0.251
Intercept	587.78	1	587.78	715.31	< 0.001
Groups	1.11	1	1.11	1.35	0.251
Error	35.33	43	0.82		
Total	717.00	45			
Corrected Total	36.44	44			

[a] R Squared = 0.03 (Adjusted R Squared = 0.01)

Table D.161: People: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	4.00	0.17	3.67	4.33
2	3.67	0.23	3.19	4.14

Table D.162: People: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.33	0.29	0.251	-0.24	0.91
2	1	-0.33	0.29	0.251	-0.91	0.24

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.163: People: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	1.11	1	1.11	1.35	0.251
Error	35.33	43	0.82		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.21 Weather

Table D.164: Weather: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	5.38[a]	1	5.38	3.88	0.055
Intercept	435.60	1	435.60	314.28	< 0.001
Groups	5.38	1	5.38	3.88	0.055
Error	59.60	43	1.39		
Total	592.00	45			
Corrected Total	64.98	44			

[a] R Squared = 0.08 (Adjusted R Squared = 0.06)

Table D.165: Weather: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.67	0.21	3.23	4.10
2	2.93	0.30	2.32	3.55

Table D.166: Weather: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.73	0.37	0.055	-0.02	1.48
2	1	-0.73	0.37	0.055	-1.48	0.02

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

Table D.167: Weather: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	5.38	1	5.38	3.88	0.055
Error	59.60	43	1.39		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.22 Reception

TABLE D.168: Reception: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	0.04^a	1	0.04	0.03	0.854
Intercept	587.78	1	587.78	452.41	< 0.001
Groups	0.04	1	0.04	0.03	0.854
Error	55.87	43	1.30		
Total	721.00	45			
Corrected Total	55.91	44			

[a] R Squared = 0.00 (Adjusted R Squared = -0.02)

TABLE D.169: Reception: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.87	0.21	3.45	4.29
2	3.80	0.29	3.21	4.39

TABLE D.170: Reception: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.07	0.36	0.854	-0.66	0.79
2	1	-0.07	0.36	0.854	-0.79	0.66

Based on estimated marginal means
[a] Adjustment for multiple comparisons: Sidak.

TABLE D.171: Reception: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	0.04	1	0.04	0.03	0.854
Error	55.87	43	1.30		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.10.23 Noise

Table D.172: Noise: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	8.10[a]	1	8.10	4.76	0.035
Intercept	523.21	1	523.21	307.77	<0.001
Groups	8.10	1	8.10	4.76	0.035
Error	73.10	43	1.70		
Total	622.00	45			
Corrected Total	81.20	44			

[a] R Squared = 0.10 (Adjusted R Squared = 0.08)

Table D.173: Noise: Estimates

Groups	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	3.17	0.24	2.69	3.65
2	4.07	0.34	3.39	4.75

Table D.174: Noise: Pairwise Comparisons

Groups (I)	Groups (J)	Mean Difference (I - J)	Std. Error	p^a	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-0.90*	0.41	0.035	-1.73	-0.07
2	1	0.90*	0.41	0.035	0.07	1.73

Based on estimated marginal means
* The mean difference is significant at the 0
[a] Adjustment for multiple comparisons: Sidak.

Table D.175: Noise: Univariate Tests

	Sum of Squares	df	Mean Square	F	p
Contrast	8.10	1	8.10	4.76	0.035
Error	73.10	43	1.70		

The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

D.11 Reliability Tests

Table D.176: Reliability Tests: Reliability Tests: Case Processing Summary

		N	%
Cases	Valid	45	100
	Excluded	0	0
	Total	45	100

Table D.177: Reliability Tests: Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.832	0.859	23

Table D.178: Reliability Tests: Item Statistics

Components	Mean	Std. Deviation	N
Building Profile	3.78	1.15	45
Floor Layout	3.87	1.10	45
Floor Number	4.29	0.90	45
Room Number	4.33	0.83	45
Toilet and Bathroom	4.36	0.65	45
Entrance and Exit	4.51	0.51	45
Door	4.62	0.54	45
Emergency Exit	4.29	0.73	45
Lighting	3.29	1.39	45
WiFi Coverage	3.09	1.38	45
Walkable Path	4.18	0.81	45
Tactile Pavement	4.16	1.02	45
Stairs	4.27	0.72	45
Steps, Dropoff, Curb	4.31	0.56	45
Elevator	4.20	0.55	45
Escalator	4.02	0.72	45
Event and Exhibition	3.67	0.77	45
Furniture	4.04	0.74	45
Dangerous Area	4.33	0.80	45
People	3.89	0.91	45
Weather	3.42	1.22	45
Reception	3.84	1.13	45
Noise	3.47	1.36	45

Table D.179: Reliability Tests: Item-Total Statistics

Components	**Scale Mean if Item Deleted**	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach's Alpha if Item Deleted**
Building Profile	88.44	89.62	0.284	0.520	0.831
Floor Layout	88.36	89.14	0.324	0.656	0.828
Floor Number	87.93	88.29	0.475	0.776	0.821
Room Number	87.89	89.51	0.441	0.668	0.823
Toilet and Bathroom	87.87	91.62	0.409	0.584	0.825
Entrance and Exit	87.71	92.57	0.438	0.542	0.826
Door	87.60	92.38	0.430	0.609	0.826
Emergency Exit	87.93	93.20	0.239	0.572	0.830
Lighting	88.93	86.84	0.320	0.518	0.831
WiFi Coverage	89.13	89.66	0.211	0.470	0.838
Walkable Path	88.04	91.00	0.354	0.603	0.826
Tactile Pavement	88.07	88.34	0.401	0.656	0.824
Stairs	87.96	89.45	0.523	0.802	0.821
Steps, Dropoff, Curb	87.91	92.17	0.430	0.674	0.825
Elevator	88.02	91.98	0.458	0.752	0.825
Escalator	88.20	89.57	0.511	0.817	0.821
Event and Exhibition	88.56	89.30	0.495	0.501	0.822
Furniture	88.18	89.42	0.511	0.796	0.821
Dangerous Area	87.89	90.06	0.422	0.664	0.824
People	88.33	86.05	0.605	0.735	0.816
Weather	88.80	85.89	0.431	0.759	0.823
Reception	88.38	85.06	0.517	0.728	0.819
Noise	88.76	87.55	0.302	0.711	0.832

Table D.180: Reliability Tests: Inter-Item Correlation Matrix

Components	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.000	0.102	0.108	0.056	0.263	0.318	0.416	0.052	-0.044	0.085	0.068	0.030	0.211	0.253	0.253	0.088	0.069	0.200	0.232	0.085	0.053	0.131	0.389
2		1	0.571	0.300	0.100	0.248	0.106	0.021	0.070	0.098	-0.127	-0.001	0.132	0.255	0.045	0.004	0.161	0.260	0.207	0.280	0.281	0.185	0.180
3			1	0.697	0.330	0.369	0.281	0.253	0.187	0.126	-0.010	0.074	0.125	0.226	0.158	0.166	0.275	0.256	0.276	0.208	0.136	0.429	0.017
4				1	0.327	0.399	0.137	0.215	0.132	0.153	0.148	0.153	0.229	0.165	0.151	0.216	0.179	0.311	0.345	0.171	0.128	0.326	0.020
5					1	0.197	0.135	-0.030	0.035	0.270	0.007	0.225	0.085	0.065	0.309	0.080	0.107	0.157	0.206	0.340	0.355	0.484	0.118
6						1	0.394	0.208	0.044	-0.034	0.330	0.063	0.179	0.391	0.197	0.093	0.214	0.060	0.470	0.274	0.048	0.262	0.274
7							1	0.229	0.242	0.016	0.107	0.027	0.150	0.404	0.109	0.140	0.295	0.101	0.409	0.426	0.216	0.277	0.123
8								1	0.208	0.291	0.182	0.152	0.197	0.222	0.251	0.334	0.298	0.060	0.105	-0.053	-0.193	0.056	-0.117
9									1	0.211	0.298	0.000	0.148	0.116	0.012	0.219	0.496	0.231	-0.068	0.403	0.302	0.348	-0.097
10										1	0.170	0.103	-0.002	-0.214	0.066	0.044	0.264	0.085	-0.007	0.189	0.167	0.243	-0.156
11											1	0.269	0.308	0.178	0.381	0.227	0.391	0.139	0.047	0.306	0.177	0.281	0.068
12												1	0.499	0.193	0.309	0.426	0.039	0.232	0.325	0.337	0.330	0.199	0.405
13													1	0.582	0.611	0.687	0.288	0.705	0.317	0.289	0.050	-0.004	0.335
14														1	0.462	0.321	0.248	0.353	0.426	0.294	-0.064	0.079	0.314
15															1	0.620	0.270	0.540	0.208	0.274	0.041	0.125	0.116
16																1	0.341	0.681	0.184	0.246	0.144	0.200	0.336
17																	1	0.307	0.037	0.368	0.300	0.358	-0.022
18																		1	0.167	0.279	0.258	0.036	0.251
19																			1	0.428	0.086	0.059	0.461
20																				1	0.619	0.382	0.153
21																					1	0.547	0.181
22																						1	0.197
23																							1

1: Building Profile
2: Floor Layout
3: Floor Number
4: Room Number
5: Toilet and Bathroom
6: Entrance and Exit
7: Door
8: Emergency Exit
9: Lighting
10: WiFi Coverage
11: Walkable Path
12: Tactile Pavement
13: Stairs
14: Steps, Dropoff, Curb
15: Elevator
16: Escalator
17: Event and Exhibition
18: Furniture
19: Dangerous Area
20: People
21: Weather
22: Reception
23: Noise

Appendix E

Building Rating System - Expert Review Questionnaire

E.1 Questionnaire for Researcher and Developer Experts

Participant Information Sheet

Study Title: Development and testing of a building rating system for people with visual impairment by the use of spatial representation framework.

Investigator: Watthanasak Jeamwatthanachai
Ethics number: ERGO/FPSE/40754

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
This study attempts to develop a building rating system that can be used to measure a level of accessibility for people with visual impairment is provided in the building. This study consists of two parts as follows:

- Review of the success criteria for building classifications, which will be used in the rating system.
- Testing of the rating system in actual buildings

Why have I been chosen?
For the expert review, you are chosen based on your knowledge and experience (e.g., architectures, interior design, building inspection, etc.), being able to give comments and reviews on validity and improvements for the system.

For testing of the building rating system, the rating system is intentionally designed for everybody. Thus, participants will be anybody (e.g., students, building inspectors, etc.)

What will happen to me if I take part?
For the expert review, you will be given a list of success criteria for each type of area (or space). You will be later asked to check, comment and review if any improvement is needed. Your comments and reviews will be used towards the improvements of the rating system.

For the testing of the rating system, you will be asked to fill out the question forms during a building survey by using the building rating system. Later, you will be asked to give a feedback based on your experience after using the rating system.

Are there any benefits in my taking part?
Taking part in this study, you have the opportunity to help us to develop the state-of-the-art technology to help visually impaired and blind people to have freedom and confidence in navigating inside buildings by themselves.

Are there any risks involved?
There is no any risk involved for participants completing the question forms

Will my participation be confidential?
Participation will be kept anonymous. All data will be safe in a protected computer. All will be destroyed once the research is completed.

What happens if I change my mind?
You have the right to withdraw from doing the questionnaire or interview at any time.

What happens if something goes wrong?
If you have any concern or complaint with this study, please contacts Watthanasak Jeamwatthanachai at wj1g14@ecs.soton.ac.uk

Where can I get more information?
If you would like to get more information about this study, please feel free to contact Watthanasak Jeamwatthanachai at wj1g14@ecs.soton.ac.uk

Expert Review

Study Title: Development and testing of a building rating system for people with visual impairment

Investigator: Watthanasak Jeamwatthanachai
Ethics number: ERGO/FPSE/40754

Invitation

Thank you for reading this document. I would like to invite you to take part in my research study by reviewing the building rating system given in this document and then completing a set of question given in the questionnaire accordingly. It is entirely up to you whether you participate but your response would be valuable. You have been identified as an expert in the related field by your knowledge and experience in the fields of system designs (research and development); accessibility and usability; and interior design, building safety inspection.

My study attempts to create the building rating system that use to measure a level of accessibility provided in buildings that people with visual impairment are going to visit. This technology will open opportunities for them to know how good the visiting building is. Speaking of which, this will indirectly help people with visual impairment to have the freedom and confidence to perform independently navigate inside unfamiliar spaces and buildings.

The questionnaire is anonymous and your confidentiality is assured:

- Completed questionnaires will be scanned to create a single PDF file.
- This single PDF file will not be duplicated - only one copy will be created.
- This PDF file will be stored on a password protected computer at the University of Southampton.
- This PDF file will be destroyed 1 year after the completion of my PhD study.
- The original questionnaire sheets (paper transcripts) will be stored in a locked filing cabinet at the University of Southampton.
- The original questionnaire sheets (paper transcripts) will be destroyed 1 year after the completion of my PhD study.

If you have any questions, please contact the investigator (Watthanasak Jeamwatthanachai, PhD researcher) and my supervisors.

Yours Sincerely,

Watthanasak Jeamwatthanachai	Investigator, PhD researcher	wj1g14@ecs.soton.ac.uk
Prof Gary Wills	Primary Supervisor	gbw@ecs.soton.ac.uk
Prof Mike Wald	Secondary Supervisor	mw@ecs.soton.ac.uk

Instruction:

This questionnaire will take approximately 1.30 - 2 hours to finish.

Questions can be answered in 3 ways:

- Boxes: Insert an X mark in the appropriate box e.g. ☑
- Letters: circle the appropriate letter e.g. (a.) important
- Spaces: Write the answer in the space provided e.g. [2 years]

This study aims to help visually impaired and blind people to have the freedom and confidence to independently navigate unfamiliar spaces inside buildings.

In ALL cases, the questions refer ONLY to unfamiliar spaces inside buildings.

The questions do NOT refer to: Familiar spaces (regardless of whether these familiar spaces are inside or outside) Outdoor spaces (regardless of whether these outdoor spaces are familiar or unfamiliar)

Scenario

Once upon the time, you have been given the task and working with colleagues, which one of them has visual impairment having a lot of difficulties in navigating inside the office and elsewhere that he has to go. The problem has been raised by him that how to know if the visiting building is good and suitable to him as sometimes he has to go alone for the meetings and you cannot attend. He asks if there is a system being able to tell him how good of accessibility providing to him.

Creating a technology to solve the problem, the (manually operated) building rating system is introduced in this document. However, the system is not well-designed and validated yet, so as

Researcher/Developer Do you have any idea and feedback on the building rating system (BRS) described in the Section 2?

Accessibility designer Do you think three conformance (A, AA, and AAA) levels defined with the given requirement are sensible towards determining the level of accessibility that will be used to inform people with visual impairment about the accessibility is provided in the visiting building?

Architect/Interior designer/Building inspector Do you think the given requirements in each conformance levels for all spaces are correct and conforming the design standard of buildings?

Section 1 Basic information

1. Which area you are expert in?
    - a. Research and Development
    - b. Accessibility
    - c. Architecture, Interior design, or building safety inspection
    - d. Other, please specify ____________________

2. According to Question 1, how long have/had you worked in the field?

    ____________ years (approximately)

3. Have you ever worked with or developed technologies for people with disabilities before?
    - a. Yes (visual impairment)
    - b. Yes (other disabilities, please specify please specify ____________________
    - c. No

Section 2 Design of A Building Rating System

Instruction: Please read the information given below before answer the questions

Section 2.1 Design of the building rating system

In these days, measuring the level of accessibility provided inside the buildings is still almost impossible due to many reasons. For instance, the complexity of the building which will be resulting in a number of processes in the auditing process; there is no such a set of success criteria to be used for an accessibility classification for building accessibility measurement; etc. However, when it comes into auditing the environment, there is a set of checklists used to guide user how to create the inclusive built environments [18], which cannot be used for the accessibility measurement. Since no such a building rating system has been invented, this study attempts to create one, which focus on the accessibility for people with visual impairment only at this state.

Due to complexity in designing the system, it is essentially to think of how the building is going to be rated and how its rating scores and interpretation are used. In fact, buildings are comprised of a number of spaces inside the building e.g., entrance, horizontal circulation, vertical circulation, WCs, etc. Thus, it is reasonable to scale down to space level, and then measuring the level of accessibility for each space accordingly is sensible instead of measuring the level of accessibility of building as a whole. However, the level of accessibility of each space resulted from doing so can be used to rate the level of accessibility of building in overall by an average approach as shown in Figure 1.

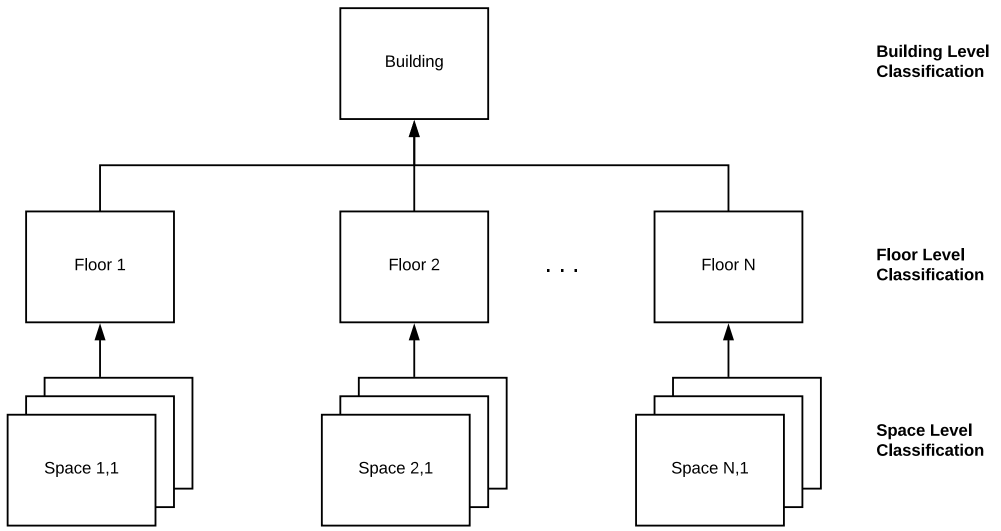


Figure 1: Bottom-up Design of the Building Rating System

Section 2.2 Space Classification

Towards the building classification as shown in the big picture (Figure 1), each space in building are classified into one of three levels of conformance levels: A, AA, and AAA, adopted from WCAG 2.0 [7], describing the level of accessibility provided in the space. For achieving each conformance, a set of success criteria for each conformance are designed based on the use of MoSCoW prioritisation approach [16], where Must-Have, Should-Have, and Could-Have are used to define a set of success criteria for Conformance A, AA, and AAA, respectively.

The success criteria to be used in the building rating system are organised based on the impact on the design and improvement of spaces and building for better independent indoor navigations by people with visual impairment and accessibility. This means that the higher level of conformance the high level of accessibility is provided to people with visual impairment, in other words, the more restraining in designing of spaces is required.

According to the previous study, the findings have shown that the most important thing in the indoor navigation is safety. People with visual impairment are afraid of visiting somewhere that they do not know the features installed or cannot access the facilities provided in the spaces and buildings. As a result, there are three level of conformance are described with their requirements shown in Table 1 and Figure 2.

Table 1: My caption

Conformance	**Requirements**	**Definitions**
No Conformance	-	No conformance level, providing no any accessibility in the space due to the failure of meeting the minimum levels requirement. In this level, people with visual impairment are not advice to visit this space.
A	The space must satisfy all the Must-Have success criteria. OR The Level A conforming alternate version is provided	A minimum level, providing an ability to navigate to the space without any hazard to people with visual impairment. In this level, people with visual impairment likely need assistances to perform some activities.
AA	The space must satisfy all the Level A and the Should-Have success criteria. OR The Level AA conforming alternate version is provided.	A sufficient level of accessibility, providing features in addition to improving the independent navigation by people with visual impairment. In this level, people with visual impairment may need assistances to perform some activities. Note that this level is used as a general policy that all buildings must be applied.
AAA	The space must satisfy all the Level A, Level AA, and all the Could-Have success criteria. OR The level AAA conforming alternate version is provided.	An enhanced level, providing features in addition to enabling an ability to access all of facilities provided in the space to people with visual impairment. In this level, people with visual impairment unlikely need any assistances to perform the activities.

