A DESIGN FRAMEWORK FOR SYNTHESIZING THE MOBILE AND STATIC WAYFINDING INFORMATION IN COMPLEX ENVIRONMENTS

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A Design Framework for Synthesizing the Mobile and Static Wayfinding Information in Complex Environments

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CERTIFICATE OF ORIGINALITY

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Hassan IFTIKHAR

(Name)

(Signature of the Student)

This thesis is dedicated to my parents and friends who helped me in every stage of life.

ABSTRACT

Wayfinding involves navigation and destination finding using different environmental cues and dedicated wayfinding aids, (i.e., static or mobile aids). This activity is influenced by various factors like individual differences, spatial design, design of wayfinding aids, other environmental and visual factors. These factors can affect the wayfinding activity and provide hurdles in the intuitive navigation of people, especially in public institutions. Public institutions like hospitals, shopping malls, passenger terminals, and academic campuses attract thousands of visitors and workers from different locations. The public sector institutions located in the dense urban areas or city centres of metropolitan cities have been transformed into spatially complex environments. The high-rise buildings with the scarcity of space make these environments challenging to navigate and find the required destination. Owing to this, these public institutions need to face navigation difficulties for the public daily, which leads to disorientation and cause severe time losses. The legibility of public institutional environments requires less spatial complexity or efficient wayfinding systems to mitigate the public navigation problems.

A wayfinding system consists of different dedicated wayfinding aids informing users about the routes, facilities, destinations, and overall spatial familiarity. The wayfinding aids help users find their required destination with minimal effort to make the institutional environment more efficient. Traditional wayfinding aids consist of directional signs, identification signs, building landmarks, pathways, intersections, artistic landmarks, etc. With the advent of technological advancements, multiple mobile wayfinding aids have been introduced. These mobile wayfinding aids use GPS or different beacon-based technologies to provide context-aware information to the navigator. The context-aware information helps reorient the lost person towards the required destination. Due to the technical limitations in GPS and beacon-based technologies, the complex spatial environments

are still considered to be hard to transform into an efficient institutional environment. Various research studies have been performed in quantifying the factors of disorientation and tried to provide the requisite wayfinding solution. However, both static and mobile wayfinding aids and solutions were insufficient to eradicate the wayfinding issues significantly.

This study investigated the potential wayfinding issues in complex environments of public sector institutions that are largely ignored. An intensive literature review has been identified involving several research questions. The literature review has been performed to identify the factors that make an environment complex to navigate. Existing wayfinding metrics and human-related differences have been explored from the previous work. This review has delineated several issues in the wayfinding aids for complex environments, including individual differences of preferences and behaviour in obtaining environmental information. Based on this, a mixed-method research study has been planned to explore the current wayfinding issues in complex environments and current user practices of wayfinding in such environments. The studies have identified the cultural and individual differences in obtaining the wayfinding information from static information sources like signages and maps. In addition to that, this research identifies potential limitations of mobile wayfinding aids as well for estimating the navigator's exact location and orientation. Both wayfinding aids have not been efficient enough to reduce the wayfinding issues.

This study also suggested synthesising the information sources on the individual level and improving the system design of wayfinding information sources. Current user practices recommended a significant need for providing context-aware information. The context-aware information may include current location, orientation, visible directions at decision points and environmental validation after arriving at the destination. The study also investigated the current user practices of information symbiosis and investigated users' performance, behaviour and preferences while performing various wayfinding tasks. The acquired data has been analysed and transformed into theoretical design guidelines for improving the current wayfinding issues in public sector institutions. The design guidelines have been constructed to guide the navigators to synthesise static and mobile information for individual practices. Moreover, the guidelines will provide a complete insight for the environmental and information designers to incorporate the syntheses of various environmental information sources. The improvements for the wayfinding system design have also been suggested for the complex public institutional environment.

Keywords: Complex environments, institutional facilities, wayfinding information design, wayfinding syntheses, static & mobile wayfinding information.

PUBLICATIONS

Journal Papers

1. Iftikhar, H., Asghar, S., & Luximon, Y. (2020). A Cross-Cultural Investigation of Design and Visual Preference of Signage Information from Hong Kong and Pakistan, The Journal of Navigation, 0:0 1–19, DOI:10.1017/S0373463320000521
2. Iftikhar, H., Asghar, S., & Luximon, Y. (2020). The efficacy of campus wayfinding signage: a comparative study from Hong Kong and Pakistan. Facilities. DOI:10.1108/F-04-2020-0035
3. Iftikhar, H., Shah, P., & Luximon, Y. (2020) Human wayfinding behaviour and metrics in complex environments: a systematic literature review, Architectural Science Review, DOI:10.1080/00038628.2020.1777386
4. Iftikhar, H. & Luximon, Y. (2022) The syntheses of static and mobile wayfinding information: An empirical study of wayfinding preferences and behaviour in complex environments- (Facilities), DOI: 10.1108/F-06-2021-0052
5. Multiple layer digital wayfinding information: A study of user preferences for information content and design in wayfinding applications- *(International Journal of Human-Computer Studies) (Under Revision).*
6. Wayfinding information syntheses: a study of wayfinding efficiency and behaviour in complex environment- *(HERD: Health Environments Research & Design Journal) (Under Revision)*

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CHAPTER 1: INTRODUCTION

1.1 CHAPTER HIGHLIGHTS

This chapter consists of the research background and its fundamental objectives and significance. The chapter also explains the research methodology of the project and the potential research questions for the initiation of said research.

1.2 RESEARCH BACKGROUND

It has been a complex task to search for a shorter and more efficient route towards the required building or a destination in a complex spatial setting. This task requires a complete understanding of the spatial settings and some navigational aids to direct a navigator in the right direction. This requisite task of finding a destination is known as wayfinding. It can also be described as a general navigation task from one point to another (Golledge, 1999; Ruddle and Lessels, 2006). 'Kevin Lynch introduced wayfinding' as a term in his well-renowned book *The Image of the City,* and since then, it has been a topic of great interest for city planners and designers (Lynch, 1960). As per Lynch's definition, it is an activity that uses the sensory information from the environment and processes it afterwards. Since then, quite many researchers have investigated the said topic in detail, exploring different dimensions.

Wayfinding tasks also require a significant number of cognitive efforts to process the environmental information and develop the required strategies for route finding (Brugger, 1999; Foster and Afzalnia, 2005). Therefore, the environmental wayfinding information should be efficient and easy in understanding and deploy the plan in a real environment. The real environmental settings will be hard to navigate for the navigators if this is complexly designed and challenging to recall while navigating (Iftikhar, Shah and Luximon, 2020). Such environments are complex for wayfinding and general navigation. In such environments, the navigational and spatial information is unclear and misleading for the navigators (Stankiewicz and Kalia, 2007). Most of the public institutions and places situated in the centre of the city can be described as complex environments, including both indoors and outdoors. Such environments like university campuses, hospitals, malls, or other complex spatial settings are hard to navigate effectively. Owing to this, many navigators encountered spatial disorientation which can further leads to frustration and mental stress (Haake, Smith and Pick-Jr., 1984; Chang, 2013). Wayfinding in such environments has gained the interest of multiple researchers to investigate the parameters and metrics further to overcome the spatial complexity. Multiple studies (Garling, Book and Lindenberg, 1986; Emo *et al.*, 2014; Meneghetti *et al.*, 2017; Afrooz, White and Parolin, 2018) have investigated these complex environments by taking the examples of city centre university campuses. They have identified several issues for spatial disorientation, especially for the newcomers or visitors.

The spatial complexity in public sector institutions has been enhanced due to the unplanned and post-occupancy extensions of building structures. Due to high-rise building structures with shortened axial lines, the whole environment looks quite complex visually. Concurrently less attention has been given to the design and planning of wayfinding systems; this further leads to morphing such spatial settings, which is hard to memorise in the first stage and hard to recall. Wayfinding research has been there for a long time; however, this research focused on city-wide or pedestrian wayfinding. For city wayfinding or pedestrian wayfinding, certain elements have been proven effective in assisting wayfinding, i.e., well-identified roads, crossings, identified walkable areas and directional signs. Whereas in public institutions' complex environments of public institutions there is a lack of well-identified walkable areas, fused nature of facilities, cross-cultural and individual differences in understanding the wayfinding aids, visual cluster, and crowd influence (Delnevo *et al.*, 2018), this perfectly develops a fused and complex environment that has low environmental legibility.

There are specific parameters to understand the complex environments and make them efficient for the public to ensure organizational efficiency. The spatial ability and wayfinding performance are dependent on several parameters, including environmental features and the wayfinding information (Miller and Lewis, 1999). One of these parameters is the wayfinding guiding system to inform the navigators about their wayfinding tasks. The wayfinding guiding systems include the wayfinding aids like maps, signage, pathways, intersections, and digital devices. Studies (MacEachren, 1992; Wiener, Büchner and Hölscher, 2009) have identified that if the navigators navigate a complex environment or an unfamiliar environment, they obtain the environmental information through purposely designed wayfinding aids. Multiple studies (Carpman and Grant, 1993; Fewings, 2001; Holscher *et al.*, 2007; Rodrigues, Coelho and Tavares, 2018) have investigated the impacts of different wayfinding aids and proved that it could make the complex environment spatially legible for navigators, hence can be very effective for aiding the wayfinding tasks. The design of a wayfinding system consists of two major divisions, (i.e. Static wayfinding information systems and mobile wayfinding information systems) (Jeffrey, 2017). The static system of wayfinding information includes signage, printed maps, and environmental information leaflets. In comparison, the digital wayfinding information system includes digital displays (Sykes, Pentland and Nardi, 2015) interactive booths/kiosks, smart devices and application-based wayfinding.

The static and digital wayfinding systems should work hand in hand to address the wayfinding issues in contemporary institutional environments. The static information system can describe the physical environmental features effectively in real-world settings. Effective and efficient wayfinding systems combine the features of the environment and navigation information design (Rodrigues, Coelho and Tavares, 2018). The mobile digital information systems can accommodate a greater volume of wayfinding information. The wayfinding systems consisting of static and mobile information need to be synthesized to mitigate contemporary wayfinding issues (Jeffrey, 2017). The complex university environments require a robust design for the effective delivery of environmental information due to the inefficacy of the current wayfinding system (Iftikhar, Asghar and Luximon, 2020b). Therefore, it is necessary to investigate the user behaviour for static and mobile wayfinding aids for mitigating the navigation issues in public sector complex environments.

1.3 AIMS & OBJECTIVES

The objectives of this research are as under as follows:

- Literature review related to human wayfinding behaviour
- Identify the effective wayfinding aids in complex environments
- Investigate the individual differences in wayfinding behaviour
- Investigate the visual understanding of static wayfinding information
- Investigate the role of digital wayfinding information in complex environments
- Investigate the most appropriate strategies for designing the wayfinding information content

- Develop guidelines necessary for efficient syntheses of the static and digital wayfinding information

1.4 RESEARCH SIGNIFICANCE

In the public institutional environment, wayfinding has been considered an essential parameter due to its importance in saving professional time losses, stress, and frustration. The public institutions situated in the middle of populated urban areas have been developed into a complex environment due to various factors. These factors include post-occupancy construction, scarcity of space, fused facilities, and extension of buildings. This environment building is necessary due to the professional requirements of the selected institutions; however, the existing infrastructure structure has not been disturbed. Owing to this condition, the environment becomes homogenous, visually cluttered, and less legible for general navigation. Most of these public institutions require general visitors to navigate the environment, which reduces the environmental efficiency due to the disorientation of the navigators. Public university campuses, hospitals, malls and travelling terminals are the most common examples

Table 1.1 Environmental features of complex university settings

of such environments.

Sr.	Features
1.	Campuses have a large cluster of buildings, unlike hospitals
2.	Complex spatial planning due to fused intersections & pathways
3.	Fused facilities for students, visitors & staff
4.	Many Cross-cultural students and visitors every semester
5.	New and unfamiliar environment for newcomers
6.	Varied information signage understanding due to individual differences
7.	Visual absence of spatial information due to visual clutter
8.	Limited visual access
9.	Spatial anxiety and stress
10.	Crowd influence

This research has considered the complex university environmental settings for developing a theoretical framework for the efficient wayfinding information system. The public sector campuses located in the heart of metropolitan cities have been transmuted into complex environments because of repeated structural extensions within a limited space. A cluster of high-rise buildings has been constructed to answer this issue while producing a minor disturbance to the official operations. These university campuses are also less legible due to their fused nature of facilities, irregular structures, fused intersections, fused pathways, visual complexity, and limited visual access, as depicted in Table 1.1. To overcome the mentioned issues of human navigation, several aids have been designed to aid the navigator in wayfinding. These aids include maps, signage, landmarks. However, several studies as mentioned in the literature review have mentioned cultural and individual-related issues like gender, age, spatial capability. They are affecting the information gathering from these wayfinding aids. With the advent of technological advancements, many digital and interactive mobile wayfinding information has been designed to inform the navigator about the location, direction, and routes.

Figure 1.1 Differences of static & digital information content

The two systems, i.e., static and mobile wayfinding information systems, have been studied and found inefficient individually to provide the requisite environmental information, especially if the navigator is new to the environment. The said information systems often used static and digital information content to facilitate the navigators. Both information contents have potential benefits and shortcomings in terms of displaying the information, user understanding and operational resources. A brief comparison has been drawn in Figure 1.1 from the literature review performed in the thesis. This research has focused on investigating the necessary information required by the navigators while performing the different wayfinding

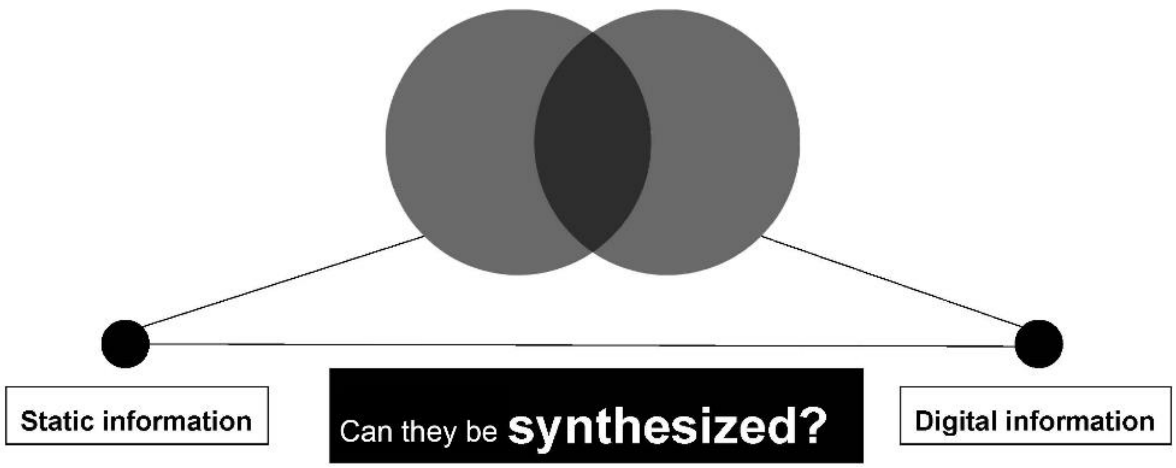


Figure 1.2 Information syntheses

tasks.

Different cultural and individual factors have also been investigated to study human wayfinding behaviour and wayfinding preferences. This study also investigated the navigators' information obtaining behaviour from the static and mobile wayfinding aiding systems. This study aimed to develop a theoretical framework for wayfinding information designers to design efficient wayfinding systems for complex institutional environments. This framework will help the designers reduce public disorientation events and enhance environmental efficiency by saving the navigator's professional time and cognitive efforts. Many public institutions like hospitals or university campuses situated in dense urban areas have limited space.

To accommodate the requisite facilities, the institutions are required to build multi-storey structures with multi-level access to the facilities. These complex-built environments are challenging to navigate for new and unfamiliar visitors due to insufficient information retrieval from wayfinding aids. During indoor wayfinding, digital wayfinding information through mobile devices with built-in GPS trackers has signal issues and requires heavy resources in alternative options. This research has investigated the factors instrumental in delivering adequate wayfinding information through a static and digital medium. Also, this research tried to identify the necessary parameters for the potential synthesizing of digital and static wayfinding information.

1.5 RESEARCH PLAN

For performing the research on the said topic, a comprehensive research plan has been developed with the identified key stages. The key stages have consisted of the three phases as identified in Figure 1.3 i.e. Phase 1: Barriers identification, Phase 2: Barriers Assessment and Phase 3: Framework Development. Phase 1 deals with the literature related to analysing and mitigating the wayfinding problems in complex environments like public educational institutions located in city centres. The second phase has been proposed related to the user wayfinding behaviour along with the influence of environmental information and individual differences. The final phase has been related to the framework development for user behaviour and their information requirement while performing the wayfinding tasks.

The overall study plan has been incorporated in Figure 1.3, along with the details of each study in the mentioned schematic diagram. The said research has been planned as mixed-method exploratory research to investigate the potential parameters for improving the current wayfinding systems, especially in complex environments. The start of the research has been constituted an intense and detailed literature review. The literature review has been performed for the types of wayfinding information systems, the requisite metrics, and technological advancements in aiding the wayfinding tasks. A detailed literature review has been performed and concerned research material published from 1990 to 2019 has been included to formulise the further exploratory investigations.

1.5.1 RESEARCH QUESTIONS

The study is informed by the following research questions:

Research Question 1: How do <u>cultural and individual differences</u> affect the acquiring of wayfinding information?

Research Question 1.1: What are the problems in obtaining the wayfinding information?

Research Question 1.2: What is the user's behaviour for the search of wayfinding information?

Research Question 1.3: What is the user's perception about the accuracy of obtained wayfinding information?

Research Question 2: What is the user's preference regarding static wayfinding information?

Research Question 3: What is the user's preference regarding the style and volume of information?

Research Question 4: How do users' access and perceive the digital app-based wayfinding information for complex environments?

Research Question 5: What are the parameters necessary for efficiently synthesizing the static and digital wayfinding information?

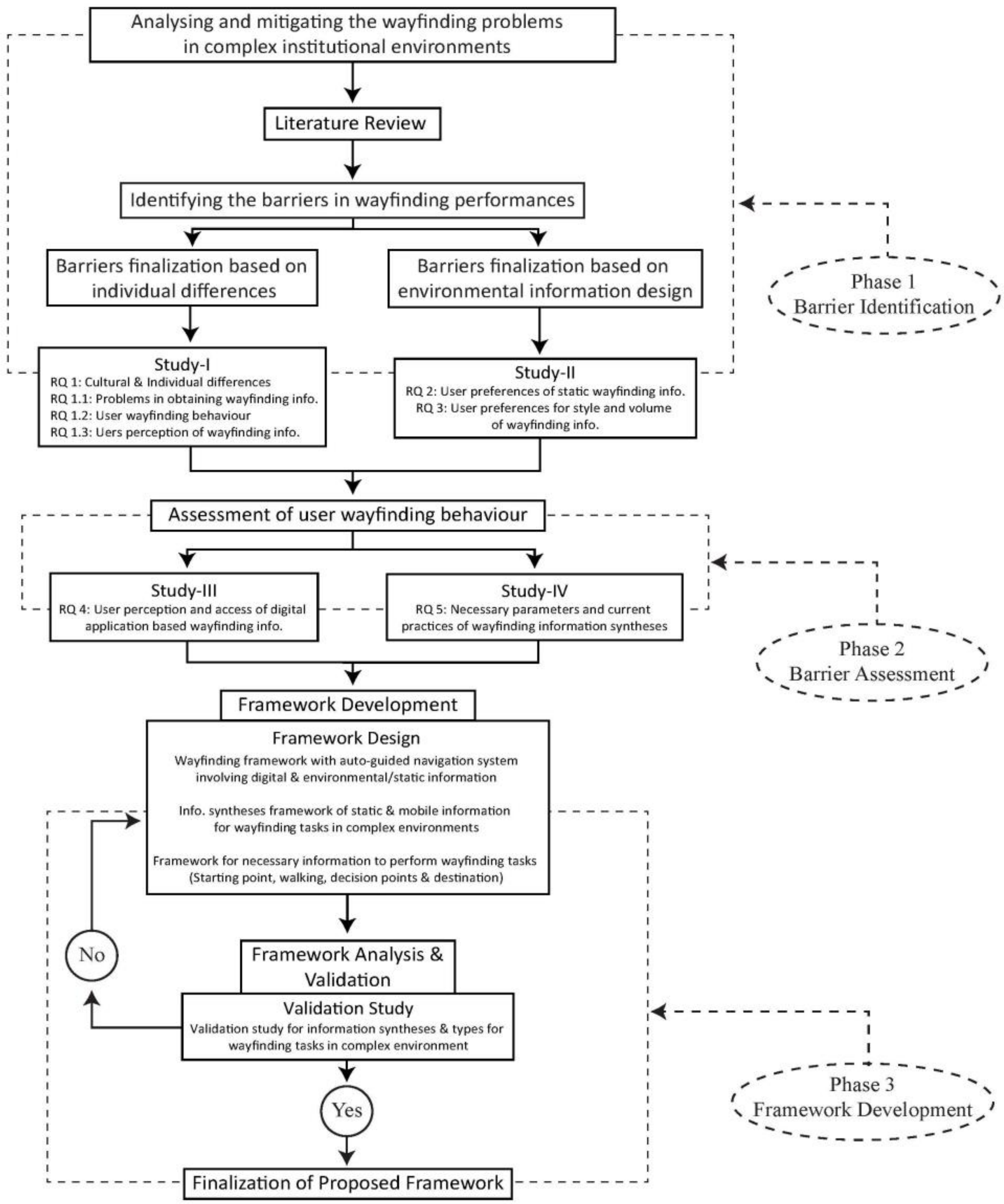


Figure 1.3 Research Plan

Study 1 was designed while performing the online survey through a structured questionnaire to investigate the fundamental wayfinding problems and peculiar wayfinding behaviour while navigating the complex institutional environment. As a case study, a complex university setting has been selected to investigate navigators' problems and behavioural differences. The questions have been asked in a structured manner from the participants of two different cultural groups, i.e., Pakistan and Hong Kong. The study investigated common problems and behavioural differences while performing wayfinding tasks in complex environmental settings. Owing to this finding, further study has been planned to investigate the user preferences regarding the wayfinding information.

Study 2 has been designed to investigate the information system preferences by the navigators. The information systems have been developed based on several parameters including the information medium, design, type, and volume necessary to deliver the relevant information to the navigators. In the said study, twelve wayfinding information options have been designed to be presented to the navigators, investigating their preferences. Participants from both cultures, i.e., Individualists and collectivists have participated in the said investigation representing HK and PAK. The results have presented the cultural and individual differences in the design preferences for the wayfinding information. Both studies have enunciated the individual related differences in understanding and acquiring the wayfinding information. Based on the current findings, a need to redesign the wayfinding information system has been raised for complex institutional settings.

Study 3 has been delineated to investigate the users' interaction with the mobile information sources and their navigation pattern for finding and acquiring the information. Specific parameters and preferences have been identified by using qualitative research methods. The user information preferences for digital wayfinding applications have been investigated. This study elaborated the pattern of users' digital information retrieval from a digital mobile device like smartphones. Study 4 has been designed to investigate the current practices of acquiring the wayfinding information from environmental information sources and specially designed wayfinding aids, including but not limited to signage and purposely designed mobile devices. The objective of this study was to investigate the wayfinding practices and behaviour currently practised by the navigators using the above-mentioned information sources. A synthesis of information has been observed by the navigators using static and mobile information sources. However, no consideration has been found for both systems to be integrated into a cohesive and singular information source to guide the navigators.

After having thoughtful insights from all the studies, a comprehensive framework has been presented for the information syntheses of static and digital wayfinding information systems to be considered in complex institutional settings. The presented framework is expected to be equally significant in all the complex institutional settings having less space while offering several facilities. After acquiring the syntheses practices, a study has been performed while taking some of the recommended design suggestions to validate the findings of the presented information design framework. This information design framework for synthesizing the static and mobile information systems will help designers understand the user information requirements, preferences, and behavioural patterns to access and understand the wayfinding information from purposely designed environmental information sources. This framework will also help the information and environmental designers to design the respective environmental aids in a more holistic approach to provide the users updated and accurate context-aware information.

After proposing the framework for synthesising the wayfinding information in complex environments, a validation study has been conducted to validate the wayfinding information requirements and their efficacy. This validation study has been conducted using a virtual reality experiment by presenting the environmental settings in 360-degree pornographic. The participants were invited for an experiment, and they were directed to perform wayfinding tasks in an experimental setting using mentioned variables to test the efficiency of the proposed wayfinding framework. The proposed framework has different wayfinding information requirements and amounts to aid the wayfinding process and enhance users' efficiency in a complex and illegible environment. In addition to that, project limitations and future works have also been delineated in further chapters to describe the significance and the potential of the said research work.

CHAPTER 2: LITERATURE REVIEW

A research article has been published from this chapter, *Iftikhar, H., Shah, P., & Luximon, Y. (2020) Human wayfinding behaviour and metrics in complex environments: a systematic literature review, Architectural Science Review, DOI:10.1080/00038628.2020.1777386*

2.1 CHAPTER HIGHLIGHTS

This chapter presents an extensive literature review on wayfinding information, human navigation behaviour, environmental quality, and legibility. The literature review also outlines the individual related differences in acquiring, understanding, and preferring the wayfinding information from external sources.

2.2 WAYFINDING INTRODUCTION

Wayfinding plays an integral part in daily life, from commuting within the city to walking to the desired destinations every day. It has been a matter of great difficulty while roaming in the large developments (Scurlock and Wise, 1985) as the buildings and spatial context become more complicated. The primary purpose of this activity has been defined as to find the optimized route for reaching the destination by taking the aid from environmental indicators and estimating the factors of distance and survey knowledge (Siegel and White, 1975; Cheung, 2006). The acquired survey knowledge using the cartographic or environmental aids may strongly depend on the user's familiarity with a particular environment (Holscher *et al.*, 2006). In addition to the environmental familiarity, wayfinding tasks may also have some potential influencing factors depending upon the types of wayfinding segregations. A study (Allen, 1999) has described the three significant segregations of wayfinding involving exploratory navigation, travelling to a known location and travelling to an unknown location.

Moreover, the study has also described various wayfinding tasks, including roaming between landmarks, path integration. Few wayfinding tasks are well defined and researched, e.g., path integration (Loomis *et al.*, 1993), while some are a bit imprecise, like cognitive mapping and schematic tasks (Kitchin, 1994). Cognitive mapping and path searching strategies have been influential in affecting wayfinding abilities. It has been suggested to examine one's decision making and problem-solving abilities for wayfinding problems to evaluate the wayfinding performance for real-time applications (Trulove, Sprague and Colony, 2000; Rodrigues, Coelho and Tavares, 2018). Wayfinding performance and behaviour have contained several influential factors based on the human interaction with the surrounding environment. Several significant elements taken from the existing literature have been further discussed.

2.2.1 COMPLEX ENVIRONMENTS

The terminology of complex environments has been considered quite relevant to those spatial environments in which spaces are not well defined for navigation. Complex environments are reflected as those environments where navigational, spatial or geometric cues are unclear and confusing (Stankiewicz and Kalia, 2007). Most indoor and outdoor systems of spatial surroundings can be referred to as this kind of setup, including public spaces, city centres, health care settings and educational institutions. Wayfinding in these complex environmental settings can lead people to disorientation which has further linked to stress and frustration(Chang, 2013). Spatial design features have been of critical importance in the legibility of complex environments, and they have also proven to be crucial in the user's wellbeing (Arthur and Passini, 1992).

Wayfinding research at university campuses or hospitals has gained the interest of several researchers due to its complex nature and excessive roaming within environmental settings. Several studies (Emo *et al.*, 2014; Meneghetti *et al.*, 2017; Afrooz, White and Parolin, 2018) have used university settings as the experimental environment for the research on wayfinding performance and behaviours. University settings have several new students and visitors each year, having a negligible level of environmental familiarity. The spatial aids are not helpful enough to demonstrate the peculiar naming and locations of different facilities; this leads to the disorientation of visitors and students and caused professional time losses, stress, frustration, and the disturbance of scheduled timing. The wayfinding research based on complex city settings cannot be directly applied to the complex institutional settings, although they both share the same socio-economic and environmental structure (Torres-Sospedra *et al.*, 2015).

City setups have the structure of roads, walking paths, clear landmarks, and different cues to guide the user, whereas, in the complex institutional setup, almost the entire outdoor is walkable and accessible, causing confusion for directed wayfinding and exploration. Concerning the complex institutional settings situated in the centre of the densely populated urban areas, several factors may enhance the complexity of its environment. Absence of discrete boundaries (Cheung, 2006), complex layout planning (Hidayetoglu, Yildirim and Cagatay, 2010), lack of efficient environmental cues (Dogu and Erkip, 2000), diffused walkable paths, shared social spaces, heavy concentration/traffic of people, visual richness, complexity in gaining familiarity and lack of functional space hierarchies can be considered as the influential factors reducing the legibility of institutional environment.

2.2.2 WAYFINDING METRICS

The effectiveness of wayfinding design solutions along with the wayfinding performance can be evaluated with the help of wayfinding metrics. A three-level metric for wayfinding evaluation in virtual environments has been developed (Ruddle and Lessels, 2006). The first level has been defined as task performance measured based on time, distance, and the count of errors. The other level has been described as evaluating human behaviour based on time classification, error classification, the path followed and observations. The third level has been styled as a rationale, involving a questionnaire, think-aloud protocol and interviews. Various studies have been performed to evaluate the human wayfinding performance based on task performing criteria. These studies have been studied by measuring the time taken for task completion (Zhai *et al.*, 1999; Bowman, Johnson and Hodges, 2001), travel distance in reaching the destination, and the count of errors made while performing the wayfinding tasks (Ruddle and Jones, 2001).

Furthermore, the wayfinding behaviour has also been studied based on the time and error classification (Bowman, Johnson and Hodges, 2001) and by observing and path following metrics to evaluate the behaviour qualitatively (Darken and Sibert, 1996). According to the mentioned vital metrics, wayfinding behaviour has been further studied to justify individual actions. These justifications for selective behaviour have also been studied through post-experiment questionnaires and think-aloud protocols (Murray *et al.*, 2000).

2.2.3 SPACE SYNTAX

In the interior spaces, wayfinding metrics and tasks could vary depending upon the building's interior spatial structures and visibility range of potential ways to roam around. The combination of methodologies used for wayfinding evaluation of interior spaces has been reflected as space syntax (Hoeven and Nes, 2014). This methodology has been observed to improve the overall usability of a building and to simplify the wayfinding tasks. Space syntax is the set of methodologies and theories used to quantify and interpret a building's spatial features (Hillier, Hanson and Graham, 1987). This concept has been comprised of three critical methodologies consisting of convex spaces, isovist fields and axial lines (Hoeven and Nes, 2014). The first methodology (convex space) has been defined as all those points joined to all other points within a space without crossing the space boundary (Hillier, 1988), while isovist is the user's personal view in a spatial environment with a specific perspective (Benedikt, 1979).

Moreover, axial lines have been defined as the longest possible sightline within building structures or interior spaces (Hoeven and Nes, 2014). By applying these concepts, the assessment of interior spatial structures can be formulated for increasing environmental legibility. Spatial structures can further have a substantial role in the evaluation of human wayfinding behaviour and cognitive strategies. Although the metrics for wayfinding may seem to be excluded from the described methodologies of space syntax (Ratti, 2004), the concept of axial lines have a vital insight into the metrics of wayfinding (Turner, 2007; Jiang and Liu, 2009). A study (Holscher, Brosamle and Vrachliotis, 2006) has been conducted using space syntax to show the influence of environmental familiarity on navigators' cognitive strategies in a complex building structure. However, another study (Davies and Peebles, 2010) has discussed the possible barriers in opting for the space syntax for orientation performance in three-dimensional spatial layout because it relies on two-dimensional schematics. Also, the space syntax methodologies cannot evaluate the impacts of spatial forms, decision point actions and effectiveness of signage in real-time wayfinding behaviours (Tzeng and Huang, 2009).

2.2.4 ENVIRONMENTAL FAMILIARITY

The familiarity of the wayfinding environment has been considered quite significant in the wayfinding tasks, performance and navigator's behaviours in both real and virtual environmental settings. Finding the way in a known setting can be reflected as searching for a new location in an already known environment (Wiener, Büchner and Hölscher, 2009). Human actions and behaviours can be very different in known surroundings than when the environment is not familiar enough. A study (Garling, Book and Lindenberg, 1986) has suggested identical findings by repeating the wayfinding experiment with different levels of environmental familiarity. Users may differ in approaches in an unfamiliar environment while instigating the information gathering, interpretation, destinations, choice of routes, cognitive strategies and environmental cues (Newell, 1980; MacEachren, 1991). The environmental familiarity allowed the users to deduce the gathered information in a relaxed and flexible way with different views (Sholl, Kenny and DellaPorta, 2006; Iachini, Ruggiero and Ruotolo, 2009; Marchette *et al.*, 2011), and with the confidence of not getting lost.

Similar interpretations have been derived from multiple studies (Evans *et al.*, 1980; Garling, 1989) that people who already know the environmental settings rely greatly on memory for information retrieval, cognition and previous mental mapping of the environment rather than on the provided spatial information. Memory nodes and information retrieval from long-term memory have been influential in wayfinding planning and defining route strategies. Also, these actions of spatial planning can further be optimized with the repeated exposure of the environment (Garling *et al.*, 1981). Familiarity influences the real-time wayfinding environment, but it also significantly influences environmental cues like signage. A study (Tang, Wu and Lin, 2009) on signage has suggested that people have a different response in virtual wayfinding experiments in which a difference of signage facility was present. They showed better performance in the presence of familiar signages and deciphered the interpretation of signages comfortably. Also, few studies (Leonard, Verster and Coetzee, 2014; Rodrigues, Coelho and Tavares, 2018) has suggested that standardizations and consistency of spatial cues can play a significant role in enhancing spatial comprehension.

2.3 VISUAL-SPATIAL FACTORS

Several spatial factors affecting wayfinding performance and behaviour, spatial lights and colours, have been considered among the mentioned factors. In evaluating wayfinding performance and behaviour, lights and colours being part of the surrounding environment can considerably affect the participants' cognitive decision and strategy building. In outdoor environments, the effects of daylight and night alter the psychological presence of spatial factors like landmarks, signages, path intersections and axial lines. Therefore, it affects the behaviour and cognitive strategies during the navigational experiments in the indoors and outdoors complex environmental settings (Rousek and Hallbeck, 2011; Basri and Sulaiman, 2013). The human cognitive approach and psychological behaviour may have been varied with the surrounding lights, spatial colours, and usage in environmental cues. The impacts of lights and colours have been previously explored using multiple experimental setups with diverse influences, including participants' psychological state, customers' shopping behaviour and consumer attractiveness of the spatial settings (Stone, 2003; Yildirim and Akalin-Baskaya, 2007). Lights and colours, along with the variation of intensity and temperature, also tend to direct the participants in a particular direction during the spatial navigation; in addition to that, a change in mood can also be achieved by using the appropriate aggregate of all of the factors in combination or separately (Manav and Küçükdogu, 2006; Hidayetoglu, Yildirim and Akalin, 2012).

2.3.1 VISUAL CLUTTER

The visual aspects of the wayfinding information play an essential role in delivering spatial information to the navigators. Visual clutter may be defined as the visual obstruction in noticing the wayfinding information. It can be a direct obstruction like viewing angles or points of placements. In addition to that, it can be due to the visual overload in the environment due to landmarks, buildings and advertised information. Multiple studies (Ozel, 2001; Akizuki *et al.*, 2010) have investigated and mentioned factors affecting the visibility of wayfinding information and suggested that environmental visual clutter strongly affects the wayfinding information visibility for the users. It is also recommended by requisite authorities ('Department of Health', 2005) to avoid the placement of wayfinding information in a visually cluttered environment; this decreases the users' attention and affects the users' understanding of the information.