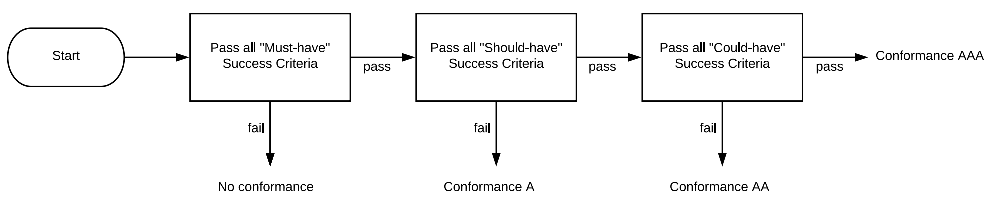


Figure 2: Space classification - Workflow

Section 2.3 Floor and Building Level Classifications

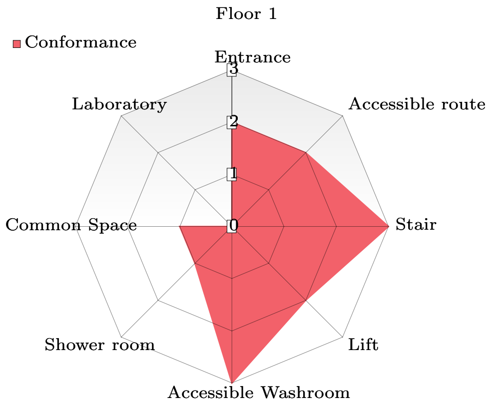
In the floor and building levels classification, a simple average approach is used. As already mentioned that a space level is the bottommost level, where many spaces can be combined into a bigger space (e.g. floors and a building). For this reason, the average score approach is sensible and used to determine the level of accessibility in overall. So does the building level classification, it uses the average scores from floor level to determine the level of accessibility in overall.

Section 2.4 Success Criteria

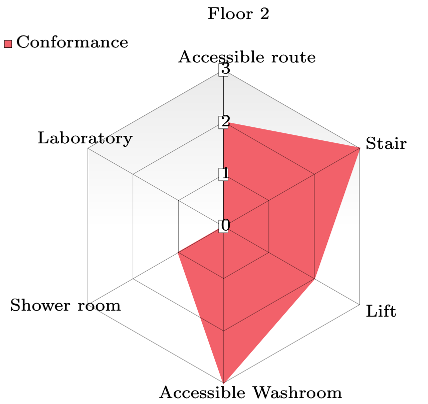
Success criteria to be used in the space classification will be discussed in Section 3

Section 2.5 Results and Interpretation

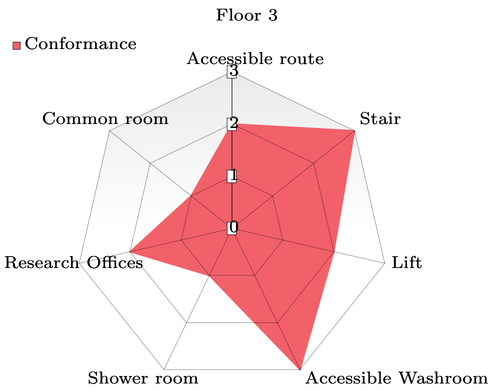
Once the building (all spaces) is measured, the results will be reported in forms of spider (radar) charts, representing the level of accessibility at one particular floor achieved for each category of spaces in three scales (1: minimum, 2: sufficient, and 3: enhanced) of conformance. The example of space classification can be seen in Figure 3, and later the overall building is shown in Figure 4.



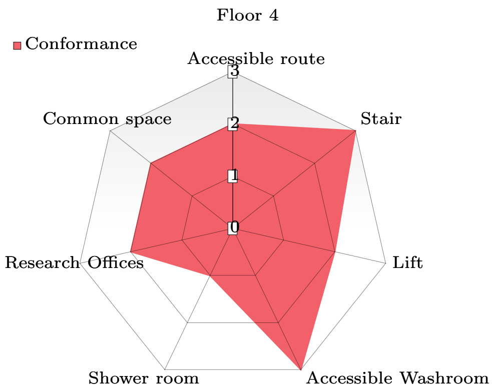
(a) Mountbatten Floor 1 (average 1.75)



(b) Mountbatten Floor 2 (average 1.83)



(c) Mountbatten Floor 3 (average 2.00)



(d) Mountbatten Floor 4 (average 2.14)

Figure 3: Example of space classification in Building 53 (Mountbatten), University of Southampton

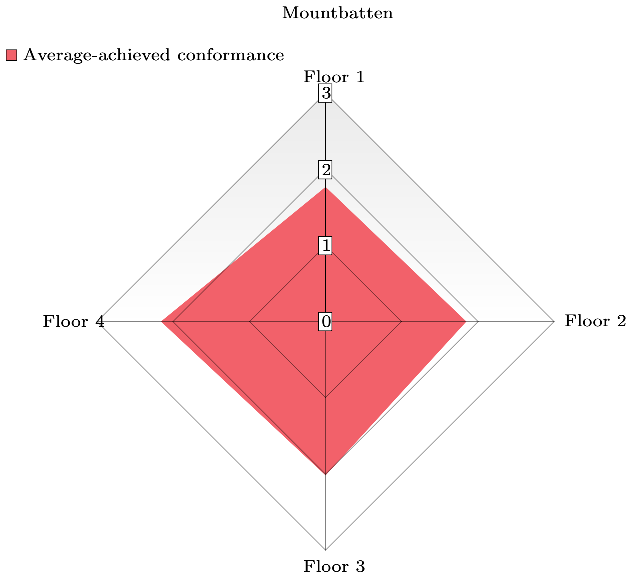


Figure 4: Level of accessibility in Building 53 (Mountbatten) by the use of average approach

From Figure 3 and 4, the examples have been shown by the use of the space classification, and later calculated into the overall scores indicating how well the accessibility is provided in each floor. At the end, in Figure 4, the achieved score in overall is 1.93, meaning that this building has almost meet the Conformance AA (a general policy that all building must be applied). This means people with visual impairment may ask for an assistance when they visit this building.

Instruction: Please answer the following questions

Question 4-5 are for Section 2.1 "Design of the building rating system"

4. Do you agree with the design of the building rating system? Please give your reason and explanation.
5. Do you think if any improvement needed for the design of the building rating system?

Question 6-7 are for Section 2.2 "Space Classification"

6. Do you agree with the conformance to be used in the space classification? Please, give your reasons and explanation.
7. Do you think any improvement would be needed for the space classification?

Question 8-9 are for Section 2.3 "Floor and Building Classification"

8. Do you agree with the conformance to be used in the floor and building classification? Please, give your reasons and explanation.
9. Do you think if any improvement needed for the floor and building classification?

Section 3 Success Criteria

Success criteria can be divided into three stages of criteria according to the conformance level (A, AA, and AAA), which each set of criteria are those criteria that constitute a level of accessibility (minimum, sufficient, enhanced level, respectively). Determining which criteria to be included for each set of the success criteria essentially requires understanding of the design of building to meet the needs of people with visual impairment. Thus, in this study, a number of design standards, design guideline, and building regulation for designing the success criteria [1–6, 8–15, 17, 19].

In this section, thirteen types of space will be used in the space classification as follows:

1.	Entrances	Section 3.1
2.	Foyers	Section 3.2
3.	Horizontal circulation (e.g. corridor and passageway)	Section 3.3
4.	Vertical circulation Stairs	Section 3.4
5.	Vertical circulation Ramps	Section 3.5
6.	Vertical circulation Lifts	Section 3.6
7.	Sanitary Ambulant Disable WCs	Section 3.7
8.	Sanitary Accessible Washroom	Section 3.8
9.	Sanitary Bathrooms and shower rooms	Section 3.9
10.	Bedrooms	Section 3.10
11.	General space (e.g. office, living room, refreshment room)	Section 3.11
12.	Utility spaces (e.g. kitchen, laundry, and storage room)	Section 3.12
13.	Hall and statium (e.g. lecture room, conference room, auditorium, and stadium)	Section 3.13

All success criteria will be first used in the manually operated audit as pass/fail checklist for measuring the level of accessibility. In the auditing process, there will be four options that users can select, which will affect the score at the end of the process, as follows:

Pass	The space passes the requirement
Fail	The space fails the requirement
Can't tell	Users cannot tell either pass or fail due to technical difficulties, which will require the further (visual) inspection to fulfil the measurement indicated by (*) asterisk in the spider chart. <u>This will not be accounted in measuring the level of accessibility.</u>
Not applicable (N/A)	Users cannot tell either pass or fail due to no existence of the particular object referred in the requirement. <u>This will not be accounted in measuring the level of accessibility.</u>

Note:

In Section 3.1 to 3.13, drawing diagrams may be referred as used in terms of explanations how spaces should be organized in a good manner. All diagrams to be included are come from [10].

Section 3.1 Entrance

Instruction: Please read three following tables and answer the questions.

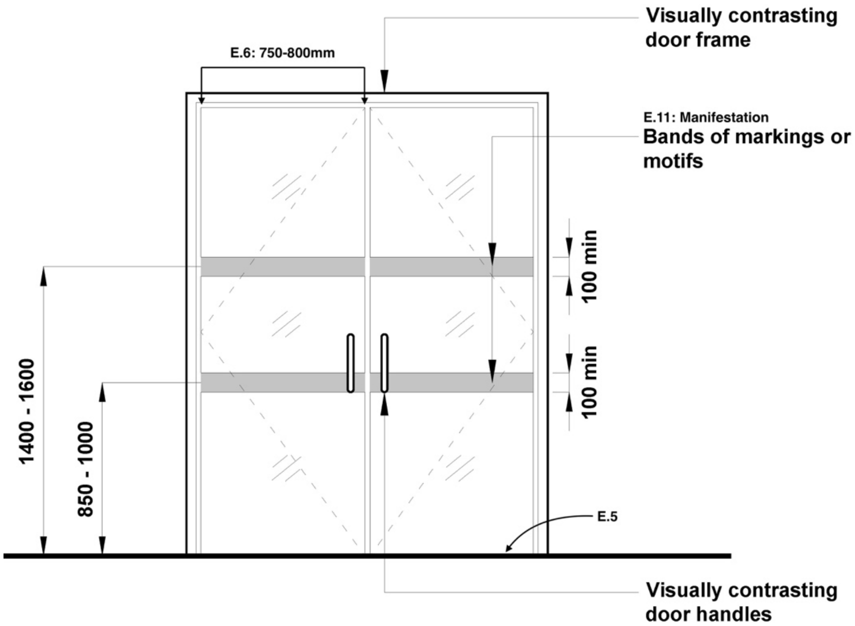


Figure 5: Entrance Space

Entrance Space - Conformance A		
Categories	**Provisions: Must-have items**	
Entrance	E.1	The main entrance is clearly visible when approaching the building
	E.2	The entrance doors are recessed or guarding is provided
	E.3	Transitional lighting is provided for people entering the building
Entry System (if provided)	E.4	The position of the entry system is clearly identified using visual contrast
Thresholds	E.5	The maximum threshold upstand is 15 mm with chamfered or rounded edges
Entrance Door	E.6	The minimum clear operating width through one leaf is 750 mm to 800 mm
	E.7	The swing area is protected adequately to prevent collisions
Glass Doors (if provided)	E.8	If glass doors are provided, the frame contrasts with the surrounding wall/screen OR the presence of the doors is differentiated from the rest of the wall/screen
	E.9	Edges of doors are clearly visible when held in the open position
	E.10	Door furniture is distinguishable in terms of visual contrast with the door
	E.11	Manifestations are provided at 850-1000 mm and 1400-1600 mm above floor level (where possible)
	E.12	Manifestation is effective at all times the building is in use
Automatic Doors (if provided)	E.13	Automatic doors are provided with either manually or automatically operated control mechanism
	E.14	Warning of the presence of the automatic doors is provided

... Continued on next page

Entrance Space - Conformance A		
Categories	**Provisions: Must-have items**	
	E.15	Warning of the direction of opening of the automatic doors is provided
	E.16	Opening and closing door speed is appropriate
	E.17	Doors remain open for an appropriate time
	E.18	Appropriate safety arrangements are provided to prevent doors closing if there is an obstruction
Revolving Doors (if provided)	E.19	If a revolving door is provided, there is an accessible entrance
	E.20	The accessible entrance is provided with an automatic opening device
	E.21	The accessible entrance is operational at all times when the revolving door is in use
Doormats (if provided)	E.22	Mats must not present a tripping hazard
	E.23	Mats must be securely fixed on the surface
Lobbies (if provided)	E.24	The minimum space between two hinged doors or pivoted doors in a series shall be 1200 mm plus the width of the door swinging into that space

Entrance Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Entrance	E.25	Appropriate signage is provided from the boundary of the property to identify the location of the main entrance
	E.26	The location of the main accessible entrance (if this not the main entrance) is clearly signposted from the boundary of the site and the main entrance
Entry System (if provided)	E.27	Entry systems are suitable for use by visually impaired people
	E.28	The position of the entry system is logical
Entrance Door	E.29	There is a 300 mm clear space beside the leading edge.
	E.30	The maximum pressure needed to open the door should be appropriate for visually impaired people to open the door
	E.31	Delayed action closers are provided
	E.32	Doors opens inwards OR If door opens outwards, it must be recessed
	E.33	Vision panels with a visibility zone extending between 500 mm and 1500 mm above floor level are provided
Glass Doors (if provided)	E.34	Door handles can be reached, gripped and used with minimum effort

Entrance Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Entrance	E.35	A canopy providing adequate shelter is provided over the entrance doors
Entry System (if provided)	E.36	Swipe card entry systems are appropriately positioned 750 mm to 1000 mm above floor level
	E.37	The top operational button of the entry is 1200 mm above floor level or less
	E.38	Appropriately designed signage is provided with instructions on how to use the entry system
	E.39	Appropriately designed signage is provided with instructions on how to get assistance if a disabled person cannot use the entry system

10. Do you agree with the success criteria shown in Entrance Space - Conformance A?
11. If no, what the success criteria of Entrance Space - Conformance A should be?
12. Do you agree with the success criteria shown in Entrance Space - Conformance AA?
13. If no, what the success criteria of Entrance Space - Conformance AA should be?
14. Do you agree with the success criteria shown in Entrance Space - Conformance AAA?
15. If no, what the success criteria of Entrance Space - Conformance AAA should be?

Section 3.2 Foyers

Instruction: Please read three following tables and answer the questions.

Foyer Space - Conformance A		
Categories	**Provisions: Must-have items**	
Approaching	F.1	The approach to the reception area is smooth and level
Reception Desk	F.2	The reception desk is logically placed
	F.3	The position of the reception desk is identifiable from the entrance to the building
	F.4	Lighting at the desk is appropriate to allow the face of the receptionist to be clearly seen
	F.5	Reflective glass screen is not provided at the reception desk
Lighting	F.6	Lighting to the reception area is appropriate to allow easy communication and comfort for users
	F.7	The minimum average illuminance at floor level in the reception area is 300 lux

Foyer Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Approaching	F.8	Directional signage to identify the position of the reception area is appropriate in terms of provision and design
Reception Desk	F.9	There is sufficient maneuvering space in front of the reception desk
	F.10	Lighting at the desk is sufficient to enable the completion of any forms, etc.
	F.11	Lighting provides a minimum illuminance at reception desk level of 500 lux

Foyer Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Reception Desk	F.12	Communication is possible across the desk from the standing or seated position
	F.13	Illuminance at the desk is controllable
Seating	F.14	A variety of seating with arms is provided
	F.15	Seating is sufficiently robust to allow someone to use the arms as assistance when sitting or standing
	F.16	Seating contrasts visually with all backgrounds against which it will be viewed

16. Do you agree with the success criteria shown in Foyer Space - Conformance A?
17. If no, what the success criteria of Foyer Space - Conformance A should be?
18. Do you agree with the success criteria shown in Foyer Space - Conformance AA?
19. If no, what the success criteria of Foyer Space - Conformance AA should be?
20. Do you agree with the success criteria shown in Foyer Space - Conformance AAA?
21. If no, what the success criteria of Foyer Space - Conformance AAA should be?

Section 3.3 Horizontal Circulation

Instruction: Please read three following tables and answer the questions.

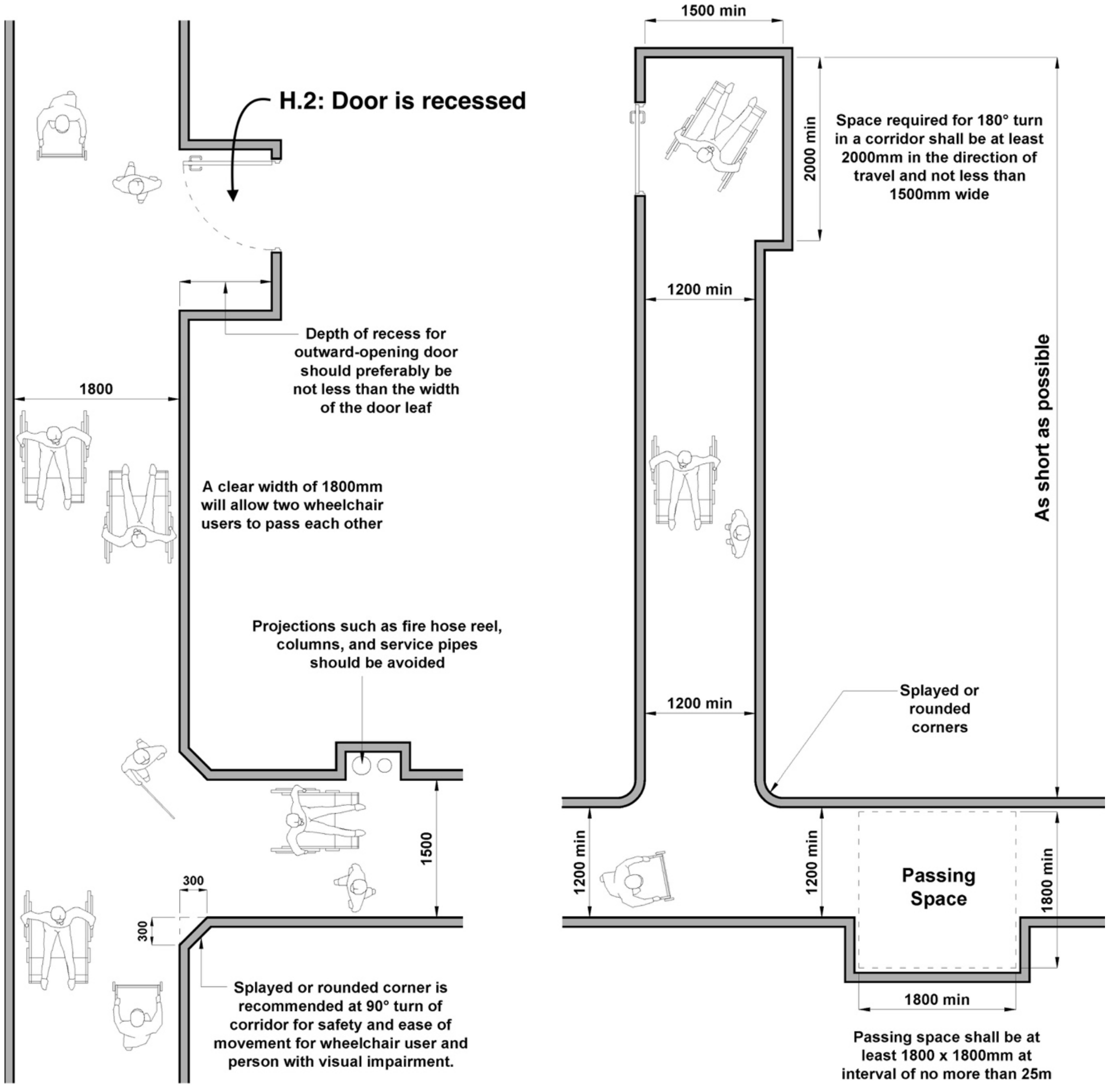


Figure 6: Horizontal Circulation

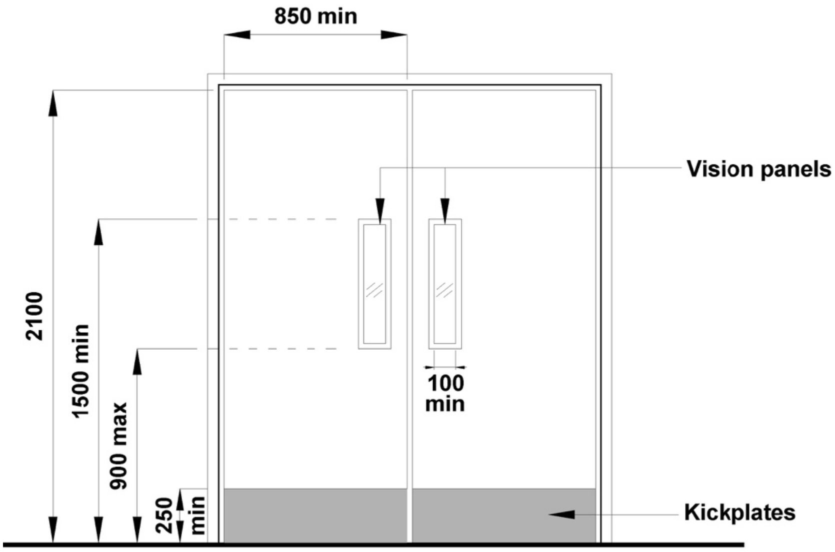


Figure 7: Internal Door

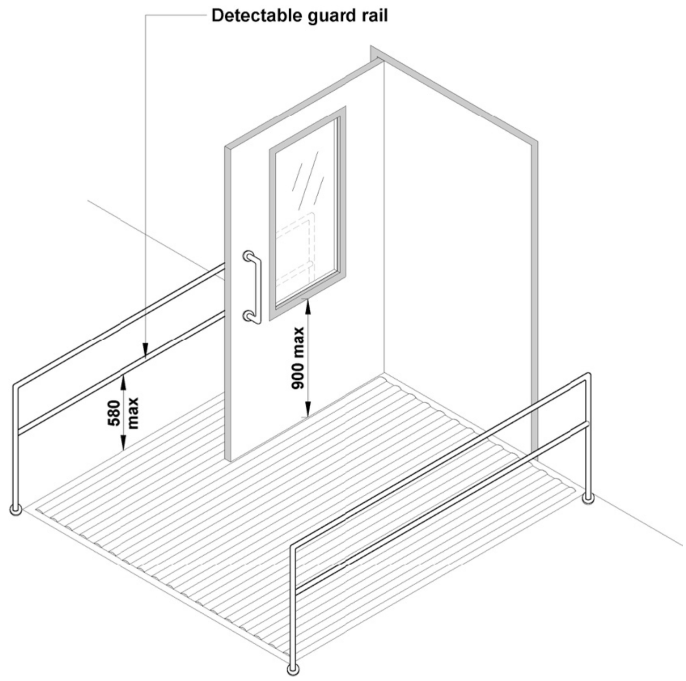


Figure 8: Guardrail for internal doors that opens outwards into the horizontal circulation

Horizontal Circulation Space - Conformance A		
Categories	**Provisions: Must-have items**	
Corridors and Passageways	H.1	Corridors have a minimum clear width of 1200 mm
	H.2	Doors along the corridors must not open into circulation routes OR The doors must be recessed
	H.3	Corridors are splayed or rounded at corners
Surfaces	H.4	The floor surface finishes are firm
	H.5	The floor surface is matte OR low reflectivity
	H.6	The floor surfaces are slip-resistant, especially when wet
	H.7	The floor surfaces are not shiny and potentially slippery
	H.8	The pattern of any floor covering is plain or with a subtle pattern
	H.9	Junctions between finishes are level and firmly fixed
Wall	H.10	Appropriate visual contrast is provided at the junction of the floor with the wall
	H.11	Wall surfaces are smooth to touch
Glazed walls screens and doors	H.12	Appropriately designed manifestation is provided to glass screens
	H.13	Manifestation contrast with the background against which it is viewed, both from inside and outside, in all lighting situations
Internal Doors	H.14	The minimum clear opening width of all internal doors is 750 mm
	H.15	If double doors are provided, the minimum clear opening width of one leaf of the doors is 750 mm
	H.16	There is swing protection for all doors that open into the circulation routes OR The doors are recessed
	H.17	All door furniture (handles, kicking plates and finger plates) contrast visually with the surface of the door
	H.18	The internal door is capable of being operated in manual, powered and/or power-assisted mode
	H.19	Internal doors are clearly identifiable in terms of visual contrast with the surrounding wall
	H.20	The leading edge of all internal doors is visually contrasted and is clearly visible when open
	H.21	For glass doors that may be held open, they are protected with appropriate guarding to prevent people from colliding with the leading edge
	H.22	Glass doors (within glazed screens) are clearly differentiated from adjacent glazed screens by a visually contrasting strip to the top and both sides of the door
	H.23	For glass doors that may be held open, they are protected with appropriate guarding to prevent people from colliding with the leading edge
Lobbies	H.24	Internal lobbies are appropriately designed to allow easy maneuverability (1200 mm minimum space is preferred)
lighting	H.25	The minimum illuminance at floor surface level is 100 lux
Acoustics	H.26	The surfaces of the floor or walls must not adversely affect the acoustics

Horizontal Circulation Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Corridors and Passageways	H.27	A series of double doors of unequal width are provided along the circulation routes; the wider leaf is on the same side of the corridor throughout its length
Glazed walls, screens and doors	H.28	The manifestation is located at two levels: Lower area: 850 mm - 1000 mm above floor level Upper area: 1400 mm - 1600 mm above floor level
	H.29	Manifestation on glass doors is in the form of a logo or sign at least 150 mm high and repeated on adjacent screens OR Manifestation is provided in the form of a decorative feature such as broken lines or continuous bands at least 50 mm high
Internal Doors	H.30	There is a minimum 300 mm clear space beside the leading edge
	H.31	Door handles are lever style
	H.32	Door and side panels wider than 450 mm are provided with minimum zones of visibility (vision panels) that extend between 500 mm and 800 mm above floor level, and between 1150 mm and 1500 mm above floor level

Horizontal Circulation Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Handrails	H.33	A handrail is provided along the length of the corridors
Internal Doors	H.34	Delayed action door closers are provided

22. Do you agree with the success criteria shown in Horizontal Circulation Space - Conformance A?
23. If no, what the success criteria of Horizontal Circulation Space - Conformance A should be?
24. Do you agree with the success criteria shown in Horizontal Circulation Space - Conformance AA?
25. If no, what the success criteria of Horizontal Circulation Space - Conformance AA should be?
26. Do you agree with the success criteria shown in Horizontal Circulation Space - Conformance AAA?
27. If no, what the success criteria of Horizontal Circulation Space - Conformance AAA should be?

Section 3.4 Vertical circulation - Stair

Instruction: Please read three following tables and answer the questions.

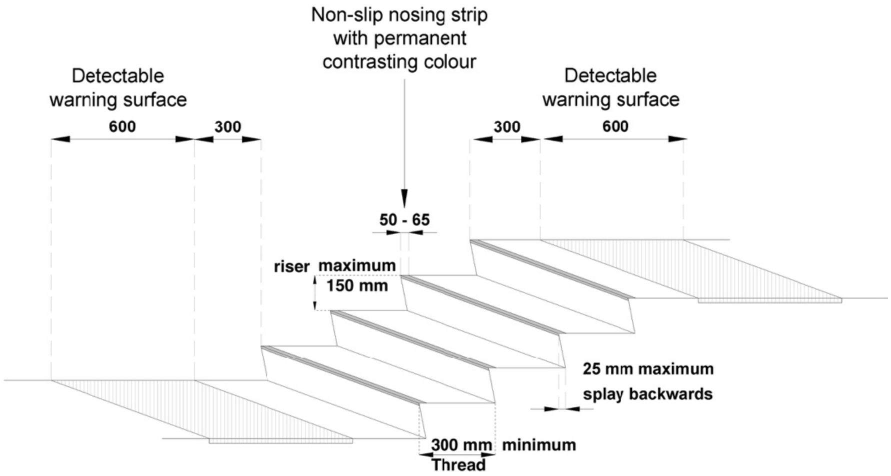


Figure 9: Stair - Isotopic view

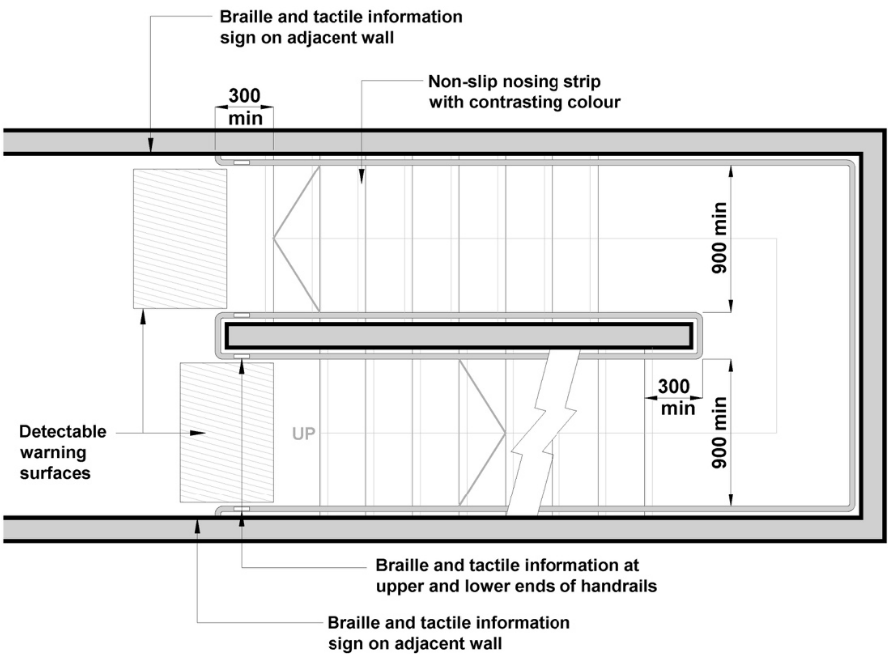


Figure 10: Stair - Top view

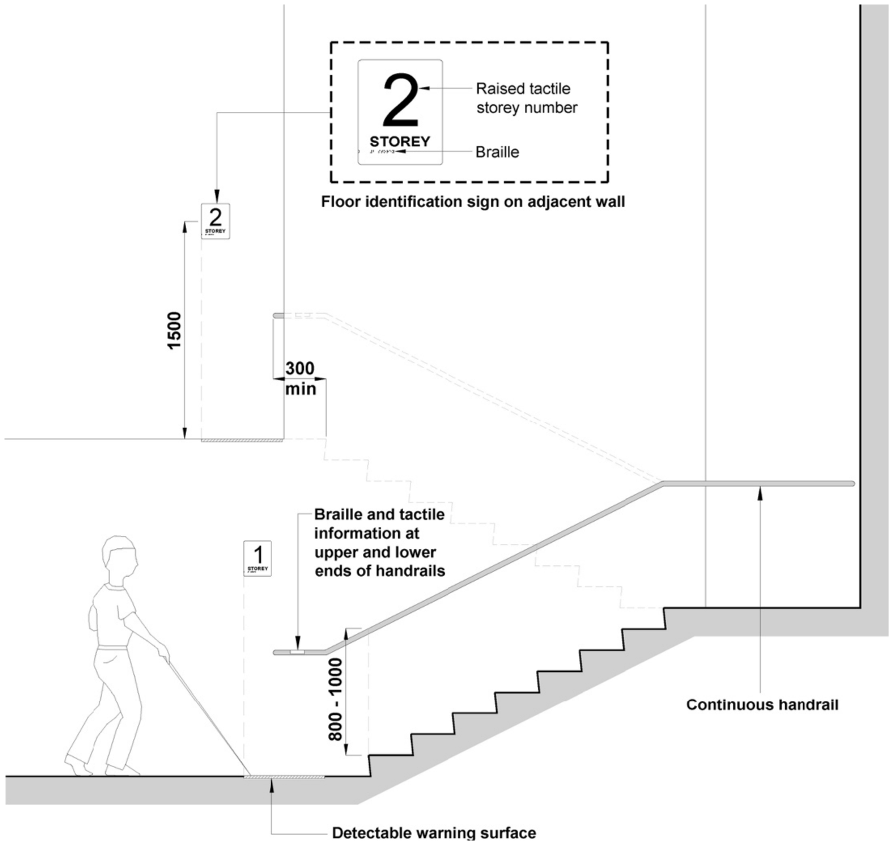


Figure 11: Stair - Side view

Vertical circulation	Stair Space - Conformance A	
Categories	**Provisions: Must-have items**	
Stairs	VS.1	The stairs are made up for a straight flight or flights of stairs
	VS.2	None of the stairs are spiral or contain sections which have winders
	VS.3	The stairs do not have open risers
	VS.4	Underside stairs are protected to prevent users colliding with the stairs
	VS.5	The minimum surface width of the stairs is 900 mm
	VS.6	The minimum width between handrails is 900 mm
	VS.7	No change in level is provided with only one step
	VS.8	There is a tactile warning surface or a change of floor color and texture at the head and foot of the stairs that give adequate warning of the presence of the stairs
	VS.9	There is a clear landing of 900-1200 mm at the top of each flight
	VS.10	There is a clear landing of 900-1200 mm at the bottom of each flight
	VS.11	There is no door swing that encroaches onto the landing area
	VS.12	The risers on each step are the same dimension
	VS.13	The thread on each step are the same dimension
	VS.14	The height of the risers are between 150 - 190mm
	VS.15	The going of each step is between 280 - 400 mm
	VS.16	The minimum headroom on stairs giving access between levels is 2000 mm

. . . Continued on next page

Vertical circulation	Stair Space - Conformance A	
Categories	**Provisions: Must-have items**	
Handrail	VS.17	A handrail is provided to each side of the stair
	VS.18	The surface finish to handrails is not reflective
	VS.19	The handrail extends horizontally at least 300 mm beyond the first and last nosing in the flight
	VS.20	The handrail is continuous around landings (including intermediate landings)
	VS.21	The handrails are securely fixed to the supporting wall
Nosing	VS.22	There is no projecting nosing on the steps OR Nosing is at the acceptable standard of 25 mm
	VS.23	The nosings are in good order and securely fixed on the steps
	VS.24	The nosings must not present a tripping hazard or are in poor condition
Contrast	VS.25	The nosing on each step is visually contrasted
	VS.26	The contrast to the nosing can be seen when ascending and descending the stairs
Lighting	VS.27	Illuminance at tread/floor level is a minim of 100 lux
	VS.28	The lighting is not provided is in the riser of the steps
	VS.29	The lighting to the stairs is even
	VS.30	The lighting to the stairs must not cause glare or disorientation to users

Vertical circulation	Stair Space - Conformance AA	
Categories	**Provisions: Should-have items**	
Stairs	VS.31	A flight has no more than 16 risers
Handrail	VS.32	The handrail is between 32 mm - 50 mm diameter OR The handrail is oval with dimensions of 50 mm wide and 39 mm deep
	VS.33	The handrail can be easily gripped along its full length (meaning that it is smooth, no rough surface)
	VS.34	The handrail is made easy and comfortable to grip, slip-resistant and smooth
	VS.35	On a wide flight of stairs (> 2000 mm), a central handrail is provided
	VS.36	There is a clear space 50 mm - 75 mm between handrail and the adjacent wall
	VS.37	There is a clear space of at least 50 mm between the underside of the handrail and any supporting wall
	VS.38	The top of the handrail is 900-1000mm above the nosing
Nosing	VS.39	Nosing extends between 50-65 mm on the treads
	VS.40	Nosing extends between 30-55 mm on the risers

Vertical circulation	**Stair Space - Conformance AAA**	
Categories	**Provisions: Could-have items**	
Tactile Information	VS.41	Tactile information indicating floor levels is provided on the handrails
	VS.42	Tactile information indicating floor destination is provided on the handrails

28. Do you agree with the success criteria shown in Vertical circulation Stair Space - Conformance A?
29. If no, what the success criteria of Vertical circulation Stair Space - Conformance A should be?
30. Do you agree with the success criteria shown in Vertical circulation Stair Space - Conformance AA?
31. If no, what the success criteria of Vertical circulation Stair Space - Conformance AA should be?
32. Do you agree with the success criteria shown in Vertical circulation Stair Space - Conformance AAA?
33. If no, what the success criteria of Vertical circulation Stair Space - Conformance AAA should be?

Section 3.5 Vertical circulation - Ramp

Instruction: Please read three following tables and answer the questions.

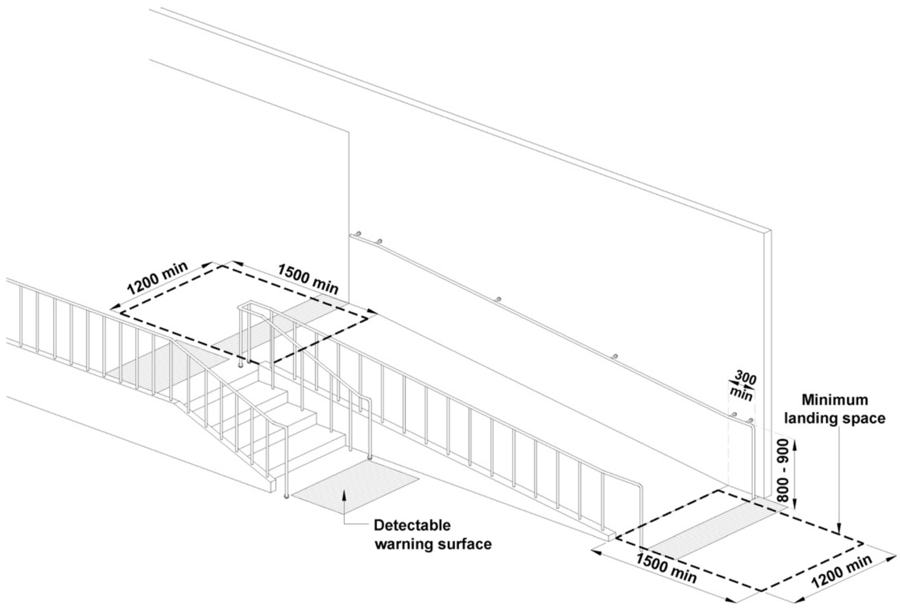
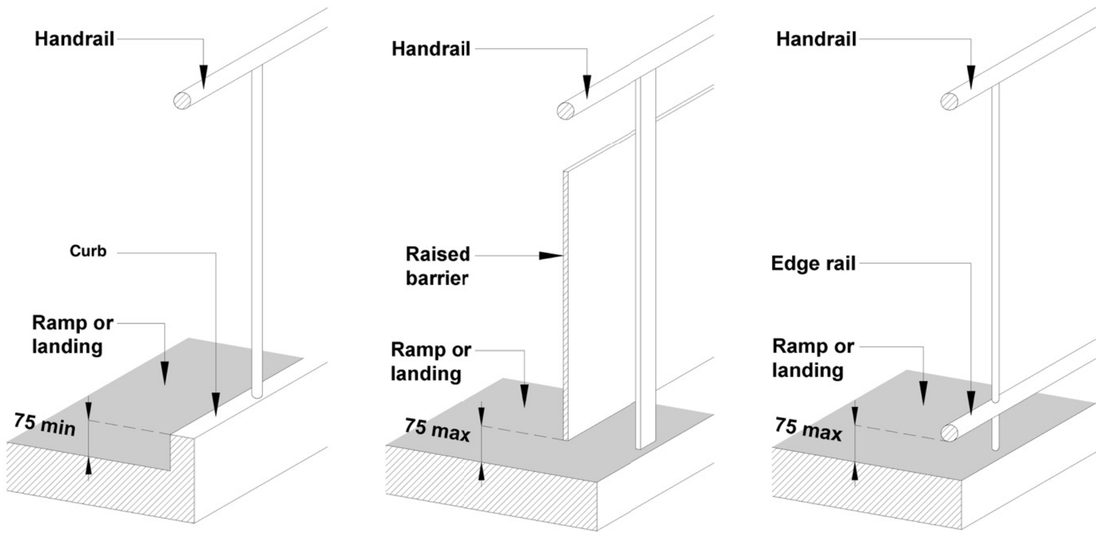
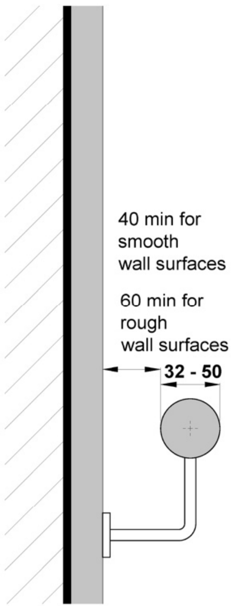