2.4 ENVIRONMENTAL SETTINGS

Wayfinding research has been conducted in different scenarios and has been applied in varied environmental settings to assess the efficiency of a suggested method. The perception of intuitive human responses concerning wayfinding behaviour has influenced designing the interior and exterior surroundings. Healthcare settings have been considered most appropriate for studies as these spaces are complex, and there is a time constraint to prevent unaffordable time loss. The standardization of spatial cues has helped people impeccably find their way in an unfamiliar environment (Gakopoulos, 2009; Rousek and Hallbeck, 2011; Lee *et al.*, 2014).

Correspondingly, studies (Olmstead, 1999; Foster and Afzalnia, 2005) have tried to standardize the spatial cues, specifically symbols and pictograms, to improve the user experience inside the spatial envelope. This area of standardization has been an important parameter in understanding individual behaviour varied because of users' individual and cultural differences (Carrillo *et al.*, 2014; Romera, 2015). However, by providing training, the meaning can be learned and taught (Cowgill, Bolek and Design, 2003). Moreover, adequate studies (White, 2010; Barclay and Scott, 2012; Serfass, 2012; Polger and Stempler, 2014) has explored the spatial behaviour inside libraries in conjunction with other spatial settings. Prior studies in this area were majorly comprised of studies conducted in public indoor environments due to its potential limitations in terms of human visibility range (axial lines) and spatial cues (landmarks, path specification and interconnection density).

2.5 INDIVIDUAL RELATED DIFFERENCES

2.5.1 CULTURAL DIFFERENCES

Culture is an inherently diverse and essential element in defining the human wayfinding behaviour because of the differed understanding and demonstration of spatial cues (signages and pictograms) across different cultures (Tijus *et al.*, 2007; Karimi, 2015). Several researchers have always been ambitious to investigate the cross-cultural impacts and influences in various fields of psychology, design and healthcare (Asghar, Torrens and Harland, 2018). Culture and human cognition were relative and essential issues in the field of cross-cultural psychology (Berry and Dasen, 1974), and therefore, many definitions have been coined for its description. A study (Cole *et al.*, 1971) described that cultural differences and human cognition are paired behaviour for different situations and environmental setups. Cultural differences can also affect the cognitive behaviour for the abstraction and understanding of the provided meaning (Asghar, Torrens and Harland, 2019); this infers that the potential possibilities of cognitive strategies for responding to the same situation may be defined as a cultural difference.

Cognitive strategies can define an individual's manner of perception, memory, and information delivery regarding a particular set of situations (Dornëy, 2005). This finding has been considered valid for multiple studies with little change by describing cognitive behaviour as the preferred way of reacting to the inherited one (Dasen, 2018). These cognitive strategies influence the decision-making skills of an individual in various aspects. During wayfinding tasks, there are multiple decision points for providing directions to the destination. The whole behaviour of wayfinding can be different based on the difference in decision-making strategies. Moreover, the varied interpretation and meaning of spatial cues due to cultural and individual differences may have a substantial impact on the cognitive strategies (Foster and Afzalnia, 2005). The significant influence of cultural background has already been proven on the interpretative strategies, meaning conception, cognitive decisions, and comprehension of spatial cues.

2.5.2 GENDER DIFFERENCES

Gender-related differences in human wayfinding behaviour, performance and information preferences have been investigated in the wayfinding literature for several environmental and mental conditions. For several environmental conditions, gender differences have been found in wayfinding performance and ascribed behaviour. A study (Lawton and Kallai, 2002) investigated gender-related differences in developing and implementing the wayfinding strategies and found that men preferred the global reference points whereas women preferred strategy-based information. For location identification, men outperformed women in several studies (Lawton, Charleston and Zieles, 1996; Lawton and Morrin, 1999) where the direction of unseen landmarks needed to be identified. The gender-related differences in orientation strategy and preferences while performing the wayfinding tasks have also been instrumental in multiple studies (Munroe and Munroe, 1997; Waller, Hunt and Knapp, 1998; Edwards, 2000) across different cultures. However, a study (Sandstrom, Kaufman and Huettel, 1998) found no gender differences in wayfinding performance. This type of individual difference in wayfinding behaviour is quite challenging to understand due to multiple confounding factors, including but not limited to the environmental conditions, personal skill level, spatial ability, and self-efficiency in problem-solving.

2.5.3 SPATIAL ABILITIES

Individual related differences also include one’s ability to freely understand the spatial layout and understand the environmental information to search the desired destination. Spatial abilities may involve visuospatial abilities, understanding the wayfinding information, building better wayfinding strategies, route planning and location identification. Visuospatial ability can be defined as building up spatial information while understanding and processing the wayfinding information (Linn and Petersen, 1986; Yang, Conners and Merrill, 2014). Spatial abilities also involve understanding the wayfinding information through signage, landmarks, pathways, or any preferred information source. It also involves the cognitive ability to use and understand environmental information sources (Simon *et al.*, 1992). Spatial ability has been different in different individuals based on their gender, education, past experiences, spatial familiarity, and cognitive ability. Multiple studies (Lawton and Kallai, 2002; Chang, 2013; Vandenberg *et al.*, 2016) have investigated the wayfinding performance and behaviour in different spatial settings and found it influential in describing the behaviour and efficiency wayfinding tasks.

2.5.4 OTHER FACTORS

Individual related differences also include age as an influential factor for wayfinding studies. Human cognitive abilities are going to change and improved with age (Devlin, 2014). Owing to this, the wayfinding and spatial abilities can be higher with the increased age (Davis, Therrien and West, 2009; Taillade *et al.*, 2013). However, the age gaps which are influential in wayfinding studies are debatable. Multiple studies have been performed to explore the age-related influences in wayfinding performance and behaviour; however, fewer studies have been focused on investigating the adequate age gaps. Age gaps from 2-5 years can be influential in studies where the study sample consists of young adults. Whereas, in older adults, the age gap can be increased to 10-15 years to be compelling enough.

In addition to that, the level of education and profession can also influence the wayfinding behaviour and performance. A study (Dogu and Erkip, 2000) has stated that education and profession are among the factors. Multiple studies (Peters, Chisholm and Laeng, 1995; His, Linn and Bell, 1997; Sorby and Baartmans, 2000) have suggested that the visual and spatial skills can be higher in the participants from an engineering background as well as all technical professions, this could be due to the regular practice of problem-solving exercises which is an essential part of their profession.

2.6 WAYFINDING TECHNOLOGIES

Many confounding factors have accompanied wayfinding experiments in a real-time environment for evaluating behaviours. These factors may include diversion of visual and cognitive attention, path and route association, outdoor lights with reflections, crowd movements, people interactions, change of weather conditions. It is quite challenging to achieve complete control over the studying variables in a real-time wayfinding experiment. Previous studies (Morganti, Carassa and Geminiani, 2007; Vilar, Rebelo and Noriega, 2014) have suggested that virtual computer environments can be considered an effective alternative for real-time wayfinding experiments as the researcher can have the required control over all of these confounding factors. Virtual environments in computer simulations have been used in research for spatial navigation for the last two decades. Multiple studies have used virtual environments on a computer screen like desktop virtual reality (DVR) (Omer and Goldblatt, 2007) and Augmented reality (AR) systems (Hedley, 2008; Lonergan and Hedley, 2014).

2.6.1 VIRTUAL REALITY

With the advent of technology, the possibility of fully immersive virtual environments has been developed for further investigation in wayfinding. Head-mounted displays (HMD's) have been used to display the fully immersive virtual environment by allowing the user to have a 360-degree view of the experiment. A study (Niehorster, Li and Lappe, 2017) has used the equipment (HTC VIVE) in conjunction with the steam VR positioning system for wayfinding research. Multiple studies (Meng and Zhang, 2014; Young *et al.*, 2014) have been conducted in computer simulations with different variations of HMD's for the exploration and evaluation of indoor and outdoor wayfinding. For assessing the emergency scenarios, virtual environments can be used, as emergencies are quite complicated to conceive, control and perform in a real-time environment. Multiple mass egress models for indoor wayfinding research have been proposed under fire, earthquake, and other emergency scenarios. For experiments, these emergencies can only be produced in the virtual environment due to potential safety hazards. Virtual reality has been proved a reliable technological aid for spatial navigation research; however, it also has potential limitations, including virtual reality motion sickness and a dichotomous sense of presence in the simulated and real world.

2.6.2 AUGMENTED REALITY

Augmented reality is a mixture of virtual graphics and real environments. This fusion can be achieved by adding the virtual 3d models and graphical information by overlaying the real environmental setups. This combination can be visualised on mobile devices like cell phones and portable head-mounted glasses. Augmented reality can be quite valuable in eliminating wayfinding problems, specifically in complex environments. A study (Barfield and Caudell, 2001) has used the see-through display, which allows the projection of computer graphics onto the real world.

Similarly (Kim *et al.*, 2015) has tried to implement an augmented reality wayfinding system in complex environments. This technology has immense technical benefits in mitigating the wayfinding problems; however, it comes with a very high cost and technology expenditures. Augmented reality displays can contribute to assisting the individual wayfinding tasks, but for the crowd, the environmental information still needs to be delivered through static information medium, e.g., signage. As Mollerup agrees:

"It is a safe prediction that we will not dump the traditional wayshowing media including signage in a foreseeable future. Some designers will work on improved user interfaces of digital devices, and some (most) will work on environments that assist unplugged wayfinders directly." (Mollerup, 2014)

2.6.3 MOBILE DEVICES

With the use of an inbuilt GPS tracker, mobile gadgets such as smartphones, PDA's, digital assistants, tablets, smartwatches, and smart glasses can also deliver context-aware information based on the location. The GPS tracker is efficient to provide information during outdoor navigation by utilizing well-identified roads, sidewalks, and infrastructure. Research (Devlin, 2014) evaluated the influences of smart devices in outdoor wayfinding and discovered that they help in displaying accurate directions. However, due to the partial or entire lack of GPS signals, the scenario is slightly different for indoor navigation. Researchers (Willis, 2005; Song, 2006; Chumkamon, Tuvaphanthaphiphat and Keeratiwintakorn, 2008) have created unique beacon systems that use radio frequency identification (RFID) technique to direct smart devices during indoor navigation. The methodology was unique, but it was still highly personalized and resource-intensive compared to conventional navigational information systems. Mobile devices rely on several factors to provide effective wayfinding information. These factors include:

- A working mobile device with enough power level
- Require signals of GPS, RFID, WIFI or other wireless beacons

- Time consuming & personalised information
- Require digital literacy
- Demands constant device attention
- Demands high cognitive efforts in case of map-based information
- Demands high-cost infrastructure in case of augmented reality-based information
- Require efficient and accessible digital interfaces

Wayfinding metrics for spatial navigations may vary for the pedestrian navigators in complex environments due to the potential variations in spatial structures and clues. Several studies have been done based on different real-time environmental settings to explore human navigation behaviours. In real-time wayfinding experiments, many confounding factors can influence or alter the experimental findings. In the presence of influencing factors like crowd influence, spatial familiarity, route association, people interactions, and user's differences, likely, the outcomes from this research may not depict the actual behaviour.

2.7 WAYFINDING INFORMATION SYSTEMS

Several external information sources have been influential in delivering environmental information to the wayfinders. These sources are including the wayfinding signage (Chambers and Bowman, 2011), landmarks (Rechel, Buchan and McKee, 2009), maps (He, Ishikawa and Takemiya, 2014), kiosks (Delvin and Bernstein, 1997) and mobile wayfinding applications (Vandenberg *et al.*, 2016). The information sources provide a variety of information using static and digital resources. Static resources are sturdier and more permanent; however, the digital resources are easily upgradeable and can accommodate the large volume of wayfinding information (Jeffrey, 2017).

With the advent of technological advancements, the number of adults having affordable portable smart devices is gradually getting increased around the globe (Devlin, 2014). A new normal has been perceived that the smartphone is meant to be with the users, every time of the day. Due to such behaviour, most everyday tasks have shifted from the physical paradigm to the virtual one, especially wayfinding (Rodriguez-Sanchez *et al.*, 2014). Wayfinding applications on mobile devices are built on digital platforms to deliver the requisite information on the go efficiently and can enhance wayfinding performance (Ishikawa *et al.*, 2008; Vandenberg *et al.*, 2016). Most of the wayfinding applications have been developed on the

Android and IOS platforms to facilitate the target audience. These applications used GPS signals and other location-based services to locate the navigator's real-time position in a spatial environment (Kaasinen, 2003; Török *et al.*, 2018). The mobile devices having wayfinding applications can be considered a personal wayfinding assistant (Reilly *et al.*, 2009), and it has several advantages over the static and fixed environmental information sources such as signage and wayfinding kiosks.

Wayfinding tasks require detailed knowledge about the spatial environment and the offering facilities. If the environment serves the purpose of a public institution, then these tasks possess critical importance (Passini, 1996). Most public institutions have designed the spatial layouts to facilitate wayfinding; however, these layouts become complex by building new structures for the extension in facilities and require a post-occupancy evaluation [POE] (McGrath and Horton, 2011; Oyelola, 2014). These complex layouts need regularly updated wayfinding information sources to effectively counter the environmental complexity (Carlson *et al.*, 2010). The design of information sources is critical as it needs to acquire the users' attention and deliver the requisite message (Lawton and Kallai, 2002; Liu, 2015; Sadek, 2015).

2.7.1 STATIC WAYFINDING INFORMATION

Wayfinding information systems are facilitating the wayfinding needs through static mediums like signage, interactive kiosks and information maps. Static information systems like signage and printed maps are proved to be an excellent aid for navigators for wayfinding in the built environment (He, Ishikawa and Takemiya, 2014). However, certain aspects need to be considered before designing the information and deciding the location of placements. Signage and other environmental information, if not effectively designed and thoughtfully placed, then the ability to acquire the wayfinding information is affected (Rechel, Buchan and McKee, 2009; Sadek, 2015). Due to this, navigators need to rely on memorising the route or actively exploring the space to find the destination.

The information design of signage tends to minimise an individual's confusion and frustration during the wayfinding tasks (Carpman and Grant, 1993). There are four significant types of signage based on information content, i.e., direction, identification, information and regulatory signage (Shohamy and Gorter, 2008). The directional signage is majorly placed in the outdoor environments and the large indoor environments with directional arrows. The

Figure 2.1 Directional, information, identification and regulatory signage in HK polytechnic university

signage placed on the intersection points to direct the navigator in the respective direction. In comparison, the identification signage describes the name of a building, location or facility (Tzeng and Huang, 2009). A study (Larson and Quam, 2010) has suggested that the directional and identification signage are an integral part of any indoor environment to make it legible for wayfinding. The wayfinding signage is effective in delivering the information; however, self-location identification is very crucial with the provided information. For that reason, content-aware signage introduced the concept of filtered and necessary wayfinding information to avoid confusion from information clutter. A study (Sykes, Pentland and Nardi, 2015) has suggested using context-aware digital signage, which can deliver the wayfinding information based on its location. Although both environments require different cognitive abilities and wayfinding strategies of users (Vilar, Rebelo and Noriega, 2014), signage and maps proved an efficient indoor and outdoor wayfinding system.

Wayfinding kiosks have several benefits over other static wayfinding aids. These can display diversified information including 2D, semi 3D and complete 3D maps. Most of the wayfinding kiosks have programmed search engines for instantly finding the required information. In addition to that, they can provide a complete 3d floor plan, users' current position, orientation, real-time walkthrough etc. The information on digital wayfinding kiosks can be provided in multi-lingual mediums along with the customised user interfaces, which can be very effective in delivering the wayfinding information to a larger volume of users. Wayfinding kiosks can be served for digital advertisement as well when not in use by the navigators. However, the access and ease of use are quite limited due to its static nature in the environment. Users need to search for such information kiosks to gain environmental information. The wayfinding kiosk placed in K-11 Musea in Hong Kong as depicted in Figure 2.2 serve its purpose quite well as used by several navigators throughout the day.

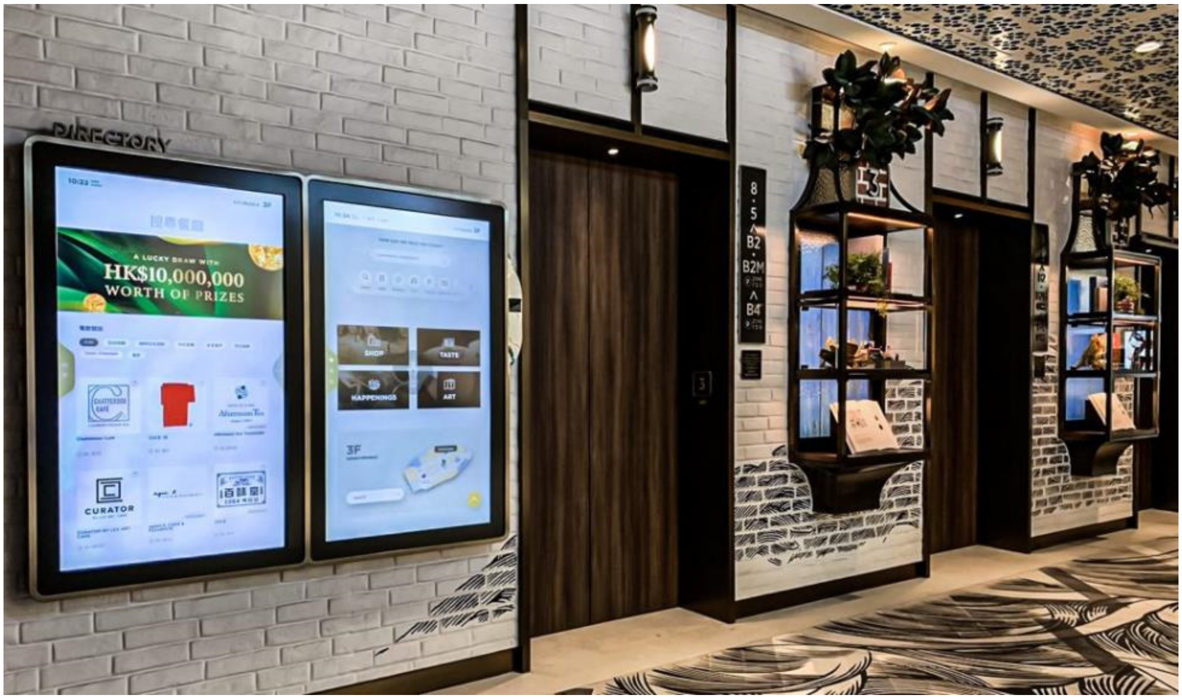


Figure 2.2 Wayfinding kiosk at K-11 musea Hong Kong

Static wayfinding aids are quite a in use due to several reasons. These aids are meant for a larger audience and provide a context-aware information due to their placement in the environment. In addition to that, these information sources are effective, durable and low in maintenance, due to which they are quite in use. In public stations and airports, the static information sources also include the information displays informing arrival and departure times as well as the transport schedules. These information displays often direct the navigators for their desired location along with the schedule information. As presented in Figure 2.3, the information regarding flight gates and estimated walking distance has been presented in the display. The navigators can plan their journey according to the advised time displayed on the information panels. These information displays work hand in hand with the regular static wayfinding signage for efficiently delivering the environmental information. The said information display informs the navigators about boarding gates, estimated time to reach there and informs that which wayfinding information one needs to follow. The wayfinding requirements of a certain environment depends on the type and complexity of the environment. Which further suggests the type of wayfinding information as well as the optimum volume of that information.

Figure 2.3 Information and wayfinding display at Heathrow airport London

2.7.2 MOBILE WAYFINDING INFORMATION

With the advent of technological advancements in mobile location tracking, many other solutions have emerged for indoor and outdoor wayfinding problems. Smartphones and hand-held devices are amongst those technology dependant digital solutions. The smartphones and digital devices use the GPS (Global Positioning System) based location identification system to locate the navigator's current position and direct them via digital wayfinding information. The efficiency of the system varies depending upon the GPS signal strength and the speed of internet data. Mobile devices aid the wayfinding process, but they are not the ultimate solution to all the wayfinding problems (Vandenberg *et al.*, 2016). The complete shifting of the wayfinding system from static to digital information medium is not feasible. Both information systems have potential benefits and deficiencies on their own. In combination with other systems of wayfinding information, mobile devices are proving an excellent asset for wayfinding research (Devlin, 2014). However, mobile devices require a significant dependence on the internet or any position identification system, i.e., GPS or indoor beacons. The GPS location identification system is quite efficient and effective in outdoor environments with simple layout settings (Mollerup, 2014; Iftikhar, Asghar and Luximon, 2020b). However, GPS is not efficient enough to provide real-time location and directional information for the complex outdoor and indoor settings.

Several beacon-based techniques have been suggested to overcome this issue using Bluetooth, Wi-Fi, RFID (Radio Frequency Identification). For enhanced and effective wayfinding information in indoor navigation, a study (Chumkamon, Tuvaphanthaphiphat and Keeratiwintakorn, 2008) has designed the RFID based beacon system for real-time guidance. The system identifies the RFID tags scattered on multiple positions throughout the layout to display the concerned information. Another study (Legge *et al.*, 2013) has designed and recommended a digital sign system (DSS) that provides directional wayfinding information using the handheld tag reading device. Different signs or digital tags contain relative location-based information to guide the navigator for the destination.

2.8 DIGITAL WAYFINDING INFORMATION

The digital information sources can and cannot be portable; however, they can contain a substantial volume and variety of wayfinding information compared to the printed or painted ones. Therefore, the digital information has been presented in multilayers, requiring the user's cognitive effort for content navigation. This extensive volume of information requires a thoughtful design of content for the intuitive user experience. The intuitive user experience and usefulness are essential attributes for accepting the new technology (Yi and Hwang, 2003; McFall, 2005; Park, 2009). The information in wayfinding applications has been presented in single or multiple level interface designs depending upon the user requirements and preferences (Lemoncello, Sohlberg and Fickas, 2010; Vainio, 2011). With the development of mobile technologies, wayfinding applications have emerged as a new and reliable solution to wayfinding problems by efficiently delivering the required information.

In mobile applications, certain limitations have been instrumental in delivering adequate wayfinding information. Due to the portable nature of mobile devices, screen sizes are needed to be small and pocket-sized. This size range (from 4.5" diagonally to 6.5") is viable for mobile devices, leaving limited room for displaying information content. Therefore, information designers have devised techniques based on information layering for displaying the entire content. The information can be presented in a single layer or multiple layers depending upon the content.

2.8.1 SINGLE/MULTIPLE-LAYER INFORMATION

In mobile applications, the information content has been presented to the users using the hierarchal structure. Unlike static wayfinding information, digital devices can save and recall a large volume of wayfinding information per the user's demand. For the representation of information content on mobile devices, multiple layers of information have been used to deliver the necessary content. The multiple layers are necessary to use due to the smaller screen sizes and a large volume of information. Displaying the large volume of information on a single layer can cause information overload due to less negative design space, hence requiring a significant cognitive effort (Adipat, Zhang and Zhou, 2011). A study (Brewster, 2002) has mentioned that the presentation can be better and more accessible for understanding if presented at multiple levels. Through multiple levels, the user can easily navigate throughout the entire desired content with ease; however, it also depends upon the user's navigation patterns and context of application usage. In the hierarchal structure, the information should be designed based on user preferences and the context of use. A study (Ayob, Hussin and Dahlan, 2009) has described the user's context of usage as a significant factor for designing intuitive navigation for the information content of any mobile application. This intuitive navigation pattern can also be influenced by several factors including but not limited to the cognitive approach, cognitive abilities, and memory capacity.

2.8.1.1 *SHORT-TERM MEMORY*

The navigation pattern and layer's accessibility in a mobile wayfinding application are quite dependent on the user's short-term memory. While using the digital wayfinding application, information has been presented in many layers that occupy the space as events in short-term memory. This memory can store a limited number of events for a shorter duration of time (Cowan, 2008; Lokka and Coltekin, 2019) with a limit of five to seven events/chunks at a time (Simon, 1974; Cowan, 2001). The accessibility to information layers during the navigation of the wayfinding application can be affected by this human limitation. Therefore, a limited number of information layers can be memorised during navigation and will be approached again if the number of accessed information layers increases. Owing to this behaviour, a maximum number of approachable information layers for digital wayfinding content should be explored to efficiently design and deliver the required wayfinding information.

2.8.2 TYPES OF NAVIGATION STYLES

The navigation styles in the mobile application usually depend upon the types of information content, i.e., graphical or textual. A menu-oriented design has been involved and considered a typical navigation approach in most mobile applications (Garrett, 2010). Although navigation styles in mobile applications are quite inspired by web navigation, the exact adaptation of these styles into mobile applications would be troublesome due to many factors (Petrovčič *et al.*, 2017). A global shift from feature phones to smartphones has changed user interactions due to the different input methods for respective devices. Smartphones are consisting of a touch screen input method requiring a touch-friendly user interface and information content design. Multiple studies (Tidwell, Brewer and Valencia-Brooks, 2010; Neil, 2014; Li and Luximon, 2020) have mentioned the most widely used navigation patterns in touch screen smartphone applications. These patterns consist of menu orientation and content orientation design patterns. The menu-oriented patterns include tab, side drawer and springboard styles, whereas the content-oriented patterns include lists, gallery/grids and card styles (Li and Luximon, 2020). Most of the wayfinding applications have majorly used both navigation styles due to mixed information content, i.e., graphical and textual.

2.8.3 TYPES OF INFORMATION CONTENT

In wayfinding applications, various information content has been included related to the user's wayfinding needs. There are two major information content categories necessary for performing wayfinding tasks. The first category is related to the allocentric wayfinding information, and the second category is related to environmental information. The allocentric information includes the navigator's current position, tentative route plan on the map, directions for navigation and orientation. The allocentric information is reasonably necessary for a navigator to understand the current position and orientation in a spatial environment. A route plan is necessary for alleviating the wayfinding problems and enhancing task performance.

The second type of information in a wayfinding application is related to the spatial environment. This information includes the signage (Weisman, 1985), landmarks, dedicated pathways (Vandenberg *et al.*, 2016), intersections, building information, building internals, facilities (Iftikhar, Asghar and Luximon, 2020b), emergency exits and transports. This information content is necessary to explore the whole environment and build up the cognitive maps for independent navigation while experiencing the environment. The environmental information helps plan the route as well as perform the whole wayfinding task. Most of the wayfinding applications have been providing this information by using the global positioning system (GPS) requiring internet service for continuous data transfer to obtain context-aware information. Some wayfinding applications have incorporated micro level information of their respective institutes. While other applications like google maps etc. have only macro level information consisting of highways, roads for navigation at the city's scale. The localised wayfinding applications are more suitable and preferred for institutional wayfinding like universities, hospitals, airports, and shopping malls for an enriched experience of offered facilities.

2.8.4 WAYFINDING INFORMATION MODELS

The literature also identified several theoretical frameworks to facilitate the wayfinding information requirements; however, these theoretical models answer very particular information requirements as well as for the specific spatial environment. The wayfinding models presented in several studies (Gopal and Smith, 1990; Timpf *et al.*, 1992; Chen and Kay M. Stanney, 1999; Li, 2006; J. C. Xia *et al.*, 2008; Giannopoulos *et al.*, 2014) have defined the wayfinding information requirements along with the user understanding. The first model (Gopal and Smith, 1990) discussed the cognitive processes of the wayfinders in an urban environment discussing the memory requirement and behaviour. In addition to that, the model presented (Timpf *et al.*, 1992) discussed a significant level of information and planning abstraction on the road wayfinding. (Chen and Kay M. Stanney, 1999) presented a very comprehensive theoretical model for wayfinding information requirements in virtual environments. This model discussed users' objectives, motives, behaviour decision makings while performing the virtual wayfinding activity. In another study (J. C. Xia *et al.*, 2008) the presented model discussed the cognitive maps and their differentiation within users. Whereas the model presented by (Giannopoulos *et al.*, 2014) only identified the wayfinding decision model based on the three-staged concepts for decision making during the wayfinding activity.

However, none of the discussed models has identified the complex public institutions and their navigators as a prime source of investigation. The described theoretical models have been influential in identifying the required research gap.

2.9 LITERATURE REVIEW SUMMARY

Wayfinding activity depends upon several factors including but not limited to the environmental factors, personal abilities and the types of wayfinding information being used to facilitate the navigators. Environmental factors include spatial complexity, environmental legibility and visual clutter. The environmental factors can enhance the user's ability of wayfinding if designed systematically; however, these factors are not solely responsible for efficient wayfinding. In addition to that, personal abilities/differences also affect the wayfinding activity like cultural differences, gender differences, spatial abilities and age differences. Most importantly the wayfinding information design, volume and type can greatly affect the user's information understanding as suggested by the literature discussed above. In today's indoor and outdoor environments, the type of wayfinding information greatly changes based on the type of technology they are using to provide the necessary information. The two major types like static and mobile wayfinding information use digital and printed mediums to facilitate the navigators for wayfinding activity. Figure 1.1 described the fundamental differences between these two information systems which majorly describe their limitations in providing the necessary wayfinding information. In addition to that, Table 1.1 suggests the specialised wayfinding information requirements for spatially complex public institutions. Based on the studies covered in the literature review, it has been quite evident that these two information systems are facilitating two different kinds of environments and somehow work in isolation.

The literature related to wayfinding systems and design in complex environments suggests the need to investigate the user-related defences in the wayfinding design preferences and the ascribed behaviour. Previous studies also suggested that the wayfinding system design is majorly dependent on the users who are using it. This indicates the fact that users' current behaviour and practices are very important in understanding the designed information for effortless navigation. With the advent of technology, mobile wayfinding information systems are also influential in guiding the users for wayfinding problems in addition to the regular static wayfinding information system. However, these two systems are working in isolation as identified by the previous literature. The said research gap has been visually presented in Figure 1.2 in detail. This thesis addresses the identified research gap and develops a theoretical framework for mitigating the wayfinding issues.

The studies presented in the literature review suggested several pros and cons of the static and mobile wayfinding information including user understanding and perceiving the wayfinding information. For synthesising the wayfinding information sources, it is necessary to understand the modern user’s wayfinding information requirement in spatially complex environments. And how users perceive and understand that wayfinding information based on their cultural and individual differences. For that reason, several research questions have been identified in chapter 1 necessary to understand the modern user’s wayfinding information requirement and ascribed behaviour.

In the next chapter, a detailed study plan has been delineated to address the current objectives of this thesis along with a detailed methodology for conducting the said research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 CHAPTER HIGHLIGHTS

This chapter describes the methodology of this thesis in detail. It discusses the rationale behind the research design and methodology adopted. It also provides details about various methods employed, the reasons behind their selection, and how they were executed. Further, the chapter summarizes the techniques used for the data analysis.

3.2 MIXED-METHOD APPROACH

As suggested by the prospective research questions, this research study relied on more exploratory and explanatory research approaches. This study was conducted inductively to define the additional dimensions in current navigation and wayfinding theories based on specific metrics; this is to investigate human navigation behaviour and knowledge as it relates to cultural factors. This research was done using a mixed-method approach. This study requires a thorough examination of navigational information and user behaviour considering various individual-related differences. These differences may include cultural differences, spatial ability, spatial familiarity, gender, age, and education. Mixed method research has many types regarding the combination of qualitative and quantitative research methods. "The Exploratory Design" was preferred for this research (Greene, Caracelli and Graham, 1989) as wayfinding behavioural research requires in-depth exploration and explanation. In exploratory design research, the researcher investigates the issue using qualitative approaches and then uses quantitative methods to develop the survey instrument and generalize the findings based on the information gained (Tashiro, 2002). The research approach suited the potential research questions but will also aid in a thorough grasp of the subject.

3.3 METHODOLOGIES OF PRECEDING STUDIES

As previously stated in the literature, significant research has already been conducted on human navigation behaviour and attributed cognitive processes. There are several research techniques available based on the collected data and identified study objectives. Most of the existing research has been based solely on quantitative or quantitative methods respectively. The exploratory and explanatory research techniques were used in most earlier investigations (Hashim, Alkaabi and Bharwani, 2014). The exploratory research approach was used in this study to investigate the cultural influences on the wayfinding system design for a hospital. Multiple studies were carried out to investigate prospective hospital user behaviour and signage qualities (Greenroyd *et al.*, 2018). Similarly, a deductive technique was used to investigate the quality of complex environmental navigation (Walford *et al.*, 2011).

Several studies have investigated different factors linked to wayfinding in the complex space and explained certain elements like spatial recognition and human wayfinding behaviour (Raubal, 2001; Nilsson, 2009). Several studies relied solely on qualitative data to answer their queries, whilst others relied on quantitative assessments (Teng *et al.*, 1994). Qualitative research methodologies have greatly aided in eliciting the actual core of human navigation behaviour. Many researchers have used triangulation strategies in their study to confirm their data's conclusions. Several studies have highlighted the significance of triangulation (Hickman, 2008). As a result, researchers used data and method triangulation for evaluating and validating the studies. A researcher (Oyelola, 2014) also utilized data and method triangulation. To investigate the study questions, she relied on qualitative data.

In recent studies on wayfinding and navigation, mixed-method research is emerging as an effective methodology. In the field of navigation and wayfinding, researchers frequently employed specific standard mixed-method research methods. Explanatory, exploratory, embedding and contemporary research approaches are some examples of mixed-method research. Each technique combines qualitative and quantitative data gathering, analysis, and retrieval.

3.4 PROPOSED RESEARCH METHODOLOGIES

The proposed methodology for the current study has been developed based on comparing preceding techniques used to investigate the wayfinding studies. The mixed-method research methodology has been considered appropriate for exploring the wayfinding behaviour along with the ethnographic studies. A comprehensive comparison has been detailed out as a reason of choice for the opted methodological approach.

3.4.1 **SURVEY QUESTIONNAIRE**

The complex university environment has been chosen for the proposed research based on its suitability as a complex navigable environment with diffused pathways and complex wayfinding. Participants were selected based on their ethnicity, age, and level of environmental familiarity. A preliminary survey questionnaire was distributed to university visitors who were only partially familiar with the campus and freshly enrolled students. The interviews are reliable (Hickman, 2008); however, survey questions offer other benefits. Questionnaires need less contact time, are less expensive, reach a considerable number of individuals, and are simple to administer compared to interviews, which require significant time and individual attention. Data from a survey questionnaire would be more unbiased, concentrated, precise, and easier to manage in the early stages of research than data from interviews. The questionnaire will inquire about their most recent experiences of disorientation as well as the probable explanations. The survey questionnaire contains semi-structured questions (having close-ended and open-ended questions). The number of questions in the survey questionnaire would be reduced since it is simpler for participants to answer fewer questions (Deutskens *et al.*, 2004) and much necessary to retain the participant's interest. The semi-structured survey questionnaire will improve comprehension of the navigation of the complex institutional environment and the users' perspectives on it. Secondary questions have focused on the function of signage in disorientation (misleading information) as well as the role of colour coding and pictograms. The preliminary results assisted the researchers in developing the next step of research methodology, which is an exploratory and controlled experiment in the actual and virtual environments, respectively.

In addition to the survey questionnaire, participant observation and video analysis can also be used as a methodology to strengthen and triangulate the findings. However, in participant observation and video analysis, there are several complicating variables. These elements include crowd impressions, other potential distracting variables (light, sound, glares), and user familiarity with the place. These variables can change the information requested by the study questions. As a result, an experimental design in a controlled context is required, emphasising the users' cross-cultural impact on retrieving signage information. During the lab experiment, factors or variables may be easily controlled to validate the results. The research would concentrate on the information conveyed through colour coding and pictograms. There may be some differences between the actual world and the lab setting due to several factors, which may affect the outcomes of the VR experiment (Vandenberg *et al.*, 2016). However, this may be accomplished in the lab by utilizing completely immersive VR technologies like head-mounted displays to provide the participant with a complete sense of presence in the wayfinding experiment.

3.4.2 REAL ENVIRONMENT EXPERIMENT

The findings from the initial exploratory studies require further investigation as they may contain some findings which differ from the actual user behaviour. The questionnaire study explored their preferences and potential behaviour of wayfinding; however, the actual behaviour during wayfinding tasks can be different. Therefore, it is also necessary to conduct an experimental study that should explore the users' current practices regarding obtaining and understanding the wayfinding information from different environmental resources. In addition to that, several factors like spatial layout, environmental features, visual clutter, and crowd influence can also be influential in affecting user behaviour. Due to that reason, a significant need has been observed for a real environment-based experiment for further exploration of the users' wayfinding information preferences and behaviour.

Owing to this, an experiment has also been designed in the real environment for investigating the current practices of wayfinding information gathering and syntheses. In this experiment design, participants have been observed real-time and using the first-person view video recording to have an in-depth understanding of their potential wayfinding behaviour. The first-person view was considered a necessary tool to record their head movement and the direction of viewing. For this reason, multiple data recording tools have been used, including a head-mounted camera. Participants were also directed to use the think-aloud protocol to investigate and understand their thinking process. The details of the said experiment design have been delineated in the following chapters.

After conducting the studies, a thorough understanding has been formed regarding the wayfinding processes and information requirements to complete the tasks efficiently. The findings from the current studies and the previous literature have been put together, and a comprehensive theoretical framework for wayfinding has been proposed. The proposed framework has been presented as an iterative cycle of information gathering, processing and wayfinding actions. A detailed explanation of the model has been presented in the requisite chapter. After proposing the theoretical framework, a need of validating some of the components have been observed. Owing to this, a validation study has been designed using the virtual environment in a controlled lab facility. The details of the experiment have been presented in the validation study chapter of this thesis.

3.4.3 VALIDATION EXPERIMENT

There are several reasons why the lab experiment was chosen as a viable technique of validation during the exploratory mixed method design research. This project's experiment necessitates strict control over confounding factors such as crowd conditions, light glares, situational and environmental familiarity, and spatial association. Because of this, a lab experiment would have been preferable to a field experiment. There are several advantages to doing a lab experiment over a field experiment (Kagel & Roth, 2015). Due to the controlled lab setting, lab studies provide a high level of control over confounding factors; however, field studies do not control the variables. Various real-world uncertainties might skew the results. During the lab environment, the convenience of setting up signage props and route information displays and the convenience of altering experimental settings may be observed. If used on a real-world scale and conditions, this factor may be highly problematic. Causality is easily created since factors rely heavily on variables. There are fewer ethical difficulties because each participant is dealt with one at a time, and the remaining arrangements are in virtual reality. Because of the excellent control over confounding factors, lab experiments can be necessary for this project. The study variables can be easily analysed and validated in lab experimental settings, and they have a high degree of reliability. The experimental setting, including participants, study variables, and instrumental measures, may be controlled entirely.

The participants were chosen based on various criteria, including culture, spatial ability, and spatial familiarity. Several studies have recruited cross-cultural participants based on their language, their countries, and their permanent residence. Few studies have looked at geographical placement to describe culture (Ertan & Eker, 2000). The chosen participants were invited to the controlled lab facility and asked to complete the information required form. Following that, about an hour-long experiment was launched, preceded by a five-minute training session in the virtual world. The participants were asked through a questionnaire regarding the potential difficulties in using the desktop-based VR systems and navigating the VE. If the participants show no sign of problems, they could proceed further and complete the rest of the experiment. In addition to that, participants have also been asked to report the Santa Barbara Sense of Direction scale to measure their spatial ability (Hegarty *et al.*, 2006). Spatial ability has been instrumental in investigating the participant's ability to identify the location and orientation in the real environment.

3.4.4 PROPOSED DATA ANALYSIS

The data analysis for the mixed-method study can qualitatively predict the quantitative findings. The data analysis for the first part of the survey questionnaire conduction comprised of many statistical tests. Because the survey questionnaire was created semi-structurally, the data analysis section included both qualitative and quantitative data and methodology. Based on the data type, Chi-Square, Mann Whitney U test, Pearson Coefficient of Correlation, and Kendall Tau's tests were utilized for the structured components. The Shapiro-Wilks Test in SPSS software was used to assess the normality of the collected data. Due to the various variables, two-way ANOVA and the Kruskal-Wallis Test were performed based on the received data due to the type of variables. For a more in-depth understanding, the qualitative part of the questionnaire was evaluated using Content Analysis and Pattern Matching. A study has (Seidel, 1998) used the three-staged approach to building a suitable tool for acquiring qualitative information. For data mining and classification, this paradigm includes the Noticing, Collecting, and Thinking stages. These stages can be applied to the intriguing items described in the question's open-ended sections for code generation and theme creation. In the following chapters, the exact procedures used for data analysis for each investigation are provided in-depth.

3.4.5 LIMITATIONS

Predetermined and specific criteria do not constrain this study's methodology. It is more of a creative effort to put the sequences together and derive a linkage between the said topics. This research methodology only includes the one proposed to carry out the research mentioned in the topic. Because this research was exploratory, it necessitated a qualitative examination of human behaviour in complicated wayfinding tasks. Especially when the textual information is hard to comprehend (in the local language). The qualitative study has some limitations in generalizability (Digital course materials: A case study of the Apple iPad in the academic environment (Verdine, 2011). This is because of confounding variables in data collecting, which causes inconsistency in data analysis (Elo and Kyngäs, 2008). The data organizing and abstraction processes in a qualitative investigation take a long time (Bowen, 2006). As a result, the sample size should be maintained limited. Hence the mixed-method approach of exploratory design has been proposed. This strategy offers several advantages in terms of subjective generalization, data mining, and so on. The methodology is implemented in phases using this strategy. This study method has several limitations as well. Because the study procedure is lengthy, individuals may be uninterested in participating in the following stage. Because this is exploratory research, more validation studies cannot be planned before the original studies are completed. To explore the issue mentioned above, a systematic study design method is required.

CHAPTER 4: STUDY 1 – CULTURAL AND INDIVIDUAL-RELATED INFLUENCES ON HUMAN WAYFINDING BEHAVIOUR

A research article has been published from this study, *Iftikhar, H., Asghar, S., & Luximon, Y. (2020). The efficacy of campus wayfinding signage: a comparative study from Hong Kong and Pakistan. Facilities. DOI:10.1108/F-04-2020-0035*

4.1 CHAPTER HIGHLIGHTS

In this chapter, research question 1 along with the subsequent research questions have been investigated.

Research Question 1: How do cultural and individual differences affect the acquiring of wayfinding information?

Research Question 1.1: What are the problems in obtaining the wayfinding information?

Research Question 1.2: What is the user's behaviour for the search of wayfinding information?

Research Question 1.3: What is the user’s perception about the accuracy of obtained wayfinding information?

The requisite research questions have been concerned with the issues related to the cultural and individual differences in obtaining the wayfinding information from designed wayfinding aids in the environment. In addition to that, the investigation explored the user behaviour and perception regarding the provided wayfinding information, especially in complex institutional environments. Complex environments contain a scarcity of visual information, making navigating difficult, especially for first-time visitors. The environmental legibility of university campuses in central metropolitan locations having large structures and complex spatial settings is low. International students and guests from various cultural backgrounds who visit these complex spatial areas feel lost while navigating them. The objectives of this research were to investigate the individual-related and cultural impacts that influence wayfinding behaviour. A questionnaire was used to perform an online campus navigation survey with 170 university students and visitors from Hong Kong and Pakistan. A five-point bipolar Likert scale was used to analyse user behaviour with questions divided into navigational issues and ascribed behaviour. Culture has a significant effect on decision-making and navigational behaviour, according to our findings. The study found that culture is more important than age, gender, spatial familiarity and education in driving decisions. Age and geographic familiarity were also significant factors influencing respondents' opinions, with age and geographic familiarity being key factors.

This study has been conducted through an online survey by the participants of Hong Kong and Pakistan. The selected sample have been selected based on the various cultural dimensions. For investigating the cultural influences on wayfinding behaviour, Pakistan and Hong Kong sample groups have been selected as convenience sampling and due to their distinctive cultures. Hong Kong and Pakistan can be labelled as individualistic and collectivists respectively based on their distinctive cultural behaviour. Although some cultural model do not distinguish a lot between these two cultures based on individual and collectivist nature (Hofstede, 2001). However, in some of the cultural models (Hall, 1985; Hall and Mildred, 1990) the difference in cultures can be described as high context and low context cultures. In the high context cultures, there are many contextual elements that can be seen as unwritten rules which may cause misunderstanding for the people who are not from the similar cultures. In addition to that, the individualist cultures tend to be more independent and try to avoid the unnecessary help from others. Whereas collectivists cultures are quite dependent on each other in terms of daily tasks and activities. This particular behaviour influences their approach towards getting the environmental information for wayfinding tasks.

Another dimension which is different in Hong Kong and Pakistani culture is the uncertainty avoidance (Shah and Amjad, 2011). The people from Pakistan are outward directed and believed that the future is out of their control unlike the people from Hong Kong (Hodgetts *et al.*, 2006). Due to this believe, the performance of daily life tasks is more driven on the basis of surrounding environment rather than focusing on the initial aim. For this reason, during wayfinding the uncertainty avoidance can play an important role for describing their actions. While performing the wayfinding tasks, the initial aim and search for the required environmental information is very necessary for efficient completion of the task. Owing to this, an exploratory study for the behavioural differences between these two cultures was planned. Such cultural studies haven't been performed before between these two cultures stating its importance and need for improving the institutional wayfinding. Being considered as a multi-cultural environment, educational institutions in Hong Kong require in-depth understanding of the wayfinding behavioural differences. In this study, several questions based on the wayfinding problems and behaviours have been asked from the participants from Hong Kong and Pakistan.

4.2 RESEARCH METHODOLOGY

A five-point bipolar scale (strongly disagree as 1 to strongly agree as 5) have been used to record the participants' responses. The participants were mostly students or visitors of university campuses in Pakistan and Hong Kong. The university in Pakistan has a dedicated area of 60 hectares for its campus with more than 100 buildings consisting of academic departments, student hostels, libraries and other facilities. The spatial settings of the campus can be considered as a mixture of the grid- and radio-centric layout planning. This university campus serves around 15,000 students, more than 1,000 faculty members and around 3,000 employees. 8% of the total students are international students from various regions around the globe. The international students mostly belong to the Middle East regions, Africa and central

Asia. While the university in Hong Kong has a dedicated campus area equivalent to 10 hectares with more than 25 high-rise buildings, the campus has irregular spatial planning because of the number of planned extensions. This campus serves around 25,000 local and 1,000 international students. Many of the international students are from Europe, Africa, South America and Southeast Asia. The campus settings also accommodate approximately 5,500 staff members. Both universities have complex spatial layouts involving fused facilities for students/staff, indistinguishable pathways and multi-level building access with compromised visual access to the wayfinding information. The participants were invited to access the survey and record their responses through Google Forms. Ethical approval (APPENDIX I) was obtained from the requisite authorities. The protocol was followed and consent was obtained by the participants for recording personal and demographic information.

4.2.1 QUESTIONNAIRE DESIGN

The online questionnaire was designed to collect information from participants based on the four key information categories shown in Table 4.1. The first segment included questions on personal and demographic information required for cultural group identification (Furman *et al.*, 2014; Dasen, 2018; Gagnon *et al.*, 2018) along with the groups based on individual differences. To differentiate cultural groupings, respondents were asked about their country of origin, country of current residence, and native language.

Table 4.1 Questionnaire design

Information category	Questions
Demographic/Personal information	
	Gender
	Age
	Level of education
	Country of origin/residence
	Native language
	International exposure
Environmental Familiarity (EF)	
	Nature of campus visit
	Visiting frequency
	Location Identification
	Environmental Familiarity level
Wayfinding Problems (WP)	
Difficulty	Q1. In the beginning, campus wayfinding was difficult.

Information category		Questions
		Q2. In the beginning, I was disoriented on campus.
		Q3. I always find my way through signage.
	Information Comprehension	Q6. Signage information is easy to understand.
		Q7. Campus signs are misleading sometimes.
		Q8. Campus signs are difficult to read.
		Q10. Campus planning is very complex.
		Q12. Signage is noticeable on campus.
		Q17. I have seen many disoriented visitors.
	Information Design	Q22. I always tell directions through signage.
		Q24. Signage should be simple and minimal.
		Q25. Signage information should be detailed.
		Q26. Signage design should represent the institute.
Wayfinding Behaviour (WB)		
	Information Gathering	Q4. I always look for wayfinding signage.
		Q5. For wayfinding, I had to memorize the locations.
		Q 9. I ask directions from a passer-by.
		Q11. Can find a destination without signage.
		Q13. Signage information is only for a freshman.
		Q14. Familiar with campus planning.
		Q15. Prefer verbal directions for wayfinding.
		Q16. Spatially quite familiar.
	Information Preferences	Q18. People use mobile devices for wayfinding.
		Q19. Signage is easy for wayfinding than the cell phone.
		Q20. I usually tell directions to new visitors.
		Q21. The campus is too complex.
		Q23. Signage should follow the university theme.
		Q27. Colour coded info. Should be available.
		Q28. Dual language signage is confusing.
		Q29. Signage should always have pictograms.
		Q30. Pictograms/symbols are easy to understand.

Furthermore, a section of the questions focused on any foreign exposure gained from living abroad since this might alter replies dependent on indigenous culture. The participant's navigational behaviour, cognitive spatial knowledge, and overall performance are influenced by their familiarity with the surrounding circumstances (Hegarty *et al.*, 2002; Nori and Piccardi, 2010). As a result, questions in the second section focused on the participant's cognitive familiarity with the campus's environmental settings. The impression was formed by inquiring about the nature and frequency of campus visits and landmark familiarity from the navigator. Participants were asked to self-report their level of environmental familiarity based on the information obtained. Their responses were recorded using a five-point reporting scale (not familiar as 1 to very familiar as 5). As a result, the groups were divided into two major categories: participants with limited familiarity (1 to 3) and participants with high familiarity (4 to 5).

The third section of the questionnaire included questions on identifying navigational issues (Bowman, Johnson and Hodges, 2001; Ruddle and Jones, 2001) during campus navigation. Whether the problem was retrieving information from external cues or comprehending spatial layouts. The questions were asked in a random order so order to elicit a natural response from the subject. The third section of the questionnaire, consisting of 13 questions, was aimed to collect information on the identification of navigators' wayfinding challenges. As mentioned in Table 4.1 the wayfinding problems have been further segregated into three categories i.e. difficulty in complex environments, information comprehension and information design. The questions have been formalised based on the previous literature.

The final section of the questionnaire, consisting of the remaining 17 items, was aimed to study the navigator's likely behaviour while facing problems with wayfinding. The broader categories consisting of information gathering and information preferences aimed to further investigate the user wayfinding behaviour. The constituents exploring the wayfinding behaviour (Montello, 2001; Hegarty *et al.*, 2006) was made up of the environmental wayfinding information sources, one's interpretation and preferences of the information, and the actions taken after obtaining the data.

4.2.2 DATA COLLECTION

The survey was conducted on students and general navigators from reputable universities in Hong Kong and Pakistan. Both universities are well recognized in their respective regions, attracting students and tourists from across the country. The respondents are an ideal sample since they come from different parts of the country and have shared cultural values. In all, 203 people from various Pakistan and Hong Kong areas with diverse cultural backgrounds took part in the campus wayfinding investigational research. Among the 203 participants, 170 were chosen based on the inclusion criteria of cultural groups from Hong Kong and Pakistan. Respondents were either freshmen or occasional visitors to the university campus with a medium or low degree of environmental familiarity. Although considerable navigational information is provided in multilingual mediums, i.e. (Urdu-English for Pakistan, Cantonese English for Hong Kong), English was chosen as the survey language since it was equally comprehensible in both campuses. To reduce confounding variables for cultural homogeneity while preserving distinctive individual differences, responses were obtained from individuals with very little international or cross-cultural exposure. Furthermore, the education level was maintained from below undergraduate to postgraduate level and beyond, ranging from 18 to 37 years.

4.2.3 **DATA ANALYSIS**

Responses were collected using Google Forms online services, followed by a screening procedure based on information completeness. Participants from Hong Kong and mainland China were classified as the same cultural group. Respondents from countries other than Hong Kong, mainland China, and Pakistan were omitted from the questionnaire analysis for cross-cultural comparison. The filtered data was imported into Microsoft Excel 2016 for preliminary descriptive statistics before being processed for statistical analysis using SPSS software.

Following that, the data was imported into the SPSS program for additional analysis and normality testing. The Shapiro-Wilk test revealed that the data for analysis was not normally distributed. As a result, the non-parametric test was used depending on the size of the independent groups. Because the data was obtained in a five-point bipolar Likert scale, it was classified as ordinal scale data. To link two distinct groupings, the Mann-Whitney U test (Nachar, 2008) has been applied.

Furthermore, the use of the Kruskal-Wallis test has been examined for the comparison of more than two independent groups (Corder and Foreman, 2009). The tests listed above were used to look at group variations in wayfinding behaviour, issues, and cognitive strategy development. Independent sample groups were developed based on cultural differences (country of origin) and individual characteristics (gender, age, level of education and level of environmental familiarity).

During the multiple comparison, Bonferroni’s correction has been applied to reduce the type 1 error. For this reason, all of the questions have been segregated into the sub categories. The most common approach of dividing the significance value by number of analyses have been applied. For the all the segments, the corrected significance values are 0.016, 0.008, 0.012, 0.006 and 0.006 respectively. However, most of the significant values were below the corrected range which makes the analysis more rigorous in nature.

4.3 RESULTS

An inclusion criterion was created for the questionnaire analysis based on the participant's demographic information and completion of the survey form. A total of 170 questionnaires (83.74 %) were deemed suitable for inclusion in further study.

Table 4.2 Participants summary

	Hong Kong	Pakistan	*Total*
Gender			
Female	51	41	92
Male	42	36	78
Total	**93**	**77**	**170**
Age Group			
18-22	31	38	69
23-27	42	28	70
28-37	20	11	31
Total	**93**	**77**	**170**
Education Level			
Undergraduate	35	50	85
Postgraduate & above	58	27	85
Total	**93**	**77**	**170**
Environmental Familiarity Level			
Low	48	19	67
High	45	58	103
Total	**93**	**77**	**170**

4.3.1 GENERAL DEMOGRAPHICS

The preliminary descriptive data revealed that Hong Kong received somewhat more answers (55 %) than participants from Pakistan (45 %). Furthermore, a very comparable ratio was seen for the gender of participants, with females at 55 % and males at 45 %. The participants' ages were inquired about since age is considered an influential factor in wayfinding behaviour (Davis, Therrien and West, 2009; Lin, Cao and Li, 2019). As shown in Table 4.2, the respondents were further divided into age groups ranging from 18 to 37 years old, with a five-year gap in between. Due to the decreased number of participants and the need to preserve the reliability of the results, the final two age categories from 28 to 37 years have been merged. Most participants in all groups (82%) were between the ages of 18 and 27, while the rest (18%) were between the ages of 28 and 37. In terms of education, half of the total participants were undergraduates, with the remaining half having a postgraduate or higher education level. Most of the participants were students (92 %). However, just a tiny percentage of participants (8%) were general visitors to the Hong Kong and Pakistani universities.

4.3.2 CULTURAL DIFFERENCES

As shown in Table 4.1, the questionnaire had thirty questions about wayfinding behaviour and issues. A non-parametric test (Mann Whitney U test) was considered appropriate for analysing both cultural groups (Hong Kong and Pakistan). Several inconsistent responses to wayfinding have been documented in both cultural groups. The total of twelve questions was substantially different *($p < 0.05$)*, with most of them relating to wayfinding signage and its information. To identify navigation issues, contrasting answers on access and comprehension of environmental information for directed wayfinding tasks on campus have been recorded.

In comparison to the individuals from Pakistan, the participants from Hong Kong had far greater difficulty in obtaining and interpreting the navigational information provided by signs. There might be several reasons for this, including the visual complexity of the information, placement, and a lack of understanding of symbols and pictograms. The higher mean of Q6 (3.52) and significant value ($p = 0.032$) of Pakistani participants compared to the Hong Kong group regarding the easy interpretation of information can be linked to the former group's greater degree of environmental legibility. For the participants of Hong Kong, people were more confused in looking for environmental information for wayfinding. They also find it less useful for navigation inside the complex institutional campus. The reliance on the provided information was also weak in the respondents from Hong Kong. The likely reasons for this difficulty may be recognized since the spatial layout of the university in Hong Kong is much more complicated than that of the institution in Pakistan.

Table 4.3 Cross-cultural comparison of groups

Q no.	**Question Description**			**HONG KONG**		**PAKISTAN**		***p*-value**
		Min	*Max*	*Mean*	*S.D.*	*Mean*	*S.D.*	
	Wayfinding Problems							
	Difficulty							
1	Campus wayfinding was difficult in starting.	1	5	3.33	1.27	3.69	1.22	0.074
2	In the beginning, I was disoriented on campus.	1	5	3.26	1.14	3.29	1.22	0.805

Q no.	Question Description	Min	Max	HONG KONG Mean	HONG KONG S.D.	PAKISTAN Mean	PAKISTAN S.D.	p-value
3	I always find my way through signage.	1	5	3.31	1.30	3.32	1.23	0.999
	Information Comprehension							
6	Signage information is easy to understand.	1	5	3.18	0.95	3.52	1.21	**0.032***
7	Campus signs are misleading sometimes.	1	5	3.01	1.07	2.87	1.18	0.565
8	Campus signs are difficult to read.	1	5	2.72	1.06	2.77	1.07	0.749
10	Campus planning is very complex.	1	5	2.94	1.05	2.86	1.14	0.586
12	Signage is noticeable on campus.	1	5	3.23	1.01	3.26	1.14	0.904
17	I have seen many disoriented visitors.	1	5	3.23	1.21	3.23	1.06	0.883
	Information Design							
22	I always tell directions through signage.	1	5	2.91	1.07	2.90	1.12	0.883
24	Signage should be simple and minimal.	1	5	3.43	1.33	3.99	1.19	**0.004****
25	Signage information should be detailed.	1	5	3.15	1.09	3.26	1.23	0.558
26	Signage design should represent the institute.	1	5	3.15	1.13	3.73	1.08	**0.002****
	Wayfinding Behaviour							
	Information Gathering							
4	Signage information is helpful.	1	5	3.24	1.12	3.09	1.33	0.473
5	Need to memorise the locations.	1	5	3.32	1.10	3.61	1.16	0.079
9	I ask directions from a passer-by.	1	5	2.85	1.15	3.45	1.31	**0.001****
11	Can find a destination without signage.	1	5	3.25	1.32	3.83	1.33	**0.003****
13	Signage information is only for a freshman.	1	5	2.83	1.19	3.27	1.25	**0.019***
14	Familiar with campus planning.	1	5	2.90	1.19	3.51	1.31	**0.002****
15	Prefer verbal directions for wayfinding.	1	5	2.81	1.24	3.06	1.14	0.159
16	Spatially quite familiar.	1	5	2.99	1.25	3.65	1.14	**0.001****
	Information Preference							
18	People use mobile devices for wayfinding.	1	5	3.02	1.11	2.97	1.14	0.880
19	Signage is easy for wayfinding than a cell phone.	1	5	3.02	1.15	3.35	1.09	0.055
20	I usually tell directions to new visitors.	1	5	3.01	1.06	3.79	1.07	**0.000****
21	The campus is too complex.	1	5	2.82	1.17	2.97	1.28	0.440
23	Signage should follow the university theme.	1	5	3.14	1.14	3.19	1.23	0.760
27	Colour coded information Should be available.	1	5	3.42	1.17	3.77	1.11	0.058
28	Dual language signages are confusing.	1	5	2.70	1.23	3.14	1.16	**0.020***
29	Signage should always have pictograms.	1	5	3.25	1.11	3.68	1.11	**0.013***
30	Pictograms/symbols are easy to understand.	1	5	3.24	1.14	3.78	1.22	**0.002****

***p < 0.05 for Mann-Whitney U Test** ****Significant value after Bonferroni's correction**

Multi-story building structures with scattered and less concentrated visual access have resulted in a low level of legibility in the environment. The individuals from Pakistan thought it was easier to get information from environmental cues than the individuals from Hong Kong. Both institutions make use of standardized wayfinding signage that includes bilingual information.

As shown in Table 4.3 and Figure 4.1, Pakistani participants recognized the number of details as an issue in information visibility, access, and understanding, but Hong Kong participants did not (p = 0.004). Respondents from Pakistan prefer bilingual signage with graphical information over those from Hong Kong. The difference in opinions was significant for Q28, Q29, and Q30, with p values of 0.020, 0.013, and 0.002.

Another difference in navigational behaviour between the two cultural groups is the reliance on verbal information when asking for directions. Despite signage information, Pakistanis felt more at ease and depended on verbal guidance more than the other cultural group. When compared to Hong Kong, social engagement is stronger in Pakistani society. Because of a lack of social contacts, people in Hong Kong are more hesitant to ask for directions and instead try to handle their wayfinding issues independently, as shown by the mean comparison of Q9 (Hong Kong, 2.85; Pakistan, 3.45) having the p = 0.001.

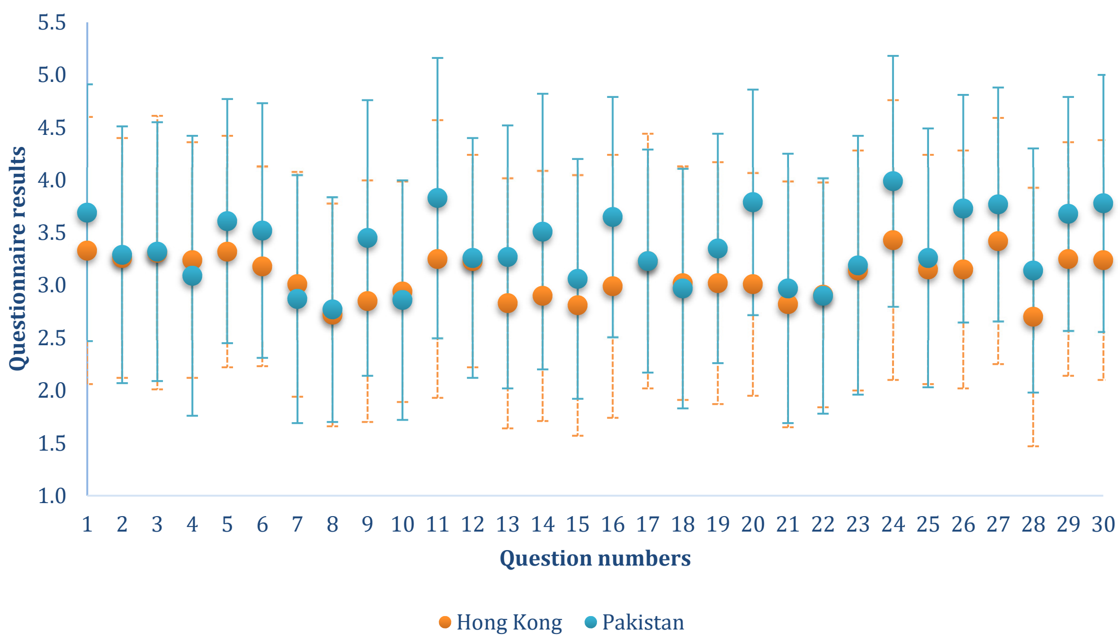


Figure 4.1 Simple statistics of cultural groups

This self-reliance behaviour is relatively common in individualistic societies with low context (Hall and Mildred, 1990), whereas the other group is considered a collectivist society. In contrast to a study (Hofstede, Hofstede and Minkov, 2010) and the cultural model depicted by the mentioned author, our study has enunciated high cultural differences between Hong Kong and Pakistan. As per our findings and study (Wong, 2001), the participants from Hong Kong showed the behaviour which is quite close to the individualistic society in contrast with the cultural model presented by hofstede insights (Hofstede, 2022). In a comparative investigation, the nomenclature of this segregation (individualistic and collectivist society) was also shown to be operative (Asghar, Torrens and Harland, 2019). Comparing the Mean values of both cultural groups also revealed that Pakistani participants have a far greater level of environmental familiarity due to adequate environmental knowledge via information signage and verbal guidance. The other cultural group is relatively comfortable giving directions, socially contributing to lessening wayfinding challenges.

As a result, the necessity for wayfinding signage is critical for Hong Kong participants, as they cannot recognize and memorize the chosen locations inside the campus due to the complicated spatial layout and the scattered and multi-story building accesses. These findings are evident when comparing the mean and standard deviation of Q13 and Q14, respectively. The cultural differences in wayfinding behaviour were seen in the results. Both groups differ in their understanding of the information and their perceptions of the campus's physical environment.

4.3.3 ENVIRONMENTAL FAMILIARITY

The familiarity with the environment played an impacting role in this study, validating the prior studies (Benthorn and Frantzich, 1999; Chang, 2013) established on similar findings. The participants were divided into two groups for this study, one with a high degree of familiarity with the environment and the other with a low degree of familiarity with the environment. Participants were asked to identify several locations on their campus. They have been assigned to the appropriate group for further study based on the information provided. A low degree of environmental familiarity was observed in 39 percent of individuals, whereas a higher degree of familiarity was identified in 61 percent.

Table 4.4 Comparison of Environmental Familiarity (EF) level

Q no.	**Question Description**			**HONG KONG**		**PAKISTAN**		***p*-value**
		Min	*Max*	*Mean*	*S.D.*	*Mean*	*S.D.*	
	Wayfinding Problems							
	Difficulty							
1	Campus wayfinding was difficult in starting.	1	5	3.33	1.27	3.69	1.22	0.074
2	In the beginning, I was disoriented on campus.	1	5	3.26	1.14	3.29	1.22	0.805
3	I always find my way through signage.	1	5	3.31	1.30	3.32	1.23	0.999
	Information Comprehension							
6	Signage information is easy to understand.	1	5	3.06	0.94	3.51	1.15	**0.000**[**]

Q no.	Question Description			HONG KONG		PAKISTAN		*p*-value
		Min	*Max*	*Mean*	*S.D.*	*Mean*	*S.D.*	
7	Campus signs are misleading sometimes.	1	5	3.01	1.12	2.90	1.12	0.332
8	Campus signs are difficult to read.	1	5	2.75	1.09	2.74	1.05	0.436
10	Campus planning is very complex.	1	5	2.97	1.09	2.85	1.10	0.504
12	Signage is noticeable on campus.	1	5	3.18	1.04	3.28	1.09	0.673
17	I have seen many disoriented visitors.	1	5	2.97	1.09	3.40	1.15	**0.012***[*]
	Information Design							
22	I always tell directions through signage.	1	5	2.82	1.07	2.96	1.10	0.814
24	Signage should be simple and minimal.	1	5	3.43	1.32	3.84	1.26	**0.012**[**]
25	Signage information should be detailed.	1	5	3.00	1.13	3.33	1.16	**0.029**[*]
26	Signage design should represent the institute.	1	5	3.15	1.13	3.58	1.12	0.104
	Wayfinding Behaviour							
	Information Gathering							
4	Signage information is helpful.	1	5	3.27	1.08	3.11	1.30	0.520
5	Need to memorise the locations.	1	5	3.36	1.16	3.51	1.12	0.198
9	I ask directions from a passer-by.	1	5	2.90	1.21	3.27	1.28	0.137
11	Can find a destination without signage.	1	5	3.06	1.31	3.81	1.31	**0.000**[**]
13	Signage information is only for a freshman.	1	5	2.66	1.15	3.27	1.23	**0.007**[**]
14	Familiar with campus planning.	1	5	2.67	1.20	3.50	1.23	**0.000**[**]
15	Prefer verbal directions for wayfinding.	1	5	2.63	1.23	3.12	1.15	**0.009**[*]
16	Spatially quite familiar.	1	5	2.72	1.14	3.66	1.17	**0.000**[**]
	Information Preference							
18	People use mobile devices for wayfinding.	1	5	2.96	1.15	3.03	1.11	0.994
19	Signage is easy for wayfinding than a cell phone.	1	5	2.78	1.04	3.43	1.12	**0.000**[**]
20	I usually tell directions to new visitors.	1	5	2.94	1.07	3.64	1.08	**0.000**[**]
21	The campus is too complex.	1	5	2.94	1.27	2.85	1.19	0.270
23	Signage should follow the university theme.	1	5	3.03	1.18	3.25	1.17	0.559
27	Colour coded information Should be available.	1	5	3.37	1.17	3.71	1.13	0.080
28	Dual language signages are confusing.	1	5	2.78	1.17	2.98	1.24	0.653
29	Signage should always have pictograms.	1	5	3.13	1.14	3.64	1.07	**0.002**[**]
30	Pictograms/symbols are easy to understand.	1	5	3.19	1.21	3.67	1.17	**0.008**[*]

***p < 0.05 for Mann-Whitney U Test** ****Significant value after Bonferroni's correction**

The participants from Hong Kong were having a low level of familiarity compared to participants from Pakistan, having 51% and 25%, respectively. 75% of the participants from Pakistan were placed in the category of high familiarity compared to Hong Kong participants that are 49%. The segregation of groups identified the more excellent value of environmental legibility in the institution situated in Pakistan than in Hong Kong. This inference is made because most respondents (92%) of this survey are current students of the respective institution in Pakistan and Hong Kong.

The Mann Whitney U test was used for statistical analysis to analyse answers based on the level of environmental familiarity since the groups were taken as two independent samples. Statistical analysis enunciated some interesting insights regarding the impact and influences of environmental familiarity on wayfinding behaviour and human perception concerning information gathering. As shown in Table 4.4, many statistically significant answers have been collected regarding environmental information comprehension. The difference in mean values of Q6 (Low, 3.06; High, 3.51) with $p = 0.000$ has shown that individuals with low spatial familiarity had difficulty interpreting environmental information. This issue significantly influences their ability to comprehend the spatial environment, reducing their confidence in locating the desired destination. As a result, as the mean values of responses Q11 revealed, participants from both groups must rely on information cues for directed navigation tasks, i.e. (Low, 3.06; High, 3.81). This result contradicts the research (MacEachren, 1992) that found that environmental information is only helpful for freshmen and newcomers to the institution.

If the environmental settings are quite complex with a low level of environmental legibility, people need to rely more on the information cues than their memory and cognition. The reliability of memory for identifying a destination can only be instrumental once a certain level of familiarity is achieved, as found in the previous studies (Evans and Pezdek, 1980; Garling and Golledge, 1989). Despite their lack of environmental knowledge, the participants prefer not to ask for directions verbally when it comes to guided navigation. Participants with a high level of Environmental Familiarity, on the other hand, are more comfortable creating social contact and inquiring about an unknown destination from a passer-by. Participants have responded favourably to the existence of navigation challenges on their respective campuses, despite being familiar with the setting. These results might also indicate that the lack of differentiating spatial features and landmarks makes it harder to memorize the spatial environment. As a result, although having a substantial difference in behaviour with a competitive group ($p = 0.000$), the group with high EF did not respond significantly in favour of thoroughly understanding and memorizing the surroundings as reflected by their mean values for Q16 (Low EF, 2.72; high EF, 3.66).

Being a source of information, mobile devices also proved to be influential in providing wayfinding directions, especially for participants with low EF. Participants with low EF found it difficult to comprehend their directions on mobile devices, including interactive maps and

YAH (you are here) maps. Due to the availability of relevant cognitive mapping and memory nodes, individuals with high EF may easily interpret the information on these devices, as demonstrated by the p = 0.000 for Q19.