Figure 12: Ramp

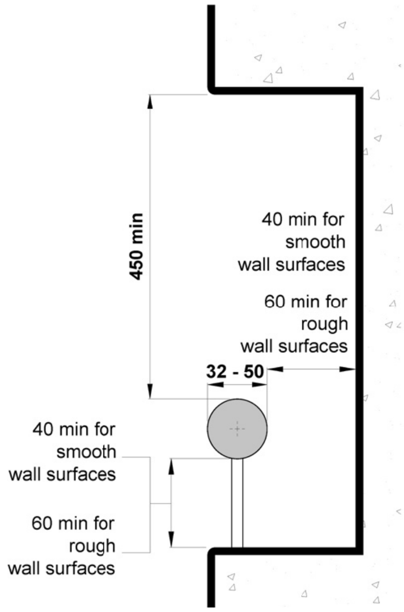


(a) Kerb (b) Raised Barrier (c) Tapping rail

Figure 13: Ramp Protection



(a) Handrail clearance from wall



(b) Handrail in recess

Figure 14: Handrails

Vertical circulation	**Ramp Space - Conformance AAA**	
Categories	**Provisions: Must-have items**	
Alternative Steps	VR.39	Alternative stepped approach is provided when there is a change in level served by the ramp that is more than 300mm
	VR.40	Alternative stepped approach is designed in accordance with Vertical Circulation Stairs

Vertical circulation	**Ramp Space - Conformance A**	
Categories	**Provisions: Should-have items**	
Slope	VR.1	The gradient of the ramp does not exceed 1:20 when the length of the ramp is less than 10m
	VR.2	The gradient of the ramp does not exceed 1:15 when the length of the ramp is less than 5m
	VR.3	The gradient of the ramp does not exceed 1:12 when the length of the ramp is less than 2m
Surfaces	VR.4	The surface to the ramps is smooth
	VR.5	The surface of the ramps is slip-resistant when wet
	VR.6	The surface of the ramps is in a color that contrasts visually with that of the landings
	VR.7	Surface pattern (cross stripes, etc.) must not be used if they could visually appear as steps
Width	VR.8	The minimum surface width of the ramp between walls, upstands or kerbs is 1200mm
	VR.9	There is a clear unobstructed view along the whole length of the ramp
Handrails	VR.10	A handrail is provided on the ramp
	VR.11	The surface finish to the handrails is not reflective
Landings	VR.12	There is a landing at least 1200mm long at the top of the ramp
	VR.13	There is a landing at least 1200mm long at the bottom of the ramp
	VR.14	There is no door swing that encroaches onto the landing area
	VR.15	All landings are level
	VR.16	No landings allow water to stand on the surface
Lighting	VR.17	Illuminance on the floor surface of the ramp is at a minimum of: 100 lux in general environments 200 lux in communal environments
	VR.18	The lighting to the ramp is even
	VR.19	The lighting to the ramp must not cause glare or disorientation to users
Protections	VR.20	Appropriate guarding is provided for ramps and landings with an open side to prevent falling
	VR.21	A kerb of 100mm minimum height is provided
	VR.22	The kerb contrasts visually with the ramp and the landing
	VR.23	The minimum clear headroom to ramps and landings is 2m

Vertical circulation	**Ramp Space - Conformance AA**	
Categories	**Provisions: Could-have items**	
Handrails	VR.24	A handrail is provided on both sides of the ramp
	VR.25	If a very wide ramp is provided, there is a central handrail
	VR.26	The handrail is between 32 mm - 50 mm in diameter OR The handrail is oval with dimensions of 50 mm wide and 39 mm deep
	VR.27	The handrail can be easily gripped along its full length (meaning that it is smooth, not a rough surface)
	VR.28	The handrail is made with easy and comfortable to grip, slip-resistant and smooth

... Continued on next page

Vertical circulation	**Ramp Space - Conformance AA**	
Categories	**Provisions: Could-have items**	
	VR.29	There is a clear space 50 mm - 75 mm between the handrail and the adjacent wall
	VR.30	There is a clear space of at least 50 mm between the underside of the handrail and any supporting wall
	VR.31	The handrail is continuous around landings
	VR.32	The top of the handrail is 900-1000mm above the nosing
	VR.33	The top of the handrail is 900-1100mm above the nosing
	VR.34	The handrails are securely fixed to the supporting wall
Landings	VR.35	There is an intermediate landing provided at each change of direction of the ramp
	VR.36	If an intermediate landing is provided, it is at least 1500mm long
Surfaces	VR.37	If different surface finishes are used on the ramp, landings and approach paths, the coefficients of friction of all surfaces are similar
Width	VR.38	The minimum surface width of the ramp between walls, upstands or kerbs is 1500mm

34. Do you agree with the success criteria shown in Vertical circulation Ramp Space - Conformance A?
35. If no, what the success criteria of Vertical circulation Ramp Space - Conformance A should be?
36. Do you agree with the success criteria shown in Vertical circulation Ramp Space - Conformance AA?
37. If no, what the success criteria of Vertical circulation Ramp Space - Conformance AA should be?
38. Do you agree with the success criteria shown in Vertical circulation Ramp Space - Conformance AAA?
39. If no, what the success criteria of Vertical circulation Ramp Space - Conformance AAA should be?

Section 3.6 Vertical circulation - Lifts

Instruction: Please read three following tables and answer the questions.

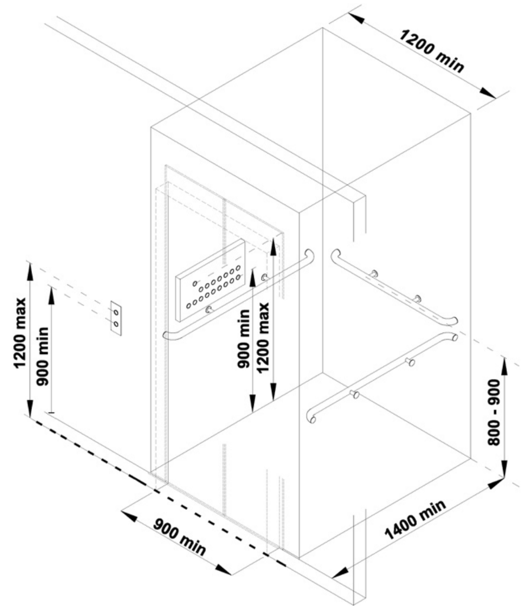


Figure 15: Lift

Vertical circulation	Lifts Space - Conformance A	
Categories	**Provisions: Must-have items**	
Lift Cars	VL.1	The entrance door to the lift has a clear opening width of at least 800mm
	VL.2	The floor surface inside the lift is firm
	VL.3	The floor surface inside the lift is slip-resistant
	VL.4	Flooring to the lift is light in color which is visually contrasted
Calling the lift	VL.5	The position of the lift landing and car doors are distinguishable visually from the adjoining walls
Using the lift	VL.6	The doors remain open for at least 5 seconds
	VL.7	The door-reactivating device operates on infrared or photo eye sensors
Contrast and Lighting	VL.8	The position of the lift is adequately identified using visual contrast and is well-illuminated
	VL.9	Minimum illuminance within the car is 100 lux
General	VL.10	The surface finishes used within the lift are not highly reflective
	VL.11	The surface finishes used within the lift do not create an unacceptable acoustic environment

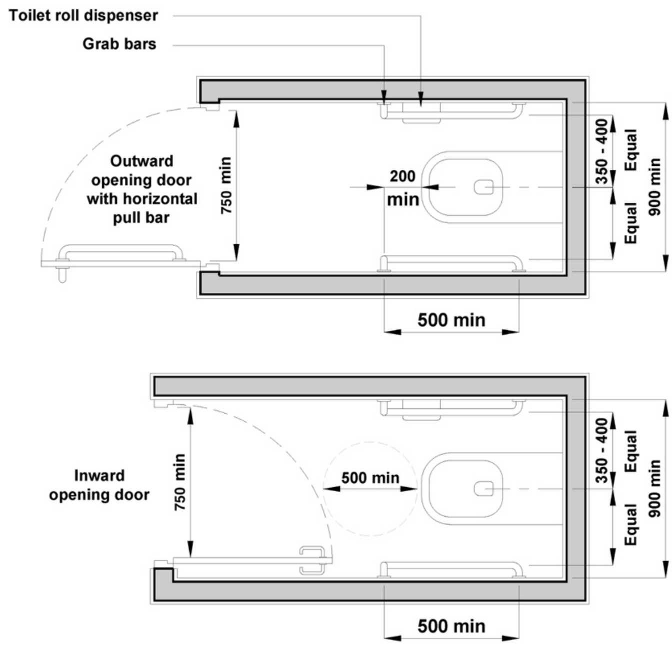
Vertical circulation	Lifts Space - Conformance AA	
Categories	**Provisions: Should-have items**	
Lift Cars	VL.12	A handrail is provided on three sides inside the lift
	VL.13	The handrail can be easily gripped (32-50mm diameter or 50mm wide and 39mm deep)
	VL.14	The handrail is located at 900mm above floor level
Calling the lift	VL.15	The position of the buttons to call the lift is logical
	VL.16	The call panel is clearly distinguishable in terms of visual contrast from its background
	VL.17	The buttons illuminate when pressed
	VL.18	The buttons are placed between 900mm and 1100mm above floor level
	VL.19	The buttons are placed at least 500mm from any return wall
	VL.20	Lift arrival indication is given by using a text or a symbol
	VL.21	Lift arrival indication is given by audible sound
Using the lift	VL.22	The volume and clarity of the audible sound is appropriate
	VL.23	The floor level arrived at is announced audibly and visually
Control within the lift	VL.24	The control panel is situated logically within the lift
	VL.25	Call or control buttons are located between 900mm and 1200mm above floor level and at least 400 mm away from any return wall
	VL.26	Call buttons illuminate when pressed
	VL.27	Call buttons are not touch-sensitive

Vertical circulation	Lifts Space - Conformance AAA	
Categories	**Provisions: Could-have items**	
Calling the lift	VL.28	The information on the buttons is appropriately embossed (e.g. tactile)
Using the lift	VL.29	Audible warnings of the doors opening and closing are provided
	VL.30	Floor level indicators can be seen when the lift is full
	VL.31	Tactile and visual floor level indicators are provided outside the lift with clear visibility to users when the life door opens
Control within the lift	VL.32	Information on the call buttons is provided in Braille embossed at 1 mm

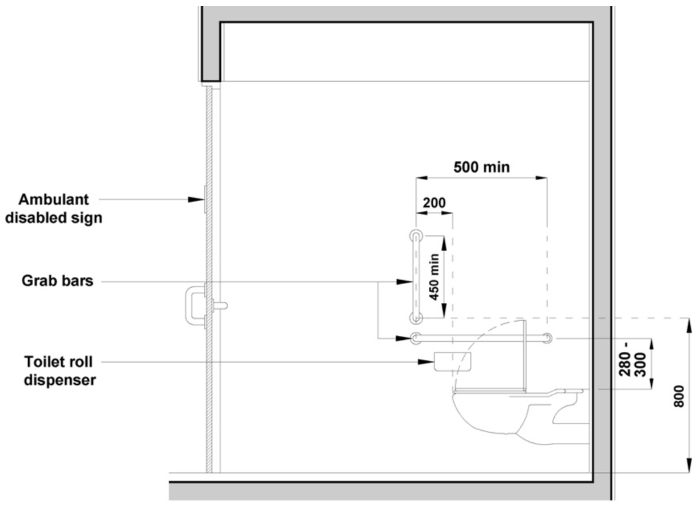
40. Do you agree with the success criteria shown in Vertical circulation Lifts Space - Conformance A?
41. If no, what the success criteria of Vertical circulation Lifts Space - Conformance A should be?
42. Do you agree with the success criteria shown in Vertical circulation Lifts Space - Conformance AA?
43. If no, what the success criteria of Vertical circulation Lifts Space - Conformance AA should be?
44. Do you agree with the success criteria shown in Vertical circulation Lifts Space - Conformance AAA?
45. If no, what the success criteria of Vertical circulation Lifts Space - Conformance AAA should be?

Section 3.7 Ambulant Disable WCs

Instruction: Please read three following tables and answer the questions.



(a) Top view



(b) Side view

Figure 16: Ambulant Disabled Water Closet

Ambulant Disable WCs Space - Conformance A		
Categories	**Provisions: Must-have items**	
Number of accessible toilet	AD.1	There is at least one ambulant-accessible compartment in each standard male/female toilet
Layout	AD.2	The internal dimensions of the compartment allow at least 750mm activity space clear of door swings in front of the WC
Door	AD.3	The door to the cubicle opens outwards OR If the door opens inwards, it can be opened outwards or removed easily in case of emergency
Lighting	AD.4 AD.5	The minimum average illuminance at floor level is 100 lux The light must not produce glare
Visual contrast	AD.6 AD.7	The sanitary fittings and facilities provide adequate visual contrast with their background Visual contrast is provided at between the wall and floor junctions

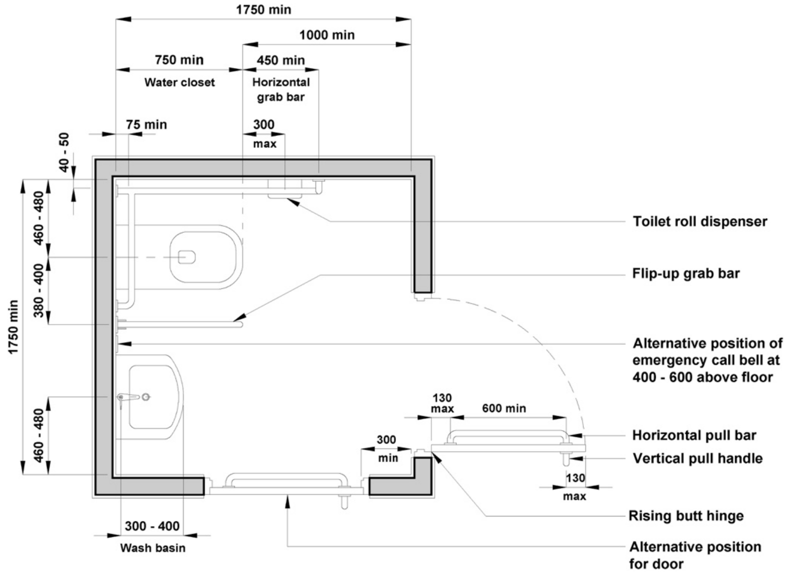
Ambulant Disable WCs Space - Conformance AA		
Categories	**Provisions: Should-have items**	
WC	AD.8 AD.9	The WC is placed centrally across the width of the WC The flush is a spatula type OR operated by a proximity sensor
Grab rails	AD.10 AD.11 AD.12 AD.13	There are two horizontal grab rails (each 600mm long) placed 680mm above floor level with their center line 650mm from the rear wall of the cubicle There is a 600mm grab rail placed vertically on one side wall. There bottom of the rail is 800mm above floor level Grab rails protrude less than 90mm into the cubicle space If a urinal is provided for use by ambulant disabled people (including people with visual impairment), a 500 mm grab rail is provided on both sides of the urinal

Ambulant Disable WCs Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Other essential items	AD.14	Coat hooks are provided at 1050mm and 1400mm above floor level

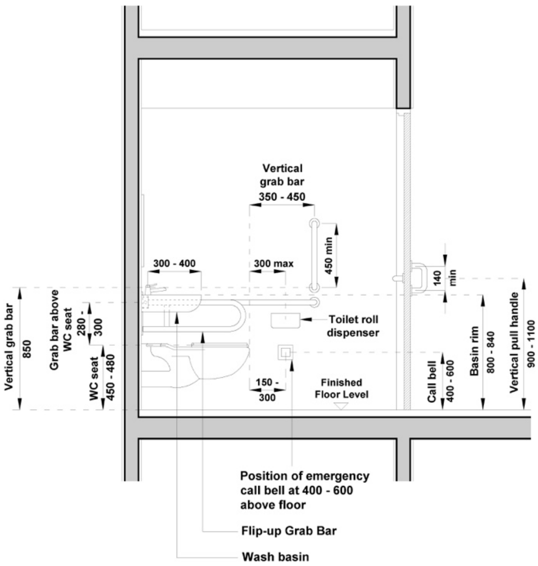
46. Do you agree with the success criteria shown in Ambulant Disable WCs Space - Conformance A?
47. If no, what the success criteria of Ambulant Disable WCs Space - Conformance A should be?
48. Do you agree with the success criteria shown in Ambulant Disable WCs Space - Conformance AA?
49. If no, what the success criteria of Ambulant Disable WCs Space - Conformance AA should be?
50. Do you agree with the success criteria shown in Ambulant Disable WCs Space - Conformance AAA?
51. If no, what the success criteria of Ambulant Disable WCs Space - Conformance AAA should be?

Section 3.8 Accessible Washroom

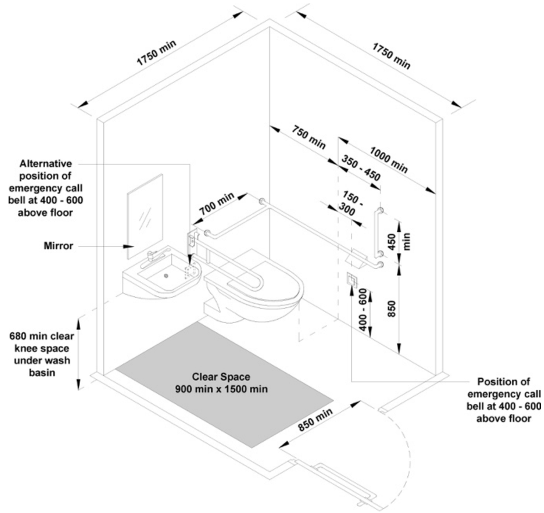
Instruction: Please read three following tables and answer the questions.



(a) Top view



(b) Side view



(c) Isotopic view

Figure 17: Accessible Washroom

Accessible Washroom Space - Conformance A		
Categories	**Provisions: Must-have items**	
Layout	AW.1	The maximum travel distance (combined horizontal and vertical) to an accessible washroom with an appropriate transfer side is 40m
Door	AW.2	The door opens outwards, and it must not encroach into the accessible route OR The door opens inwards, and it must be removed easily in case of emergency
WC	AW.3	The space between the WC and the wall is kept clear to allow a carer to assist if required
	AW.4	The seat is securely fixed and is of good quality
Lighting	AW.5	A white pull cord for the light is provided adjacent to the door OR A device is installed which automatically switches on the light when the toilet door is opened
	AW.6	Lighting is not activated by a passive infrared (PIR) motion detector
	AW.7	The lighting provided a minimum 100 lux at floor level
	AW.8	The lighting must not produce glare
Visual contrast	AW.9	The sanitary fittings and facilities provide adequate visual contrast with their background
	AW.10	Visual contrast is provided at between the wall and floor junctions
Other essential features	AW.11	The floor covering is slip-resistant
	AW.12	Wall tiles or finishes are non-reflective
	AW.13	Facilities for disposable items are provided in a manner that does not impinge upon the clear space (transfer and maneuvering) within the WC

Accessible Washroom Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Accessibility	AW.14	Signage indicating the route to, and position of, the toilet facilities is adequate
	AW.15	An accessible washroom is provided at every location where standard toilet facilities are provided
	AW.16	The accessible washroom is a unisex toilet facility that can be accessed independently of other toilet accommodations
	AW.17	The accessible washroom is able to be locked by leaver type
Layout	AW.18	There is minimum clear space of 1750mm by 1750mm
WC	AW.19	The flush is a spatula type
	AW.20	The flush is on the open transfer side
Dispensers	AW.21	There is a single-sheet toilet paper dispenser within easy reach of the WC
Grab rails	AW.22	There is a drop-down rail that is easy to operate from the seated position placed 350mm from the center line of the WC
	AW.23	There is a vertical grab rail that extends between 800mm and 1400mm above floor level, and is placed to the open side of the WC, its center line 470mm from the center of the WC