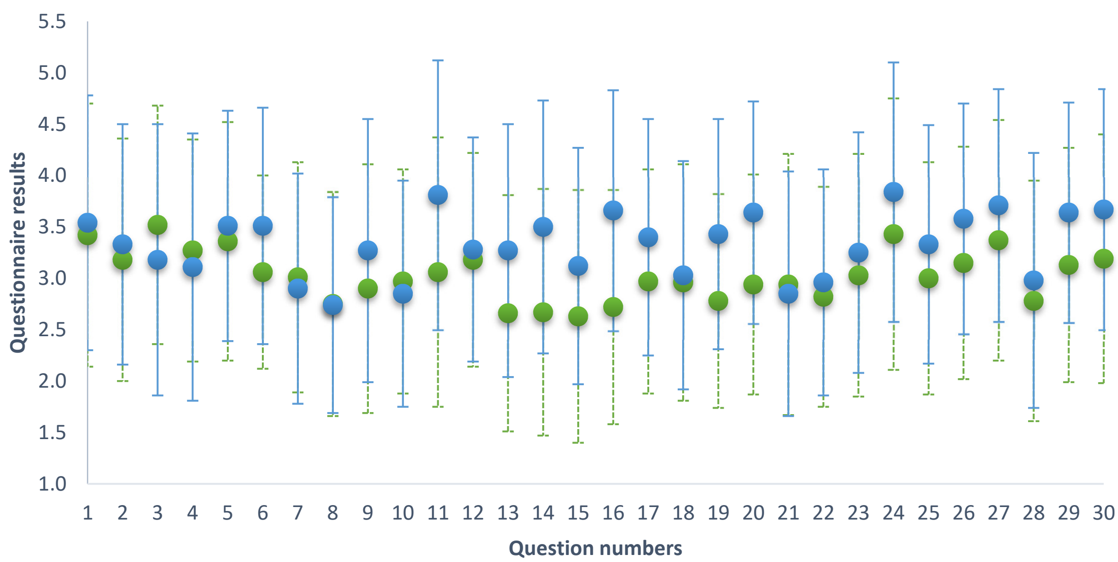


Figure 4.2 Simple statistics of Environment Familiarity (EF) level

In terms of the data, there have been inconsistencies in the minimal and detailed information on environmental wayfinding cues, as illustrated in Figure 4.2, particularly in the last questions, i.e., Q30. The low EF participants preferred detailed information presence (multilingual, pictograms, and symbols), whereas the other group supported limited information presence on environmental cues. Participants reported significant variations in the volume of information for Q24, Q29, and Q30, with p-values of 0.017, 0.002, and 0.008, respectively. Individuals with a high EF preferred graphical information (pictograms and symbols) because it is regarded as simple to understand. On the other hand, the other group preferred extensive information in the form of multilingual signage and graphical information.

4.3.4 INDIVIDUAL DIFFERENCES

In the demographic section, the respondents were asked about their gender to explore and validate the findings of previous studies. The Man Whitney U test was used for the group based on these two independent samples, and it was divided into two groups based on gender segregation. Table 4.5 and Figure 4.3 show some of the significant inconsistencies that were investigated.

The survey discovered that female respondents had thought about concerns related to navigation on the university campus. The information on the signage was confusing and difficult to understand, making it difficult for them to find information about their destination. On the other hand, Males have had fewer issues with campus navigation; yet, they have found environmental information to be challenging to comprehend. Significant p-values (0.020, 0.002, and 0.017) have been observed concerning the issues mentioned above.

Table 4.5 Comparison of gender

Q no.	**Question Description**			**HONG KONG**		**PAKISTAN**		***p*-value**
		Min	*Max*	*Mean*	*S.D.*	*Mean*	*S.D.*	
	Wayfinding Problems							
	Difficulty							
1	Campus wayfinding was difficult in starting.	1	5	3.19	1.31	3.75	1.15	**0.016****
2	In the beginning, I was disoriented on campus.	1	5	3.04	1.16	3.47	1.16	0.064
3	I always find my way through signage.	1	5	3.24	1.22	3.38	1.31	0.535
	Information Comprehension							
6	Signage information is easy to understand.	1	5	3.38	1.11	3.29	1.07	0.194
7	Campus signs are misleading sometimes.	1	5	2.73	1.10	3.13	1.11	**0.002****
8	Campus signs are difficult to read.	1	5	2.62	1.06	2.85	1.06	**0.017***
10	Campus planning is very complex.	1	5	2.78	1.18	3.00	1.01	0.134
12	Signage is noticeable on campus.	1	5	3.24	1.10	3.24	1.05	0.807
17	I have seen many disoriented visitors.	1	5	3.13	1.19	3.32	1.10	0.425
	Information Design							
22	I always tell directions through signage.	1	5	2.91	1.16	2.90	1.03	0.437
24	Signage should be simple and minimal.	1	5	3.60	1.34	3.75	1.25	0.335
25	Signage information should be detailed.	1	5	3.22	1.20	3.18	1.12	0.690
26	Signage design should represent the institute.	1	5	3.33	1.12	3.48	1.16	0.482
	Wayfinding Behaviour							
	Information Gathering							
4	Signage information is helpful.	1	5	3.17	1.13	3.17	1.29	0.687
5	Need to memorise the locations.	1	5	3.40	1.10	3.50	1.17	0.213
9	I ask directions from a passer-by.	1	5	2.78	1.19	3.41	1.25	**0.001****
11	Can find a destination without signage.	1	5	3.28	1.41	3.71	1.28	**0.045***
13	Signage information is only for a freshman.	1	5	2.99	1.26	3.07	1.21	0.418
14	Familiar with campus planning.	1	5	3.04	1.28	3.29	1.27	0.147
15	Prefer verbal directions for wayfinding.	1	5	2.88	1.23	2.96	1.19	0.801
16	Spatially quite familiar.	1	5	3.12	1.26	3.43	1.22	0.089
	Information Preference							
18	People use mobile devices for wayfinding.	1	5	2.87	1.12	3.11	1.11	0.312
19	Signage is easy for wayfinding than a cell phone.	1	5	2.99	1.18	3.33	1.07	0.245

Q no.	**Question Description**			**HONG KONG**		**PAKISTAN**		***p*-value**
		Min	*Max*	*Mean*	*S.D.*	*Mean*	*S.D.*	
20	I usually tell directions to new visitors.	1	5	3.15	1.15	3.54	1.08	**0.046***
21	The campus is too complex.	1	5	2.90	1.21	2.88	1.23	0.826
23	Signage should follow the university theme.	1	5	3.21	1.26	3.13	1.10	0.532
27	Colour coded information Should be available.	1	5	3.49	1.22	3.65	1.09	0.857
28	Dual language signages are confusing.	1	5	2.82	1.21	2.97	1.22	0.583
29	Signage should always have pictograms.	1	5	3.37	1.13	3.50	1.12	0.302
30	Pictograms/symbols are easy to understand.	1	5	3.41	1.28	3.54	1.13	0.350

***p < 0.05 for Mann-Whitney U Test** ****Significant value after Bonferroni's correction**

According to our findings, females are more socially engaged than males when asking and giving directions to passers-by. This behaviour has developed a strong sense of environmental knowledge in them, due to which they feel quite confident in finding out their respective destination without relying on environmental information. We can speculate from the findings that women tend to find their way through memory recall instead of putting the load on their cognition by getting wayfinding information from signage. Other than these interesting insights, no significant difference in behaviour has been recorded for the rest of the wayfinding questions.

The collected data was divided into four age groups with a five-year gap between them to investigate further the effects of age differences on wayfinding behaviour, ranging from 18 to 37 years. The final two groups (28-32, 33-37) were combined with preserving the statistical analysis' credibility due to the reduced number of participants. The first two categories constitute most of the responses, with 40% and 41%, respectively.

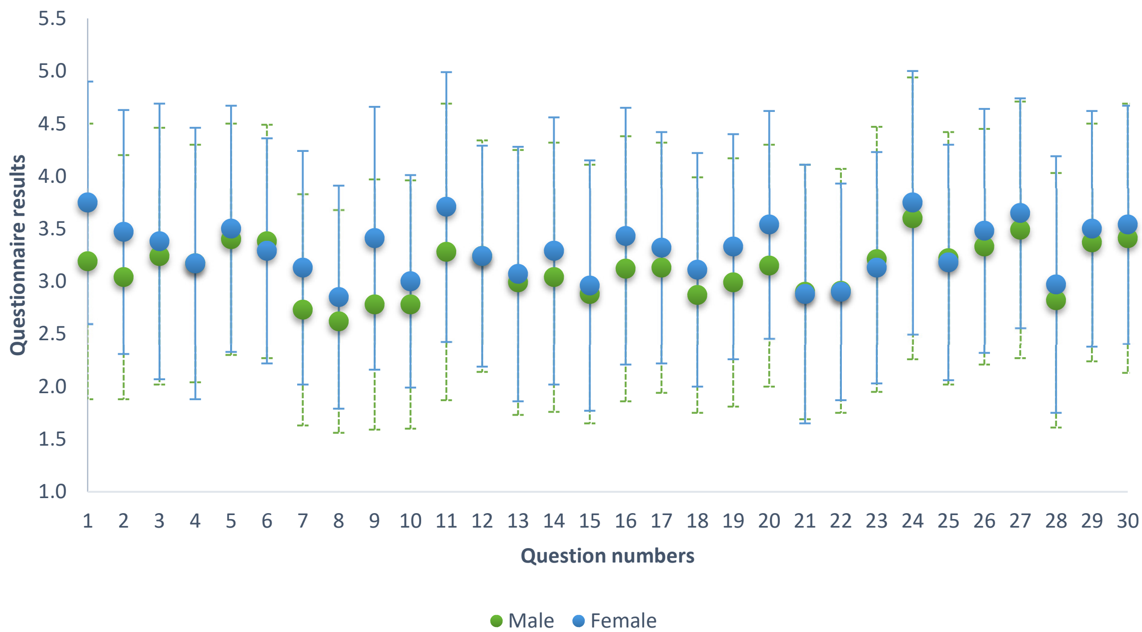


Figure 4.3 Simple statistics of gender

The Kruskal Wallis test was chosen to analyse this non-parametric ordinal data since three independent samples were in this group (Corder and Foreman, 2009). According to the survey results, there were no significant discrepancies in campus navigation behaviour among respondents of various ages. The finding was considered quite contrasting to the studies (Head and Isom, 2010), where age substantially impacted cognitive behaviour and spatial memory. The narrower age gap (5 years) between the age groups is most likely the cause of this finding. Prior studies (Davis and Therrien, 2012; Hidayetoglu, Yildirim and Akalin, 2012) have indicated the age-related differences in wayfinding behaviour; however, the age groups were distant from each other, e.g. children and older adults.

Aside from age differences, another variable that influenced the outcome was the educational background. The information obtained was divided into two categories:

undergraduates and postgraduates and above. Both categories have almost the same number of participants. The Man Whitney U test was chosen for statistical analysis since there were two independent group samples. In most of the questions on wayfinding behaviour, the effect of education has not been significant enough. Some insights, on the other hand, may delve deeper into their behaviour.

Compared to the first group, the higher education group has shown a substantial interest in seeking out wayfinding information in the spatial environment while considering spatial planning complicated. The p-values for both questions on information searching and complex spatial planning were 0.007 and 0.012, respectively, in the two groups. The findings for the remaining questions did not indicate any significant results.

As per our study, we can infer from this finding that the level of education might not be that influential in wayfinding behaviour. Alternatively, else we can assume that the level of education was not distinctive enough to influence the wayfinding skills. Similar research can be performed in the complex university environment with a more significant difference in education amongst the participants for future studies. Regarding the complex environment of university settings, the expected visitors may or may not have much difference in education that can further challenge the need for such research.

4.3.5 CORRELATION ANALYSIS

The gathered data was analysed for correlation using Kendall tau's correlation test, as shown in Table 4.6, for further study. The correlation test revealed some interesting information on institutional wayfinding based on users' behaviour, perception, and preferences. Wayfinding signage has been a cause of concern for the responders since it may be misleading at times. The signage is difficult to see and comprehend, identified as the primary source of misinformation. The strong correlation coefficient for Q7 and Q8 (0.598) indicates that when the environmental settings and layout planning are complicated, signage legibility suffers. The correlation coefficient of Q10 (0.401) with Q8, where the relationship is related to spatial complexity, supports this conclusion.

The location of signage and the interaction of visitors with it has also been proven to have a strong relationship. We may conclude from this that signage placement and visibility are unlikely to be the source of campus disorientation. People tend to use other sources of environmental knowledge, such as mobile phones, due to the insufficiency of available information on signage, as expressed by respondents in the correlation between Q17 and Q12, Q18 and Q12, where people tend to use other sources of environmental knowledge, such as mobile phones.

However, due to the absence of correlation between the map and the real environment, mobile devices are insufficiently useful for wayfinders. Individuals also ask passers-by for directions to gather environmental knowledge and feel confident enough to give instructions once they have a suitable degree of information. This conclusion was drawn from the correlations of Q20 with Q9, Q11, Q14, Q15, Q16, Q17, and Q19, which further indicated the navigators' professional time loss and the inadequate information delivery of campus signage.

The participants indicated that the information design on signage should be consistent and relevant with the institution theme along with the specific and thorough information. Because the standardised designs for campus wayfinding signage may not accomplish their fundamental purpose, colour coding the relevant information may be more beneficial. If the signage is designed according to the amount of environmental complexity, the institution's main colour, including primary and helpful information using pictograms and symbols, should be more legible.

Table 4.6 Kendall tau's correlation test

Sr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.000
2	**0.610****
3	0.369**	0.325**
4	0.207**	0.270**	0.507**
5	0.312**	0.268**	0.142*	0.165**
6	0.174**	0.097	0.273**	0.321**	0.163**
7	0.275**	0.299**	0.299**	0.254**	0.233**	-0.037
8	0.248**	0.277**	0.160**	0.093	0.271**	-0.142*	**0.598****
9	0.282**	0.279**	0.195**	0.098	0.187**	0.136*	0.263**	0.257**
10	0.290**	0.328**	0.177**	0.154**	0.272**	-0.017	**0.379****	**0.401****	0.273**
11	0.333**	0.268**	0.081	0.025	0.315**	0.272**	0.093	0.081	0.329**	0.134*
12	0.153**	0.126*	0.243**	0.319**	0.172**	0.413**	0.117*	-0.029	0.109	0.066	0.280**
13	0.171**	0.085	0.042	0.036	0.201**	0.177**	0.066	0.109	0.189**	0.102	**0.351****	0.208**
14	0.130*	0.100	-0.104	-0.095	0.226**	0.172**	0.078	0.181**	0.294**	0.085	**0.476****	0.163**	0.504**
15	0.096	0.038	-0.029	0.042	0.144*	0.143*	0.055	0.071	0.346**	0.123*	0.251**	0.177**	0.148**	0.265**
16	0.141*	0.068	-0.033	-0.060	0.281**	0.222**	0.012	0.060	0.178**	0.018	**0.459****	0.208**	0.440**	**0.559****	0.233**
17	0.206**	0.128*	0.244**	0.273**	0.296**	0.199**	0.244**	0.163**	0.160**	0.167**	0.261**	**0.354****	0.261**	0.169**	0.207**	0.260**
18	0.162**	0.096	0.225**	0.215**	0.222**	0.152**	0.275**	0.212**	0.123*	0.240**	0.139*	**0.326****	0.194**	0.154**	0.133*	0.113	**0.412****
19	0.185**	0.140*	0.142*	0.157**	0.152**	0.247**	0.208**	0.169**	0.157**	0.190**	0.264**	0.269**	0.230**	0.231**	0.152**	0.257**	0.277**	0.322**
20	0.274**	0.218**	0.054	0.017	0.239**	0.168**	0.188**	0.175**	**0.411****	0.258**	**0.452****	0.185**	0.289**	**0.357****	**0.316****	**0.402****	**0.328****	0.222**	**0.390****
21	**0.331****	**0.302****	0.252**	0.198**	0.110	0.028	0.289**	0.256**	0.229**	**0.391****	0.081	0.155**	0.114*	0.088	0.130*	-0.039	0.162**	**0.344****	0.168**	0.174**
22	0.127*	0.136*	0.262**	0.290**	0.026	0.169**	0.202**	0.158**	0.119*	0.170**	0.077	**0.366****	0.225**	0.104	0.155**	0.083	0.228**	**0.326****	**0.331****	0.146*	0.259**
23	0.147*	0.119*	0.117*	0.158**	0.149**	0.182**	0.163**	0.150**	0.099	0.149*	0.193**	0.207**	0.207**	0.270**	0.108	0.226**	0.244**	**0.295****	0.297**	0.232**	0.268**	0.259**
24	0.298**	0.134*	0.214**	0.199**	0.293**	0.253**	0.130*	0.134*	0.246**	0.150**	**0.360****	0.226**	**0.349****	0.293**	0.228**	**0.336****	0.251**	0.238**	0.265**	**0.364****	0.187**	0.183**	**0.305****
25	0.186**	0.185**	0.159**	0.287**	0.224**	0.255**	0.158**	0.142*	0.137*	0.165**	**0.291****	0.272**	0.258**	0.265**	0.243**	0.282**	**0.305****	0.264**	**0.326****	0.225**	0.175**	0.219**	**0.439****	**0.420****
26	0.249**	0.119*	0.117*	0.144*	0.264**	0.215**	0.191**	0.156**	0.165**	0.130*	0.267**	0.231**	**0.301****	**0.327****	0.203**	**0.355****	**0.320****	**0.349****	0.239**	**0.362****	0.199**	0.213**	**0.474****	**0.490****	**0.397****
27	0.220**	0.160**	0.216**	0.215**	**0.317****	0.223**	0.246**	0.210**	0.202**	0.171**	**0.334****	0.269**	0.281**	**0.325****	0.221**	**0.351****	**0.332****	**0.324****	**0.309****	**0.366****	0.236**	0.203**	**0.387****	**0.545****	**0.377****	**0.479****
28	0.128*	0.072	0.076	0.072	0.052	0.207**	0.168**	0.105	0.143*	0.128*	0.177**	0.212**	0.269**	0.252**	0.122*	0.104	0.103	0.209**	0.257**	0.246**	**0.298****	0.222**	**0.338****	0.173**	0.228**	0.271**	0.157**
29	0.246**	0.173**	0.217**	**0.309****	0.270**	0.208**	0.258**	0.203**	0.274**	0.222**	**0.301****	0.246**	0.240**	0.277**	0.254**	0.262**	0.325**	**0.300****	**0.323****	**0.350****	0.277**	0.180**	0.284**	0.472**	**0.311****	**0.393****	**0.536****	0.257**
30	0.242**	0.170**	0.180**	0.241**	0.223**	0.166**	0.254**	0.185**	0.281**	0.206**	0.285**	0.159**	0.285**	0.293**	0.260**	0.242**	0.282**	0.227**	**0.295****	**0.359****	**0.300****	0.136*	0.238**	**0.530****	**0.312****	**0.357****	**0.492****	0.251**	**0.724****	1.000

**** Correlation is significant at the 0.01 level (2-tailed)** *** Correlation is significant at the 0.05 level (2-tailed)**

4.4 DISCUSSION & FINDINGS

The conducted mixed-method study concerning the wayfinding behaviour in complex environmental settings has provided interesting findings as directed by research question 1 with subsequent research questions. Two different cultural groups were selected to analyse cultural and complex environmental impacts on human cognition. The selected groups were rarely selected in the previous studies for such kind of research. The participants from Hong Kong and Pakistan have been inducted into the research due to their respective differences in cultural backgrounds, as the culture can be defined based on nationalities (Bluszcz and Quan, 2016). The participants from Hong Kong can be considered as an individualistic society due to the strong influence of British ruling until the late nineties.

On the other hand, the respondents from Pakistan are from a collectivist society as they have a strong culture of social relationships (Asghar, Torrens and Harland, 2019). The two cultural groups were analysed to explore the cultural influences on wayfinding behaviour, especially when the environment is complex in layout and planning. University settings from both countries have been chosen due to the higher capacity of attracting new students and visitors every year, raising the issues in wayfinding. For the respective study, a questionnaire has been developed based on the five-point bipolar scale to record the responses from concerned participants. The questions were based on experiencing different wayfinding problems and ascribed behaviour.

Interesting insights on the nature of the wayfinding challenge regarding information gathering, understanding, and information dependence for directed wayfinding tasks have been gathered for the cultural aspects. Participants from collectivist societies encountered some navigational issues on campus, but they attempted to overcome this by relying on their social interactions for verbal wayfinding information. In keeping with the earlier study, social interactions were found to impact wayfinding behaviour and performance (Hund, Schmettow and Noordzij, 2012). The group mentioned above preferred simple and easy to understand information sources. On the other hand, individualistic cultures rely more on themselves for obtaining and deciphering information due to a reluctance to engage in social relations. As a result, environmental familiarity is challenging to achieve, necessitating specific spatial layout information. The probable cause of this behavioural difference can be uncertainty avoidance as mentioned by hofstede insights. The participants from Hong Kong preferred the information gathering while maintaining the initial aim of the wayfinding task. Whereas, the participants from Pakistan relied more on the information gathered by the passer-by and producing less focus on finding the required information by themselves.

Despite the cultural difference, most participants have identified the complex spatial planning responsible for wayfinding problems. The participants have been segregated into two groups based on their level of environmental familiarity from this exploration. The results have reflected that environmental familiarity, even in complex settings, can heavily affect the wayfinding behaviour as appeared in the previous studies (Sholl, Kenny and DellaPorta, 2006; Li and Klippel, 2012). Participants with a low level of environmental knowledge had a difficult time getting around the campus. Because of the low level of knowledge in their heads, the group must rely on signage information rather than memorizing spatial features such as landmarks or path integration. While having difficulty comprehending the information, the group has experienced increased frustration, time loss, and confusion. Like the study (Cheung, 2006), the campus environment has been characterized as hard to get familiar with and legible due to reduced exposure to the surrounding environment, complicated spatial planning, and diffused spaces.

The participants were separated by gender for further investigation of wayfinding behaviour due to individual differences. Gender differences have already been highlighted as a potentially relevant element in prior research (Gagnon *et al.*, 2018). Females had more difficulty finding their way about campus in this study due to a lack of understanding of signage information. To address the issue mentioned above, female participants relied more on verbal directions than on designated cues to obtain information. By considering the environmental information misleading, a significant gender difference was observed for Q7 ($p = 0.002$). Males, on the other hand, outperformed females in the understanding of signage information. As a result, they had fewer difficulties finding their way around than females. According to the literature, the age difference has been acknowledged as another variable affecting individual differences. To assess the differences in behaviour, the participants were divided into four age groups. There were no apparent differences in behaviour across the age groups in this investigation. The shorter age difference between the groups may have contributed to this observation. In previous research (Taillade *et al.*, 2013; Lee *et al.*, 2014), the age gaps between the participants were more significant enough (> 15 years) to identify the difference. The age gap selected for this study was kept minimum due to the average age of the university student and visitor. The average age for university students lies between 18 years to 25 years. For the individual differences, the next factor of influence considered was the level of education (Morley and Cobbett, 1997). The participants were grouped into two groups based on their provided education level. For this individual difference, the results were quite like the previous factor. No significant insights into the wayfinding behaviour were observed for the difference in the level of education, possibly due to the minute influence of such difference.

Certain limitations identified in the study above that restricts the generalizability of the current findings. There were many university students in the sample population, but there was a lot fewer ordinary visitor. The findings can apply to newcomers to the mentioned places, although the results may have some limitations for general tourists. Furthermore, different navigational behaviour might be confounded by spatial planning and layout. Both institutions are located in the highly populated central regions of the city; but, due to the presence of high-rise structures and multilevel access to the buildings and their facilities, the spatial layout of the university in Hong Kong is regarded as more complex. Another issue is that the university in Hong Kong has a larger crowd than the institution in Pakistan. As a result of this, navigational behaviour may be compromised, as visual access and comprehension of information may be hindered. Further research will utilize fully immersive computer simulations to examine the navigator's natural behaviour during wayfinding to minimize confusing variables.

4.5 CONCLUSIONS

The primary objective was to explore the effects of cultural and individual-related differences in navigation behaviour among university campus navigators to eliminate wayfinding issues. The goal was to identify probable causes for wayfinding issues and reasons of disorientation during navigation inside the university campus while treating it as a complex environment. Furthermore, the finding has the potential to improve the efficiency of campus navigation for newcomers and general visitors, reducing time losses, self-disorientation, and frustration. Because this is an exploratory study, specific factors for wayfinding issues were defined in the literature review and provided before the survey was conducted. Complex spatial planning, cultural differences, level of environmental familiarity, gender, age, and level of education were all found as influential factors. Cultural differences have been found as a crucial element in the various cultures' wayfinding behaviour.

Two groups were developed for the mentioned exploration because the participants from Hong Kong and Pakistan came from distinct cultures. Several cross-cultural differences in the gathering of environmental information, signage implications, and environmental familiarity have been observed. Despite being familiar with the environment, the participants from Hong Kong relied more on spatial information provided by signage than the other cultural groups. As they were classified as collectivists, the Pakistani participants deciphered environmental knowledge through verbal communication as well as signage information. Wayfinding behaviour is significantly influenced by spatial familiarity. However, no significant findings have been found for age or education level. Participants who were familiar with the environment relied on their cognitive memory for navigation rather than signage information.

Furthermore, it has been discovered that when the spatial layout is more complicated, it is more difficult for participants to memorize the entire environment. A consistent signage design with suitable colour coding is essential for the complex university setting while yet distinguishing out enough from the surroundings. An effective signage system should be established based on culturally consistent pictograms and symbols to direct navigators to their desired path. Furthermore, the gender difference had a minor impact on the behaviour. Potential limitations to the generalizability of the findings mentioned above are explored in the next section. Certain factors, including but not limited to spatial layout complexity, crowd effect, and environmental information via signage, are confounding in wayfinding research. By limiting the aspects mentioned above, it is suggested that future research be conducted utilizing immersive virtual worlds and computer simulations to build the framework for effective signage, culturally consistent pictograms, and symbols.

In the next chapter, another study has been planned to investigate the users' design preferences and visual understanding of the signage and its provided information. The current study has suggested a significant influence of individual-related differences including culture, gender and level of familiarity with the environment. This further suggests that a detailed investigation is required to understand the role of visual elements of wayfinding design and how users perceived the information from static sources like signage, maps and wayfinding kiosks. The next study investigated user preferences through an online study from more than 160 participants.

CHAPTER 5: STUDY 2 - SIGNAGE DESIGN PREFERENCE & VISUAL UNDERSTANDING

A research article has been published from this study, *Iftikhar, H., Asghar, S., & Luximon, Y. (2020). A Cross-Cultural Investigation of Design and Visual Preference of Signage Information from Hong Kong and Pakistan, The Journal of Navigation, 0:0 1–19, DOI:10.1017/S0373463320000521*

5.1 CHAPTER HIGHLIGHTS

Research questions 2 and 3 have been designed to investigate the user preferences regarding static wayfinding information.

Research Question 2: What is the user's preference regarding static wayfinding information?
Research Question 3: What is the user's preference regarding the style and volume of information?

In addition to that, how users perceive the design and volume of information in the static wayfinding aids. As previous studies indicated significant cultural and individual-related differences in wayfinding behaviour. This divergence in behaviour may be influenced by the varied perception and preference of wayfinding aids. Therefore, another study has been planned to explore the potential influencing factors for the said behaviour. This chapter presents the signage design preferences and visual understanding of the wayfinding information based on the data collected by the participants from Hong Kong and Pakistan. This research suggests that more cross-cultural research into aspects of signage design and visual perception is needed to identify potential barriers to culturally consistent university signage.

5.2 INTRODUCTION

Wayfinding has always been a valuable medium for communicating environmental information, and signage design has always been critical. Several elements, including the design of information signage and its perception, influence wayfinding behaviour in complex institutional environments. Depending on cultural and individual differences, visual perceptions and preferences of information design in wayfinding signage vary. This study aimed to see how cultural and individual differences affected people's visual perceptions and preferences for wayfinding signage and its elements. Participants from Hong Kong and Pakistan responded to an online questionnaire about their design preferences and visual perceptions of university wayfinding signage. Questions were asked on design consistency, information colour coding, and information volume. In total, 170 university students and visitors from the respective countries took part in the exploratory research. The statistical findings revealed significant cross-cultural differences in signage graphics preference and perception and information volume.

5.3 METHOD

The purpose of the research was to look at the cultural and individual implications on perception and preference in wayfinding signage design on a large university campus. Participants from Hong Kong and Pakistan performed an internet-based questionnaire as part of this project. A total of 170 students and visitors to the university campus took part in the survey and provided their opinions on wayfinding signage. The visuals of signage design have been designed and utilized to explore the user's perceptions and preferences depending on the required research variables. The questions on design preferences were asked by presenting four design visual options, followed by a question on the explanation for choice. The collected data were statistically analysed to see if there was a relationship between cultural and individual differences in preference and comprehension of wayfinding design. Before collecting data, ethical permission (APPENDIX I) was sought from the relevant institutions, and the necessary protocol was followed according to the specified recommendations.

5.3.1 QUESTIONNAIRE CONSTRUCTION

Table 5.1 Participant information in questionnaire construction

Information category	Questions
Demographic information	

Personal information	Place of birth Place of residence Native language Gender Age Literacy level

The purpose of this internet-based questionnaire is to acquire cross-cultural and individual-related information from participants. The demographic/personal information of the participants and their signage preferences were used to develop the questionnaire. The participants were questioned about demographics and personal information in the first segment (Table 5.1), as was done in previous research (Joy, Yien and Chen, 2016; Trisnawati and Sriwarno, 2018), in order to designate them as a specific group. To identify the participants as a distinct cultural group, questions regarding their birthplace, residence, and native language were asked. Based on the above-mentioned answers, participants were divided into two cultural groups: Hong Kong-China, and Pakistan. Participants in the Hong Kong (China) group have said that they were born and raised in Mainland China or Hong Kong and that their native languages were Cantonese or Mandarin. Participants who chose Pakistan as their birth and home country and Urdu as their first language were placed in the Pakistan group. The participants were also questioned about their gender, literacy level, and age to study individual differences in campus signage preferences.

Three questions on signage graphics are included in the next section of the online questionnaire, which explores the user's preference, suitability, and understanding of the signage design and content. The questions were created with design consistency, information colour coding, and the total volume of information in mind. As shown in Figure 5.1, the first signage question was designed to look at the role of consistency in wayfinding design and users' preferences for environmental information while on campus. The question was created to examine the potential effects of design inconsistency on user preference, as shown in earlier research (Rooke *et al.*, 2009; Leonard, Verster and Coetzee, 2014), where design consistency and standardisation were advised for improving wayfinding efficiency.

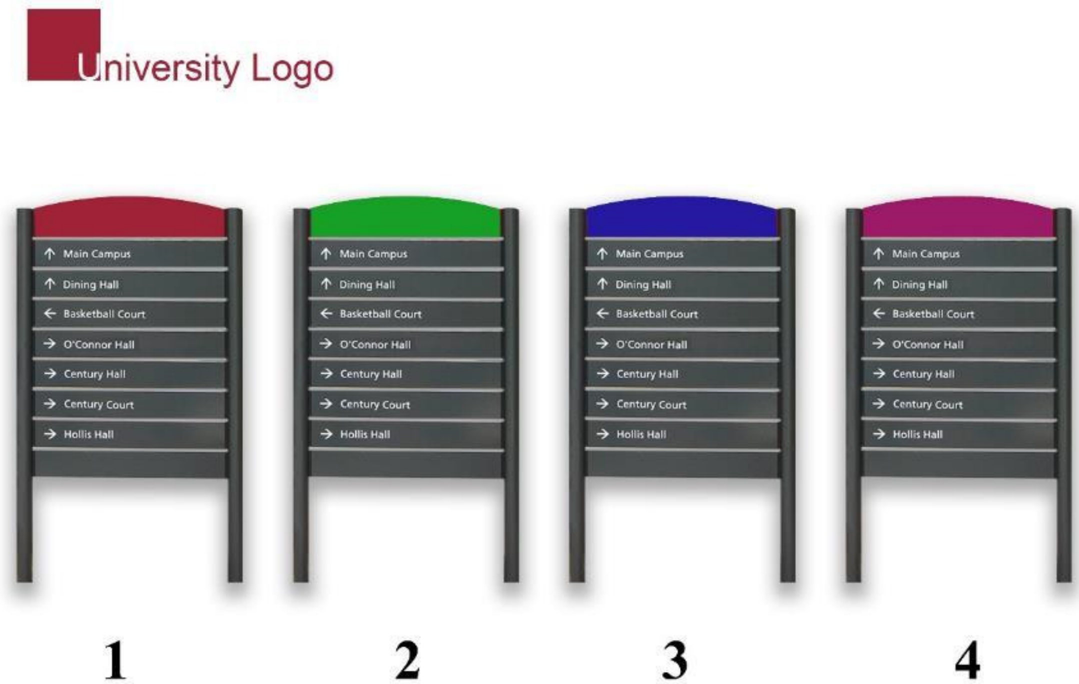


Figure 5.1 Signage design consistency

The four designs of signage in the first question (Figure 5.1) have been designed, each of which has an identical set of navigation information but differs in colour on the top plate. The first colour choice was chosen to match the institution's colour scheme, while the other three were chosen to match the signage colours found on various university campuses in Hong Kong and Pakistan. Various universities in Pakistan and Hong Kong have been searched and common colours have been added as the remaining three options. The participants were asked which colour signage would be appropriate for use at the institution, with the official colour specified in the institution logo.

The second question (Figure 5.2) investigated the impacts and effectiveness of colour coding in providing wayfinding information to the relevant people. The user's perception, attentiveness, and identification of necessary knowledge are all influenced by the colour-coded information. A study (Tzeng and Wang, 2011) investigated the effects of the factors mentioned above on human wayfinding performance, particularly in university libraries with large volumes of spatial information. The information was easier to read and recognize by the navigators; hence, the findings significantly impacted wayfinding performance.

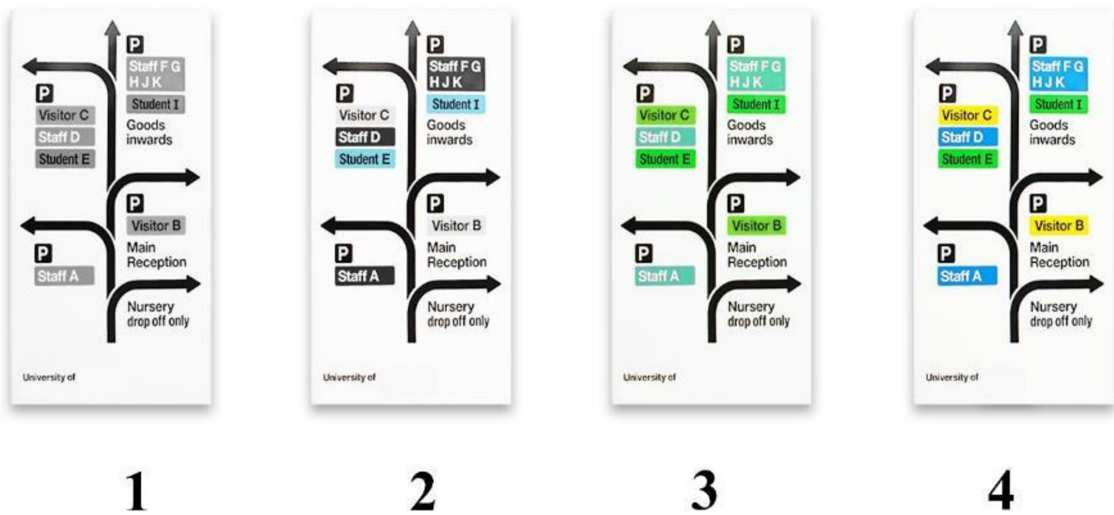


Figure 5.2 Colour coding in signage

On the contrary, the study (Delvin and Bernstein, 1997) has found that the use of colour coding in maps has little influence on wayfinding performance. To answer this question, four information graphics were created, as illustrated in Figure 5.2, ranging from greyscale or mono-colour coding to multi-colour coding for wayfinding information. All the design options have a similar level of information highlights but with a difference in the number of colours while coding. The maximum number of colours have been kept to three to avoid visual clutter. The respondents were surveyed on their preferences for the colour coding of signage to be installed on the university campus.

The third question (Figure 5.3) included four different types of signage graphics with varying information volumes due to the use of dual language and symbolic representation. Previous studies (Scialfa *et al.*, 2008; Joy, Yien and Chen, 2016) have advised reducing the number of words to provide more accurate and compelling information. Increased negative spaces for breathing space in design were also proposed to grab the user's attention and boost comprehension. Four signage designs with varying combinations of language and pictograms have been produced to investigate this user behaviour: dual language, single language, single language-pictogram, and dual language-pictogram.

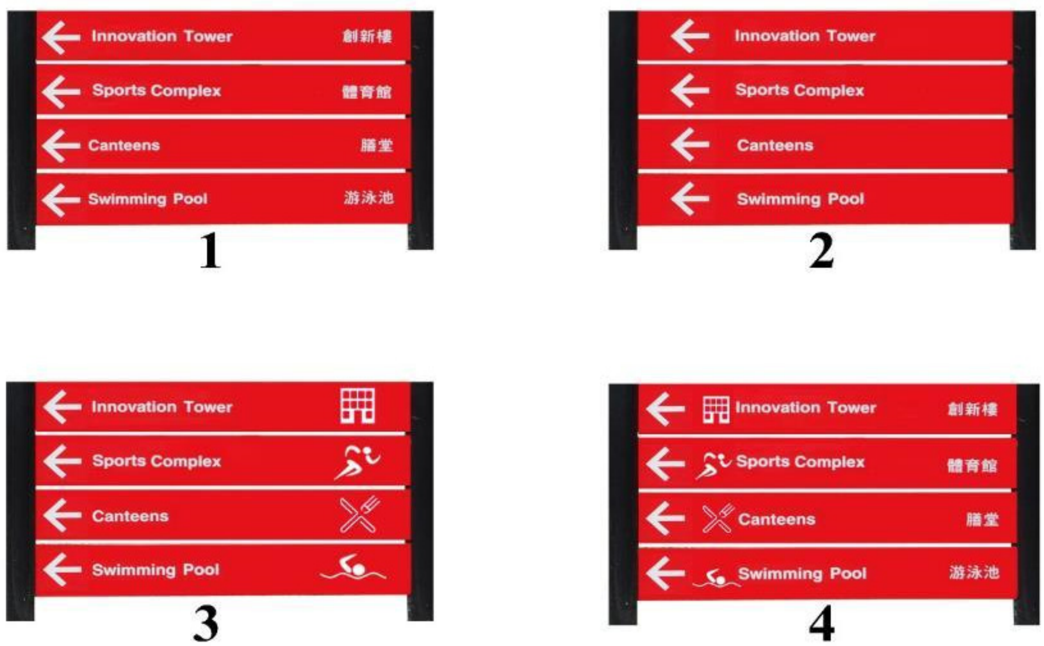


Figure 5.3 Signage information volume

Options 3 and 4 have been produced in combination with the icons for the requisite facility. In the previous studies (Chi and Dewi, 2014; Chi *et al.*, 2019) such combined icon styles have been investigated and proved efficient in delivering the information. The textual information of facilities is comprehensive and easy to understand. However, if this information is not visible, legible or readable then it has no advantage over icons and symbols (Sanders and McCormick, 1993). The participants were asked how easy it was for them to grasp the signage information that was being placed on a university campus because the amount of information detail varies when employing dual language and wayfinding pictograms. While the university campus's spatial layout is complex, much environmental information is necessary for efficient navigation.

5.3.2 DATA COLLECTION PROCESS

Participants from Hong Kong and Pakistan were invited to complete an online questionnaire for data collection. The invited respondents mainly were university students and visitors who were contacted using the Google Forms online tool to collect information. Reputable university campuses in Hong Kong and Pakistan have been chosen for this purpose because they attract students and visitors from various cultural backgrounds. The investigational research of signage design understanding and preference included a total of 200 participants. Inclusion criteria for this study were set based on the critical cultural categories and response fulfilment. One hundred seventy replies were chosen for data collection after meeting the inclusion criteria for relevant cultural groups from Hong Kong and Pakistan. Students from the respective university, as well as visitors to the campus, were the primary respondents. The questionnaire was completed in English, which is widely spoken and understood in both regions.

5.3.3 DATA ANALYSIS PROCESS

The collected information was organised into Hong Kong and Pakistan's respective independent cultural groups to conduct the data analysis. Participants born in Mainland China were also placed in the same category as those who were born in Hong Kong. The participants were divided into three groups depending on their age, gender, and literacy level to investigate individual differences. Table 8 lays out the categorisation in full. Following the necessary categorization, the data was imported into Microsoft Excel for descriptive analysis, followed by statistical analysis with SPSS software.

Participants obtained the relevant knowledge by using various visual options such as signage images and open-ended explanation questions. Pearson's Chi-square test was chosen since the participants were divided into independent groups based on cultural and individual differences (McHugh, 2013). With the aid of detecting the sequential pattern methodology, the data mining methodology was used to categorise the findings into meaningful classes (Friedman, 1998). The tests stated above were used to investigate the expected cultural differences in visual perception, understanding, and preference in university wayfinding design.

5.4 RESULTS

The preliminary descriptive revealed that each group had enough participants to complete the statistical analysis due to cultural and individual differences. Following the application of the original inclusion criteria, about 170 (84%) replies were chosen to be included in the research. The first descriptive information in Table 8 has also resulted in a reasonable distribution of participants among both cultural groups.

5.4.1 INITIAL DESCRIPTIVE STATISTICS

A wide distribution of individuals belonging to the independent sample group may be seen in the summary of general demographics. The response rate of Hong Kong participants was greater than that of Pakistani participants, with 55 percent and 45 percent, respectively. Furthermore, a similar proportion was found for the group depending on gender, with females accounting for roughly 54 percent and men accounting for roughly 46 percent. The participants' ages were also divided into four groups, ranging from 18 to 37 years old, with a five-year gap between each group for further investigation of individual differences. The gathered data revealed that the fourth group of 33-37 years had fewer members than the third group of 28-32 years; therefore, the group was combined with the third group of 28-32 years to maintain an appropriate range in the individual group for statistical analysis, as shown in Table 5.2. Because the respondents were mostly university students, the first two age groups (18-22 years, 23-27 years) accounted for most of the participants (81 percent). The literacy level was the other quantitative element when it came to signage perception. The participants were asked about their current educational level, and based on the information gathered, two groups were formed: (below undergraduate) and (postgraduate and above). Each of the two groups mentioned above has an equal number of participants (85) each. Following the broad classification, the data was loaded into SPSS to identify further research variables related to signage design perception.

Table 5.2 Summary of general demographics

		Frequency	Percentage
Cultural group			
	Hong Kong (China)	93	55 %
	Pakistan	77	45 %
Gender			
	Male	78	46 %
	Female	92	54 %
Age Group			
	18-22	69	40 %
	23-27	70	41 %
	28-37	31	19 %
Literacy Level			
	Undergraduate	85	50 %
	Postgraduate & above	85	50 %
Total			
		170	100 %

The responses were gathered based on the user's preference and knowledge in the second part of the online questionnaire, which included questions on the design of signage information. As shown in Table 5.3, the most comprehensive choice for signage design consistency has been given to design option 1 with 61 percent, followed by option 2 with 22 percent. The second question addressed users' preferences for wayfinding information colour coding, and users preferred design option 4 with 59 percent of responses, followed by option 2 with 24 percent. The responses to the question on signage information volume were dispersed, with 47 percent, 36.5 percent, and 13.5 percent for options 4, 3, and 1, respectively. Table 5.3 contains a full breakdown of the replies from the participants about design preferences. Every question about design preferences featured a follow-up question on the participant's reason for their choice. Because the explanatory questions were open-ended, the data was gathered and processed by recognising sequential patterns. In addition, the whole set of responses has been categorised based on the patterns identified in Table 5.4.

Table 5.3 Summary of questions responses

	Option 1	Option 2	Option 3	Option 4
Question 1 (Signage design consistency)				

Frequency	104	37	16	13
Percentage	61%	22%	9.5%	7.5%
Question 2 (Colour coding in signage design)				
Frequency	6	41	23	100
Percentage	3.5%	24%	13.5%	59%
Question 3 (Signage information volume)				
Frequency	23	5	62	80
Percentage	13.5%	3%	36.5%	47%

Table 5.4 Summary of questions explanation responses

Question 1 explanation (Signage design consistency)

	Attractive Colour	Colour Matches Logo	Quick Understanding
Frequency	84	80	6
Percentage	50%	47%	3%

Question 2 explanation (Colour coding in signage design)

	Ample Information	Attractive colour	Quick Understanding	Less Colours	Colour Coding
Frequency	29	3	9	32	97
Percentage	17%	2%	5%	19%	57%

Question 3 explanation (Signage information volume)

	Ample Information	Dual Language	Quick Understanding	Pictograms
Frequency	28	82	22	38
Percentage	17%	48%	13%	22%

5.4.2 CROSS-CULTURAL COMPARISON

The data was organised based on the cultural backgrounds of the participants to investigate cross-cultural differences in signage comprehension. Many Hong Kong respondents (69, 13) chose the first and second options in the questions on design consistency, respectively. The reasoning for the choices was made with the university's attractiveness and the university's official colour in consideration. The participants from Pakistan, on the other hand, displayed a fragmented attitude to signage selection. As shown in Tables 5.5 and 5.6, thirty-five, twenty-four, and fourteen Pakistani participants selected the first, second, and third alternatives, respectively.

Table 5.5 Summary of cultural differences in design selection

	Option 1	Option 2	Option 3	Option 4
Q1 (Signage design consistency)				
Hong Kong	69	13	2	9
Pakistan	35	24	14	4
Q2 (Colour coding in signage design)				
Hong Kong	4	33	8	48
Pakistan	2	8	15	52
Q3 (Signage information volume)				
Hong Kong	20	2	14	57
Pakistan	3	3	48	23

Table 5.6 Summary of cultural differences in questions' explanation

Question 1 explanation (Signage design consistency)

	Colour Matches Logo	Attractive Colour	Quick Understanding
Hong Kong	51	38	4
Pakistan	29	46	2

Question 2 explanation (Colour coding in signage design)

	Ample Information	Attractive Colour	Quick Understanding	Colour Coding	Less Colour
Hong Kong	28	3	3	46	13
Pakistan	1	0	6	51	19

Question 3 explanation (Signage information volume)

	Ample info.	Dual Language	Quick Understanding	Pictograms
Hong Kong	9	62	11	11
Pakistan	19	20	11	27

The Pakistani participants chose the requisite selections because they preferred colour attractiveness more than colour matching quality with the university's official theme. The chi-square test was used to analyse the correlation between the responses of both cultural groups statistically. For questions on signage design consistency, there was a significant relationship between the two cultural groups, $\chi 2$ (3, 170) = 24.016, p = 0.000. Whereas the explanation for the respective choice have also a significant relation, $\chi 2$ (2, 170) = 6.026, p = 0.049.

The respondents have differing opinions on the second question based on the colour-coded information on signage due to cultural influences. Option 4 with multi-coloured information coding was preferred by many participants from both groups, followed by option 3 for Pakistani participants and option 2 for Hong Kong participants. Pakistani participants preferred the single colour information coding after multi-colour, choosing a monochromatic style with different shades and tints of the same colour. On the other hand, respondents from Hong Kong preferred the greyscale design option with a single colour that was monotone.

Table 5.7 Summary of cultural differences in questions' explanation

	Q1	**Q1 exp**	**Q2**	**Q2 exp**	**Q3**	**Q3 exp**
χ^2	24.016	6.026	16.844	29.274	44.751	30.586
p	**0.000***	**0.049***	**0.001***	**0.000***	**0.000***	**0.000***
Φ	0.376	0.188	0.315	0.415	0.513	0.424

***$p < 0.05$ for Pearson chi square test**

The use of colour-coded signage design options has been proven to have a significant relationship between both cultural groups, χ^2 (3, 170) = 16.844, p = 0.001. Because of the differences in design choices, there has been a substantial variation in the explanations provided for the various choices, χ^2 (4, 170) = 29.274, p = 0.000. The high value of phi (0.415) in Table 5.7 has also demonstrated the significance of the relationship amongst both cultural groups. The third group of design options was created with the amount or volume of information required for navigational tasks in mind. The first two design choices in this collection were based on the information provided by two different languages.

Furthermore, the other two design options were created by combining the consideration of

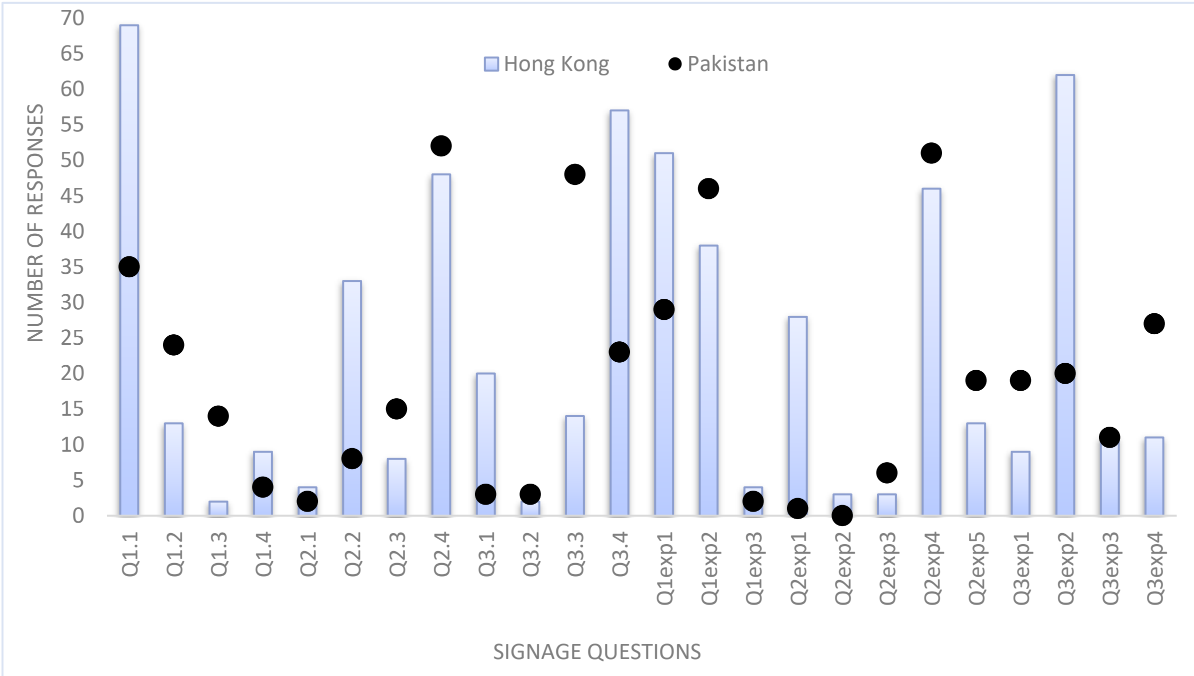


Figure 5.4 Simple statistics of cross-cultural comparison

linguistic and symbolic information. Figure 5.4 depicts the cross-cultural variations in the perception of signage design using a simple statistical comparison. The fourth option was selected by Hong Kong participants, followed by the first and third options. The information offered by the dual language was of more concern to the Hong Kong participants. On the other hand, pictograms were the primary explanation given by Pakistani participants, followed by the availability of dual language.

Several Pakistani participants indicated enough information as another reason for choosing design option 3. A significant association between the two above-mentioned cultural groups for the choice of signage design was discovered using Pearson's chi-square test, $\chi 2$ (3, 170) = 44.751, p = 0.000. The high value of phi (0.513) also demonstrates the strength of the association between Hong Kong and Pakistani respondents. Furthermore, when examining the explanations for these responses, a significant association between both participatory groups was discovered, $\chi 2$ (3, 170) = 30.586, p = 0.000.

5.4.3 INDIVIDUAL INFLUENCES

Individual differences in the perception of wayfinding signage design were explored using the online questionnaire, which inquired respondents about gender, age, and education level. Two groups were constructed based on the gender of the participants to identify gender-related differences in signage perception. The chi-square test was used to evaluate the relationship between males and females (Table 5.8). For this study, there was no significant association between males and females when it came to analysing the perception of university signage design.

Table 5.8 Statistical analysis of gender differences

	Q1	Q1 exp.	Q2	Q2 exp.	Q3	Q3 exp.
χ^2	3.169	0.897	5.904	4.922	1.563	2.032
p	0.366	0.639	0.116	0.295	0.668	0.566
Φ	0.137	0.073	0.186	0.170	0.096	0.109

Table 5.9 Statistical analysis of age differences

	Q1	Q1 exp.	Q2	Q2 exp.	Q3	Q3 exp.
χ^2	5.707	2.793	7.356	7.515	4.630	6.395
p	0.457	0.593	0.289	0.482	0.592	0.380
Φ	0.183	0.128	0.208	0.210	0.165	0.194

In addition, this study was necessary to investigate the age-related differences in signage perception that had previously been discovered in the literature. For statistical analysis to study the association between the three age groups mentioned, the obtained information has been organised into the three age groups specified in Table 5.2. According to the chi-square test, there is no significant association between the age groups (Table 5.9). Regardless of the respondents' age groups, the wayfinding signage was perceived. Because the participants were either university students or university campus visitors, there were fewer age differences in this study. Since the difference in age groups is so small, it has been assumed that such a slight variation will not affect how people perceive signage design.

As a result, the respondents have been divided into groups depending on their indicated educational level. Participants in the first category had an education level of undergraduate or less, while those in the second category had an education level of postgraduate or above. The Chi-square test was used to see if there was a significant correlation between the two groups. Except for the question about explaining the information volume, there were no statistically significant correlations between both education level groups (Table 5.10), χ^2 (3, 170) = 10.208, p = 0.017. Because of the presence of simplicity, dual language, and pictograms, participants with an undergraduate and below favoured the signage design options 3 and 4 for question 3. Participants with a higher education level, such as postgraduate and above, prefer the alternatives because of the ease of comprehension provided by the dual language. We may extrapolate from this data that people with a higher level of education prefer textual information over pictograms and information density in the design of wayfinding signage.

Table 5.10 Statistical analysis of literacy level

	Q1	Q1 exp.	Q2	Q2 exp.	Q3	Q3 exp.
χ^2	4.233	0.915	6.646	6.454	5.855	10.208
p	0.237	0.633	0.084	0.168	0.119	0.017*
Φ	0.158	0.073	0.198	0.195	0.186	0.245

***p < 0.05 for Pearson chi square test**

Similarly, in the comparison for question 2, where different information colour coding levels were provided, participants with higher education prefer less presence of colour-coded information. In contrast, the other group prefers colour-coded designs because they are more attracted to the signage's colourful designs. Although the proposed relationship is not statistically significant, the slightly higher phi value (0.198) reflects this understanding, χ^2 (3, 170) = 6.646, p = 0.084. The insights mentioned above were also described in the respondents' explanation response for the relevant selections. The individuals with lower education levels indicated colour coding as a pivotal role in their decision, whereas those with higher education levels reported other factors such as the presence of less colour and a large amount of information.

5.4.4 CORRELATION ANALYSIS

In addition to the correlation between cultural and individual differences, spearman's correlation analysis was used to investigate a correlation between the questions in the information collected. Other than the previously mentioned correlations in Table 5.2, the respective study yielded some intriguing insights based on the individual's preferences and perceptions. Between the Q1 and Q1exp is illustrating the choice of signage design and its related explanations, a statistically significant link has been identified and displayed in Table 5.11. The participants preferred design option one over design option two because of the colour matching with the institution theme rather than the attractiveness of the colour. Participants who selected design option 2 in question 1, on the other hand, indicated why they think the attractive colour should be used in the design of campus wayfinding signage. Similarly, respondents who opted for the university theme-related signage design choice preferred design option four in question three because it had comparatively more information. We can deduct from this study that if the university signage design follows the signage design consistency, people will feel comfortable reading and comprehending the large volume of wayfinding information.

Table 5.11 Spearman's correlations

	Q1	**Q1exp**	**Q2**	**Q2exp**	**Q3**	**Q3exp**
Q1	1.000					
Q1exp.	**0.376****					
Q2	0.131	0.031				
Q2exp.	0.016	0.008	**0.209****			
Q3	**-0.193***	-0.051	0.117	-0.004		
Q3exp.	0.061	-0.081	-0.098	0.011	-0.129	1.000

****Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed).**

Subsequently, a statistically significant correlation has been found between Q2 and Q2exp. Participants who chose design option 4 in Q2 mentioned colour coding as the primary reason for their decision. The remaining design options in Q2 were, on the other hand, meticulously chosen due to the usage of fewer colours. We may extrapolate that participants preferred colour coding information but used fewer colours in information coding, especially when the signage design must be placed in spatially complicated university settings.

5.5 DISCUSSION AND FINDINGS

Since it was exploratory, this study revealed a significant number of variations in the perception and choice of university signage design due to cultural factors and individual differences. Multiple studies (Hashim, Alkaabi and Bharwani, 2014; Troncoso, 2014; Ahmed, 2015) The purpose of the study was to compare the preferences of participants from Hong Kong and Pakistan for signage design in order to understand the cultural impact on user perception. Statistically, significant differences have been recorded for the preference of colour consistency in the design of campus wayfinding signage. Studies (Hohmann, 2001; Leonard, Verster and Coetzee, 2014). The proposed proposal was correct for the Hong Kong participants since they chose colours that matched the university's theme and emblem. The signage graphics, in their opinion, need not always match the overall institutional theme. Respondents from both cultural groups supported using information colour coding, although they preferred using fewer colours. Furthermore, Hong Kong participants preferred signage designs with grey and single colour coding, whereas the other cultural group prefers the use of colour tints and shades rather than several colours.

Additionally, significant variations in the amount and type of signage information have been observed. Studies (Wilkinson *et al.*, 1997; Mahmoud, 2015) have shown that visual information can be comprehended better than pictograms/symbols since deciphering the information needs much cognitive work. Our findings are compatible with the research mentioned above for Hong Kong participants; however, Pakistani individuals comprehended information better in the form of pictograms and symbols. The Hong Kong group prefers signage with a large amount of detail, whereas the other cultural group wants essential and fundamental information. The results also showed that Pakistani participants were less reliant on signs because they relied on verbal navigational information from passers-by, as investigated in a previous study (Ahmed, 2015) done in a culturally comparable and neighbouring country (India). The substantial differences in all of the questions indicated cultural diversity in signage design perceptions, consistent with the prior study (Foster and Afzalnia, 2005).

The gender differences in choice and perception of wayfinding signage design were also investigated in this study. According to the findings, there were no significant gender differences in signage design consistency, colour coding, information kind, and knowledge volume. The results are thought to be consistent with a recent study (Lee *et al.*, 2014) that found no gender differences in signage understanding or visual preference for information. Although previous studies (De Goede and Postma, 2015; Hund, 2016) have been examined across various age groups for future investigation, the preferences for signage design have been examined. There was no statistically significant association between the different age groups regarding signage information perception, as per the findings. Multiple studies (Head and Isom, 2010; Taillade *et al.*, 2013) have looked at how age affects wayfinding performance and is crucial in determining user behaviour. The outcomes of our study, on the other hand, revealed no link between the age mentioned above groups.

In addition, the association between education level and wayfinding signpost interpretation and perception was investigated in this study. In the previous literature, a study (Joy, Yien and Chen, 2016) has discovered a variation in consumer perception based on educational level. On the contrary, the study (Dowse and Ehlers, 2003) investigated the association mentioned above and discovered that the association was not statistically significant. Our research into signage choice and perception discovered a significant association between the amount and kind of information in the wayfinding signage design in question Q3exp. Participants with a lower literacy level preferred a variety of types of information, including textual and symbolic references and minimal and effective environmental knowledge. Participants with a higher literacy level, on the other hand, favoured detailed textual information and the use of dual language. This might be further interpreted as people with a higher educational level prefer detailed textual knowledge over the use of symbolic and pictographic information.

In addition, spearman's correlation test was also used to explore the interrelationship of signage questions to understand detailed user behaviour better. According to the correlation research, the consistency in design for wayfinding signage influences the user's perception and comprehension. The higher volume of information can be perceived better among users if the design and colour consistency is maintained. Once a certain amount of design and colour familiarity has been attained, it becomes less confusing for wayfinders when receiving environmental data. The findings of this study were in accordance with the principle of signage design (Bao, 2004) in complex university settings. Although colour coding of information on wayfinding signage helps deliver wayfinding information, our research suggests that monochromatic colours be used instead. They are perceived to be easier to comprehend, especially when the environment legibility is poor and there is much distracting information.

5.6 CONCLUSIONS

Finding a destination in a complexly planned, multi-storey institutional setting is a challenging task that needs a great deal of mental effort, environmental assistance, and route knowledge. Wayfinding aids come in a variety of forms, from signage to landmarks. The preceding literature has demonstrated the usefulness and reliance on signs for navigation information and the necessity for easy and standardised comprehension. In this context, complexly built university campuses need a significant amount of research, as these campuses draw a wide variety of visitors with varying individual and cultural backgrounds. The focus of this research was to look at the characteristics that might function as barriers to accessible and consistent comprehension and perception. Research questions, 2 and 3 explored the user preferences and perceptions regarding the design and volume of the wayfinding information. The disparity between collected signage information and its perception has been identified as a primary driver in this inquiry.

Participants from Hong Kong preferred a signage design that was consistent with institutional official colours and themes and textual information because it was found in earlier studies to be less demanding on one's cognitive efforts. On the other hand, participants from Pakistan were drawn in by the attractiveness of the signage design, colours, and symbolic content. The reason for this behaviour might be due to the Pakistani participants' different wayfinding cultures. People are increasingly drawn to verbal information, landmark identification, and symbolic information due to the scarcity of functional signage design. As a result, individuals are no longer completely reliant on signage information for environmental knowledge. Symbols have been shown to have a crucial influence on both cultural groups' understanding and reliance on university wayfinding signage. This conclusion holds true for individuals with different levels of education since symbolic or pictographic information may entice users regardless of their educational background. Future study on symbolic comprehension in complex environmental settings as well as wayfinding knowledge is also recommended. The produced symbols may also be examined in a variety of environmental contexts with varying levels of spatial complexity employing computer simulations to reduce the effects of environmental complexity.

In the next chapter, users were investigated with their preferences for mobile wayfinding information and how they approach this information. The study has been planned as mobile wayfinding applications are getting popular in the recent past for aiding the navigators while performing the wayfinding tasks. The current and previous studies explained the user preferences related to the static wayfinding information sources and their effectiveness. In addition to that, the mobile information sources are also aiding the wayfinding process but with certain limitations. It was deemed necessary to investigate the user behaviour regarding the wayfinding applications while performing the wayfinding tasks in complex environments. This will further elaborate the interaction of wayfinding systems with the users, which will further help the researchers to understand the said relationship.

CHAPTER 6: STUDY 3- INFORMATION CONTENT AND DESIGN IN DIGITAL WAYFINDING APPLICATIONS

6.1 OVERVIEW OF CHAPTER

In this chapter, research question 4 have been investigated related to the wayfinding information obtained from digital mobile applications.

Research Question 4: How do users' access and perceive the digital app-based wayfinding information for complex environments?

Digital mobile applications have been influential in guiding the navigators while wayfinding due to the presence of smartphones with everybody nowadays. The wayfinding mobile applications have several factors including application interface, technical familiarity and information design. This chapter presents the user preferences for the information content, type and design of wayfinding information in the digital wayfinding application. This research aimed to investigate user preferences regarding mobile information content while navigating in a complex environment.

6.2 INTRODUCTION

Wayfinding applications on mobile devices are gradually becoming efficient in delivering environmental information. These applications provide a variety of navigation information such as location, orientation, route planning, spatial layout and provided facilities. The information is presented in multiple layers that require a thoughtful design to deliver the information effectively, especially in complex environments. This study explored the user preferences for information content and design in wayfinding applications. A wayfinding experiment was conducted in a complex university setting using the wayfinding application with a multi-layered information design. Twelve participants have performed four wayfinding tasks using the purpose-built wayfinding application. Data has been collected by mobile screen recording, pre- and post-experiment interviews. Significant behavioural patterns have been observed for accessing the information content, and user preferences have also been explored for the information design. Accurate location pointer, written directions and five to six-layered information design have been preferred for the mobile wayfinding information. Information for validation in the real environment has been a significant factor during wayfinding tasks. A synthesis of wayfinding information from digital and real-world sources has been suggested to improve the existing wayfinding systems in complex institutional environments.

6.3 METHOD

The present study aimed to investigate the user's preferences regarding the type of information content and its design. Therefore, an experiment has been designed to perform specific wayfinding tasks in a complex institutional environment using a purpose-built wayfinding application. Data collection has been designed in three major segments. These segments constitute pre-experiment interview, wayfinding experiment and post-experiment interview. The participants have been inducted through convenience sampling from a reputed public sector university in Hong Kong. The data has been recorded in the form of mobile screen recording and interview responses. After the experiment, the recorded data has been qualitatively analysed considering the provided research questions.

6.3.1 PARTICIPANTS

The participants have been invited to perform the wayfinding experiment from a reputed public sector university situated in the heart of the Kowloon district of Hong Kong. The participants were approached using a convenience sampling method. All the participants were students having an acceptable level of smartphone literacy. The participants were aware of using mobile applications using common application navigation patterns. An acceptable level of English understanding while using the mobile application has also been considered before inducting the participants. Twelve participants have participated in the said experiment consisting of 66.6% and 33.3% of male and female participants, respectively. All the participants were partially aware of the environmental settings and the offered facilities; however, they were not confident enough to find any place inside the university campus on their own. All the participants have completed the required wayfinding tasks, and their actions have been recorded. Before the experiment, the consent of each participant has been obtained for sharing the research findings on public forums. Ethical approval (APPENDIX I) has been obtained for conducting the experiment. Precautionary measures, including face masks and six feet distance, have also been adopted and maintained during the experiment due to the COVID-19 pandemic.

6.4 DATA COLLECTION

For this study, participants' responses and behavioural actions were required to understand the user preferences for wayfinding applications. The participants were invited to the ergonomics design lab for having a pre- and post-experiment interview. The interview was documented using written documents.

6.4.1 PRE-EXPERIMENT INTERVIEW

The pre-experiment interview was designed in further three sections consisting of participants' demographic information, questions related to the smartphone familiarity & dependency, followed by the third section related to the usage and dependency on the mobile wayfinding information. The interview has been designed in a semi-structured way consisting of open-ended questions for in-depth exploration of the ascribed behaviour as well as questions based on the Likert scale for investigating personal preferences.

Table 6.1 Pre-experiment Interview questions

Sr.	Questions	
Demographic Question		
	Gender	Age
	Education	Field of Study
Section 1: Questions related to smartphone familiarity and dependency		
Q1	I always keep my mobile device with me.	
Q2	I use wayfinding applications on my mobile device.	
Q3	Wayfinding through a mobile device is easier than using signage.	
Q4	I always use a wayfinding application in unfamiliar environments.	

Sr.	Questions
Q5	What mobile applications do you use for wayfinding?
Q6	Other than social media and games, what mobile applications do you use?
Q7	Do you find it easy to use a mobile device for daily tasks?
Section 2: Questions related to the use and dependency on mobile wayfinding information	
Q8	I can find my way in complex environments without using mobile applications.
Q9	I always use mobile applications for wayfinding in complex environments.
Q10	Wayfinding through a mobile application is easy.
Q11	I do not need other information while using the wayfinding application.
Q12	I always get accurate wayfinding information through the application.
Q13	I always consider the ideal route planned by the application.
Q14	The map is very useful in wayfinding applications to understand your position.
Q15	Interactive maps should be there in wayfinding applications.
Q16	I prefer both textual and graphical information in wayfinding applications.
Q17	I prefer minimal information design in wayfinding applications.
Q18	I prefer the one-page detailed information design of wayfinding applications.
Q19	I prefer textual information more than symbolic information.
Q20	I prefer both (signage and wayfinding applications) to find my way in complex environments.

Data: The responses of this interview have been recorded in the form of written documents and analysed further by using qualitative methods. The actual questions asked in the interview has been presented in Table 1.

6.4.2 WAYFINDING EXPERIMENT

6.4.2.1 *PROCEDURE*

After having the initial interview regarding the participant's existing perception of the mobile wayfinding application and its provided information, a wayfinding experiment has been performed. The participants were instructed to use the wayfinding application while performing the wayfinding tasks in the actual environment. Participants have performed three wayfinding tasks to find the unknown location inside the university campus using the wayfinding application and other environmental information sources. The participants were introduced to the basic layout and navigation pattern of the wayfinding application. They were also allowed to take their time and practice a little more with the wayfinding application for interface familiarity. Once they were familiar with the wayfinding application, they were directed to the starting point. After that, the participants were asked to start the wayfinding task and search the required locations.

6.4.2.2 ***DATA***

During the experiment, the data has been recorded in the form of the mobile screen and the participant's voice recording. The participants were also instructed to use the think-aloud protocol (Kinsley, Schoonover and Spitler, 2016; Schrom-Feiertag, Settgast and Seer, 2017), which has been instrumental in wayfinding and behaviour research.

6.4.2.3 ***INSTITUTIONAL ENVIRONMENT***

The experiment has been performed in the complex spatial settings of a university campus. The university campus has been situated in the heart of Hong Kong with multi-storey buildings and interconnected facilities. The university campus has been designed with multiple wayfinding aids and landmarks for memorising the spatial layout; however, the campus plan still requires much effort to recall the cognitive map. During the experiment, the university campus was almost empty of students due to the COVID-19 pandemic and a limited number of persons could walk inside the campus.

6.4.2.4 ***MOBILE DEVICE***

A smartphone has been provided to the participants with a pre-installed purpose-built wayfinding application specially designed for the respective university campus. The provided smartphone was enabled with GPS location along with the university provided Wi-Fi. The provided smartphone was Samsung (C7) with an android (Orio) operating system having a 5.7" AMOLED display. The brightness was kept at total capacity (422 nits) due to the outdoor environment.

6.4.2.5 ***WAYFINDING APPLICATION & CODING***

The wayfinding application has been purposely designed by the respective institution using the list menu navigation as well as the springboard navigation style. The home screen has a fully interactive map of the university campus along with two list menus and one springboard style instruction menu. The list menus have been coded as "L1" and "L2", whereas the springboard has been coded as “t”. The screenshots of the respective wayfinding application and the coding names have been presented in Figure 6.1. The screenshots that have been labelled from “a” to “s” are sub menus and information screens. The information screens have wayfinding information in different forms ranging from the written directions to the reference images of the destination. The list menu (L1) can be accessed from the top left corner of the home screen, whereas the list menu (L2) can be reached at the lower right of the display. The question mark on the top right area of the home display represents the springboard instruction menu.