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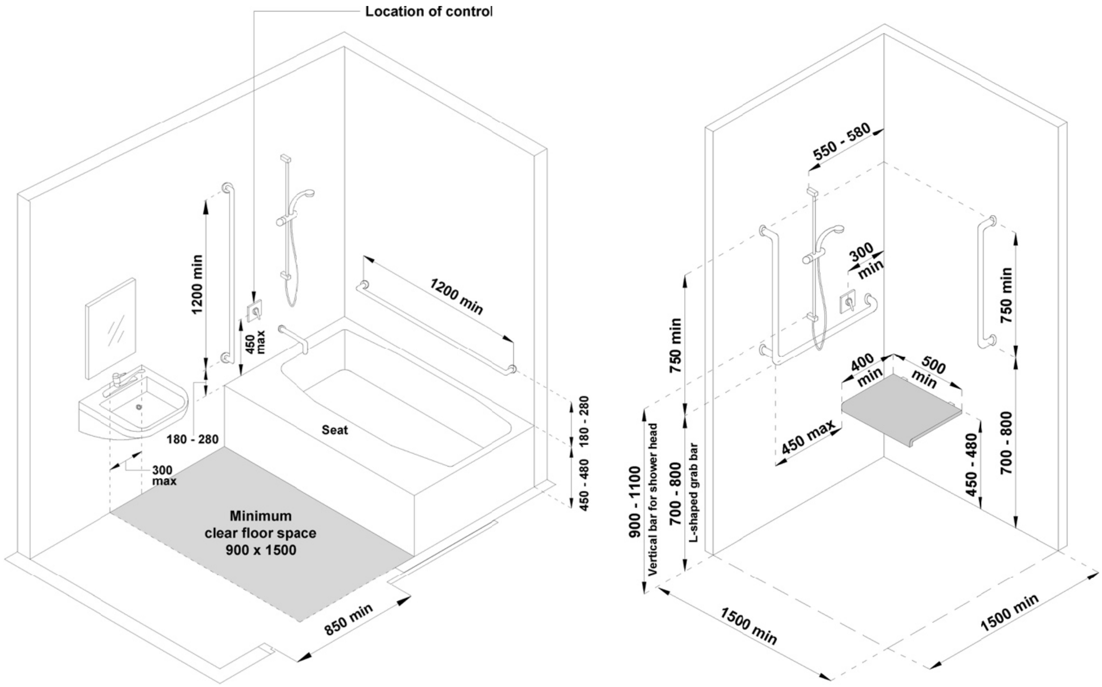
Accessible Washroom Space - Conformance AA		
Categories	**Provisions: Should-have items**	
	AW.24	There is a grab rail on the wall adjacent to the WC that is 600mm long and is placed 680mm above floor level. One end of the grab rail is 250 mm away from the wall supporting the WC
	AW.25	There is a grab rail on the door at a height that will enable the user to pull the door closed
	AW.26	The diameter of all grab rails is between 32mm and 35mm, and they are easy to grip even when wet
Washing and drying hands	AW.27	There is a wall-supported wash hand basin provided at the top of the basin, 720-740mm above floor level
	AW.28	The basin is 140-160mm away from the WC
Alarm	AW.29	An emergency assistance alarm should be provided with a pull cord reachable from the bath or shower and the adjacent floor area

Accessible Washroom Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
WC	AW.30	There is a low-level cistern that could be used as a backrest OR A backrest with a padded section is provided 680mm above floor level
Dispensers	AW.31	There is a dispenser for hand wipes within easy reach of the WC
Grab rails	AW.32	There are two vertical grab rails placed on both sides of the wash hand basin, which extend between 800mm and 1400mm above floor level
Washing and drying hands	AW.33	A single-lever mixer tap is provided
	AW.34	A soap dispenser is provided
	AW.35	The temperature of the water is controllable
	AW.36	A manually operated or automatic proximity warm-air dryer (with the activation button at 1200mm above floor level) is provided adjacent to the hand basin
Other essential features	AW.37	Coat hooks are provided at 1050mm and 1400mm above floor level
	AW.38	A mirror is provided above the hand basin

52. Do you agree with the success criteria shown in Accessible Washroom Space - Conformance A?
53. If no, what the success criteria of Accessible Washroom Space - Conformance A should be?
54. Do you agree with the success criteria shown in Accessible Washroom Space - Conformance AA?
55. If no, what the success criteria of Accessible Washroom Space - Conformance AA should be?
56. Do you agree with the success criteria shown in Accessible Washroom Space - Conformance AAA?
57. If no, what the success criteria of Accessible Washroom Space - Conformance AAA should be?

Section 3.9 Bathrooms and Shower

Instruction: Please read three following tables and answer the questions.



(a) Bathtub (b) Shower stall

Figure 18: Bathroom and Shower room

Bathrooms and Shower Space - Conformance A		
Categories	**Provisions: Must-have items**	
Shower	BS.1	The accessible bathroom provide either a bathtub or a shower
	BS.2	The accessible bathroom should contain a shower stall rather than the bathtub
Layout	BS.3	For each bathroom, the minimum clear space of 900 mm by 1500 mm is provided
Surface	BS.4	Each bath should have a flat, slip-resistant base, a transfer seat, a rim height of 480mm and a horizontal or angled support rail
	BS.5	Flooring in bathrooms and shower rooms should be slip-resistant when both dry and wet
Lighting	BS.6	A white pull cord for the light is provided adjacent to the door OR A device is installed which automatically switches on the light when the toilet door is opened
	BS.7	Lighting is not activated by a passive infrared (PIR) motion detector
	BS.8	The lighting provides a minimum 100 lux at floor level
	BS.9	The lighting must not produce glare
Visual contrast	BS.10	The sanitary fittings and facilities provided adequate visual contrast with their background

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Bathrooms and Shower Space - Conformance A		
Categories	**Provisions: Must-have items**	
	BS.11	Visual contrast is provided at between the wall and floor junctions

Bathrooms and Shower Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Accessibility	BS.12	Signage indicating the route to, and position to the shower facilities is adequate
WC	BS.13 BS.14	Each accessible bathroom contains a WC The WC is in accordance with WC provisions
Washing and drying hands	BS.15 BS.16 BS.17	There is a wall-supported wash hand basin provided at the top of the basin, 720-740mm above floor level The basin is 140-160mm away from the WC There is a paper towel dispenser that can be reached while seated on the WC
Essential features	BS.18	The shower should be fitted with a tip-up seat, grab rails and a shower curtain enclosing the seat, and a shelf for toiletries
Emergency	BS.19	An emergency assistance alarm should be provided with a pull cord reachable from the bath or shower and the adjacent floor area

Bathrooms and Shower Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Washing and drying hands	BS.20 BS.21 BS.22 BS.23	A single-lever mixer tap is provided A soap dispenser is provided The temperature of the water is controllable A manually operated or automatic proximity warm-air dryer (with the activation button at 1200mm above floor level) is provided adjacent to the hand basin

58. Do you agree with the success criteria shown in Bathrooms and Shower Space - Conformance A?
59. If no, what the success criteria of Bathrooms and Shower Space - Conformance A should be?
60. Do you agree with the success criteria shown in Bathrooms and Shower Space - Conformance AA?
61. If no, what the success criteria of Bathrooms and Shower Space - Conformance AA should be?
62. Do you agree with the success criteria shown in Bathrooms and Shower Space - Conformance AAA?
63. If no, what the success criteria of Bathrooms and Shower Space - Conformance AAA should be?

Section 3.10 Bedroom

Instruction: Please read three following tables and answer the questions.

Bedroom Space - Conformance A		
Categories	**Provisions: Must-have items**	
General	B.1	Accessible bedrooms should located on accessible routes that are direct and obstruction-free
Bed	B.2	Sufficient space is provided around the room and transfer to one side of the bed
Door	B.3	A clear opening width at a minimum of 750mm is provided
Lighting	B.4	Sufficient lighting is provided at a minimum of 100 lux
	B.5	There is an even level of light throughout the room and no dark areas
	B.6	Lighting is well-positioned to prevent shadows from objects or from people moving around the room
	B.7	Table and floor lamps are positioned to avoid trailing wires and risk of trips or bumps
Storage and Wardrobes	B.8	Wardrobe and cupboard doors do not cause obstructions when used

Bedroom Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Sanitary	B.9	Sanitary accommodation is satisfied in accordance with the WC and Bathroom provisions for at least Level AA
Door	B.10	Door handle should be easy to grip and operate by people with visual impairments, and should contrast visually with the door
Emergency	B.11	Each accessible bedroom is fitted with an emergency assistance alarm operated by a pull cord that can be reached from the bed and from an adjacent floor area
General	B.12	People with visual impairments should be able to gain access to all the facilities in the room and sanitary accommodations
Storage and Wardrobes	B.13	Wardrobes and large cupboards have interior lights that are operated by an accessible switch or automatically turn on and off after a short period

Bedroom Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Sanitary	B.14	Sanitary accommodation should be en-suite type
Door	B.15	Electronic card-activated locks or electrically-powered openers for bedroom entrance doors are provided with clear visibility and audible indications

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Bedroom Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Emergency	B.16	A telephone is provided next to an electrical socket suitable for lighting and connections of call systems or tele-care equipment
Lighting	B.17	Lights are individually switched and can be dimmed
	B.18	Task lighting is available wherever it may be required (e.g. over drawers, dressing tables, beside beds and at desks)
	B.19	Vertical blinds are provided in order to reduce glares
Other	B.20	Each accessible bedroom has a connecting door to an adjacent room for a companion or assistant

64. Do you agree with the success criteria shown in Bedroom Space - Conformance A?
65. If no, what the success criteria of Bedroom Space - Conformance A should be?
66. Do you agree with the success criteria shown in Bedroom Space - Conformance AA?
67. If no, what the success criteria of Bedroom Space - Conformance AA should be?
68. Do you agree with the success criteria shown in Bedroom Space - Conformance AAA?
69. If no, what the success criteria of Bedroom Space - Conformance AAA should be?

Section 3.11 General space

Instruction: Please read three following tables and answer the questions.

General Space - Conformance A		
Categories	**Provisions: Must-have items**	
General	G.1	Circulation routes around the room are free of obstacles
	G.2	Most furniture is against the walls in order to provide a clear space in the center of the room
Lighting	G.3	Sufficient lighting is provided at minimum of 100 lux
	G.4	There is an even level of light throughout the room and no dark areas
	G.5	Table and floor lamps are positioned to avoid trailing wires and risk of trips or bumps
	G.6	Lighting is well-positioned to prevent shadows from objects or from people moving around the room
Sockets, Controls, and Equipment	G.7	There are sufficient and suitably-placed electrical sockets for all equipment to be used without trailing wires

General Space - Conformance AA		
Categories	**Provisions: Should-have items**	
General	G.8	People with visual impairment should be able to gain access to all the facilities in the room
Lighting	G.9	Lights are individually switched and can be dimmed
Sockets, Controls, and Equipment	G.10	All sockets and controls for heating, windows, lights and electrical equipment can be used without moving furniture

General Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Lighting	G.11	Task lighting is available wherever it may be required (e.g. over drawers, dressing tables, beside beds and at desks)
	G.12	Vertical blinds are provided in order to reduce glare
Sockets, Controls, and Equipment	G.13	Tactile input is provided on the controls and equipment
Emergency	G.14	A telephone is provided nest to an electrical socket suitable for lighting and connection of call systems or tele-care equipment
Guide dog	G.15	There is sufficient space for a guide dog's bed and equipment

70. Do you agree with the success criteria shown in General Space - Conformance A?
71. If no, what the success criteria of General Space - Conformance A should be?
72. Do you agree with the success criteria shown in General Space - Conformance AA?
73. If no, what the success criteria of General Space - Conformance AA should be?
74. Do you agree with the success criteria shown in General Space - Conformance AAA?
75. If no, what the success criteria of General Space - Conformance AAA should be?

Section 3.12 Utility spaces

Instruction: Please read three following tables and answer the questions.

Utility Space - Conformance A		
Categories	**Provisions: Must-have items**	
General	KU.1	The layout is logical (e.g. the a sink and cooker are close together)
	KU.2	There is clear space for people to move around and between different areas, and they are free of obstacles and hazards
Cupboards	KU.3	Cupboard doors do not cause any hazards when opened
Lighting	KU.4	Sufficient lighting is provided at a minimum of 100 lux at on the floor surface
	KU.5	There is an even level of light throughout the room and no dark areas
	KU.6	Lighting is well-positioned to prevent shadows from objects or from people moving around the room

Utility Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Cupboards	KU.7	Contrasting colors differentiate equipment or appliances and cupboard from floors, surfaces and walls
	KU.8	Shiny or reflective surfaces is minimized
Lighting	KU.9	Sufficient lighting is provided at a minimum of 300 lux at on the kitchen surface
	KU.10	Lights are individually switched
Sockets, Controls, and Equipment	KU.11	There are clear and distinct controls and indicators that contrast with their background
	KU.12	The control settings are understandable by sound or touch

Utility Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Lighting	KU.13	Task lighting is available wherever it may be required (e.g. kitchen counter)
	KU.14	Vertical blinds are provided in order to reduce glares
Sockets, Controls, and Equipment	KU.15	Tactile input is provided on the controls and equipment

77. Do you agree with the success criteria shown in Utility Space - Conformance A?
78. If no, what the success criteria of Utility Space - Conformance A should be?
79. Do you agree with the success criteria shown in Utility Space - Conformance AA?
80. If no, what the success criteria of Utility Space - Conformance AA should be?
81. Do you agree with the success criteria shown in Utility Space - Conformance AAA?
82. If no, what the success criteria of Utility Space - Conformance AAA should be?

Section 3.13 Hall and stadium

Instruction: Please read three following tables and answer the questions.

Hall and stadium Space - Conformance A		
Categories	**Provisions: Must-have items**	
Accessible Route	L.1	Routes are accessible and of sufficient width to allow visually impaired people with a guide dog to circulate
	L.2	Handrails are provided on stepped and ramped routes

Hall and stadium Space - Conformance AA		
Categories	**Provisions: Should-have items**	
Seating	L.3	People with visual impairments should have access to the full range of seating locations and be able to sit alongside a disabled or non-disabled companion

Hall and stadium Space - Conformance AAA		
Categories	**Provisions: Could-have items**	
Guide dog	L.4	Space for the guide dog is provided adjacent to seating and clear of circulation routes
Emergency	L.5	Emergency egress procedures should take account of the needs of all people who need assistance, whether they are seated in designated areas or not

83. Do you agree with the success criteria shown in Hall and stadium Space - Conformance A?
84. If no, what the success criteria of Hall and stadium Space - Conformance A should be?
85. Do you agree with the success criteria shown in Hall and stadium Space - Conformance AA?
86. If no, what the success criteria of Hall and stadium Space - Conformance AA should be?
87. Do you agree with the success criteria shown in Hall and stadium Space - Conformance AAA?
88. If no, what the success criteria of Hall and stadium Space - Conformance AAA should be?

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Appendix F

Building Rating System - Raw Data and Experts Agreement

In this Appendix, raw data collected from the expert validation and review were converted into the experts' agreement shown in Table F.2, F.3, and F.4 for Research and Development, Accessibility, and Building and Interior Design areas, respectively using the coding system shown in tab:appx-expert-analysis-conversion.

Table F.1: Agreement scale - a coding system for quantifying qualitative data used in the expert review.

Scale	Coding	Criteria and Descriptions
1	Strongly disagree	Disagree; Proposed element is not to be sensible and workable in practice. The proposed element needs to be redesigned, accordingly.
2	Disagree	Somewhat disagree; Some part of a proposed element does not seem to be sensible and workable in practice. Suggestions are either made with what to be concerned and fixed for the proposed element.
3	Neutral	Neither agree or disagree
4	Agree	Agree but there is a room for improvements; The proposed element seems to be sensible and workable in practice. Suggestions are either made for improving the proposed element.
5	Strongly agree	Agree; The proposed element is well-designed, sensible and workable in practice.

F.1 Research and Development Experts

Table F.2: Raw data and Experts' agreement - Research and Development area

Category	**Questions**	**Research and Development Experts**				
		RDE1	**RDE2**	**RDE3**	**RDE4**	**RDE5**
Basic	Experience in the field (years)	12	14	15	3	3
	Have you ever worked with or developed technologies for people with disabilities?	Visual impairment	Other disability (Deaf)	Other disability (Deaf)	No	No
Design of Building Rating System						
Building Rating System	Agreement scale	5	4	4	5	5
	Do you agree with the design of the building rating system?	Agree	Agree	Agree	Agree	Agree
	Do you think if any improvement needed for the design of the building rating system?	The bottom-up design is sensible with detail in space level since we cannot measure the whole accessibility	Type of building to be measured should be specified before using the building rating system		This design is great and understandable. If we implement this in the real system, it would be not too difficult to create	well-designed and practical. This system is a good and I think if we follow the system, we may use this to help disabled people in navigating around buildings
Space Classification	Agreement scale	4	4	4	4	4
	Do you agree with the conformance to be used in the space classification?	Agree	Agree	Agree	Agree	Agree

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Category	Questions	Research and Development Experts				
		RDE1	RDE2	RDE3	RDE4	RDE5
	Do you think any improvement would be needed for the space classification?	Sometimes, answers could be multi-level rather than pass/fail. How to define which floor that stair is attached?	How about level 4 "technology" since some terms can be solved by the technology. For example, headroom can be solved by infrared sensor when people approaching	The definition of each level should be made clear to the users i.e. people with visual impairment. Each criterion should be easy to judge and can be judged subjectively.		
Floor and Building Classification	Agreement scale	2	2	1	1	1
	Do you agree with the conformance to be used in the floor and building classification?	Disagree	Disagree	Disagree	Disagree	Disagree

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Category	Questions	Research and Development Experts				
		RDE1	RDE2	RDE3	RDE4	RDE5
	Do you think any improvement would be needed for the floor and building classification?			Average may be too coarse to used especially in terms of safety. For example, the building may have high average score but still have a few spaces that have no conformance. Furthermore, some spaces more be more critical that others such as main entrance or restroomsPercentage of building area fall in each accessibility level (0, A, AA, AAA) may be used instead of the average score.	Due to the method, what if some floor falls into "No conformance level" or zero, this means there is no any accessibility provided in any space of the floor. On the other hand, the overall building score is probably about 2 or over, if there is full accessibility provided in other floors. It is because the average score is only considered. The overall score can be high, but it cannot indicate that every floor provides good accessibilities for people with visual impairment.	With the average approach, it does not work as said it could be too naive and could cause a bias in terms of interpretations.
Success Criteria						
Entrance	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4

... Continued on next page

Category	Questions	Research and Development Experts				
		RDE1	RDE2	RDE3	RDE4	RDE5
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Foyers	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree

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Category	Questions	Research and Development Experts				
		RDE1	RDE2	RDE3	RDE4	RDE5
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Horizontal Circulation	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Vertical Circulation - Stair	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree

... Continued on next page

Category	Questions	Research and Development Experts				
		RDE1	**RDE2**	**RDE3**	**RDE4**	**RDE5**
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					Any marker indicating the last stair
Vertical Circulation - Ramp	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					

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Category	Questions	Research and Development Experts				
		RDE1	**RDE2**	**RDE3**	**RDE4**	**RDE5**
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Vertical Circulation - Lift	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
WC. - Ambulant Disabled Water Closet	Agreement scale - A	4	3	3	3	4

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Category	Questions	Research and Development Experts				
		RDE1	RDE2	RDE3	RDE4	RDE5
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
WC. - Accessible Washroom	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree

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Category	Questions	Research and Development Experts				
		RDE1	RDE2	RDE3	RDE4	RDE5
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Bathroom and Shower	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					

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Category	Questions	Research and Development Experts				
		RDE1	**RDE2**	**RDE3**	**RDE4**	**RDE5**
	Other notes					
Bedroom	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
General Space	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					

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Category	Questions	Research and Development Experts				
		RDE1	**RDE2**	**RDE3**	**RDE4**	**RDE5**
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Utility Space	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree

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Category	Questions	Research and Development Experts				
		RDE1	**RDE2**	**RDE3**	**RDE4**	**RDE5**
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Hall and Stadium Spaces	Agreement scale - A	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	3	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Neutral	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					

F.2 Accessibility Experts

Table F.3: Raw data and Experts' agreement - Accessibility area

Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
Basic	Experience in the field (years)	10	3	3	10	3
	Have you ever worked with or developed technologies for people with disabilities	Visual impairment	Other disability (motor, blinds, deaf)	Visual impairment	Visual impairment	Visual impairment
Design of Building Rating System						
Building Rating System	Agreement scale	4	4	4	4	4
	Do you agree with the design of the building rating system?	Agree.	Agree	Agree	Agree	Agree
	Do you think if any improvement needed for the design of the building rating system?	this system is well-designed considering the big picture at the first place and broken down in to sub level which will make it easy to measure.			The design of the rating levels (number of levels, definition of each level) should be verified and subjectively judged by direct users, which here is people with visual impairment	The system should be extended to other disabilities
Space Classification	Agreement scale	5	2	4	5	5
	Do you agree with the conformance to be used in the space classification?	Agree	Disagree	Agree	Agree	Agree