6.4.2.6 *NAVIGATION PATTERNS IN WAYFINDING APPLICATION*

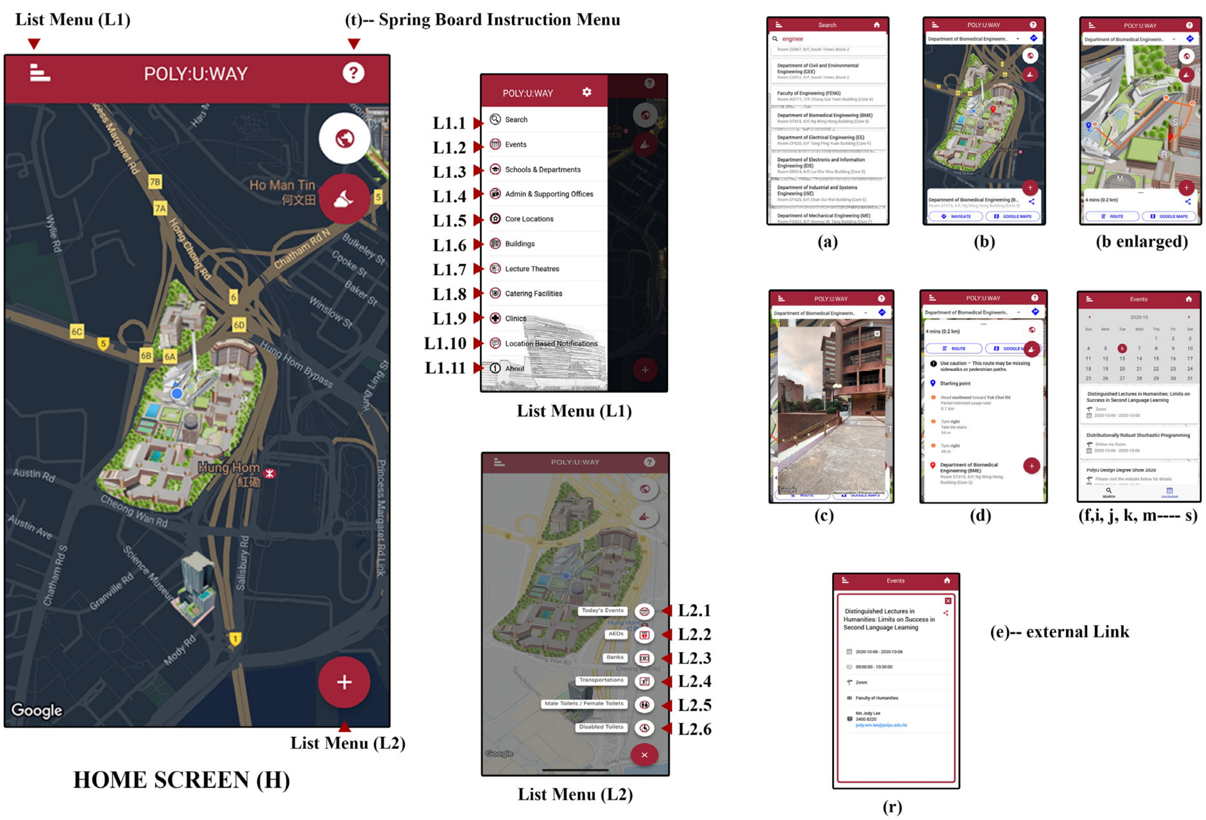


Figure 6.1 Coding of application menu

The information related to the institutional facilities, especially academic facilities, has been on the first menu. The second menu contains information related to public facilities, including toilets, banks and transportation. The list menu "a" displays the search bar and results regarding the user's input. Where the "b" menu displays the tentative route to the desired location starting from the user's present position. The menu coded as "c" displays the information regarding the reference images of the destination. These reference images can be rotated in three dimensions allowing the users a full view of the desired location. The other menus display the written directions along with the designated content based on the user's navigation pattern.

A complete potential navigation pattern has been presented in Figure 6.2 as an information wireframe. The information content has been displayed in multiple layers. The first layer of information is the home screen with two lists and one springboard menu. The second and third layers have been delineated in Figure 6.2 as list details and results, respectively.

6.4.3 POST-EXPERIMENT INTERVIEW

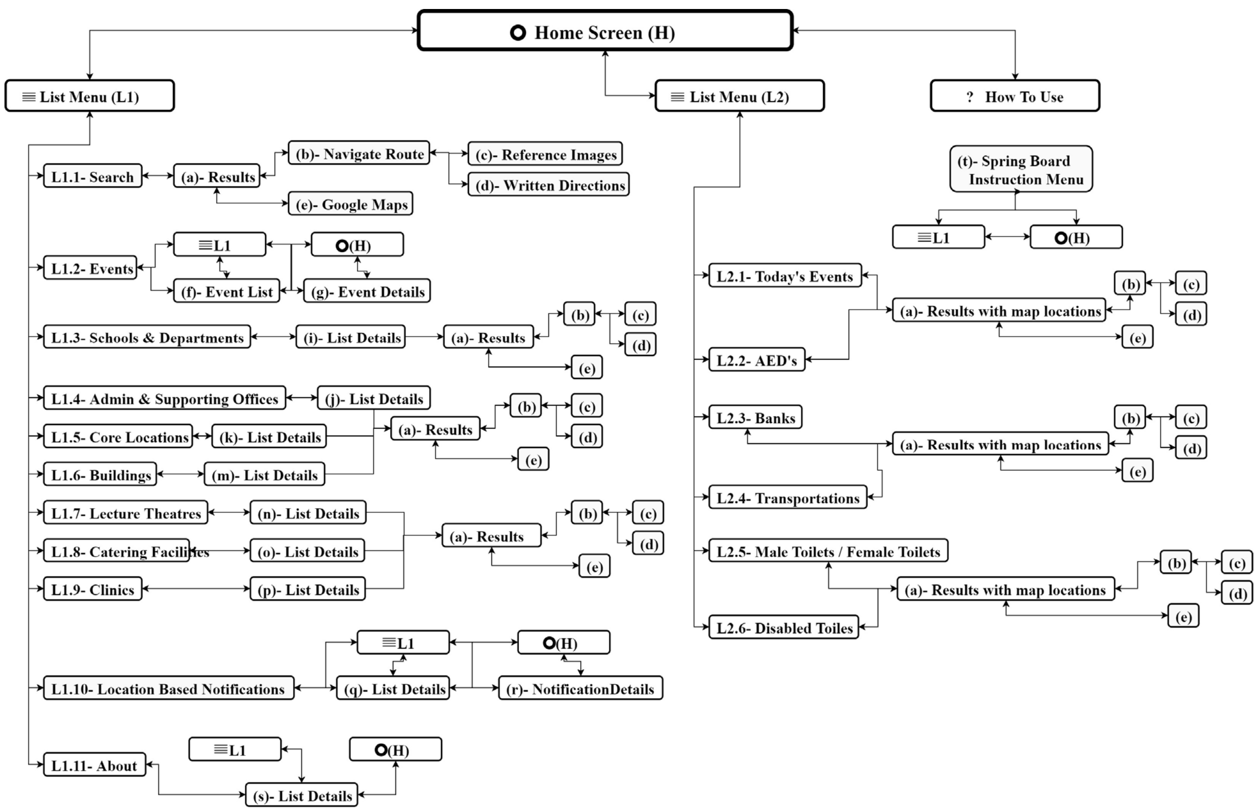


Figure 6.2 Navigation pattern of the wayfinding application

A post-experiment interview has been designed to gather in-depth information about the users' behaviour. During the experiment, specific behavioural patterns have been observed in accessing the wayfinding information from the application. The questions asked in this interview were majorly based on the user preferences regarding the type of wayfinding information content, its design and placement within the application. The participants were inquired about their experiences while using the application. The participants were also asked about their favourite features and suggestions to improve the application's effectiveness for delivering wayfinding information. The details of the interview questions have been provided in Table 6.2.

Data: The post-experiment interview has been recorded in the form of written documents. The responses from each participant have been carefully documented, along with a further explanation. Some of the questions were based on open-ended type questions, whereas somewhere open-ended. The participants were also inquired about their familiarity with the mobile wayfinding information and the problems faced while using the application.

Table 6.2 Pre-experiment Interview questions

Section 3: Questions related to the preferences in mobile wayfinding application	
Q21	What do you prefer (signage, mobile, augmented reality, landmark, pathways) & why?
Q22	Do you think that wayfinding information in the application is reliable and useful?
Q23	What are the problems while using mobile for wayfinding?
Q24	What are your favourite features in the wayfinding application and why?
Q25	Do you prefer colour coding in wayfinding information design & why?
Q26	Do you prefer the reference images with the wayfinding information & why?
Q27	What information do you think is missing in the wayfinding application & why?
Q28	What improvements do you think this application need?
Q29	Was this application useful?
Q30	I freely navigated and found my way with the application.
Q31	This application has all the information content needed for wayfinding.
Q32	Application information was easy to understand.
Q33	There was no difference in provided information with real-world settings.
Q34	The planned ideal route by the application was ideal and short.
Q35	It was easy to maintain a sense of direction while using the application.
Q36	I do not feel any frustration while using the wayfinding application.

6.5 DATA ANALYSIS

The collected data has been recorded in the form of videos and written documents. The participant's videos have been obtained through mobile screen recording where every action and navigation pattern have been recorded. Whereas the handwritten documents have been prepared using the participant's responses from pre- and post-experiment interviews.

Likert Scale: For some of the questions in the pre- and post-experiment interview, the Likert scale has been used to record the participant's answers. A seven-point Likert scale has been used in section 1 from Q1 to Q4, section 2 for all questions and section 3 from Q30 to Q36. This scale has previously been used in a similar study (Li, Chen and Ni, 2013) to document their rating of personal preferences and peculiar behaviour.

Content Analysis: The remaining questions in both interviews have been designed in the form of explanatory questions to have a thorough exploration of the users' preferences and behaviour. The videos and remaining written data have been analysed and coded using the qualitative technique of content analysis. The recorded data has been searched for themes and patterns for navigation behaviour. The data was also coded for specific navigation patterns in the mobile wayfinding application. The content analysis has been influential in exploring human interaction with mobile applications, as practised in the previous study (Li and Luximon, 2020).

Type of Information Content: The information in the mobile application has been coded concerning the type of information. Small alphabets from "a" to "s" have been used to identify the different categories of information. The details of each alphabet and its relevant type of information have been presented in Figure 6.2. Video recordings have been analysed, and a complete navigation pattern has been recorded for each user. The pattern has been observed, and the most used information content for wayfinding has been identified.

Layers of Information: The information has been designed in multiple layers in this mobile wayfinding application to avoid the information overload on each layer. The home screen in the application has been considered as the starting point for digital navigation. Both list menus L1, L2 and springboard instruction menu have been considered in layer one. The number of information layers will be considered accordingly as users navigate forward or backwards in the application. Switching between two layers has also been considered as one additional layer of information.

Correlation Analysis: A correlation analysis has been applied to investigate the individual differences in accessing and preferring the wayfinding information. Each participant's data has been carefully observed and analysed for correlation between participants. The analysis has also been instrumental in investigating the difference in personal preferences for wayfinding information based on gender, age, education and field of study.

6.6 RESULTS

The current study results presented some interesting insights regarding user behaviour, preferences for mobile wayfinding information, and its content. In section 1 of the pre-experiment interview, the participants were analysed for their familiarity/dependency level on mobile devices. This analysis has been performed to investigate whether it can influence the participant's preferences for the wayfinding information content or not. The study indicated that all the participants were highly dependent on their smartphones regarding daily connectivity, entertainment, productivity and wayfinding. 83.3% of users use wayfinding applications on their mobile devices as well as 91.7% of users always use wayfinding applications in an unfamiliar environment. 25% of users think that wayfinding through mobile applications is very easy; however, the remaining users perceived it moderately easy. All the participants have used famous wayfinding applications before like Google maps, Gaode maps and Baidu maps. They have quite a good idea of how these applications interact with the user. This analysis confirmed that all the participants were on a similar level of digital literacy.

Section 2 of the interview was designed to investigate user behaviour regarding digital wayfinding information. 58.3% of participants have reported that they cannot find their way in complex environments without using the application. Complex environments are challenging to construct a mental map, and because of that, a user needs continuous input of information from different environmental sources. Many participants (83%) have mentioned the need for wayfinding information from other sources as well to complete the wayfinding tasks. Participants also perceived the mobile wayfinding information accurate in open environments, while in the complex environments, the provided information needs to be validated through other sources as well. For non-complex environments, the participants preferred several types of information, i.e., route planning, position pointer, orientation, interactive map, and reference images. They have also mentioned signage as an information validator for most environments, especially for complex ones.

6.6.1 TYPES OF INFORMATION CONTENT & USAGE

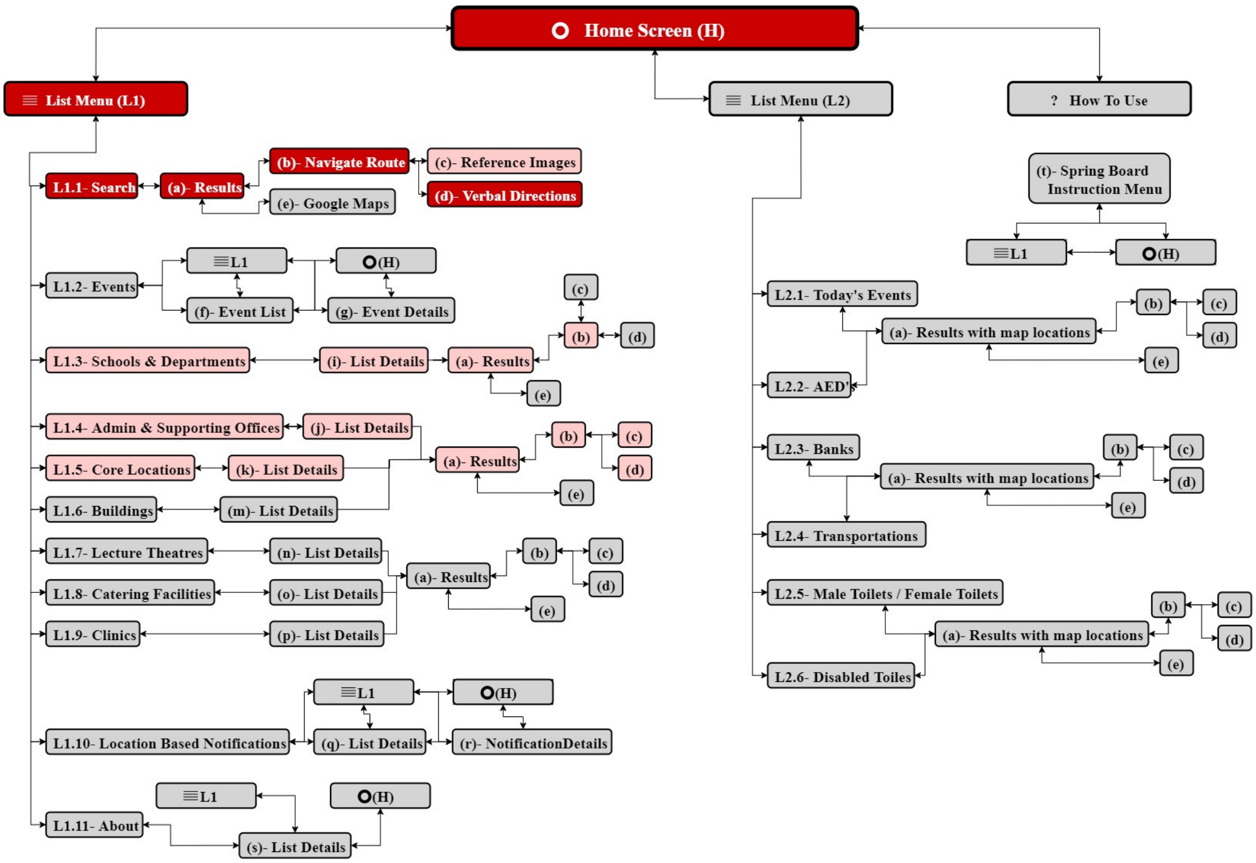


Figure 6.3 Information content accessed by the participants

During the experiment, the participants' actions have been recorded with the help of mobile screen recording. The mobile application has several types of information content designed to be approached in single or multiple layers. This study intended to explore the types of information content which is significant and approachable by the participants. All the information content has been presented in Figure 6.2 along with the possible navigation patterns. Whereas, in Figure 6.3, the most accessed information content has been presented in colours depending upon the number of times this information has been accessed. Participants have accessed the search bar feature in the list menu 1 with the greatest number of times.

In comparison, some of the participants have accessed a similar feature through list menus 1.3, 1.4 and 1.5. These list menus presented similar information but with already displayed names of the buildings and facilities. The participants using the search bar function have mentioned many times the problem in typing the required keywords for the destination. So, they need to type the requisite information more than one time to search the required destination through the search bar function correctly.

The kind of information content and the number of times the participants have accessed it have been presented in Figure 6.4. The location pointer of the participant's location has been accessed the highest number of times. The participants faced problems identifying their location in real-world settings due to the validation of the provided information. Written directions have also been accessed very frequently, followed by the search results and search bar. The search results were quite different as the participant was typing different types of keywords for the destinations. That is why they need to search for their required destination from several results.

6.6.1.1 ***LIST MENU & SEARCH BAR***

The navigations patterns have been colour coded in three colours in Figure 6.3. The red colour represents the most used, the pink colour represents the seldom used, and the grey colour represented the unused navigation patterns. The participants have approached the search bar from the list-menu one instead of using the already provided destination names. They find it difficult to search for a destination by going through the whole menu than searching from the search bar. The list menu two has majorly consisted of institutional facilities like banks, transportation. However, the destinations assigned to the participants were mainly related to the academic and student-related facilities that are why most of the participants did not approach list menu 2. In list menu two, the destinations have also been presented in the form destinations list, which would be difficult for the participants to search as per the previous practice.

6.6.1.2 *LOCATION POINTER, ROUTE & WITTEN DIRECTIONS*

After searching the required destination from the provided list menu and search bar, the participants have been directed towards the route planning screen where the wayfinding application planned the ideal route. The route planning screen has the information regarding the ideal route, participant's position and some written directions. This information screen has been coded as "b" in Figures 6.2 and 6.3. All the participants have tried to access and validate their existing position in the real environment. However, owing to the complex environmental settings, the wayfinding application was unable to track the GPS location accurately. Due to this reason, participants need to access other information content like written directions coded as "d". The written directions were quite helpful if and only if they are aligned with the actual egocentric orientation of the participant. The written directions were presented as egocentric directions; however, environmental validation was necessary to self-orient the participants. The participants have switched several times from "b" to "d" and vice versa only to synthesize both information content with the environmental settings.

6.6.1.3 *REFERENCE IMAGES*

Reference images of the real-world environmental settings have also been presented as the fifth layer of information in the respective wayfinding application. The purpose of these reference images was to enable the respective user to identify the real-world settings by collating information efficiently. However, in our study, participants did not rely on this type of environmental validation. In the post-experiment interview, 50% of the participants who responded in favour of reference images usage also mentioned several problems. These problems include the differences in viewing angle between participants and the presented images in the application. Particularly the environments where a significant amount of visual homogeneity is present, like the environment in which this study has been conducted. Some participants have also mentioned that the provided images of some routes and destinations in the application were not updated. In the application, the images were presented as a clear view of a building; however, the actual building was partially covered with some advertisements of ongoing events in the real world. So, in these environments where events are an essential part of the institutions like university campuses, it is quite hard to maintain the visual similarity in actual and reference images.

6.6.2 STEPS OF INFORMATION

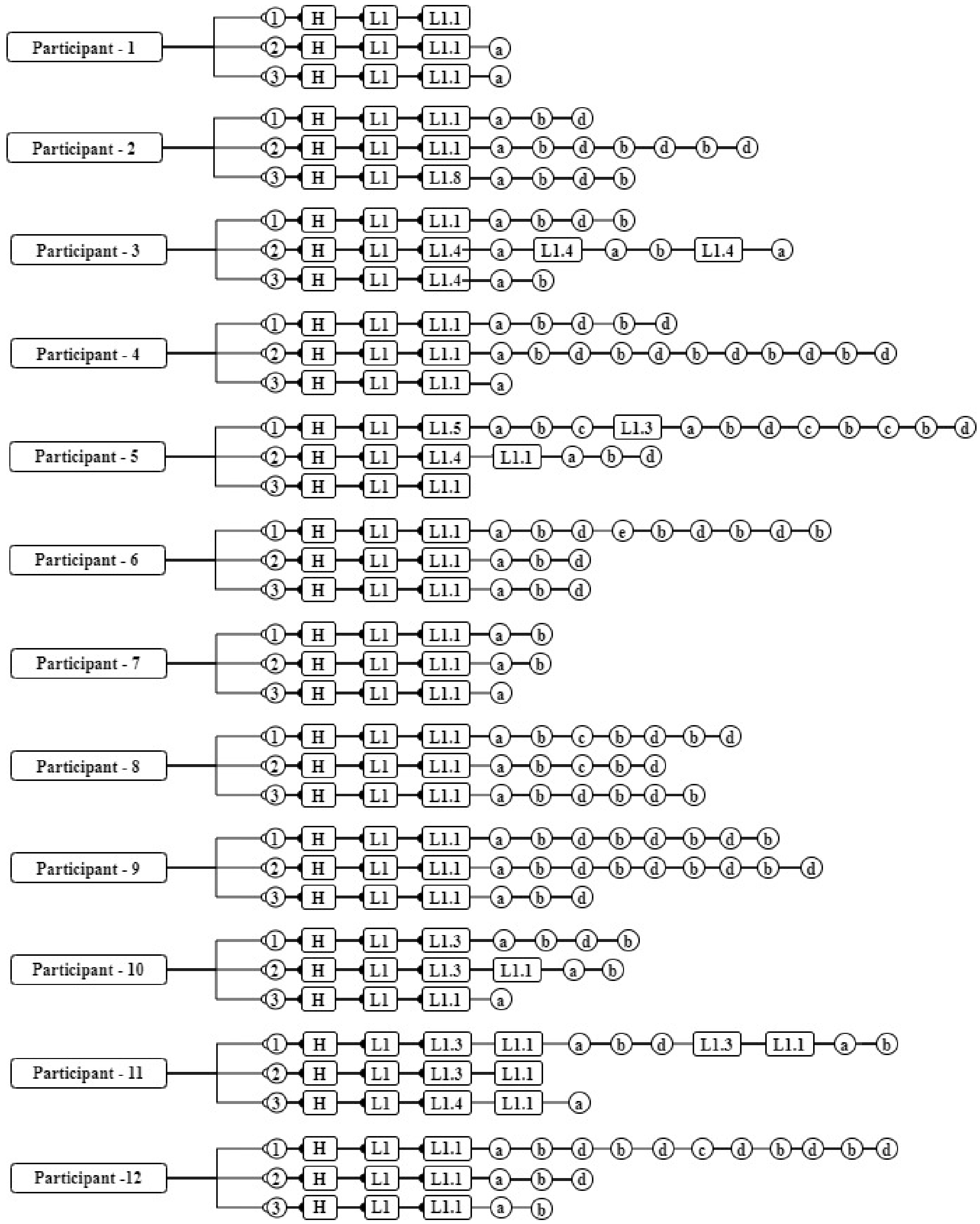


Figure 6.4 Steps of information & navigation pattern

The digital wayfinding information can store and display a large volume of information in single or multiple information layers. The users can access these information layers through different interactive menu types, causing an additional cognitive load to the users. In the usability of digital information content, disorientation during digital navigation is the most reported issue by multiple studies (Mi *et al.*, 2014; Wagner, Hassanein and Head, 2014; Gao *et al.*, 2015). This issue can alter the way user's access information content. For this reason, our study has investigated how many layers, users are accessing in obtaining the wayfinding information from the application.

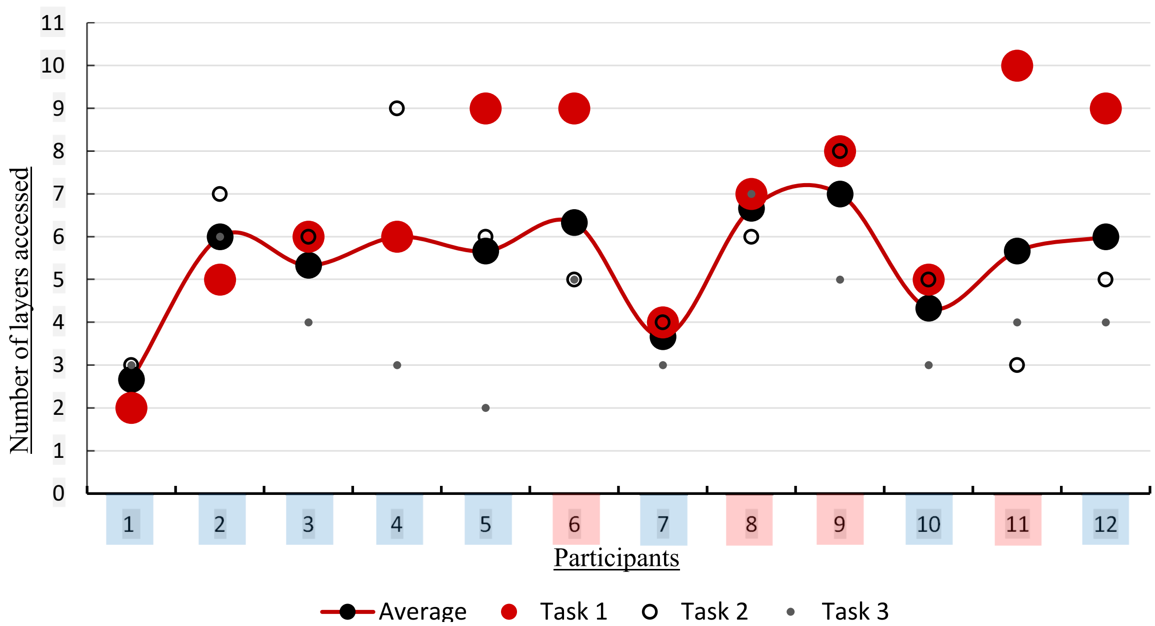


Figure 6.5 Information layers access for multilayer information content

The wayfinding application used in this study has a 6-7 layered information content model for each content starting from the home screen and onwards. Whereas switching from different layers of content has also been considered as accessing an additional layer. The navigation patterns of the participants have been delineated in Figure 6.4, and their accessed number of information layers have been presented in Figure 6.5. The highest number of layers that have been accessed is ten layers by the eleventh participant. On the contrary, the lowest number of layers is two, by the first participant. The higher number shows that the provided information content is not enough for the required task. On average, five to six layers has been approached by the participants for obtaining wayfinding information. This indicates that the relevant and most necessary information content should be presented within the limit of five to the six-layered design of information to complete a wayfinding task.

6.6.3 PREFERENCES FOR INFORMATION CONTENT & DESIGN

The participants have mentioned several preferences regarding the information content and its design for a trouble-free wayfinding experience. These preferences have been recorded in the post-experiment interview and encapsulated in the following part.

6.6.3.1 *MOBILE DEVICE*

Participants have preferred the wayfinding information through digital devices, primarily through their smartphones. They have strong reliability on their smartphones due to extensive usage throughout the day. Participants have also considered the other environmental sources influential for wayfinding only in conjunction with the mobile application. They have suggested the need to synthesise the environmental sources with wayfinding application for a complete and synchronised wayfinding experience even in complex environments (university campuses) as well.

6.6.3.2 *ACCURATE LOCATION POINTER*

An accurate location pointer is very important for delivering context-aware information to the wayfinders. The most preferred and accessed feature of the wayfinding application was the accurate location pointer showing the participant's location in the interactive map. The location pointer was considered very useful; however, it was not functioning accurately due to the GPS signal limitations in the complex environments. The accuracy in location and orientation is quite necessary to make the self-location identification. Participants also suggested that if the location would be accurate, they need to validate the provided information in the real environment. The validation part is quite hard for the participants due to visual homogeneity in the institutional environment.

6.6.3.3 ***WRITTEN DIRECTIONS***

Written directions have also been accessed in conjunction with the location pointer. The participants have faced difficulty in understanding the orientation related written directions. The provided information was egocentric; however, the participants could not locate and orient themselves by solely using this type of information. They recommended a synthesis of written information with the existing real-time information sources of the environment.

6.6.3.4 ***INFORMATION COLOUR CODING***

The participants have considered the importance of information colour coding with mixed responses. Half of the participants think it is significant to quickly identify the necessary information, whereas the remaining participants have considered it a complete distraction. In this regard, a suggestion has been advised to include the option for switching colour coding on and off in the application controlled by the respective user.

6.6.3.5 ***PERSONALIZED EXPERIENCE***

Participants have also suggested an option for personalised information content due to previous experience or behaviour. One of the suggestions was to include a Login/Logout feature to record the user's personal preferences for the future and display the required information as per the user's preferences. The participants have also suggested incorporating the building internals along with the route and location information to experience complete wayfinding guidance.

6.6.4 **INDIVIDUAL DIFFERENCES**

The recorded data has been analysed to investigate peculiar behaviour patterns concerning the participant's individual differences. No significant differences in the behaviour have been observed based on their age and education. However, subtle behavioural patterns have been observed based on gender. In our study, the females have accessed a greater number of layers while using the wayfinding application. This notion can be observed in Figure 6.5 for sixth, eighth, ninth and eleventh participants who are females. The participant numbers have also been colour-coded (i.e., blue for males and pink for females) for a clear representation. The navigation pattern for female participants in Figure 6.5 shows that they have accessed a higher number of layers in all three tasks than the male participants. During the post-experiment interview, female participants have also mentioned the difficulty in validating the information obtained through the application in the real environment. At the same time, male participants tried to validate through signage and landmarks.

6.7 DISCUSSION

This study tried to investigate the user preferences for wayfinding information content and its design, especially while using digital mobile wayfinding applications. The study was necessary to understand the user behaviour for searching the wayfinding information presented in multi-layered information content. In this investigation, certain types of wayfinding information content have been presented to the participants through a purpose-built wayfinding application for complex environments. The participants have preferred and accessed the information related to their location concurrently while performing wayfinding tasks. In conjunction with that, they have preferred the ego-centric written direction-based information as well to validate their location in the real environment. It has been observed that there is a gap of information between the digital environment in the application and the real environment. All the participants need to validate the provided information through some external information sources in the real environment like signage, pathways or landmarks. Even if they are too sure about their orientation and direction, they still need to validate to confirm. The participants have mentioned this in the post-experiment interview while suggesting improvements in the whole wayfinding information system. For this reason, the synthesis of wayfinding information is quite necessary for the current digital wayfinding systems, especially for complex environments. This finding is constant in relation to the previous literature (Jeffrey, 2017), suggesting the information syntheses for different wayfinding information sources.

The information types already used for location validation in the real environment, like reference images and validation signage, are thought to be helpful for the participants. However, in our study, participants have mentioned that reference images are not quite helpful in validating purposes as the institutional environment is visually changing continuously due to events advertising and related stuff. Similarly, list menus provided in the wayfinding applications are not quite useful due to several reasons. Participants have mentioned that they need to search the whole list for their desired location, which takes time. Also, they need to identify the potential categories in which their destination could be present. Instead of using the list menus, they have preferred the global search bar that accepts the related keywords and searches the destination.

The provided wayfinding application has been designed in the 6-7 layered information design for each content. For example, to find the location pointer, the participants need to explore a minimum of 5-6 layers of information in the provided application. For other destinations or other information content, the process needs to be repeated as described in navigation patterns in Figure 6.2. In our study, the participants have accessed the 2-3 layers for each content and collectively 5-6 layers for each task. The participants have mentioned in the post-experiment interview that the navigation in the application should be simple and have a maximum of two to three information layers. After the experiment, the participant also mentioned forgetting the information they have accessed before and where to access it. This notion can be expressed by the limited availability of event spaces in human short-term memory. Therefore, participants were not able to access the greater number of information layers than two to three layers for each information content, as presented in Figure 6.5.

Information colour coding has been an effective technique in arranging the information for the required visual order. It makes the content easier to understand and grasp the users' attention. However, in our study, half of the users have shown their preference in favour of the above statement, while half of them consider this coding method as a complete visual distraction. The participants have also mentioned that if colour doing is meant to create the visual hierarchy, use light and less distracting colours. This will serve the purpose of understanding visual hierarchy without distracting the others who do not. Another preferred arrangement of information content is the Login and Logout feature for personalised wayfinding information. Instead of using and displaying all the supported features by the wayfinding application, the personalised information will allow the user's preferred set of information. Personalised wayfinding information will allow the application to maintain the minimal layout with fewer information layers benefitting the respective target users.

The individual differences based on education, gender, and age have been quite evident in previous wayfinding studies for differences in performance, spatial and cognitive abilities. In our study, slight differences have been recorded for males and females accessing the multi-layered information content. The female participants have accessed a greater number of layers than the male participants due to the difference in understanding the information. Also, they have faced difficulties in validating mobile information in real environments. Both groups have not shown any significant differences in their behaviour for the rest of the information content.

6.8 CONCLUSION

The wayfinding applications are the preferred form of environmental information for contemporary wayfinders. These mobile applications are available on platforms like IOS and android to target a mass audience. The complex institutional environments, where a high level of visual homogeneity is present, is quite difficult to navigate, especially for newcomers and visitors. For these environments, regular wayfinding aids like signage or landmarks are not enough. The wayfinding applications have been designed to make the wayfinding experience more interactive, communicative and personalised. However, some guidelines need to be considered while designing the information content for these mobile applications. The most important feature is the self-location and orientation on the interactive map of the respective institution. This type of information should be accurate and accessible on the home screen. If the accuracy is dependent on GPS location, then digital beacon-based systems should be devised to make the position and orientation accurate. The accurate location can also be influential in providing context-aware information throughout the campus while keeping it visually minimal.

The information content in the mobile application should be able to accommodate and synthesise the real environment sources like the locations of information signage, landmarks and famous intersections. A minimum number of information layers should be presented in the wayfinding applications for intuitive user access. The validation process should also be explained in applications like the reference image showing a large identification sign or the written direction instructing to look for an eagle-shaped landmark. The mobile wayfinding information is found consistently useful without significant individual differences due to its dynamic nature. Therefore, designing the syntheses of mobile wayfinding information with the wayfinding information sources in the real environment is suggested. The syntheses of mobile and real environment wayfinding information can reduce the technical limitations in developing culturally consistent, accurate wayfinding information systems.

In the next chapter, the actual user behaviour has been investigated while experimenting in the real-time environment. The current and the previous study mentioned significant individual differences in the wayfinding behaviour and design preferences for wayfinding information design. It was considered necessary to investigate users' current practices in the real environment for validating the findings from the current study. Also, previous studies described the importance of mobile wayfinding information sources. It was considered necessary to investigate the current user behaviour concerning the syntheses of the information sources. For this reason, the next study has been planned to further explore the user behaviour regarding the information syntheses. The design and behavioural preferences along with the actual behaviour for wayfinding will further help in investigating the wayfinding issues in complex environments.

CHAPTER 7: STUDY 4 – WAYFINDING PREFERENCES AND BEHAVIOUR IN COMPLEX ENVIRONMENTS FOR THE SYNTHESES OF WAYFINDING INFORMATION

7.1 OVERVIEW OF CHAPTER

In this chapter, the actual user behaviour has been investigated as directed by the research question 5.

Research Question 5: What are the parameters necessary for efficiently <u>synthesizing the static and digital</u> wayfinding information?

The said investigation has been aimed to explore how users perform wayfinding tasks while using digital mobile aids as well as static environmental aids. The users were provided with the purposely designed wayfinding application and directed to perform the required wayfinding tasks using their preferred sources of environmental information. This chapter investigates human spatial behaviour, especially concerning synthesizing the wayfinding information from environmental sources. The study has been conducted by using real-time on-campus experimental settings with first-person video recording instruments while implementing the think-aloud protocol.

7.2 INTRODUCTION

The efficient delivery of environmental information to wayfinders in complex environments is an uphill battle for information designers. Wayfinding tasks can be quite strenuous and frustrating in the visual absence of dedicated wayfinding cues. With the advent of digital information, the inefficacy of static wayfinding information is anticipated. This empirical study aimed to explore the wayfinding behaviour regarding the type, use and synthesis of wayfinding information in complex environments. An experiment has been designed for the participants to perform wayfinding tasks in a spatially complex university campus. The participants were instructed to use the think-aloud protocol during the experiment. The behaviour has been recorded using the head-mounted video recorder (GoPro) and mobile phone display recorder, followed by an interview. Twenty-four university students participated in this study to evaluate the wayfinding behaviour qualitatively. Each participant performed three wayfinding tasks to locate the unknown destinations inside the university campus using a purpose-built mobile wayfinding application. The results demonstrated a few contrasting behavioural preferences in acquiring wayfinding information. Most of the participants synthesised the static and mobile wayfinding information sources, while some preferred only the static ones. Gender differences have also been found for route planning and finding. The study recommends a need for a synthesised wayfinding system utilizing the static and mobile wayfinding information for unfamiliar complex environments.

7.3 METHOD

7.3.1 PARTICIPANTS

For the in-depth investigation of users' behaviour, this study recruited a group of university students for performing wayfinding tasks. All the participants were required to be either new to this university setting or unfamiliar with the testing locations. A total of twenty-four participants have been selected based on the lowest familiarity level with the campus setting. 80% of the participants were males, and the remaining 20% were females. Out of 24 participants, 13 were from Hong Kong, whereas 11 participants were from Pakistan and India. The participants from Hong Kong belong to the individualist culture, whereas Indian and Pakistani participants were representing the collectivist culture (Iftikhar, Asghar and Luximon, 2020b). The gender groups were imbalanced in numbers due to less availability of participants during the pandemic Covid-19. The participant age ranges from 21 years to 32 years.