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
	Do you think any improvement would be needed for the space classification?	The conformance to be used is sensibleSome spaces are not based on any floor. It would be better to split it from space floor level.	Using level of usability is better? For example, Level 1: physical, Level 2: colour, and Level 3: sound. This is like WCAG2.0 where Conformance A: Features may not be well-designed, please use with cautious while No Conformance means you need to bring friend to come along	The connection between space should also be evaluated for accessibility.	The space classification is appropriate designed, sensible and easy to understand	I agree with the design of space classification. It is quite clear and understandable
Floor and Building Classification	Agreement scale	2	2	2	4	4
	Do you agree with the conformance to be used in the floor and building classification?	Disagree	Disagree	Disagree	Agree	Agree
	Do you think any improvement would be needed for the floor and building classification?	Figure 3 does not say clearly about the score. What is it for? You should separate the level of conformance by not using score. How about using "+" rather than score (0.0-3.0). For example, 1-1.49: A, 1.5-1.99: A+, 2.0-2.49: AA				Can the rating be more scale e.g. "0.5"

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
Success Criteria						
Entrance	Agreement scale - A	4	3	3	1	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Disagree	Agree
	If no or any suggestion, what the success criteria should be?	Lighting matter may be in level AA since people can feel by using a white cane			No mention about entrance pathway/floor surrounding the entrance. Pathway/floor should be smooth and flat, no bump nor steps and etc. In E21, accessible door must be operational at all the time even the revolving door is not working. In addition to Must-have/Should-have criterion, guide dog should be allowed inside the building	
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	2	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Disagree	Agree

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
	If no or any suggestion, what the success criteria should be?				E38-39 should provided audible/signage/warning/etc.	
	Other notes					
Foyers	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					From reception and counter service perspective, where the reception and counter service installed should be clearly located and be able to see the entrance so staff can prompt to assist when people with disability is approaching
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
	Other notes					
Horizontal Circulation	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?				Additionally, in Category "Wall" or any suitable one, if passageway is connecting other passageway or closed to open air area (e.g. passage connecting building) guard rail with enough height must be provided	
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
Vertical Circulation - Stair	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?				Additionally, stairs and nosing should be made from non-slippery materials	
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Vertical Circulation - Ramp	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?				The surface of the ramps is slip-resistant when dry. The handrails are securely fixed to the supporting wall	signage and warning of approaching ramp should be provided

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Category	Questions	Accessibility Experts				
		AE1	AE2	AE3	AE4	AE5
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?				R34 could be in the level A (the handrail are securely fixed to the supporting wall)	
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					
Vertical Circulation - Lift	Agreement scale - A	4	3	3	2	4
	Agreement scale - AA	4	3	3	4	4
	Agreement scale - AAA	4	3	3	2	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Disagree	Agree
	If no or any suggestion, what the success criteria should be?				Braille and tactile information is provided on the control panel. Audible warning should be provided when lift arrives or lift is closing	
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
	If no or any suggestion, what the success criteria should be?					
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Disagree	Agree
	If no or any suggestion, what the success criteria should be?				VL28-29 should be in level A	
	Other notes					Some signage, line, or tactile on floor as to guide where to reach the lift
WC. - Ambulant Disabled Water Closet	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
	If no or any suggestion, what the success criteria should be?					
	Other notes					
WC. - Accessible Washroom	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					Information describing the layout of space should be provided
Bathroom and Shower	Agreement scale - A	4	3	3	1	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Disagree	Agree

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Category	Questions	Accessibility Experts				
		AE1	AE2	AE3	AE4	AE5
	If no or any suggestion, what the success criteria should be?				BS1-2 seems to be conflict when bathtub is provided, BS2 would be failed	
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					Information describing the layout of space should be provided
Bedroom	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree

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Category	Questions	Accessibility Experts				
		AE1	AE2	AE3	AE4	AE5
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					Information describing the layout of space should be provided
General Space	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
	If no or any suggestion, what the success criteria should be?					
	Other notes	Meeting room may be not classified in general space				Information describing the layout of space should be provided
Utility Space	Agreement scale - A	4	3	3	2	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Disagree	Agree
	If no or any suggestion, what the success criteria should be?				No step or ramp must not be installed in this space	
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					Information describing the layout of space should be provided

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Category	Questions	Accessibility Experts				
		AE1	**AE2**	**AE3**	**AE4**	**AE5**
Hall and Stadium Spaces	Agreement scale - A	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	3	3	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Neutral	Neutral	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes					Information describing the layout of space should be provided

F.3 Building and Interior Design Experts

Table F.4: Raw data and Experts' agreement - Building and Interior Design area

Category	Questions	Building and Interior Design Experts				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
Basic	Expert Area	Building Interior Design and Inspection for Safety	Building and Interior Design	Building and Interior Design	Building and Interior Design	Building and Interior Design
	Experience in the field (years)	10	3	6	8	7
	Have you ever worked with or developed technologies for people with disabilities	All disability	Other disability (motor, blinds, deaf)	Other disability (motor, blinds, deaf)	Other disability (Cerebral Palsy - Muscle impairment)	Visual Impairment
Design of Building Rating System						
Building Rating System	Agreement scale	3	5	4	4	3
	Do you agree with the design of the building rating system?	Neutral	Agree	Agree	Agree	Neutral
	Do you think if any improvement needed for the design of the building rating system?		Overview of the system is systematic and sensible. This research is useful for the future development. The set of spaces should be separated since each building has it owns set of spaces	The set of spaces should be separated since each building has it owns set of spaces and complication	Buildings to be measured should be selected by the most use of people. For example, hospital, civic centre	
Space Classification	Agreement scale	3	2	2	4	3
	Do you agree with the conformance to be used in the space classification?	Neutral	Disagree	Disagree	Agree	Neutral

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	Do you think any improvement would be needed for the space classification?		The option of "Can't tell" should be provided since it creates complications and inability to measure the buildings. The option of "Neutral" must not be provided in "Must-have" items	The option of "Can't tell" should be provided since it creates complications.		
Floor and Building Classification	Agreement scale	3	2	2	2	3
	Do you agree with the conformance to be used in the floor and building classification?	Neutral	Disagree	Disagree	Disagree	Neutral
	Do you think any improvement would be needed for the floor and building classification?		The average approach is not good enough. Suggested Idea: Conformance A: blind (surface/hearing –> features that blind can perceive), Conformance AA: visual impaired, and Conformance AAA: specific requirement involved.	The average approach is not good enough idea. Overlapping scores of space would be better.	The average approach is not good enough idea. Overlapping scores of space would be better selecting buildings to be a case study is necessary in terms of user evaluation	
Success Criteria						
Entrance	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree

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Category	**Questions**	**Building and Interior Design Experts**				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
	If no or any suggestion, what the success criteria should be?		More specification may be required. For example, type of mirror (e.g. temper). They may relate to the safety issue	More specification is needed		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					In Level AA, flooring system and ramp should be added
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					The operational buttons have to have two level, one for visually impaired people and one for wheelchair users
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Foyers	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination in front of reception counter is between 150-300 lux				
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for counter, desk and workspace is between 400-500 lux	Illuminance of 500 lux may be moved to level AAA	Illuminance of 500 lux may be moved to level AAA		
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Horizontal Circulation	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting and acoustic could be in level AA	Lighting and acoustic could be in level AA		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					We probably mention uses of colour or border through the provision in terms of interior design in level AAA. For example, utilising colour or border in to corridor design to leads visuality, which facilitate usability for people with visual impairment
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic could be added in	
Vertical Circulation - Stair	Agreement scale - A	4	4	4	4	4

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Category	Questions	Building and Interior Design Experts				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Vertical Circulation - Ramp	Agreement scale - A	4	4	4	4	2
	Agreement scale - AA	4	4	4	4	4
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Disagree

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Category	Questions	Building and Interior Design Experts				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		Slope 1:12 of the ramp criteria in Conformance A is enough for any length of the lamp (according to the regulation in Thailand).
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					Therefore, you can allocate other slope criteria (1:15 and 1:20) to another Conformance.
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					You can also arrange the slope 1:20 within this conformance
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Vertical Circulation - Lift	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree

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Category	Questions	Building and Interior Design Experts				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?				In addition to VL.21, the audible feedback should be provided with appropraite use of sound	
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
WC. - Ambulant Disabled Water Closet	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
WC. - Accessible Washroom	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		It could involve tile texture which point out the slip Resistance
	Agreement scale - AA	4	4	4	4	4

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Bathroom and Shower	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		It should prescribe the position of a hook
	Agreement scale - AA	4	4	4	4	2
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Disagree

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	If no or any suggestion, what the success criteria should be?					Handrail must have three side of the room.Between bathtub and basin should provide flip-up handrail.
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Bedroom	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		
	Agreement scale - AA	4	4	4	2	2
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Disagree	Disagree

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	If no or any suggestion, what the success criteria should be?				Sanitary accommodation should be moved to level AAA since it is "could-have" item	Bed might has bedside rail
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
General Space	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4

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Category	Questions	Building and Interior Design Experts				
		BIE1	BIE2	BIE3	BIE4	BIE5
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Utility Space	Agreement scale - A	4	4	4	4	2
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Disagree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		Type of tile is another important issue for kitchen. So, selecting good/appropriate tile can prevent slip hazards and also increase slip resistance as well.
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4

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Category	**Questions**	**Building and Interior Design Experts**				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	
Hall and Stadium Spaces	Agreement scale - A	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance A	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?	In Thailand, acceptance of illumination for accessible routes is between 50-100 lux	Lighting could be in level AA	Lighting could be in level AA		
	Agreement scale - AA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					
	Agreement scale - AAA	4	4	4	4	4
	Do you agree with the success criteria shown in Conformance AAA	Agree	Agree	Agree	Agree	Agree
	If no or any suggestion, what the success criteria should be?					

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Category	**Questions**	**Building and Interior Design Experts**				
		BIE1	**BIE2**	**BIE3**	**BIE4**	**BIE5**
	Other notes	Some specification need changes that comply with the standard given in each country			Acoustic should be added	

Appendix G

Building Rating System - Results of Statistical Tests

In this appendix, many statistical tests regarding the design of building rating system were conducted.

- Section G.1 explored responses acquired from the expert validation and review, focusing on correlation between 15 experts and between groups
- Section G.2 showed results of one-sample t-test for design of building rating system, space classification, and floor and building classification
- Section G.3 also described one-sample t-tests results for 13 types of space inside buildings
- Section G.4 showed one-sample t-tests for user evaluation for 95% confidence interval and 99.5% confidence interval.

G.1 Experts Review

In this section, the exploration of expert review was tested in order to find correlation between 15 experts and also between groups. The results were then used to determine whether to exclude experts or not.

G.1.1 Correlation Between Experts

Table G.1: Expert Correlations: Descriptive Statistics

	Mean	**Std. Deviation**	**N**
RDE1	3.98	0.35	42
RDE2	3.02	0.27	42
RDE3	3.00	0.38	42
RDE4	3.02	0.47	42
RDE5	3.95	0.49	42
AE1	3.98	0.35	42
AE2	2.98	0.27	42
AE3	3.02	0.27	42
AE4	3.69	0.87	42
AE5	4.02	0.15	42
BIE1	3.93	0.26	42
BIE2	3.93	0.46	42
BIE3	3.90	0.43	42
BIE4	3.90	0.43	42
BIE5	3.74	0.63	42

Table G.2: Expert Correlations: Inter-expert correlations

Expert		**RDE1**	**RDE2**	**RDE3**	**RDE4**	**RDE5**	**AE1**	**AE2**	**AE3**	**AE4**	**AE5**	**BIE1**	**BIE2**	**BIE3**	**BIE4**	**BIE5**
RDE1	Pearson Correlation	1	0.79**	0.92**	0.90**	0.99**	0.80**	0.77**	0.79**	-0.02	0.01	0.25	0.75**	0.63**	0.63**	0.08
	Sig. (2-tailed)		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.875	0.946	0.111	< 0.001	< 0.001	< 0.001	0.604
RDE2	Pearson Correlation		1	0.95**	0.96**	0.75**	0.79**	0.34*	1.00**	0.14	0.57**	-0.32*	0.21	0.02	0.44**	-0.11
	Sig. (2-tailed)			< 0.001	< 0.001	< 0.001	< 0.001	0.026	< 0.001	0.389	< 0.001	0.037	0.183	0.900	0.004	0.502
RDE3	Pearson Correlation			1	0.95**	0.91**	0.92**	0.47**	0.95**	0.07	0.41**	0	0.41**	0.3	0.59**	0
	Sig. (2-tailed)				< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.644	0.007	1.000	0.007	0.057	< 0.001	1.000
RDE4	Pearson Correlation				1	0.85**	0.75**	0.59**	0.96**	0.08	0.33*	-0.19	0.46**	0.25	0.50**	-0.06
	Sig. (2-tailed)					< 0.001	< 0.001	< 0.001	< 0.001	0.621	0.033	0.239	0.002	0.105	0.001	0.699
RDE5	Pearson Correlation					1	0.85**	0.73**	0.75**	-0.04	0.02	0.35*	0.74**	0.67**	0.67**	0.12
	Sig. (2-tailed)						< 0.001	< 0.001	< 0.001	0.824	0.923	0.022	< 0.001	< 0.001	< 0.001	0.461
AE1	Pearson Correlation						1	0.25	0.79**	0.06	0.46**	0.25	0.29	0.31*	0.63**	0.08
	Sig. (2-tailed)							0.105	< 0.001	0.726	0.002	0.111	0.061	0.046	< 0.001	0.604
AE2	Pearson Correlation							1	0.34*	-0.14	-0.57**	0.32*	0.96**	0.82**	0.40**	0.11
	Sig. (2-tailed)								0.026	0.389	< 0.001	0.037	< 0.001	< 0.001	0.009	0.502
AE3	Pearson Correlation								1	0.14	0.57**	-0.32*	0.21	0.02	0.44**	-0.11
	Sig. (2-tailed)									0.389	< 0.001	0.037	0.183	0.900	0.004	0.502
AE4	Pearson Correlation									1	0.24	-0.21	-0.18	-0.21	-0.08	-0.02
	Sig. (2-tailed)										0.129	0.187	0.261	0.180	0.612	0.909
AE5	Pearson Correlation										1	-0.56**	-0.66**	-0.70**	0.03	-0.19
	Sig. (2-tailed)											< 0.001	< 0.001	< 0.001	0.826	0.238
BIE1	Pearson Correlation											1	0.56**	0.81**	0.37*	0.33*
	Sig. (2-tailed)												< 0.001	< 0.001	0.015	0.033
BIE2	Pearson Correlation												1	0.94**	0.45**	0.19
	Sig. (2-tailed)													< 0.001	0.003	0.238
BIE3	Pearson Correlation													1	0.48**	0.27
	Sig. (2-tailed)														0.001	0.088
BIE4	Pearson Correlation														1	0.45**
	Sig. (2-tailed)															0.003
BIE5	Pearson Correlation															1
	Sig. (2-tailed)															

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

G.1.2 Overall Expert Correlation

In this section, the overall expert correlation were calculated using t-tests given by the inter-experts correlation, where the correlations of 15 experts were shown in Table G.2. The result showed in Table G.3 and G.4 that there were statistically significant positive correlation within the experts, $r = 0.36$, $N = 105$, $p < 0.001$.

Table G.3: Overall Expert Correlation: One-Sample Statistics

	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Overall Expert Correlation	105	0.36	0.41	0.04

Table G.4: Overall Expert Correlation: One-Sample Test

	Test Value = 0					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Overall Expert Correlation	8.89	104	< 0.001	0.36	0.28	0.44

G.1.3 Differences in Expert Means

TABLE G.5: Differences in Expert Means: Within-Subjects Factors

Expert	Dependent Variable	SRF	Dependent Variable
1	RDE1	9	AE4
2	RDE2	10	AE5
3	RDE3	11	BIE1
4	RDE4	12	BIE2
5	RDE5	13	BIE3
6	AE1	14	BIE4
7	AE2	15	BIE5
8	AE3		

TABLE G.6: Differences in Expert Means: Multivariate tests[a]

Effect		Value	*F*	Hypothesis df	Error df	*p*
Expert	Pillai's Trace	0.99	540.78[b]	6.00	36.00	< 0.001
	Wilks' Lambda	0.01	540.78[b]	6.00	36.00	< 0.001
	Hotelling's Trace	90.13	540.78[b]	6.00	36.00	< 0.001
	Roy's Largest Root	90.13	540.78[b]	6.00	36.00	< 0.001

[a] Design: Intercept Within Subjects Design: Expert

[b] Exact statistic

TABLE G.7: Differences in Expert Means: Mauchly's Test of Sphericity[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	*p*	Epsilonb		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Expert	0.00	.	104.00	.	0.25	0.27	0.07

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

[a] Design: Intercept Within Subjects Design: Expert

[b] May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table G.8: Differences in Expert Means: Tests of Within-Subjects Effects

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Expert	Sphericity Assumed	115.94	14.00	8.28	58.79	< 0.001
	Greenhouse-Geisser	115.94	3.47	33.37	58.79	< 0.001
	Huynh-Feldt	115.94	3.83	30.23	58.79	< 0.001
	Lower-bound	115.94	1.00	115.94	58.79	< 0.001
Error(Expert)	Sphericity Assumed	80.86	574.00	0.14		
	Greenhouse-Geisser	80.86	142.43	0.57		
	Huynh-Feldt	80.86	157.23	0.51		
	Lower-bound	80.86	41.00	1.97		

Table G.9: Differences in Expert Means: Tests of Within-Subjects Contrasts

Source	**Expert**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Expert	Level 1 vs. Level 2	38.10	1.00	38.10	820.00	< 0.001
	Level 2 vs. Level 3	0.02	1.00	0.02	1.00	0.323
	Level 3 vs. Level 4	0.02	1.00	0.02	1.00	0.323
	Level 4 vs. Level 5	36.21	1.00	36.21	533.00	< 0.001
	Level 5 vs. Level 6	0.02	1.00	0.02	0.33	0.570
	Level 6 vs. Level 7	42.00	1.00	42.00	287.00	< 0.001
	Level 7 vs. Level 8	0.10	1.00	0.10	1.00	0.323
	Level 8 vs. Level 9	18.67	1.00	18.67	24.43	< 0.001
	Level 9 vs. Level 10	4.67	1.00	4.67	6.52	0.014
	Level 10 vs. Level 11	0.38	1.00	0.38	2.78	0.103
	Level 11 vs. Level 12	0.00	1.00	0.00	0.00	1.000
	Level 12 vs. Level 13	0.02	1.00	0.02	1.00	0.323
	Level 13 vs. Level 14	0.00	1.00	0.00	0.00	1.000
	Level 14 vs. Level 15	1.17	1.00	1.17	3.46	0.070
Error(Expert)	Level 1 vs. Level 2	1.90	41.00	0.05		
	Level 2 vs. Level 3	0.98	41.00	0.02		
	Level 3 vs. Level 4	0.98	41.00	0.02		
	Level 4 vs. Level 5	2.79	41.00	0.07		
	Level 5 vs. Level 6	2.98	41.00	0.07		

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Source	**Expert**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
	Level 6 vs. Level 7	6.00	41.00	0.15		
	Level 7 vs. Level 8	3.90	41.00	0.10		
	Level 8 vs. Level 9	31.33	41.00	0.76		
	Level 9 vs. Level 10	29.33	41.00	0.72		
	Level 10 vs. Level 11	5.62	41.00	0.14		
	Level 11 vs. Level 12	6.00	41.00	0.15		
	Level 12 vs. Level 13	0.98	41.00	0.02		
	Level 13 vs. Level 14	8.00	41.00	0.20		
	Level 14 vs. Level 15	13.83	41.00	0.34		

Table G.10: Differences in Expert Means: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Intercept	545.79	1	545.76	8882.80	< 0.001
Error	2.52	41	0.06		

Table G.11: Differences in Expert Means: Estimated Marginal Means: Estimates

Expert	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	3.98	0.05	3.87	4.08
2	3.02	0.04	2.94	3.11
3	3.00	0.06	2.88	3.12
4	3.02	0.07	2.88	3.17
5	3.95	0.08	3.80	4.11
6	3.98	0.05	3.87	4.08
7	2.98	0.04	2.89	3.06
8	3.02	0.04	2.94	3.11
9	3.69	0.13	3.42	3.96
10	4.02	0.02	3.98	4.07
11	3.93	0.04	3.85	4.01
12	3.93	0.07	3.78	4.07
13	3.90	0.07	3.77	4.04
14	3.90	0.07	3.77	4.04
15	3.74	0.10	3.54	3.93

Table G.12: Differences in Expert Means: Estimated Marginal Means: Pairwise Comparisons with 95% Confidence Interval (CI) for Difference

Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
1	2	0.95*	0.03	0.000	0.83	1.08
	3	0.98*	0.02	0.000	0.89	1.07
	4	0.95*	0.03	0.000	0.83	1.08
	5	0.02	0.02	1.000	-0.07	0.11
	6	0.00	0.03	1.000	-0.13	0.13
	7	1.00*	0.03	0.000	0.87	1.13
	8	0.95*	0.03	0.000	0.83	1.08
	9	0.29	0.15	0.998	-0.27	0.84
	10	-0.05	0.06	1.000	-0.27	0.17
	11	0.05	0.06	1.000	-0.17	0.27
	12	0.05	0.05	1.000	-0.13	0.23
	13	0.07	0.05	1.000	-0.13	0.27
	14	0.07	0.05	1.000	-0.13	0.27
	15	0.24	0.11	0.964	-0.17	0.64
2	1	-0.95*	0.03	0.000	-1.08	-0.83
	3	0.02	0.02	1.000	-0.07	0.11
	4	0.00	0.03	1.000	-0.13	0.13
	5	-0.93*	0.05	0.000	-1.13	-0.73
	6	-0.95*	0.03	0.000	-1.08	-0.83
	7	0.05	0.05	1.000	-0.13	0.23
	8	0.00	0.00	0.	0.00	0.00
	9	-0.67*	0.13	0.001	-1.18	-0.16
	10	-1.00*	0.03	0.000	-1.13	-0.87
	11	-0.90*	0.07	0.000	-1.16	-0.65
	12	-0.90*	0.07	0.000	-1.19	-0.62
	13	-0.88*	0.08	0.000	-1.18	-0.59
	14	-0.88*	0.06	0.000	-1.11	-0.65
	15	-0.71*	0.11	0.000	-1.13	-0.30
3	1	-0.98*	0.02	0.000	-1.07	-0.89
	2	-0.02	0.02	1.000	-0.11	0.07
	4	-0.02	0.02	1.000	-0.11	0.07
	5	-0.95*	0.03	0.000	-1.08	-0.83

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Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference^b	
					Lower Bound	Upper Bound
	6	-0.98*	0.02	0.000	-1.07	-0.89
	7	0.02	0.05	1.000	-0.18	0.23
	8	-0.02	0.02	1.000	-0.11	0.07
	9	-0.69*	0.14	0.002	-1.23	-0.15
	10	-1.02*	0.05	0.000	-1.23	-0.82
	11	-0.93*	0.07	0.000	-1.20	-0.66
	12	-0.93*	0.07	0.000	-1.20	-0.66
	13	-0.90*	0.07	0.000	-1.19	-0.62
	14	-0.90*	0.06	0.000	-1.12	-0.69
	15	-0.74*	0.11	0.000	-1.17	-0.31
4	1	-0.95*	0.03	0.000	-1.08	-0.83
	2	0.00	0.03	1.000	-0.13	0.13
	3	0.02	0.02	1.000	-0.07	0.11
	5	-0.93*	0.04	0.000	-1.08	-0.78
	6	-0.95*	0.05	0.000	-1.13	-0.77
	7	0.05	0.06	1.000	-0.17	0.27
	8	0.00	0.03	1.000	-0.13	0.13
	9	-0.67*	0.15	0.005	-1.22	-0.11
	10	-1.00*	0.07	0.000	-1.26	-0.74
	11	-0.90*	0.09	0.000	-1.24	-0.57
	12	-0.90*	0.07	0.000	-1.19	-0.62
	13	-0.88*	0.08	0.000	-1.20	-0.56
	14	-0.88*	0.07	0.000	-1.15	-0.62
	15	-0.71*	0.12	0.000	-1.18	-0.24
5	1	-0.02	0.02	1.000	-0.11	0.07
	2	0.93*	0.05	0.000	0.73	1.13
	3	0.95*	0.03	0.000	0.83	1.08
	4	0.93*	0.04	0.000	0.78	1.08
	6	-0.02	0.04	1.000	-0.18	0.13
	7	0.98*	0.05	0.000	0.77	1.18
	8	0.93*	0.05	0.000	0.73	1.13
	9	0.26	0.16	1.000	-0.33	0.85
	10	-0.07	0.08	1.000	-0.37	0.23

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Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	11	0.02	0.07	1.000	-0.25	0.30
	12	0.02	0.05	1.000	-0.18	0.23
	13	0.05	0.06	1.000	-0.17	0.27
	14	0.05	0.06	1.000	-0.17	0.27
	15	0.21	0.12	1.000	-0.22	0.65
6	1	0.00	0.03	1.000	-0.13	0.13
	2	0.95*	0.03	0.000	0.83	1.08
	3	0.98*	0.02	0.000	0.89	1.07
	4	0.95*	0.05	0.000	0.77	1.13
	5	0.02	0.04	1.000	-0.13	0.18
	7	1.00*	0.06	0.000	0.78	1.22
	8	0.95*	0.03	0.000	0.83	1.08
	9	0.29	0.14	0.996	-0.25	0.82
	10	-0.05	0.05	1.000	-0.23	0.13
	11	0.05	0.06	1.000	-0.17	0.27
	12	0.05	0.08	1.000	-0.24	0.33
	13	0.07	0.07	1.000	-0.20	0.34
	14	0.07	0.05	1.000	-0.13	0.27
	15	0.24	0.11	0.964	-0.17	0.64
7	1	-1.00*	0.03	0.000	-1.13	-0.87
	2	-0.05	0.05	1.000	-0.23	0.13
	3	-0.02	0.05	1.000	-0.23	0.18
	4	-0.05	0.06	1.000	-0.27	0.17
	5	-0.98*	0.05	0.000	-1.18	-0.77
	6	-1.00*	0.06	0.000	-1.22	-0.78
	8	-0.05	0.05	1.000	-0.23	0.13
	9	-0.71*	0.15	0.002	-1.27	-0.16
	10	-1.05*	0.06	0.000	-1.27	-0.83
	11	-0.95*	0.05	0.000	-1.13	-0.77
	12	-0.95*	0.03	0.000	-1.08	-0.83
	13	-0.93*	0.04	0.000	-1.08	-0.78
	14	-0.93*	0.06	0.000	-1.17	-0.69
	15	-0.76*	0.10	0.000	-1.15	-0.38

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Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
8	1	-0.95*	0.03	0.000	-1.08	-0.83
	2	0.00	0.00	0.	0.00	0.00
	3	0.02	0.02	1.000	-0.07	0.11
	4	0.00	0.03	1.000	-0.13	0.13
	5	-0.93*	0.05	0.000	-1.13	-0.73
	6	-0.95*	0.03	0.000	-1.08	-0.83
	7	0.05	0.05	1.000	-0.13	0.23
	9	-0.67*	0.13	0.001	-1.18	-0.16
	10	-1.00*	0.03	0.000	-1.13	-0.87
	11	-0.90*	0.07	0.000	-1.16	-0.65
	12	-0.90*	0.07	0.000	-1.19	-0.62
	13	-0.88*	0.08	0.000	-1.18	-0.59
	14	-0.88*	0.06	0.000	-1.11	-0.65
	15	-0.71*	0.11	0.000	-1.13	-0.30
9	1	-0.29	0.15	0.998	-0.84	0.27
	2	0.67*	0.13	0.001	0.16	1.18
	3	0.69*	0.14	0.002	0.15	1.23
	4	0.67*	0.15	0.005	0.11	1.22
	5	-0.26	0.16	1.000	-0.85	0.33
	6	-0.29	0.14	0.996	-0.82	0.25
	7	0.71*	0.15	0.002	0.16	1.27
	8	0.67*	0.13	0.001	0.16	1.18
	10	-0.33	0.13	0.783	-0.83	0.16
	11	-0.24	0.15	1.000	-0.80	0.32
	12	-0.24	0.16	1.000	-0.85	0.38
	13	-0.21	0.16	1.000	-0.83	0.40
	14	-0.21	0.15	1.000	-0.80	0.37
	15	-0.05	0.17	1.000	-0.68	0.58
10	1	0.05	0.06	1.000	-0.17	0.27
	2	1.00*	0.03	0.000	0.87	1.13
	3	1.02*	0.05	0.000	0.82	1.23
	4	1.00*	0.07	0.000	0.74	1.26
	5	0.07	0.08	1.000	-0.23	0.37

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Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	6	0.05	0.05	1.000	-0.13	0.23
	7	1.05*	0.06	0.000	0.83	1.27
	8	1.00*	0.03	0.000	0.87	1.13
	9	0.33	0.13	0.783	-0.16	0.83
	11	0.10	0.06	1.000	-0.12	0.31
	12	0.10	0.09	1.000	-0.24	0.43
	13	0.12	0.08	1.000	-0.20	0.44
	14	0.12	0.07	1.000	-0.15	0.38
	15	0.29	0.10	0.605	-0.11	0.68
11	1	-0.05	0.06	1.000	-0.27	0.17
	2	0.90*	0.07	0.000	0.65	1.16
	3	0.93*	0.07	0.000	0.66	1.20
	4	0.90*	0.09	0.000	0.57	1.24
	5	-0.02	0.07	1.000	-0.30	0.25
	6	-0.05	0.06	1.000	-0.27	0.17
	7	0.95*	0.05	0.000	0.77	1.13
	8	0.90*	0.07	0.000	0.65	1.16
	9	0.24	0.15	1.000	-0.32	0.80
	10	-0.10	0.06	1.000	-0.31	0.12
	12	0.00	0.06	1.000	-0.22	0.22
	13	0.02	0.04	1.000	-0.13	0.18
	14	0.02	0.06	1.000	-0.22	0.26
	15	0.19	0.09	0.991	-0.16	0.54
12	1	-0.05	0.05	1.000	-0.23	0.13
	2	0.90*	0.07	0.000	0.62	1.19
	3	0.93*	0.07	0.000	0.66	1.20
	4	0.90*	0.07	0.000	0.62	1.19
	5	-0.02	0.05	1.000	-0.23	0.18
	6	-0.05	0.08	1.000	-0.33	0.24
	7	0.95*	0.03	0.000	0.83	1.08
	8	0.90*	0.07	0.000	0.62	1.19
	9	0.24	0.16	1.000	-0.38	0.85
	10	-0.10	0.09	1.000	-0.43	0.24

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Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference[b]	
					Lower Bound	Upper Bound
	11	0.00	0.06	1.000	-0.22	0.22
	13	0.02	0.02	1.000	-0.07	0.11
	14	0.02	0.07	1.000	-0.25	0.30
	15	0.19	0.11	1.000	-0.22	0.60
13	1	-0.07	0.05	1.000	-0.27	0.13
	2	0.88*	0.08	0.000	0.59	1.18
	3	0.90*	0.07	0.000	0.62	1.19
	4	0.88*	0.08	0.000	0.56	1.20
	5	-0.05	0.06	1.000	-0.27	0.17
	6	-0.07	0.07	1.000	-0.34	0.20
	7	0.93*	0.04	0.000	0.78	1.08
	8	0.88*	0.08	0.000	0.59	1.18
	9	0.21	0.16	1.000	-0.40	0.83
	10	-0.12	0.08	1.000	-0.44	0.20
	11	-0.02	0.04	1.000	-0.18	0.13
	12	-0.02	0.02	1.000	-0.11	0.07
	14	0.00	0.07	1.000	-0.26	0.26
	15	0.17	0.10	1.000	-0.22	0.55
14	1	-0.07	0.05	1.000	-0.27	0.13
	2	0.88*	0.06	0.000	0.65	1.11
	3	0.90*	0.06	0.000	0.69	1.12
	4	0.88*	0.07	0.000	0.62	1.15
	5	-0.05	0.06	1.000	-0.27	0.17
	6	-0.07	0.05	1.000	-0.27	0.13
	7	0.93*	0.06	0.000	0.69	1.17
	8	0.88*	0.06	0.000	0.65	1.11
	9	0.21	0.15	1.000	-0.37	0.80
	10	-0.12	0.07	1.000	-0.38	0.15
	11	-0.02	0.06	1.000	-0.26	0.22
	12	-0.02	0.07	1.000	-0.30	0.25
	13	0.00	0.07	1.000	-0.26	0.26
	15	0.17	0.09	1.000	-0.17	0.51
15	1	-0.24	0.11	0.964	-0.64	0.17

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Expert (I)	Expert (J)	Mean Difference (I-J)	Std. Error	p^b	95% CI for Difference^b	
					Lower Bound	Upper Bound
	2	0.71*	0.11	0.000	0.30	1.13
	3	0.74*	0.11	0.000	0.31	1.17
	4	0.71*	0.12	0.000	0.24	1.18
	5	-0.21	0.12	1.000	-0.65	0.22
	6	-0.24	0.11	0.964	-0.64	0.17
	7	0.76*	0.10	0.000	0.38	1.15
	8	0.71*	0.11	0.000	0.30	1.13
	9	0.05	0.17	1.000	-0.58	0.68
	10	-0.29	0.10	0.605	-0.68	0.11
	11	-0.19	0.09	0.991	-0.54	0.16
	12	-0.19	0.11	1.000	-0.60	0.22
	13	-0.17	0.10	1.000	-0.55	0.22
	14	-0.17	0.09	1.000	-0.51	0.17

Based on estimated marginal means
* The mean difference is significant at the adjustment for multiple comparisons
[b] Adjustment for multiple comparisons: Sidak

Table G.13: Differences in Expert Means: Estimated Marginal Means: Multivariate tests

	Value	F	Hypothesis df	Error df	p
Pillai's trace	0.98	280.72^a	6.00	36.00	< 0.001
Wilks' lambda	0.02	280.72^a	6.00	36.00	< 0.001
Hotelling's trace	46.79	280.72^a	6.00	36.00	< 0.001
Roy's largest root	46.79	280.72^a	6.00	36.00	< 0.001

Each F tests the multivariate effect of Expert. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
[a] Exact statistic

G.1.4 Correlation Between Groups of Experts

In this section, groups of expert correlation (RDE: Research & Development experts, AE: Accessibility experts and BIE: Building and Interior Design experts) were calculated. The results showed in Table G.15 reported that there were significant associations (positive correlation) in RDE correlated with AE ($r = 0.66$, $n = 42$, $p < 0.001$) and BIE ($r = 0.43$, $n = 42$, $p < 0.001$), while AE and BIE were insignificantly correlated with each other.

TABLE G.14: Group Correlations: Descriptive Statistics

	Mean	**Std. Deviation**	**N**
RDE	3.40	0.38	42
AE	3.54	0.24	42
BIE	3.88	0.33	42

TABLE G.15: Group Correlations

		RDE	**AE**	**BIE**
RDE	Pearson Correlation	1	0.66**	0.43**
	Sig. (2-tailed)		< 0.001	0.004
AE	Pearson Correlation	0.66**	1	0.10
	Sig. (2-tailed)	< 0.001		0.526
BIE	Pearson Correlation	0.43**	0.10	1
	Sig. (2-tailed)	0.004	0.526	

** Correlation is significant at the 0.01 level (2-tailed)

G.1.5 Differences in Expert Group Means

Table G.16: Group Correlations: Within-Subjects Factors

Expert	Dependent Variable
1	RDE
2	AE
3	BIE

Table G.17: Group Correlations: Multivariate tests[a]

Effect		Value	F	Hypothesis df	Error df	p
Group	Pillai's Trace	0.63	33.54^b	2.00	40.00	< 0.001
	Wilks' Lambda	0.37	33.54^b	2.00	40.00	< 0.001
	Hotelling's Trace	1.68	33.54^b	2.00	40.00	< 0.001
	Roy's Largest Root	1.68	33.54^b	2.00	40.00	< 0.001

[a] Design: Intercept Within Subjects Design: Group

[b] Exact statistic

Table G.18: Group Correlations: Mauchly's Test of Sphericity[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	p	Epsilonb		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Group	0.87	5.64	2	0.06	0.89	0.92	0.50

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

[a] Design: Intercept Within Subjects Design: Expert

[b] May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table G.19: Group Correlations: Tests of Within-Subjects Effects

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Group	Sphericity Assumed	5.23	2.00	2.62	41.54	< 0.001
	Greenhouse-Geisser	5.23	1.77	2.96	41.54	< 0.001
	Huynh-Feldt	5.23	1.84	2.84	41.54	< 0.001
	Lower-bound	5.23	1.00	5.23	41.54	< 0.001
Error(Group)	Sphericity Assumed	5.17	82.00	0.06		
	Greenhouse-Geisser	5.17	72.48	0.07		
	Huynh-Feldt	5.17	75.50	0.07		
	Lower-bound	5.17	41.00	0.13		

Table G.20: Group Correlations: Tests of Within-Subjects Contrasts

Source	**Expert**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Group	Level 1 vs. Level 2	0.86	1	0.86	10.64	0.002
	Level 2 vs. Level 3	4.94	1	4.94	32.32	< 0.001
Error(Group)	Level 1 vs. Level 2	3.30	41	0.08		
	Level 2 vs. Level 3	6.26	41	0.15		

Table G.21: Group Correlations: Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	***p***
Intercept	545.76	1	545.76	8882.80	< 0.001
Error	2.51	41	0.06		

Table G.22: Group Correlations: Estimated Marginal Means: Estimates

Expert	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
1	3.40	0.06	3.28	3.51
2	3.54	0.04	3.46	3.61
3	3.88	0.05	3.78	3.98

Table G.23: Group Correlations: Estimated Marginal Means: Pairwise Comparisons with 95% Confidence Interval (CI) for Difference

Expert (I)	**Expert (J)**	**Mean Difference (I-J)**	**Std. Error**	p^b	**95% CI for Difference**[b]	
					Lower Bound	**Upper Bound**
1	2	-0.14*	0.04	0.007	-0.25	-0.03
	3	-0.49*	0.06	0.000	-0.63	-0.34
2	1	0.14*	0.04	0.007	0.03	0.25
	3	-0.34*	0.06	0.000	-0.49	-0.19
3	1	0.49*	0.06	0.000	0.34	0.63
	2	0.34*	0.06	0.000	0.19	0.49

Based on estimated marginal means

* The mean difference is significant at the adjustment for multiple comparisons

[b] Adjustment for multiple comparisons: Sidak

Table G.24: Group Correlations: Estimated Marginal Means: Multivariate tests

	Value	**F**	**Hypothesis df**	**Error df**	p
Pillai's trace	0.63	33.54[a]	2.00	40.00	0.000
Wilks' lambda	0.37	33.54[a]	2.00	40.00	0.000
Hotelling's trace	1.68	33.54[a]	2.00	40.00	0.000
Roy's largest root	1.68	33.54[a]	2.00	40.00	0.000

Each F tests the multivariate effect of Expert. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

[a] Exact statistic

G.2 Design of Building Rating System

G.2.1 Overall of the Building Rating System

Table G.25: One-Sample Statistics - Design of of the Building Rating System

Design of of the Building Rating	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Do you agree with the design of the building rating system?	15	4.13	0.64	0.17

Table G.26: One-Sample Test - Design of of the Building Rating System

Design of of the Building Rating System	**Test Value = 3**					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Do you agree with the design of the building rating system?	6.86	14	< 0.001	1.13	0.78	1.49

G.2.2 Space classification

Table G.27: One-Sample Statistics - Space Classification

Space Classification	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Do you agree with the conformance to be used in the space classification?	15	3.67	1.05	0.27

Table G.28: One-Sample Test - Space Classification

Space Classification	**Test Value = 3**					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Do you agree with the conformance to be used in the space classification?	2.47	14	0.027	0.67	0.09	1.25

G.2.3 Floor and Building classifications

Table G.29: One-Sample Statistics - Floor and Building Classifications

Floor and Building Classifications	N	Mean	Std. Deviation	Std. Error Mean
Do you agree with the conformance to be used in the floor and building classifications?	15	2.22	0.94	0.24

Table G.30: One-Sample Test - Floor and Building Classifications

Floor and Building Classifications	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Do you agree with the conformance to be used in the floor and building classifications?	-3.29	14	0.005	-0.80	-1.32	-0.28

G.3 Success Criteria

In this section, success criteria were validated and reviewed. Three groups of experts were asked to have a look at the success criteria for thirteen types of spaces as follows:

- Entrance space
- Foyers
- Horizontal circulation space (e.g. passageway and corridor)
- Vertical circulation - Lift space
- Vertical circulation - Ramp space
- Vertical circulation - Stair space
- Sanitary - Ambulant disabled toilet space
- Sanitary - Accessible washroom space
- Sanitary - Bathroom and Shower space
- Bedroom space
- General spaces (e.g. office, living room, and other uncategorized space)
- Utility spaces (e.g. kitchen and storage)
- Hall and stadium spaces (e.g. hall, lecture hall, stadium, or theatre)

G.3.1 Entrance Space

Table G.31: One-Sample Statistics - Entrance Space

Entrance Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.47	0.83	0.22
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.53	0.64	0.17