All the invited participants were having an undergraduate or above education level. All the participants were asked to report the Santa Barbara Sense of Direction Scale (Hegarty *et al.*, 2002). This scale has been influential and suggested in previous wayfinding studies to measure the user's spatial ability. The participants were also inquired about their daily usage of smartphones in hours per day for estimating their familiarity with smart devices. All the participants were having an adequate level of familiarity with the mobile user interface. This has been ensured by letting them complete the basic user interface tasks. Ethical approval (APPENDIX I) from the respective institutions have been obtained, and respective protocols were followed. All the participants have completed the selected wayfinding tasks, and the data has been recorded accordingly.

7.3.2 EXPERIMENT DESIGN

The study has been planned in two sections. The first section involved a wayfinding experiment in real-world settings using a purpose-built mobile wayfinding application. The participants need to locate the unknown locations inside the university campus using the wayfinding information systems and environmental cues. The mobile application would be served as a personal wayfinding guiding device during the whole experiment. Furthermore, the second section consisted of a post-experiment interview regarding the choices of behaviour and actions during wayfinding tasks.

7.3.2.1 *PHYSICAL ENVIRONMENT SETTINGS*

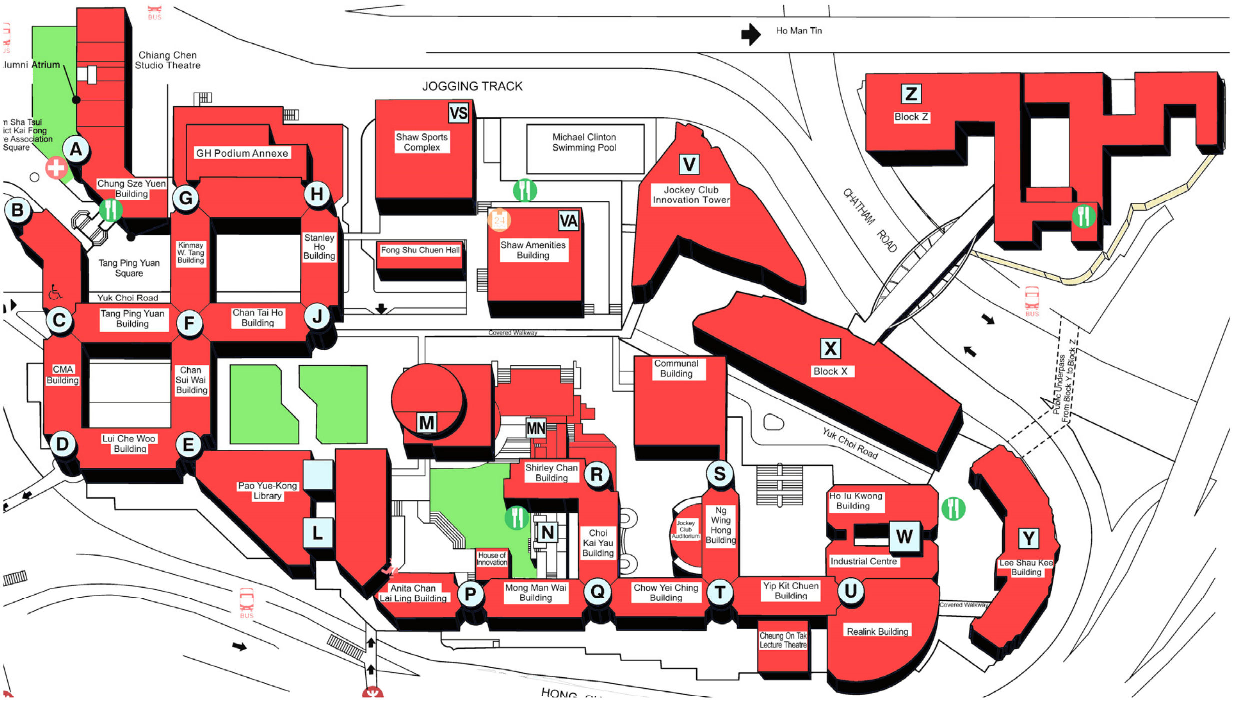


Figure 7.1 Campus Map

The experiment has been conducted on the campus of a reputed higher education institute situated in the heart of Hong Kong city. Diffused nature of facilities with intricate spatial layouts, this campus served as an ideal example of a complex environment. The selected campus has a total area of approximately 0.1 square kilometres, with more than 27 high-rise buildings. Most of the buildings, including intersections F, G, J, H, and E, have 9-10 storeys on average. At the same time, the other buildings consisting of M, V, Z, W and Y have 12-15 storeys on average.

The campus buildings have multiple and interconnected entrances and floors. This campus serves around 30,000 local and international students along with many visitors throughout the year. This campus has compromised visual access to wayfinding aids and environmental cues for navigators due to the cluster of buildings and other structures. The detailed spatial layout, along with the nomenclature of buildings and structures, has been presented in Figure 7.1. The red highlighted areas are the primary building structures, whereas the alphabets are representing the interconnection of the buildings. Some of the alphabets are also representing the buildings themselves, like M, V and VA, as depicted in Figure 7.1.

Figure 7.2 3D aerial view of campus

All the remaining areas are walkable; however, there is one walkway that is covered with rain shelter. There is also a difference in height level in the open areas of the drawn map as the top view is only accommodating the topmost podium floor plan. The road or ground level is different from the podium level (2nd floor from the ground floor). A three-dimensional delineation of the campus setting has been presented in Figure 7.2 with the help of Google maps to show the difference. The small bar on the right-hand bottom corner is representing the 20 m of viewing scale. The campus has been equipped with static wayfinding aids in terms of signage, YAH (you are here) maps, pathways, intersections and landmarks. The free Wi-Fi facility has also been provided with moderate to excellent strength of internet signals throughout the campus.

7.3.2.2 *DIGITAL ENVIRONMENT SETTINGS*

A purpose-built campus wayfinding application has also been provided to the participants as a personal digital wayfinding system. The application was installed on a Samsung smartphone (C7) with an android (Orio 8.0) operating system and was connected to the university provided free Wi-Fi. The selected device has a 5.7” HD super AMOLED main display with a ratio of 16:9 and 386 PPI pixel density. An anti-glare screen protector has also been installed to prevent unnecessary screen glare during the experiment. The wayfinding application has a minimal home page design with a side and tab menu for interacting with the application, as depicted in Figure 7.3.

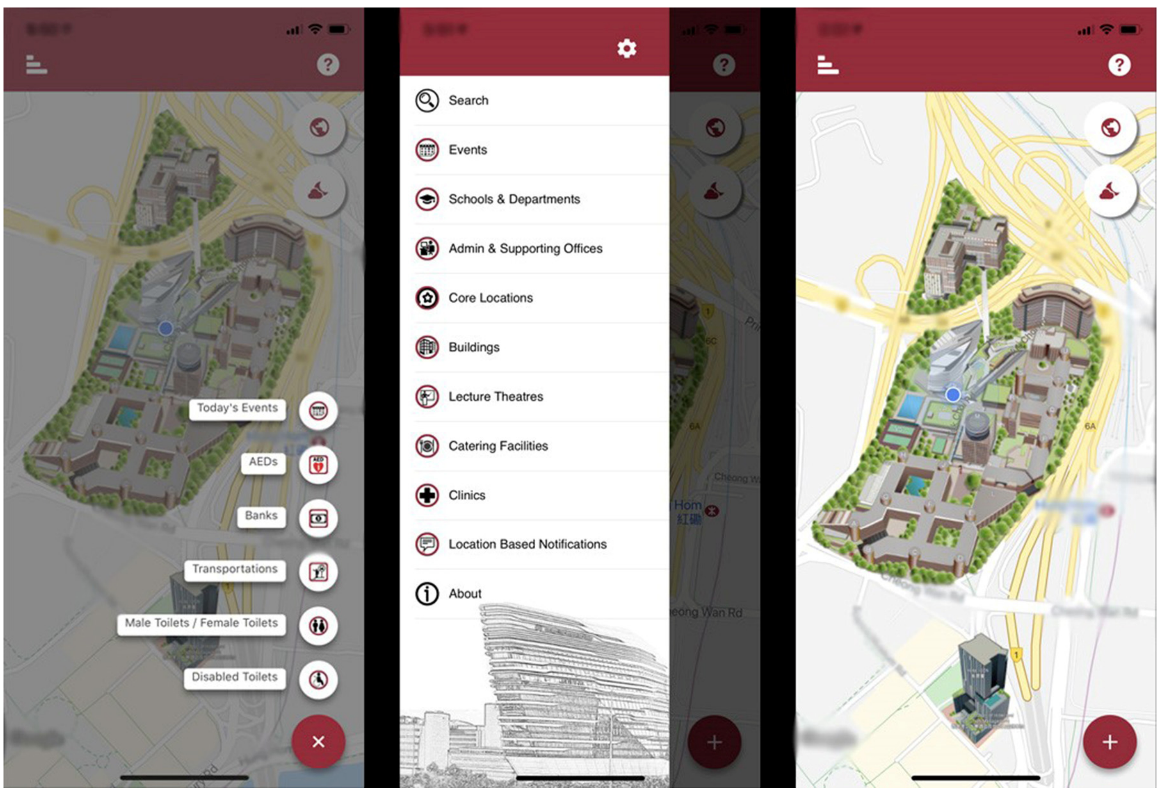


Figure 7.3 Wayfinding application (Tab menu, side bar menu, home page)

The application has all the information necessary for completing the assigned wayfinding tasks. The wayfinding application interface has the following features: A dedicated search bar, names of facilities (category wise), list of current events, notification settings, location-based notifications, complete interactive campus map with real-time location pointer, reference images of the destination, turn by turn written directions, ideal route planning and identification of user accessibility information.

7.3.2.3 ***EXPERIMENT PROTOCOLS***

Think Aloud: Think aloud protocol has been used during the experiment to record the participants' behavioural responses while performing the wayfinding tasks. The think-aloud protocol has been influential in multiple studies related to wayfinding and user behaviour research (Crampton, 1992; Baker *et al.*, 2015; Kinsley, Schoonover and Spitler, 2016; Schrom-Feiertag, Settgast and Seer, 2017). During the wayfinding tasks, navigators were directed to speak while thinking and performing the wayfinding tasks. The participants' voice and the mobile screen has been recorded while performing all the assigned wayfinding tasks. This practice can be significant in deciphering behavioural choices. The participants' activities were categorised according to the following components, i.e., information searching, planning, identifying real environment, location identification, orientation identification.

GoPro Video Recording: The experiment required the navigator's first-person view in a complex environment for a better understanding of the actual problem faced by the participant. The participants were directed to wear a head harness with GoPro (Hero 5, 4k 30 fps) to record the first-person viewing experience. The benefits of using GoPro in acquiring the first-person view have been instrumental in previous research studies. Multiple studies (Waters, Waite and Frampton, 2014; Stevenson and Kohn, 2015; Thain, 2015; Kinsley, Schoonover and Spitler, 2016) conducted by the social scientists have used the GoPro to observe the participant without distance and disturbance.

Interview Design: After the experiment, the participants were invited to the design lab for a semi-structured interview regarding the choice of actions during wayfinding tasks. The participants were asked the questions regarding their behaviour with the following prompt:

1. Why did you stop at this point?
2. What type of problem were you facing in accessing and implementing wayfinding information?
3. What type of information were you looking for?
4. What were the difficulties during this experiment?
5. How was your overall experience?
6. What are your suggestions for improving the wayfinding in complex environments?

7.3.2.4 ***EXPERIMENT PROCEDURE***

The participants were invited to the design lab to brief the experimental procedures and fill out the consent form regarding video recording and personal data collection. The experiment has been designed consisting of three wayfinding tasks. Fourteen locations inside the campus have been presented to the participants based on the different academic and non-academic facilities offered by the institution. All the provided destinations have consisted of more than five intersection points along the route. The provided locations were grouped into three categories based on the provided services provided in Table 7.1. All the locations have been assigned with their respective codes for further data analysis. Four locations consisted of different academic departments, five locations were related to the administration facilities provided by the institution and five more locations were related to the student facilities. The participants need to select three completely unknown locations from the provided categories, i.e., one from each category. They have been instructed to access the wayfinding information from application, signage, landmarks or other environmental cues whenever and wherever necessary. Before commencing the experiment, the participants were briefed about the wayfinding application, and they were instructed to practice all the features.

Table 7.1 Locations for wayfinding tasks

Experiment locations	Location codes (LC)	Category	Ideal completion time (ICT)
Dpt. of Biomedical Eng.	DFL-1	Departmental facilities (DF)	4 min
Dpt. of Industrial & Systems Eng.	DFL-2		7 min
Dpt. of Rehabilitation Sciences	DFL-3		4 min
Dpt. of Optometry	DFL-4		4 min
Office of Centre Stars	AFL-1	Administration facilities (AF)	4 min
Educational Development Centre	AFL-2		4 min
International Affairs Office	AFL-3		4 min
Institute of Entrepreneurship	AFL-4		4 min
Office of University Requirements	AFL-5		4 min
Office of Undergraduate Studies	SFL-1	Student facilities (SF)	4 min
Innovation & Technology Office	SFL-2		7 min
W-kiosk Café	SFL-3		4 min
Dental Clinic	SFL-4		4 min
Radiology Clinic	SFL-5		7 min

7.3.3 DATA ANALYSIS

The data has been collected in the form of videos obtained from GoPro recording, mobile device screen recording and interviews. For all the participants, around fifteen hours of video and audio data have been obtained and have been organised in sequential order. The data were transcribed and analysed using the content and activity analysis. Content analysis has been of great significance for qualitative researchers when they need to examine the patterns and recurrence of particular actions (Bell, Bryman and Harley, 2018). In our collected video recordings, the objective was to explore the user behaviour and ascribed actions for information synthesis in wayfinding. The analysis of particular actions may seem quite unchallenging; however, it requires hermeneutic activities (Luckmann, 1981).

7.3.3.1 ***METRICS***

The video data has been analysed for participants' wayfinding performance and behaviour. Specific activities and actions like information searching, information preferences and information syntheses have been observed and recorded while users were performing the wayfinding tasks. The data has been observed and coded by two researchers to ensure the reliability of the acquired data of users' behaviour. For observing the said behaviour, the following metrics have been developed.

<u>*The difference between Ideal and Actual Time:*</u> The difference between a participant's actual completion and ideal time of wayfinding tasks has been assessed. The provided mobile application has calculated the ideal completion time for completing the wayfinding task. In contrast, the participant's actual completion time is the time taken to complete the task physically. The differences in actual completion time (ACT) and ideal completion time (ICT) for reaching the destination has been documented as a performance metric. The higher and lower time difference has been regarded as the magnitude of a participant's performance, respectively.

<u>*Ideal vs Participants' routes:*</u> The ideal route (Figure 7.4) planned by the application has been collated with the participant's followed route (Figure 7.5) to gauge the participant's dependence on the provided information. The deviation from the ideal route has been documented and analysed for exploring the potential motivations.

<u>*Behaviour at Stop Location Points:*</u> During the experiment, when the participant stopped walking and looked for environmental information, these locations were marked as stop location points. The number of stop locations has been documented during the whole experiment and delineated as small dots in Figure 7.5. At the stop location points, the participants have been observed for specific activities like searching for information sources, identifying the real environment, their position and orientation.

<u>*Behaviour at the Decision Points:*</u> Along the route, the points have been marked as decision points where two or more than two ways intersect. Behaviour on the decision points has been recorded throughout the route assigned to the participant. Participants' actions regarding the information searching and decision making have been analysed on the mentioned decision points.

<u>*Information Syntheses of Environmental Sources:*</u> For investigating the environmental information syntheses, four sources have been identified as the key elements such as signage, landmarks, pathways/intersections and wayfinding applications. These sources of environmental information have been considered influential during the experiment, and participants' behaviour was analysed. Single and multiple sources of environmental information have been used by the participants and categorised accordingly after the content analysis of videos and post-experiment interviews. This interview was semi-structured and have been used for further exploration of participants' behaviour.

7.4 RESULTS

7.4.1 WAYFINDING PERFORMANCE

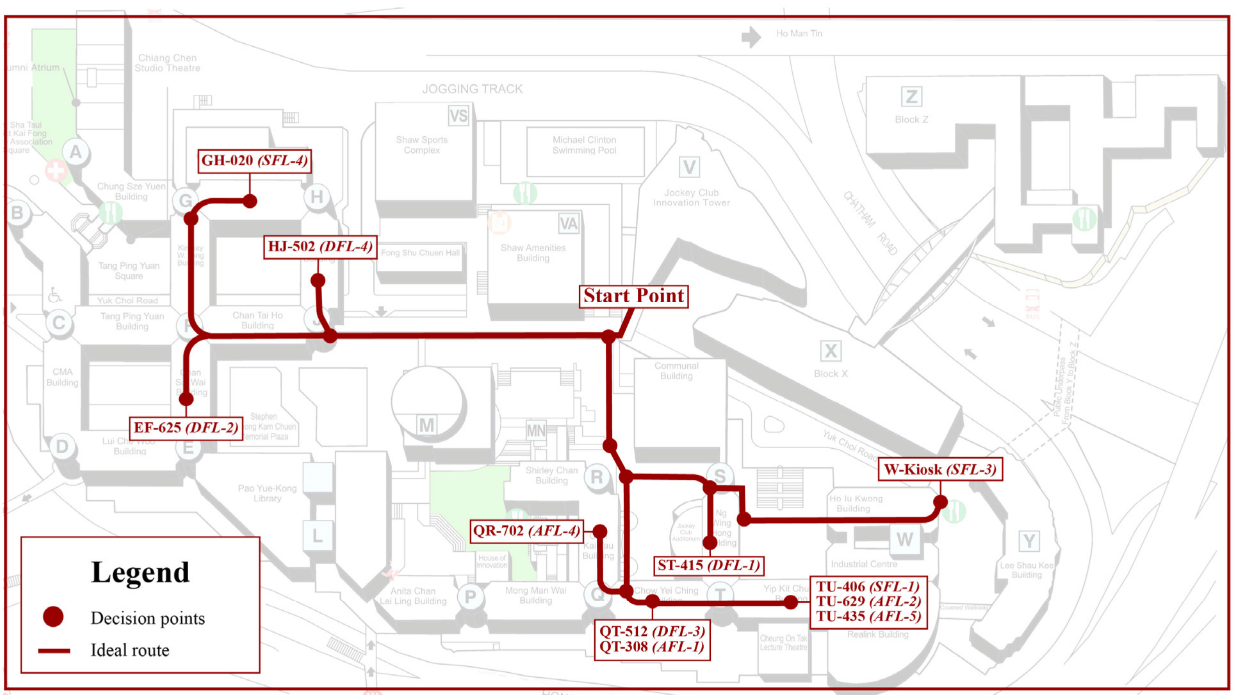


Figure 7.4 Ideal routes

The participants have selected three unfamiliar locations from the provided locations in Table 7.1, i.e., one from each category. The provided wayfinding application has calculated the ideal route with the ideal time to reach the destination. The ideal completion time (ICT) for every route has been presented in Table 7.1. 83.3% of participants have selected the locations near R, Q, S, T and U intersections of the buildings as they were unfamiliar and challenging to remember compared to the rest of the university campus. This area has congested spatial settings with limited visual access to the wayfinding aids and environmental cues. The locations have been presented to the participants as the name of the facility, as shown in Table 7.1. After selecting their respective locations, the participants were directed to locate the destinations using digital information (wayfinding app) and other environmental information sources (if required).

7.4.1.1 ***TASK INITIATION***

The wayfinding application has planned the ideal route from their starting point to the selected location using location pointers on the campus map, as depicted in Figure 7.4. Only 33.3 % of the participants have considered the planned route, while the remaining participants have faced difficulty identifying the information in real-world settings. The planned routes were quite ideal in terms of distance and travel time. In Figure 7.4, the location number of the destination has also been presented, i.e., ST415, here ST presents the location in between S & T intersection. The information regarding the coding of facility names into the location numbers has also been presented in the wayfinding application. However, unfamiliar participants were not able to identify the location by using location pointers.

All the participants have started their route from the V building, as pointed out a starting point in Figure 7.4. The participants have searched for the destination and planned their routes by using the wayfinding application while standing on the podium floor of the V building. 83.3% of the participants tried to memorise the route first and afterwards tried to identify the provided information in real-world settings. After validating their location with the surrounding environment, they started their journey to find the destination. 75% of the participants have faced trouble in synchronizing their location on the map with their location in real-world settings. The drawn routes in Figure 7.5 with thin red and green lines are representing the exact routes opted by the participants individually. Whereas the small red dots are representing the stop locations by the participants while performing wayfinding tasks. GoPro videos have shown that all participants were trying to figure out their current locations within the environment. The location pointer in the wayfinding application was quite misleading due to the limitation of GPS signals in a complex environment.

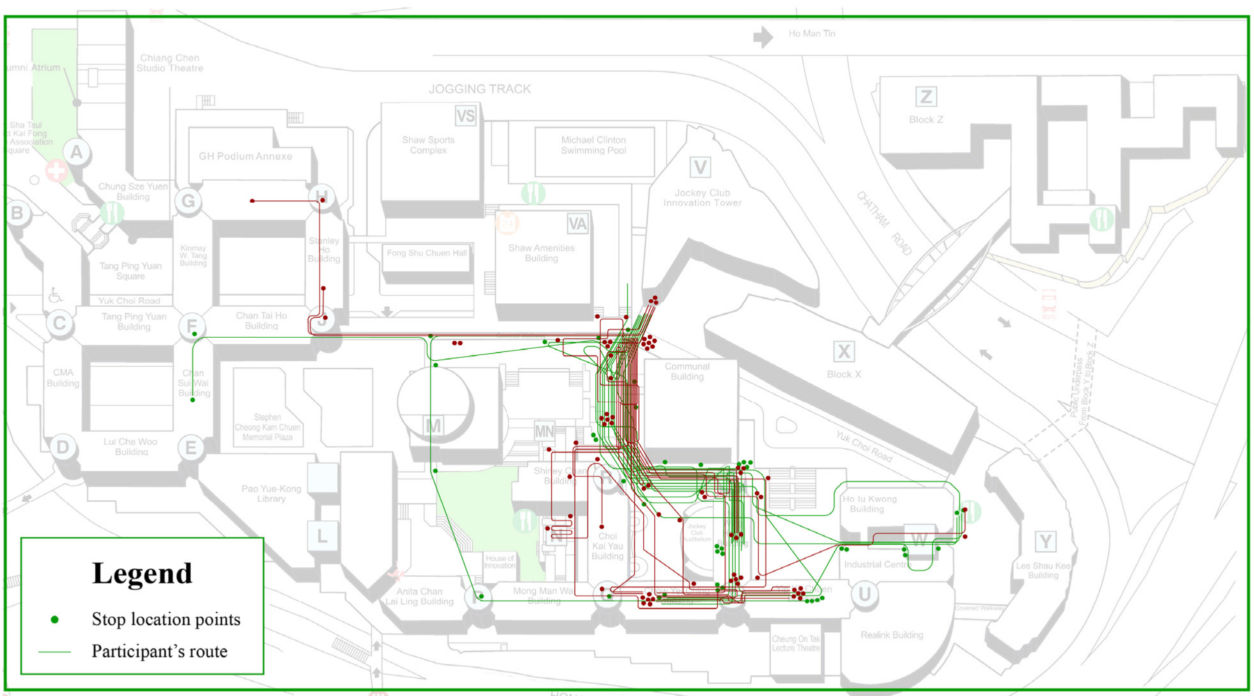


Figure 7.5 All participant route

7.4.1.2 *TASK COMPLETION TIME*

The primary stop locations were identified near the sources of environmental information and at the intersection points. The stop locations of the participants were concentrated near the directional signage alongside the route as the participants needed more information than the wayfinding application. The highest concentration can be seen at the starting point near the V building, at the intersection beside R, and at the intersection points near S, T, Q, and U. The participants have completed their wayfinding tasks longer than the ideal time for task completion.

The participants' wayfinding performance has been affected due to multiple reasons. The

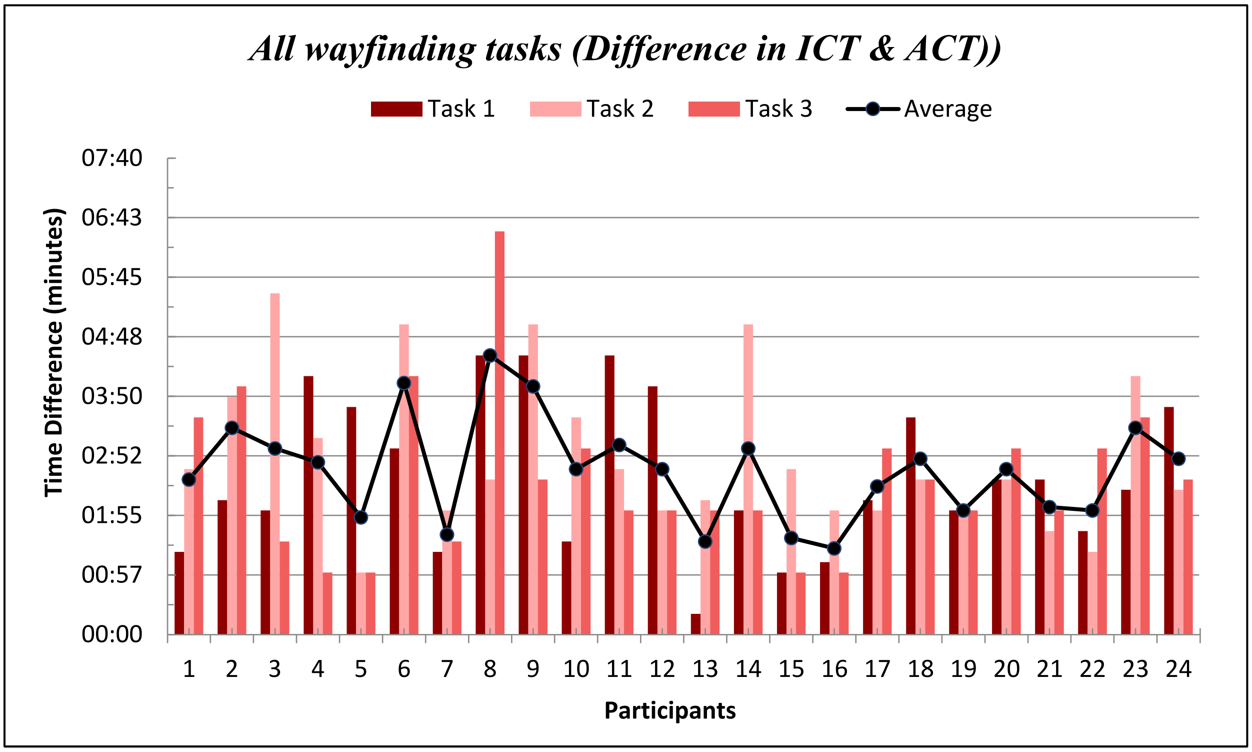


Figure 7.6 Comparison of wayfinding tasks completion time

campus layout was complex, and participants have less visual access to the wayfinding aids. That is why all the participants have taken a long time to complete the tasks in comparison to the calculated time by the application. The minimum difference in the overall ideal and actual completion time of the participant is four minutes for the sixteenth participant, while the maximum difference is 13 minutes 30 seconds for the 8^{th} participant. The average time difference between the ideal (ICT) and actual completion time (ACT) has also been presented in Figure 7.6 for individual tasks.

The graphical comparison has been drawn in Figure 7.6, where the highest peaks are for third, sixth, eighth, ninth and fourteenth participants. All the participants have initially spent their time planning the route and identifying their current location in real-world settings. Once they start walking, the remaining time was spent on finding and validating the wayfinding information through the application and other environmental cues. The higher concentration of stop locations in Figure 7.5 near building intersections was due to the presence of the identification and directional signage. The directional information through signage was not very helpful for the participants due to multiple directions in a single-pointed way.

Most of the participants have complained about the less signage information and their placement. The mobile application information was considered quite detailed; however, the major problem was to validate the information in real-world settings. The conversion of position from the interactive map to real-world settings was quite difficult due to the difference in viewing angles of users. There was a feature of reference images of the destination with surroundings, but participants did not find it helpful due to the extreme homogeneity of the physical environment.

Hence, the reference images were very identical to each other hence were not efficient enough to guide the navigators effectively. The landmarks were present in the form of sculptures, monuments and fountains; however, the participants found it difficult to memorise their positions concerning the environment. The whole campus map was quite challenging to memorise and recall during the wayfinding tasks by merely seeing it as an interactive map on the mobile device.

7.4.2 EFFICACY AND SYNTHESES OF ENVIRONMENTAL INFORMATION SOURCES

7.4.2.1 *SIGNAGE*

The wayfinding information can be obtained in many ways, either through environmental cues or through the designed wayfinding systems. The traditional or static wayfinding system cannot serve the purpose efficiently in complex environmental settings (Iftikhar, Asghar and Luximon, 2020a). In our investigation, it has been observed that the participants have opted for multiple sources of wayfinding information. For the traditional wayfinding systems, including directional and identification signage, the participants have relied more on the identification signage. As the university campus has diffused walkways and paths, so the directional signage was not enough for the participants. The directional signage can demonstrate a higher efficiency where the walkable paths were identified, such as roads and pedestrians. Most of the participants have combined the information from identification signage with the wayfinding application. The participants have obtained the route knowledge through the application and validated it with the help of identification signage or alphabets in this case. The alphabets of intersections and buildings have been visibly placed outside the structure and served the purpose of identification.

7.4.2.2 ***LANDMARKS***

Some of the participants have relied on landmarks related information. This university campus has two to three very distinctive building structures, i.e., V and ST. These structures have relatively unique architectural facades. A clock tower and some sculptures also have been placed near building M and intersection J for providing ease in the wayfinding. Some of the participants have described that this type of landmark information should be included and visible in the wayfinding application. The participants have also suggested that instead of presenting a complete detailed map, the minimal map with landmarks identification would serve the purpose better. One of the participants has given the example that the clock tower should be highlighted near building M instead of focusing on the building's structure. Significantly this would help a lot where the building's façade and rest of the visual appearance look like the environment.

7.4.2.3 ***PATHWAYS AND INTERSECTIONS***

The participants were quite confused and took a long-time near intersections and multiple pathways, as depicted in Figure 7.5. The university campus had only one dedicated and well-identified pathway for the navigators, which is covered. The rest of the space is open to walking; therefore, participants did not consider it as an aid for environmental information. The points of stop locations were quite concentrated near the intersection of the R and MN building (Figure 7.5).

For most of the participants, the combination of static and mobile information was not enough to direct them in the right direction. The intersections were considered the decision points during wayfinding, whereas multiple locations had multiple intersections in this university campus.

7.4.2.4 *WAYFINDING APPLICATIONS*

The participants have considered the interactive map quite helpful in the wayfinding tasks only if the location pointer tells the correct position and direction of the navigator. In our experiment, the GPS signals were not accurate due to the congested presence of multi-floor buildings in a smaller space. For additional information, the reference images of the destination have also been added for the navigators. The participants did not find it accessible and reliable in completing the wayfinding tasks. Participants have accessed the reference images of the destination along with the 3d view; however, all of them could not be able to recognise the destination because of environmental homogeneity. One of the participants has mentioned that the reference images had only one perspective of a building which is quite challenging to identify. A three-dimensional view would be a good option, but it should be intuitively accessible in the wayfinding application.

The campus buildings and intersections have been named alphabetically to serve as an effective environmental cue. Seventy to eighty percent of the participants have synthesised this information with the wayfinding application to perform the wayfinding tasks. The unfamiliar participants have used this information on the map and tried to locate and plan the destination with cardinal directions provided on the map. However, being identification signage, the alphabetical nomenclature served only to validate the information. The participants have identified the significant contribution of wayfinding signage as a guiding information system in conjunction with digital information systems. The combination of these two information systems is much more efficient in comparison to being working alone. The participants have also suggested to include the layout information of building internals within the existing application. In addition to that, the design of digital information should be kept minimal and intuitive.

7.4.3 GENDER DIFFERENCES

Critical differences in wayfinding performance have been observed between male and female participants. During the experiments, the males have outperformed the female participants in wayfinding performance consistent with the previous studies (Silverman *et al.*, 2000; Malinowski and Gillespie, 2001). In Figure 7.6, it has been significantly visible for the sixth, the eighth, ninth, eleventh and fourteenth participants who are females. The eighth participant has spent the longest time due to the confusion at the start of the experiment concerning the location pointer. The habit of using a location pointer to validate one's position rather than memorising the environmental features take additional effort to understand the information as well. Due to this, the zig-zag route of a female participant near intersection R and Q in Figure 7.5 was nowhere near the ideal route of rehabilitation sciences (QT308). The complete reliance on the mobile wayfinding application requires additional time and effort to process and validate the information. The respective participant has considered directional signage useless, however, considered identification signage is rather helpful.

Some of the participants with higher task completion times were partially familiar with the campus environment; however, they considered all the wayfinding tasks pretty much complex in these environmental settings. They took a long time to understand the wayfinding information from the app, especially the information related to the alphabetic nomenclature of the intersections and the buildings. Once the participants were confident to walk in the right direction, they only consulted the information related to the pointer location.

During the experiment, the male participants have provided more focus on the multiple sources of information provided by the wayfinding application. Male participants have consulted the route direction, written directions, complete route plan and the alphabetical nomenclature of the buildings. However, the female participants were more interested in the position pointer on the interactive map and their relative direction. They considered the written directional information and reference images quite difficult to understand and validate in real-world settings. The reference images were difficult to validate in the real-time environment due to the difference of viewing perspectives between the wayfinding application and the viewer. Based on their respective behaviour, thirteen significant differences have been recorded and outlined. The female participants have often used four sources of wayfinding information consisting of alphabetic nomenclature, position pointer, interactive map and identification signage. However, males have preferred the combination of most of the provided wayfinding information to complete the tasks. A detailed comparison between the gender differences in the syntheses of wayfinding information has been presented in Table 7.2.