Table G.32: One-Sample Test - Entrance Space

Entrance Space	Test Value = 3					
	t	df	p	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	2.17	14	0.048	0.47	0.00	0.93
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	3.23	14	0.006	0.53	0.18	0.89

G.3.2 Foyers

TABLE G.33: One-Sample Statistics - Foyer Space

Foyer Space	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

TABLE G.34: One-Sample Test - Foyer Space

Foyer Space	**Test Value = 3**					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.3 Horizontal Circulation Space

Table G.35: One-Sample Statistics - Horizontal Circulation Space

Horizontal Circulation Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.36: One-Sample Test - Horizontal Circulation Space

Horizontal Circulation Space	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.4 Vertical Circulation - Stair Space

Table G.37: One-Sample Statistics - Stair Space

Stair Space	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.38: One-Sample Test - Stair Space

Stair Space	**Test Value = 3**					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.5 Vertical Circulation - Ramp Space

Table G.39: One-Sample Statistics - Ramp Space

Ramp Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.53	0.64	0.17
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.40: One-Sample Test - Ramp Space

Ramp Space	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	3.23	14	0.006	0.53	0.18	0.89
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.6 Vertical Circulation - Lift Space

Table G.41: One-Sample Statistics - Lift Space

Lift Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.53	0.64	0.17
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.53	0.64	0.17

Table G.42: One-Sample Test - Lift Space

Lift Space	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	3.23	14	0.006	0.53	0.18	0.89
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	3.23	14	0.006	0.53	0.18	0.89

G.3.7 Sanitary - Ambulant Disabled Water Closet Space

Table G.43: One-Sample Statistics - Ambulant Disabled Water Closet Space

Ambulant Disabled Water Closet Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.44: One-Sample Test - Ambulant Disabled Water Closet Space

Ambulant Disabled Water Closet Space	Test Value = 3					
	t	df	p	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.8 Sanitary - Accessible Washroom Space

Table G.45: One-Sample Statistics - Accessible Washroom Space

Accessible Washroom Space	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.46: One-Sample Test - Accessible Washroom Space

Accessible Washroom Space	**Test Value = 3**					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.9 Sanitary - Bathroom and Shower Space

Table G.47: One-Sample Statistics - Bathroom and Shower Space

Bathroom and Shower Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.47	0.83	0.22
Success Criteria - Conformance AA	15	3.53	0.64	0.17
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.48: One-Sample Test - Bathroom and Shower Space

Bathroom and Shower Space	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	2.17	14	0.048	0.47	0.00	0.93
Success Criteria - Conformance AA	3.23	14	0.006	0.53	0.18	0.89
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.10 Bedroom Space

Table G.49: One-Sample Statistics - Bedroom Space

Bedroom Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.40	0.74	0.19
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.50: One-Sample Test - Bedroom Space

Bedroom Space	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	2.10	14	0.054	0.40	-0.01	0.81
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.11 General Space

Table G.51: One-Sample Statistics - General Space

General Space	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.52: One-Sample Test - General Space

General Space	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.12 Utility Space

Table G.53: One-Sample Statistics - Utility Space

Utility Space	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Success Criteria - Conformance A	15	3.40	0.74	0.19
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.54: One-Sample Test - Utility Space

Utility Space	**Test Value = 3**					
	t	**df**	***p***	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Success Criteria - Conformance A	2.10	14	0.054	0.40	-0.01	0.81
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.3.13 Hall and Stadium Spaces

Table G.55: One-Sample Statistics - Hall and Stadium Spaces

Hall and Stadium Spaces	N	Mean	Std. Deviation	Std. Error Mean
Success Criteria - Conformance A	15	3.67	0.49	0.13
Success Criteria - Conformance AA	15	3.67	0.49	0.13
Success Criteria - Conformance AAA	15	3.67	0.49	0.13

Table G.56: One-Sample Test - Hall and Stadium Spaces

Hall and Stadium Spaces	Test Value = 3					
	t	df	*p*	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Success Criteria - Conformance A	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AA	5.29	14	< 0.001	0.67	0.40	0.94
Success Criteria - Conformance AAA	5.29	14	< 0.001	0.67	0.40	0.94

G.4 User Evaluation

G.4.1 Benchmark for System Usability Scale

TABLE G.57: Benchmarks for System Usability Scales (Lewis & Sauro, 2018)

SUS Question	**Average Score**	**Good Score**
1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	≥ 3.39	≥ 3.80
2. I found the BRS unnecessarily complex.	≤ 2.44	≤ 1.85
3. I thought the BRS was easy to use.	≥ 3.67	≥ 4.24
4. I think that I would need the support of a technical person to be able to use this system.	≤ 1.85	≤ 1.51
5. I found the various functions in the BRS were well integrated.	≥ 3.55	≥ 3.96
6. I thought there was too much inconsistency in this system.	≤ 2.20	≤ 1.77
7. I imagine that most people would learn to use this system very quickly.	≥ 3.71	≥ 4.19
8. I found the BRS very awkward to use.	≤ 2.25	≤ 1.66
9. I felt very confident using the BRS.	≥ 3.72	≥ 4.25
10. I needed to learn a lot of things before I could get going with this system.	≤ 2.09	≤ 1.64

G.4.2 T-tests at 95% Confidence Interval ($\alpha = 0.05$)

Table G.58: One-Sample Statistics at 95% Confidence Interval: Descriptive

SUS Questions	N	Mean	Std. Deviation	Std. Error Mean
1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	9	4.22	0.97	0.32
2. I found the BRS unnecessarily complex.	9	1.67	1.00	0.33
3. I thought the BRS was easy to use.	9	4.33	1.00	0.33
4. I think that I would need the support of a technical person to be able to use this system.	9	3.56	1.33	0.44
5. I found the various functions in the BRS were well integrated.	9	4.11	0.60	0.20
6. I thought there was too much inconsistency in this system.	9	1.89	0.60	0.20
7. I imagine that most people would learn to use this system very quickly.	9	4.11	1.36	0.46
8. I found the BRS very awkward to use.	9	2.33	1.12	0.37
9. I felt very confident using the BRS.	9	4.11	0.78	0.26
10. I needed to learn a lot of things before I could get going with this system.	9	2.56	1.24	0.41

Table G.59: One-Sample Statistics at 95% Confidence Interval: One-Sample Test (Test = 3)

SUS Question	t	df	p	Mean Difference	99.5% Confidence Interval of the Difference	
					Lower	Upper
1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	3.77	8	0.005*	1.22	0.48	1.97
2. I found the BRS unnecessarily complex.	-4.00	8	0.004*	-1.33	-2.10	-0.56
3. I thought the BRS was easy to use.	4.00	8	0.004*	1.33	0.56	2.10
4. I think that I would need the support of a technical person to be able to use this system.	1.25	8	0.247	0.56	-0.47	1.58
5. I found the various functions in the BRS were well integrated.	5.55	8	0.001*	1.11	0.65	1.57
6. I thought there was too much inconsistency in this system.	-5.55	8	0.001*	-1.11	-1.57	-0.65
7. I imagine that most people would learn to use this system very quickly.	2.44	8	0.040*	1.11	0.06	2.16
8. I found the BRS very awkward to use.	-1.79	8	0.111	-0.67	-1.53	0.19
9. I felt very confident using the BRS.	4.26	8	0.003*	1.11	0.51	1.71
10. I needed to learn a lot of things before I could get going with this system.	-1.08	8	0.312	-0.44	-1.39	0.51

* Significantly different from 3 at 5% level of significance

G.4.3 T-tests at 99.5% Confidence Interval with Bonferroni Correction ($\alpha = 0.005$)

Table G.60: One-Sample Statistics at 99.5% Confidence Interval: Descriptive

SUS Questions	N	Mean	Std. Deviation	Std. Error Mean
1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	9	4.22	0.97	0.32
2. I found the BRS unnecessarily complex.	9	1.67	1.00	0.33
3. I thought the BRS was easy to use.	9	4.33	1.00	0.33
4. I think that I would need the support of a technical person to be able to use this system.	9	3.56	1.33	0.44
5. I found the various functions in the BRS were well integrated.	9	4.11	0.60	0.20
6. I thought there was too much inconsistency in this system.	9	1.89	0.60	0.20
7. I imagine that most people would learn to use this system very quickly.	9	4.11	1.36	0.46
8. I found the BRS very awkward to use.	9	2.33	1.12	0.37
9. I felt very confident using the BRS.	9	4.11	0.78	0.26
10. I needed to learn a lot of things before I could get going with this system.	9	2.56	1.24	0.41

Table G.61: One-Sample Statistics at 99.5% Confidence Interval: One-Sample Test (Test = 3)

SUS Question	t	df	*p*	Mean Difference	99.5% Confidence Interval of the Difference	
					Lower	Upper
1. I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	3.77	8	0.005*	1.22	-0.02	2.46
2. I found the BRS unnecessarily complex.	-4.00	8	0.004*	-1.33	-2.61	-0.06
3. I thought the BRS was easy to use.	4.00	8	0.004*	1.33	0.06	2.61
4. I think that I would need the support of a technical person to be able to use this system.	1.25	8	0.247	0.56	-1.15	2.26
5. I found the various functions in the BRS were well integrated.	5.55	8	0.001*	1.11	0.34	1.88
6. I thought there was too much inconsistency in this system.	-5.55	8	0.001*	-1.11	-1.88	-0.34
7. I imagine that most people would learn to use this system very quickly.	2.44	8	0.040	1.11	-0.63	2.85
8. I found the BRS very awkward to use.	-1.79	8	0.111	-0.67	-2.09	0.76
9. I felt very confident using the BRS.	4.26	8	0.003*	1.11	0.11	2.11
10. I needed to learn a lot of things before I could get going with this system.	-1.08	8	0.312	-0.44	-2.02	1.13

* Significantly different from 3 at 0.5% level of significance

Appendix H

Building Rating System - User Evaluation Raw Data

In this Appendix, raw data collected three focus groups were converted into System Usability Scale (SUS), as follows:

1. Focus Group 1 as shown in Table H.1
2. Focus Group 2 as shown in Table H.2
3. Focus Group 3 as shown in Table H.3

H.1 Focus Group 1

Table H.1: User Evaluation - Raw data of Focus Group 1

No	**SUS Questions**	**Participant**		
		R1	**R2**	**R3**
1	I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	5	4	4
		The system is not very complex, easy to use for performing a risk assessment in buildings	it is easy way to let people know information of the buildings and spaces about the risks in spaces	I think so, this system is not complex and simple in terms of each of use. I also think that the system does good perform in what it is designed.
2	I found the BRS unnecessarily complex.	1	1	2
		The system is very easy to use and handle	The system is very easy to use and handle	yes it is a bit complex, but it is getting better when I tried the first space
3	I thought the BRS was easy to use.	5	5	4
		I also think so that the system is easy to use once I understand a whole system	Yes, it is convenient and easy to use by all people	Yes, the system is simple and easy to use
4	I think that I would need the support of a technical person to be able to use this system.	4	4	4
		A bit difficult in the first place, if user manual is given, it would be quick and easier in using this system.	The system seems a bit complex due to many processes. The user manual must be given before using the system.	Yes, in the beginning as many technical terms have used
5	I found the various functions in the BRS were well integrated.	4	4	4
		Yes, the system is well-designed, integrating with useful functions	Even though the system is a bit complex, but yes it is well-integrated especially its functionality	The system is well-integrated and professional designed
6	I thought there was too much inconsistency in this system.	2	2	2
		The system can help people do the risk easier, I found no inconsistency in the system	I also agreed with R1. The system can help people do the risk easier, I found no inconsistency in the system	I also agreed with R1. The system can help people do the risk easier, I found no inconsistency in the system
7	I imagine that most people would learn to use this system very quickly.	4	5	5
		The data and information given are clear. Users can measure building accessibility by following the requirements	Yes, I think people would learn how to use this system quickly. However this depends on the knowledge that they have because some words are too difficult and specific in the field. For example, architecture jargon.	I agreed with R2 as well. There are some words and terminology that I do not know before. However, I think if people know these words and terminology beforehand, they would learn and use this system very quickly.

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No	SUS Questions	Participant		
		R1	**R2**	**R3**
8	I found the BRS very awkward to use.	3	3	3
		Just only the architecture/technical jargon that users have to learn and understand beforehand	Yes, it is so complex, but once we learn how to use the system, everything is easier	It would be difficult for some people using this system in the first time, but some people who usually do the risk assessment in building this system would be very useful
9	I felt very confident using the BRS.	4	4	5
		I also agree with R2. Some definitions may be changed to make it easy to understand.	yes, once I understand the system I have confidence in using this system. However, It depends on the definition given in the system. Some architecture and technical terms I don't know.	Yes, I am confident in using this system as it is ease of use.
10	I needed to learn a lot of things before I could get going with this system.	4	4	4
		Yes, there are some architecture and technical jargon that I have to learn before using this system.	This system may be easy for the English native speaker, but for non-native is would be a bit difficult since some technical jargon they do not know.	Yes, many things I have to learn beforehand, for example some technical terms and definitions used in building and space designs.

H.2 Focus Group 2

Table H.2: User Evaluation - Raw data of Focus Group 2

No	SUS Questions	Participant		
		R4	R5	R6
1	I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	4	5	4
		Absolutely, the system provide good designs and metrics that can be measure the accessibility easier.	The system is easy to use and comprehensive.	The system is easy to use and clear with its descriptions and instructions.
2	I found the BRS unnecessarily complex.	2	1	2
		No, the system have used the necessary metrics.	No, it covers everything, easy to follow with step-by-step from the essential level (Conformance A) to the full level (Conformance AAA) level of accessibility.	The system is not complex and explanation given with informative details.
3	I thought the BRS was easy to use.	5	5	4
		The system is simple, but some terms may be changed to make them easier by all people. For example, architecture terms.	The system is simple and easy to use.	The system is easy to use and clear with its descriptions and instructions. So, I can agree with Hany that this system is easy to use.
4	I think that I would need the support of a technical person to be able to use this system.	3	2	1
		Yes, for the first time only, to discuss different function of each.	I might need this help on the beginning in order to understand the big picture.	I don't think so. As said previously, the instruction is clear and easy to follow.
5	I found the various functions in the BRS were well integrated.	5	4	4
		I found the system measures the space smoothly with clear different scales usage in classify accessibility in spaces.	I also agree with Raid. The system is well-designed and well-integrated in terms of functionality required for the risk assessment.	The system is well-designed and well-integrated in terms of functionality required for the risk assessment.
6	I thought there was too much inconsistency in this system.	1	2	2
		I found no inconsistency. The system is design with terms used consistently.	I think the system is consistent. There is no complicated terms in system, but the metrics use in different space may be inconsistent. However, this depends on the standards you used in creating this system.	No, the system is consistent. There is no crash in the system while assess the accessibility in spaces.

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No	SUS Questions	Participant		
		R4	**R5**	**R6**
7	I imagine that most people would learn to use this system very quickly.	4	5	5
		Yes, after having a training before everything is so easy.	Yes, the process is easy to follow and not complicated.	The system is easy to use and not complicated.
8	I found the BRS very awkward to use.	1	1	2
		No, the system is well-designed with systematic thinking in mind.	Not at all, I found the system is systematic designed.	No, the system is well-deigned. It is not complex to use
9	I felt very confident using the BRS.	4	5	4
		Yes, the system is developed well.	In the first use it will be a bit difficult due to many technical terms and jargon used in the system. Next time should be easy straight forward.	It is convenient to use, with clear instructions and description given within the system.
10	I needed to learn a lot of things before I could get going with this system.	2	1	2
		No, I don' think so. This depends on English skills. However, for some people, they would need to learn a lot since many technical words are used in the system.	NO, the instruction given in the system is clear and easy to follow.	Not really, the system is easy to follow, but technical words I do not know need to be sorted out beforehand.

H.3 Focus Group 3

Table H.3: User Evaluation - Raw data of Focus Group 3

No	SUS Questions	Participant		
		R7	**R8**	**R9**
1	I think that I would like to use the BRS frequently when doing a risk assessment for space designs.	5	5	2
		The system is easy to use and clear with its descriptions and instructions	The system is easy to use and clear with its instruction. This system performs very well in assessing the risk in spaces.	This system cannot be used for quick assessment
2	I found the BRS unnecessarily complex.	1	1	4
		It is easy to use and understand how it performs.	It is easy to understand. Any person with or without experience will be able to use this system.	Because of the terminology and precise measurement required during the risk assessment
3	I thought the BRS was easy to use.	4	5	2
		It is easy to use and understand how it performs.	Yes, because it is clear and simple	Because of the terminology and precise measurement required during the risk assessment
4	I think that I would need the support of a technical person to be able to use this system.	5	4	5
		Yes, I have never used this kind of system before.	yes, in case you do not have experience in this kind of task	Because of the terminology and difficult words used (architecture and technical jargons)
5	I found the various functions in the BRS were well integrated.	4	5	3
		Yes, I think the system is well-integrated with its functionality and design	Yes/No or Pass/Fail make it easy to answer.	Since this system is complex and difficult to understand. I could not evaluate whether it is well-integrated
6	I thought there was too much inconsistency in this system.	2	1	3
		No, the system is consistent	Nothing at all. Functions do not crash to each other	Since this system is complex and difficult to understand. I could not find any inconsistency
7	I imagine that most people would learn to use this system very quickly.	3	5	1
		Yes, most of people can learn and use this system quickly. However, there might be some people that need help before using the system because many technical terms have been used.	Yes, it is easy to use. People can learn and use this system very quick	Because of the terminology and precise measurement required during the risk assessment

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No	SUS Questions	Participant		
		R7	**R8**	**R9**
8	I found the BRS very awkward to use.	3	1	4
		In the first time, yes it is a bit complicated but I was getting better since I have seen the big picture of the system	It is not difficult, so it is easy to use	Because of the terminology and precise measurement required during the risk assessment
9	I felt very confident using the BRS.	3	5	3
		Yes and no. there are so many terminology in architecture I do not know	Yes, once I use it the first time. I feel confident enough.	Because of the terminology and precise measurement required during the risk assessment
10	I needed to learn a lot of things before I could get going with this system.	2	1	3
		Not much, just only the terminology that I do not know	No, I was familiarised this system very quick.	Because of the terminology and precise measurement required during the risk assessment

Appendix I

Example of SRF Data Model and Specification

In this chapter, an example of SRF data model and specification are described, shown in Table I.1, covering all components in the SRF, except *External*.

TABLE I.1: Example of SRF Data Model and Specification

Attributes	Data Type	Example
ID	*Integer*	1, 2, . . . , n
Parent Object	*Integer*	1, 2, . . . , n
Type	*Integer*	
	0: Objects	Note[1]
	1: Markers	Note[2]
Profile	***Class/Structure***	
Title	*String*	"Lift"
Description	*String*	"Mountbatten lift"
Physical Information	***Class/Structure***	
Dimension	*String/Array*	[2.5m, 1.5m, 2.2m]
Color	*String/Array*	Silver [192,192,192]
Other	*String*	
Location	***Class/Structure***	
Physical Location	*String/Array*	[x, y, floor]
Other	*String*	

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Attributes	Data Type	Example
Transition	***Class/Structure***	
From	*Integer/Array*	[1, 2, 3, 4] (From)
To	*Integer/Array*	[1, 2, 3, 4] (To)
Activator	*Integer* 0: Disabled 1: Manual 2: Automatic	
Object[1]	***Class/Structure***	
Type	*Integer* 0: Unknown 1: Fixed Object 2: Rearrangeable Object 3: Transient Object 4: Sensor Object 5: Super Object 6: Transition Object 7: Self-Moving Object	
Marker[2]	***Class/Structure***	
Type	*Integer* 0: Unknown 1: Walkable Path 2: Navigational cues 3: Warning	
Data	*Array/Vector*	path = $[(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)]$ path3d = $[(x_1, y_1, z_1), (x_2, y_2, z_2), \ldots, (x_n, y_n, z_3)]$
Description	*String*	*navigational cue*: handrail is on right-hand side. *warning*: there is fire extinguisher installed on your right hand side 30 cm above the floor.
STATE	***Class/Structure***	
Moving	*Integer* 0: No 1: Yes	Note[3]
Mode	*Integer* 0: Vertical 1: Horizontal 2: Swing	Note[3] for elevator and escalator for moving pavement for door

. . . *Continued on next page*

Attributes	**Data Type**	**Example**
	3: Spin	for revolving door
Direction	*Integer* 0: No direction 1: Up 2: Down 3: Forward 4: Backward 5: Left 6: Right	Note[3]

[1] If Type is 0: Objects, *Object* attribute is required

[2] If Type is 1: Markers, *Marker* attribute is required

[3] This field is updated automatically, depending on a current state of the object.

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