Table 7.2 Comparative analysis of gender differences in wayfinding information syntheses

Sr.	Types of actions					
1	Wayfinding task completion time	*Short*	*Moderately short**	*Moderate*	*Long*	*Very long***
2	Number of wayfinding information sources	*Single*	*Mostly single***	*Moderate*	*Mostly multiple*	*Multiple**
3	Route directions in the App.	*Not used*	*Rarely used***	*Moderately used*	*Often used**	*Very often used*
4	Written directions in the App.	*Not used***	*Rarely used*	*Moderately used**	*Often used*	*Very often used*
5	Alphabetic nomenclature	*Not used*	*Rarely used*	*Moderately used*	*Often used**	*Very often used***
6	Position pointer in the App.	*Not used*	*Rarely used*	*Moderately used**	*Often used*	*Very often used***
7	Interactive map in the App.	*Not used*	*Rarely used*	*Moderately used*	*Often used**	*Very often used***
8	Reference images in the App.	*Not used***	*Rarely used*	*Moderately used**	*Often used*	*Very often used*
9	Identification signage in real world	*Not used*	*Rarely used*	*Moderately used*	*Often used**	*Very often used***
10	Direction signage in real world	*Not used***	*Rarely used**	*Moderately used*	*Often used*	*Very often used*
11	Dedicated pathway in the real world	*Not* used***	*Rarely used*	*Moderately used*	*Often used*	*Very often used*
12	Landmarks in the real world	*Not used***	*Rarely used**	*Moderately used*	*Often used*	*Very often used*
13	Verbal directions from a passer-by	*Not* used***	*Rarely used*	*Moderately used*	*Often used*	*Very often used*

** Males*
***Females*

7.4.4 DIFFERENCES BASED ON SPATIAL ABILITIES

Spatial ability is the individual's ability to explore and remember a spatial setting with ease and

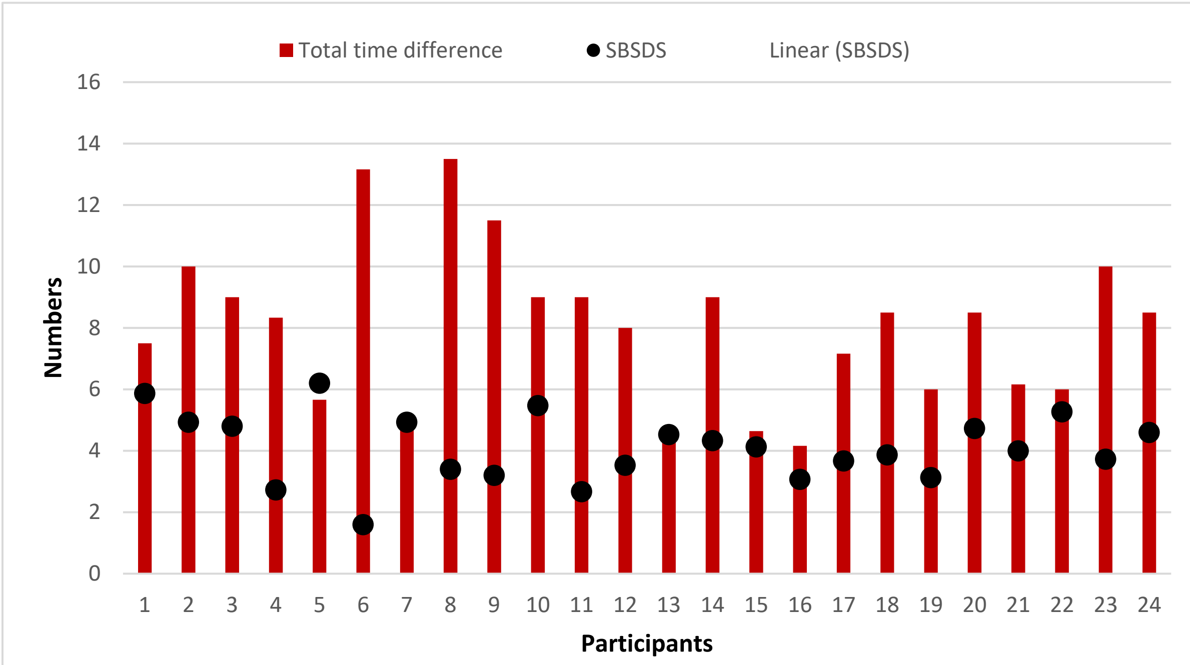


Figure 7.7 SBSDS vs Difference of total time

efficiently perform the wayfinding tasks. A study (Hegarty *et al.*, 2002) has investigated the effects of spatial ability on wayfinding performance and developed a scale to measure the individual's spatial ability through the sense of direction scale. The Santa Barbara sense of direction scale has been used by multiple previous studies (Lin, Cao and Li, 2019) to measure the spatial ability of the participants. In this study, all the invited participants have been asked to report their spatial ability through this scale. This scale has been developed using a self-reported seven-point Likert scale using 15 questions. After applying the respective coding mentioned in the scale, the participants' spatial ability has been calculated.

The spatial ability of the participants has been considered above average when the score crosses the neutral value of 4.00. Out of 24 participants, thirteen were having a higher spatial ability than the average individual. The spatial ability values and their relationship with the time taken for performing the wayfinding tasks have been graphically presented in Figure 7.7. In Figure

7.7, the greyed line represents the neutral value for spatial ability which is 4.0. Above this value, all the participants were considered with the higher spatial ability. As a general observation, we can see that those with spatial ability less than four generally take longer to complete the tasks and vice versa. However, we have applied the relevant correlation tests amongst spatial ability scores and the total time using SPSS software to investigate this effect. The correlation coefficient showed a negative relationship (*r*=-0.375), stating an inverse relationship between the two parameters as per our expectation. However, this correlation was not considered significant because of the significance level ($p > 0.05$).

Table 7.3 Significant differences based on spatial ability in wayfinding behaviour

Sr.	Questions	H	High Spatial Ability	L	Low Spatial Ability
1	Got accurate info through app	*50%*	*Agreed*	*70%*	*Agreed*
2	Prefer minimal info design in app	*75%*	*Agreed*	*50%*	*Agreed*
3	Prefer text over symbolic info	*67%*	*Agreed*	*40%*	*Agreed*
4	Preferred type of information		*Mobile, signage, landmarks (58%, 25%, 17%)*		*Mobile, signage, landmarks (80%, 30%, 30%)*
5	Problems during mobile wayfinding		*Location, Route (42%, 17%)*		*Location (50%)*
6	Signage is useless in comparison to apps		*Yes, No (8%, 92%)*		*Yes, No (30%, 70%)*
7	Favourite features in App.		*Location & direction, route, search bar, info design (50%, 25%, 8%, 25%)*		*Location & direction, search bar, info design (20%, 20%, 40%)*
8	I prefer colour coding in info. design		*Yes, No (75%, 17%)*		*Yes, No (60%, 40%)*
9	What info. Is missing in the app.		*Login/logout feature, building internals*		*Building internals, location accuracy, spatial coding legend, entrance reference images*
10	App. Route was ideal and short	*50%*	*Agreed*	*80%*	*Agreed*
11	Used other info. during experiment	*58%*	*Agreed*	*80%*	*Agreed*
12	Other info sources should be combined in app	*83%*	*Agreed*	*100%*	*Agreed*
13	Do not frustrated while using app	*58%*	*Agreed*	*90%*	*Agreed*
14	Which wayfinding is difficult		*Outdoor, Indoor (42%, 58%)*		*Outdoor, Indoor (60%, 40%)*
15	Signage should be improved		*Night visibility, placements, info design, colour coding*		*Signage quantity, minimal info, placements*
16	Signage and app are physically connected		*Yes, No (33%, 58%)*		*Yes, No (60%, 40%)*
17	How static & digital info. can combine		*Augmented reality, QR code, detail info, in-app signage info, info sources should be combined*		*QR code, validation signage, in-app signage info, info to find the signage*

Sr.	Questions	H	High Spatial Ability	L	Low Spatial Ability
18	Signage should be upgraded with tech		*Yes, No (75%, 17%)*	*100%*	*Agreed*

After investigating the differences in performance, the participants were divided into two groups, i.e., higher spatial ability and lower spatial ability. Their recorded video data has been analysed for any behavioural differences in performing the wayfinding tasks in the real environment based on these two groups. Significant differences have been observed based on the level of participants' spatial ability. All the participants were interviewed regarding potential behaviour during and after the experiment. The significant differences were related to acquiring and understanding the wayfinding information. In Table 7.3, all the significant differences have been delineated in detail.

7.4.5 CULTURAL DIFFERENCES

In the previous studies that are presented in this thesis, several individual-related differences have been observed in wayfinding information gathering, understanding and ascribed behaviours. In continuation to that, this study has also been focused on recording any cultural differences in the current practices of wayfinding information syntheses. Owing to this, participants have been divided into two groups, i.e., Hong Kong (Individualists) and Pakistan (Collectivists). These two cultural groups have been divided as in the previous studies of this thesis. Out of twenty-four participants, 11 participants belonged to the collectivist group whereas, 13 participants were from the individualist group.

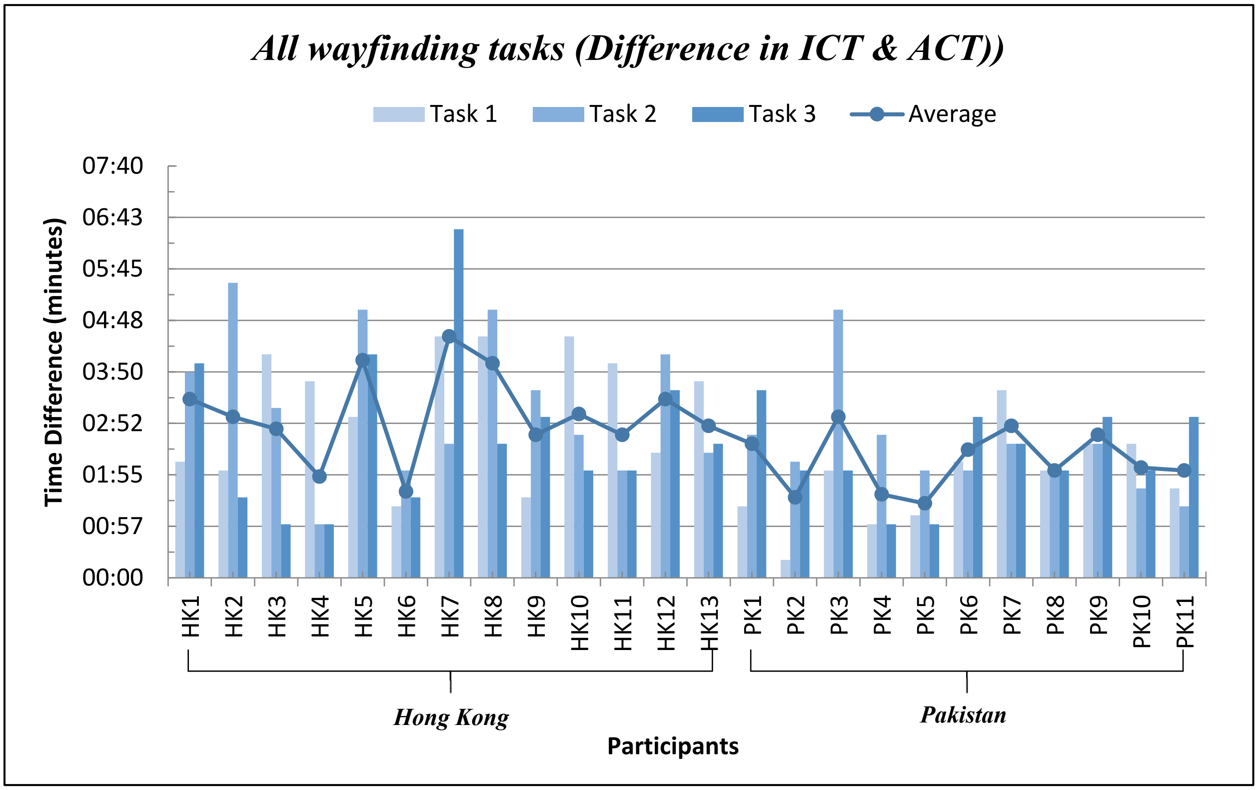


Figure 7.8 Task completion time for cultural groups

Critical differences in wayfinding performance have been observed between the participants from Hong Kong and Pakistan (Figure 7.8), consistent with the previous studies (Munroe and Munroe, 1997; Lawton and Kallai, 2002). The participants from Pakistan slightly took less time to complete the wayfinding tasks and bear some differences in wayfinding behaviour similar to the previous studies (Ahmed, 2015; Iftikhar, Asghar and Luximon, 2020a).

These studies investigated the wayfinding behaviour in the Asian subcontinent countries as a collectivistic society and compared the differences with the individualistic societies. The cultural differences in the wayfinding synthesis and behaviour have been presented in Tables 7.4 and 7.5, respectively.

Table 7.4 Comparative analysis of cultural differences in wayfinding information syntheses

Sr.	Types of actions					
1	Wayfinding task completion time	***Short***	***Moderately short***	***Moderate******	***Long****	***Very long***
2	Number of wayfinding information sources	***Single***	***Mostly single***	***Moderate******	***Mostly multiple****	***Multiple***
3	Route directions in the App.	***Not used***	***Rarely used******	***Moderately used****	***Often used***	***Very often used***
4	Written directions in the App.	***Not used******	***Rarely used***	***Moderately used****	***Often used***	***Very often used***
5	Alphabetic nomenclature	***Not used***	***Rarely used***	***Moderately used***	***Often used****	***Very often used**/****
6	Position pointer in the App.	***Not used***	***Rarely used***	***Moderately used****	***Often used***	***Very often used**/****
7	Interactive map in the App.	***Not used***	***Rarely used***	***Moderately used***	***Often used*****	***Very often used****
8	Reference images in the App.	***Not used*****	***Rarely used****	***Moderately used***	***Often used***	***Very often used***
9	Identification signage in real world	***Not used***	***Rarely used***	***Moderately used***	***Often used****	***Very often used**/****
10	Direction signage in real world	***Not used*****	***Rarely used****	***Moderately used***	***Often used***	***Very often used***
11	Dedicated pathway in the real world	***Not used**/****	***Rarely used***	***Moderately used***	***Often used***	***Very often used***
12	Landmarks in the real world	***Not used*****	***Rarely used****	***Moderately used***	***Often used***	***Very often used***
13	Verbal directions from a passer-by	***Not used****	***Rarely used***	***Moderately used*****	***Often used***	***Very often used***

****   Hong Kong***
*****Pakistan***

Table 7.5 Significant cultural differences in wayfinding behaviour

Sr.	Questions	HK	HK Remarks	PK	PK Remarks
1	Can find way without using app in complex environments.	*36%*	*Agreed*	*64%*	*Agreed*
2	Signage more useful than apps	*54%*	*Agreed*	*82%*	*Agreed*
3	Do not need other info while using app	*18%*	*Agreed*	*45%*	*Agreed*
4	Easy to match app. route in real settings.	*73%*	*Agreed*	*91%*	*Agreed*
5	Preferred type of information		*Mobile, signage, landmarks (73%, 27%, 18%)*		*Mobile, signage, landmarks (73%, 27%, 27%)*
6	App information is reliable	*91%*	*Agreed*		*Agreed (73%), Disagree (27%)*
7	Problems during mobile wayfinding		*Location, Route (73%, 18%)*		*Location, validation (27%, 27%)*
8	Signage is useless in comparison to apps		*Yes, No (27%, 73%)*		*Yes, No (9%, 91%)*
9	Favourite features in App.		*Location, route, search bar (64%, 18%, 18%)*		*Design and graphics*
10	Prefer colour coding in info. design		*Yes, No (45%, 55%)*		*Yes (91%)*
11	Prefer reference images		*Yes, No (45%, 55%)*		*Yes, No (82%, 18%)*

Sr.	Questions	HK	HK Remarks	PK	PK Remarks
12	What info. Is missing in the app.		*Login/logout feature, audio info., building internals*		*Updated routes, building internals*
13	What improvements are needed in info?		*Login/logout feature, accurate position, 3D maps*		*Building internals, colour coding*
14	Need signage info. during experiment		*Yes, No (82%, 18%)*		*Yes, No (64%, 36%)*
15	App. Route was ideal and short	*45%*	*Agreed*	*82%*	*Agreed*
16	Need to memorise the route to find way	*55%*	*Agreed*	*36%*	*Agreed*
17	Used other info. during experiment	*82%*	*Agreed*	*55%*	*Agreed*
18	It was easy to maintain sense of direction	*55%*	*Agreed*	*91%*	*Agreed*
19	Which wayfinding is difficult		*Outdoor, Indoor (64%, 36%)*		*Outdoor, Indoor (36%, 64%)*
20	Signage should be improved		*Placement, larger text, more quantity, simple design*		*Night visibility, colour coding, floor info, position & placement, minimal info.*
21	How static & digital info. can combine		*QR code, in-app info about signage placing*		*Augmented reality, not sure but should be combined*
22	Signage should be upgraded with tech		*Yes, No (73%, 27%)*	*91%*	*Agreed*

7.5 DISCUSSION AND CONCLUSION

Current practices of wayfinding in complex institutional environments required a thorough investigation due to the emergence of different types of wayfinding aids. The primary objective of this research was to investigate the current practices of wayfinding information syntheses.

User preferences for information syntheses: Campus has a unique wayfinding system of alphabetically naming the series of buildings displayed by large identification signage. The respective signage has been significantly used and preferred by the participants for validating the application-based information. The identification signage has been displayed in front of the intersection or a building in the form of large alphabets. The naming pattern, i.e., ST415, has floor information in the first digit, and the remaining two digits are the respective room numbers. However, for the participants, this information was not very helpful as most of the participants were not aware of this pattern of information, especially females. The participants have mentioned several problems while locating the destination inside the building using only a static wayfinding information system. They had to rely on the signage system while navigating indoors because the wayfinding application had not incorporated the information related to building internals.

Effective sources for information syntheses: The other environmental cues like landmarks, pathways and intersections were seldom used by the participants due to several reasons. The landmarks were present in the environment, but due to homogenous building structures, it was complicated for the participants to memorise the landmark location with respect to the environment. There were only one to two iconic buildings in the environment, whereas all the remaining were of almost similar facades and heights. There was only one well-identified pathway on the campus, while the rest of the area was also walkable and paved with tiles. Due to these spatial characteristics, the participants have identified the campus as a complicated spatial setting for wayfinding.

Gender-based preferences: The male participants have expressed that they have experienced a partial visual absence of the signage information while navigating and wayfinding inside the campus. In comparison, the female participants were completely unable to obtain the signage information due to similar obstacles. As the obstacles can increase the topological depth of the environment (Turner, 2007) and cause difficulty in wayfinding activities. The route planning and memorising were considered very difficult during the experiment, especially for the female participants. The participants have expressed that it was a continuous activity of accessing the wayfinding information from the mobile application and validating it in real-world settings. The reference images of the destination were also incorporated in the application to provide easy validation in real-world settings; however, the navigators did not access this information. The reference images were presented in the 3rd to 4th layer of information, which was difficult for the participants to access. However, all the participants were instructed about the usage of application, interface and type of information. In the interview, participants have expressed that the reference images were not helpful due to the difference between the viewer's perspective and the perspective in which the picture has been taken.

The route was presented in the written directions as well as in the wayfinding application. Some of the participants accessed this information but could not be able to decipher it for real-world settings. Some of the male participants have used the detailed YAH-campus maps placed on different locations throughout the campus. They have perceived the map information better due to the correct location pointer. However, they have experienced the wayfinding tasks from the map required much cognitive effort.

Cultural-based preferences: significant cultural differences have been observed during the said experiment. The HK participants have used written directions in mobile applications, identification signage and interactive map in the application as their key sources of wayfinding information. Whereas participants from Pakistan have focused more on the Alphabetic nomenclature of buildings, verbal directions from passers-by and reference images in the application. Overall, differences in behaviour suggested that obtaining wayfinding information can be different for different cultures; however, this can be minimised by the symbiosis of wayfinding information sources.

This study investigated the current practices of information syntheses during the wayfinding tasks in complex environments, especially when the navigators are fully or partially unaware of the environment. The study suggested that the existing wayfinding systems consisting of static and mobile systems cannot efficiently work for the navigators individually. The static wayfinding systems are better in providing real-world information but have a single level of information. The digital mobile wayfinding systems are efficient in providing detailed information with multi-level information; however, it requires cognitive effort and skills to map the information in real-world settings.

In current times, complex environments are increasing due to the rapid expansion of cities and demand for space. Inside these intricate spatial settings, the traditional wayfinding mediums are not effectively delivering wayfinding information. While the mobile information system had to rely strongly on GPS or beacon-based signals. For effective wayfinding, the mobile information systems, including mobile wayfinding devices, need to synthesise with static information and other environmental cues. Public institutions, including universities, require the active attention of wayfinding designers to mitigate the wayfinding issues. The current study suggests that the practices of wayfinding information syntheses should be explored in detail using different sets of environments and users. The participants' individual and cultural differences in practices of information syntheses should also be investigated for a better understanding of current wayfinding issues. In the next chapter, a framework for wayfinding information syntheses has been proposed as derived by the findings of performed studies.

CHAPTER 8: PROPOSED FRAMEWORK FOR AUTO GUIDED NAVIGATION SYSTEM & WAYFINDING INFORMATION SYNTHESES

8.1 OVERVIEW OF CHAPTER

This chapter presents a framework for the auto guided navigation system, including the influencing parameters. In addition to that, a wayfinding framework has also been proposed for synthesising the environmental and mobile information to facilitate the wayfinding tasks in complex environments. The presented and proposed framework has been designed based on the study findings as well as the contributions from the existing studies in wayfinding literature.

8.2 EXISTING FRAMEWORK FOR WAYFINDING INFORMATION

The wayfinding process requires a concurrent cognitive process to obtain and understand the environmental information for a successful and efficient wayfinding task. This whole process may be influenced by several factors, including environmental factors, information design, and individual-related differences. It has been suggested in the literature to identify the influencing factors and the type of influence they have during the wayfinding tasks. Owing to this, a comprehensive theoretical model has been proposed for wayfinding in virtual environments (Chen and Kay M. Stanney, 1999). This theoretical model has presented the wayfinding tasks along with the understanding of wayfinding information and the individual-related differences influencing the whole process. This wayfinding model can be considered quite relevant to wayfinding in a real-time environment. However, the studies conducted in this thesis suggested major changes in the described wayfinding model for being effective in the complex spatial settings having multi-cultural users with excessive environmental interaction due to scattered facilities. A detailed description of the said model has been presented in the following section.

8.2.1 COMPONENTS OF THEORETICAL MODEL

The existing theoretical model has been divided into two parts consisting of wayfinding and navigation. Wayfinding has been considered in this model as a complete cognitive process of building up strategies to identify the location, orientation and potential route. Whereas navigation has been presented as the tasks of locomotion consisting of decision points, turns and small route planning. The researchers have delineated this framework as a wayfinding task starting from one location to the destination. The complete process has been identified in five stages. These stages are starting point, cognitive mapping, decision making, decision execution and task finished. In the above-mentioned five-staged process, the cognition related processes have been described in detail along with the influencing factors.

8.2.1.1 ***TOOLS FOR WAYFINDING INFORMATION***

The existing model suggested the five different categories of tools that can deliver the wayfinding information in a virtual environment for aiding the wayfinding tasks. The first category of tools can display an individual's current position in the environment. The second category of information tools is the type of tools that can guide the user about their current orientation. The position and orientation are essential to understand one's current spatial settings and to obtain the environmental information from the surroundings efficiently. The third category of tools is related to the individual's movement. The real-time movement can inform the user about the remaining distance and identify the decision points on the route. The fourth category is related to the sources of information that can describe the surrounding environment like signage or well-identified pathways. The final category has consisted of the guided navigation system.

The above-mentioned tools for wayfinding information have been accessed by the users to make the surrounding environment legible enough for wayfinding. All the categories of information influence human cognition and help the users to understand their surroundings. The existing model also suggested human senses as a gateway to access human cognition. If the human senses have been compromised on any level, then the effectiveness of wayfinding information will be compromised accordingly.

8.2.1.2 *INFLUENCING FACTORS*

Several influencing factors influence the wayfinding process on different levels. Amongst those factors, environmental structure and spatial layout are quite crucial in affecting the efficiency of wayfinding tasks. If complexly planned due to scarcity of space, the environmental structure can lead to wayfinding frustration and anxiety. Similarly, the complex spatial layout also has a negative influence on wayfinding activity. Usually, the built environment has complex layouts due to post-occupancy structural extensions. The spatial environment can restrict the navigator's visual access, which ultimately compromises the cognitive map development. Owing to this, the environment becomes illegible and difficult to memorise during self or guided exploration.

Another influencing factor is the experience or previous exploration of the environment. Previous wayfinding experiences can also aid in the exploration of the environment, which enhances the wayfinding task efficiency. This experience is majorly linked to the long-term memory that generates spatial knowledge. An easy way to understand this is to take the example of having extensive experience with different wayfinding tasks in different environments. This can train the mind to store certain kinds of information in the long-term memory, like types of wayfinding aids, structural information, and standard layout designs. Spatial knowledge is quite helpful in building up the cognitive map, which is essential to find the desired destination. The model also depicted the user's spatial ability, motivation and searching strategy as integral elements in influencing the wayfinding tasks.

Spatial ability and motivation are amongst the most important influencing factors as they can increase the wayfinding performance. Spatial ability may be different in different individuals due to several factors. These factors may include gender, culture, education or past experiences that can enhance the user's ability to decipher the environmental information in identifying their own location and orientation. Based on the abilities, an individual derives his own searching strategy to find a destination in an environment. If the strategy is efficient in obtaining and understanding the environmental information through environmental cues, then the whole wayfinding process can be positively affected.

8.2.1.3 ***STAGES OF HUMAN COGNITION***

The model has described the whole wayfinding process in three significant steps: the cognitive mapping process, the decision-making process, and the decision execution process. In the first step, the users build up their cognitive map by obtaining information from different sources. These sources of information are from environmental cues as well as from their personal experiences. According to the model, spatial orientation and spatial information can be obtained by the first, second, third, and fourth categories of wayfinding information tools. The information can be obtained through these information tools and filtered through the human senses. At this stage, the spatial knowledge from long-term memory is also considered to be influential in constructing the cognitive map. After this, the information is processed to construct the cognitive map, leading to the second step of the wayfinding process.

The second step has consisted of the decision-making process, which is instrumental in developing the wayfinding plans. For this stage, categories three and four of wayfinding information tools are instrumental that can guide the user about current movement and surrounding environmental information. Past wayfinding experiences, along with the obtained wayfinding information, can help the users to develop the wayfinding plans and make decisions about this. Past experiences can also guide the users to quickly identify the routes, environments and route plans that are somehow stored in the long-term memory by the previous wayfinding activities.

The third stage of the wayfinding task consisted of the decision execution process, which is the navigation directed by the wayfinding strategies. Category five of wayfinding information tools may be quite influential at this stage to finalise the process of decision making. Once the decision has been finalised by the combination of auto guided services and the wayfinding plans, the task has been finished by reaching the destination. The whole model explains the wayfinding process in virtual environments; however, no information has been delineated for real-time wayfinding. Based on the comprehensive approach of this model, motivation has been developed to propose a refined theoretical model of wayfinding in real environments. The significant contribution of our planned studies is to combine the necessary information on influencing factors of wayfinding tasks and propose a new theoretical model for the wayfinding process.

8.3 PROPOSED WAYFINDING FRAMEWORK

The existing wayfinding framework has been studied and investigated thoroughly by having an intense literature review of wayfinding information design and ascribed human behaviour. Based on the studied literature as presented in chapter 2, further studies have been planned to investigate the role of wayfinding information and human behaviour. The planned studies were designed to investigate and validate the influencing factors for wayfinding information as well as the types of various information tools. After analysing studies synthesised with the literature findings, a comprehensive theoretical model for wayfinding processes has been developed.

8.3.1 WAYFINDING INFORMATION PROCESSING

The theoretical model of wayfinding tasks with different tools of wayfinding information has been established and presented in Figure 8.1. The model has been delineated in the form of a neural network for processing the wayfinding information. The main steps have been presented with a thick-lined rectangle, influencing factors with dotted line rectangle and information sources with rounded corner rectangles. The model has three significant stages of information receiving to processing. These three stages are information gathering, a cognitive process for information syntheses and wayfinding actions. The starting point of the wayfinding task consists of the human senses where the wayfinding information from digital and environmental cues has been received. This first process is known as information gathering from all the available resources. The visual or sensory information that has been processed at the second stage of the model is described as a cognitive process. This cognitive process synthesises the gathered information, process it, and then a decision-making process has been initiated. This whole cognitive process can be influenced by several factors including but not limited to individual-related differences. Once the decision has been made, the final stage of the wayfinding process is initiated, known as wayfinding actions. The details of the requisite theoretical model have been presented in the form of a concept diagram in Figure 8.1.

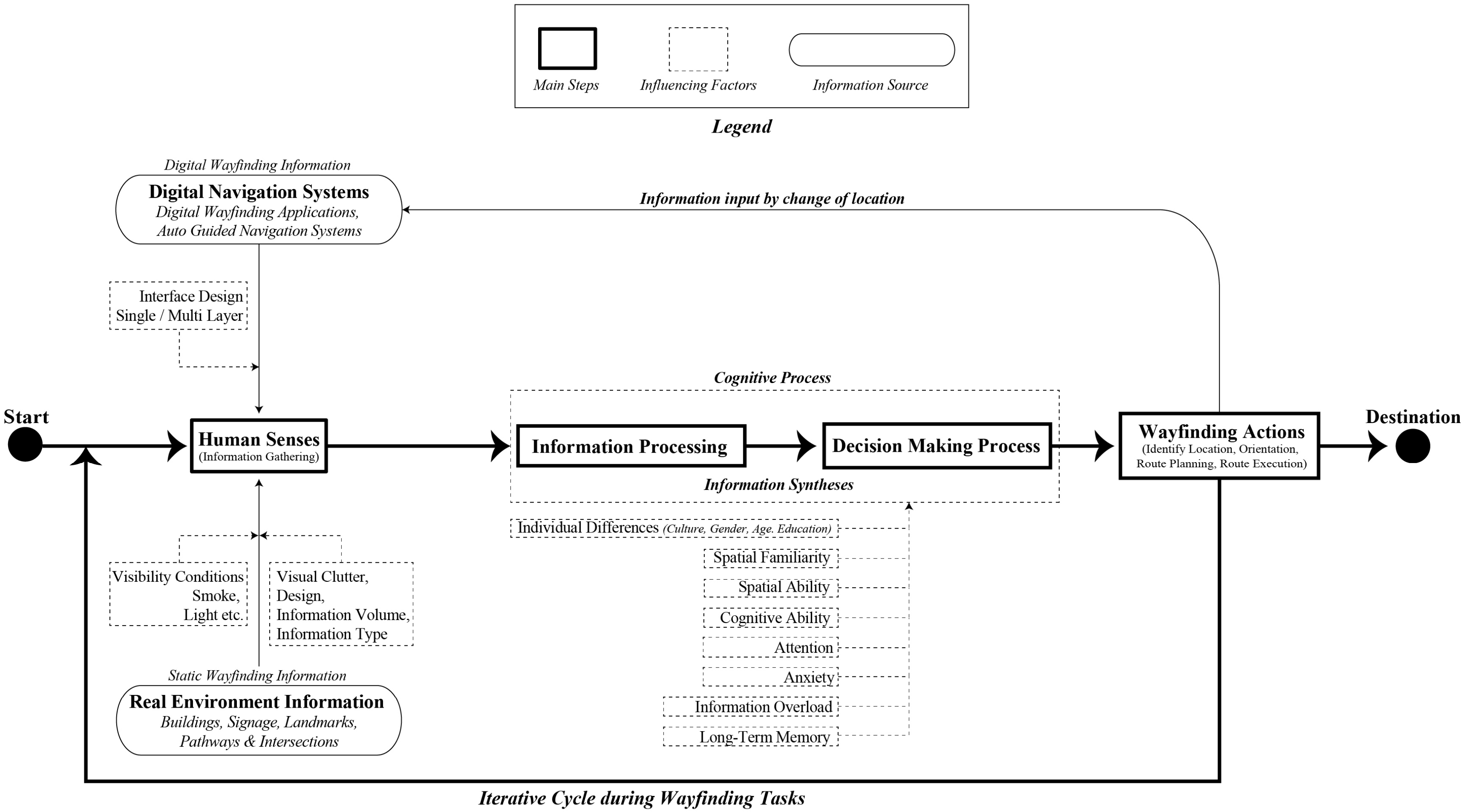


Figure 8.1 Wayfinding Framework with Auto Guided navigation system

8.3.2 TYPES OF INFORMATION TOOLS

In the presented model, two types of wayfinding information tools have been presented, i.e., digital wayfinding information and static wayfinding information. These two information systems differ in terms of technology by means of which they are providing the wayfinding information to the navigator.

8.3.2.1 *DIGITAL NAVIGATION SYSTEMS*

Digital information constitutes the types of wayfinding information that has been presented to the users in the form of a digital display, especially mobile digital displays. These types include digital navigation systems, wayfinding applications and complete auto-guided navigation systems. The wayfinding information has been delivered to the navigator with an interactive screen display, due to which specific parameters can influence the information delivery to the human sensory organs. These influencing factors include the interface designs, which has usability related issues in delivering the information. The other factor is presenting the information using a single layer or multiple layers of information styles.

8.3.2.2 *REAL ENVIRONMENT INFORMATION*

The second type of wayfinding information is the static medium. The static wayfinding information is the information designed to be presented in the real environment. This type of information includes signage information, landmark buildings, artistic landmarks, identified pathways, intersections and other distinguished environmental features to aid the navigator during wayfinding tasks. Several factors can affect the efficient delivery of this real environment information to the users. The visibility conditions in the environment like smoke, light, illumination, glare, water, rain, and fog can be the factors that can affect the user access to this information. While on the other hand, factors like visual clutter, wayfinding information design, information volume and information content can also affect the real environment information to be easily noticed by the navigators.

8.3.3 INFORMATION GATHERING

The information gathering is the first stage for the wayfinding tasks where all the wayfinding information, either from the digital information sources or the real environment information sources, has been gathered through the human senses. The influential human senses in gathering the wayfinding information are usually sight and hearing. This wayfinding information can be affected by the factors that can affect the human senses, like hindrances in visual attention or visual and auditory impairments.

8.3.4 COGNITIVE PROCESS

The next stage in the proposed wayfinding model is where all the gathered information has been processed by human cognition. This stage majorly comprises two different processes, i.e., information processing and decision making. Both processes are interlinked with each other. Once the information has been processed, it will help the decision-making process through logic and rational thinking. This cognitive process can be influenced by several factors. These factors have been delineated in the proposed theoretical model, where some of the factors like cognitive ability, attention, anxiety, information overload and long-term memory have been incorporated by the previous literature. However, the factors like individual differences, spatial familiarity and spatial ability have been incorporated by the studies performed during the research of this PhD thesis.

8.3.4.1 *INFLUENCING FACTORS FOR COGNITIVE PROCESS*

The said influencing factors can affect the wayfinding information processing and decision-making process. The first factor is the individual related differences. These differences include culture, gender, age, and education. Although these factors have been studied in the previous literature, the said factors have been studied in detail during this PhD study. For cultural differences, the sample has been taken from Pakistan and Hong Kong. The significant cultural differences and the effect has been presented in the previous chapters in detail. In addition to that, spatial familiarity and spatial ability have also been studied, and significant differences have been presented in the previous segments of this thesis. The remaining factors mentioned in the proposed model, like cognitive ability, attention and anxiety, can affect the overall thinking ability. Owing to this, the cognitive process can be affected; however, if there is a certain level of spatial familiarity, then a wayfinding decision can be made. Information overload can be influential if there is visual clutter present in the wayfinding environment or the wayfinding information is presented in a way that is not effective to attract the users' attention. The last influencing parameter is spatial knowledge present in the long-term memory. If spatial knowledge or familiarity is above a certain level, then it can improve the wayfinding efficiency irrespective of the environmental complexity.

During this cognitive process, a new concept has been introduced, which is related to the symbiotic relationship of the wayfinding information. This concept is named the information syntheses of all the wayfinding aids from real, mobile, and virtual environments.

8.3.5 WAYFINDING ACTIONS

Once a specific wayfinding decision has been made through a detailed and intense cognitive process, the respective wayfinding actions have been taken by the users. The wayfinding actions can be of many types; however, the four major types of actions have been presented in the proposed model. These tasks are to identify the location, identify orientation, route planning and route execution. To understand this whole concept, a thicker line has been drawn from the wayfinding actions to the start of the wayfinding process stating it as an iterative cycle. An example has been presented to understand the flow of the model. From the starting point, all the wayfinding information has been received by the human senses that are further goes to a cognitive process and finally towards the wayfinding action. The wayfinding actions directly lead the navigator towards the destination without any trouble; if not, then this process needs to be repeated in a similar manner to reach the destination ultimately.

8.4 WAYFINDING INFORMATION SYNTHESES

Information synthesis is a concept that has been introduced after the findings of the presented wayfinding studies. This concept suggests that the wayfinding information from different sources, including signage, landmarks, wayfinding applications, pathways, beacon-based systems, and others, should be synthesised and support each other to efficiently direct the navigators in the right direction. Especially in terms of mobile wayfinding technologies, providing the wayfinding information needs to be validated in a real-time environment. Owing to this, a synthesis of digital and real-time wayfinding information is anticipated to mitigate the current wayfinding issues in complex environmental settings.

In the current practices, all the information sources are providing wayfinding information in

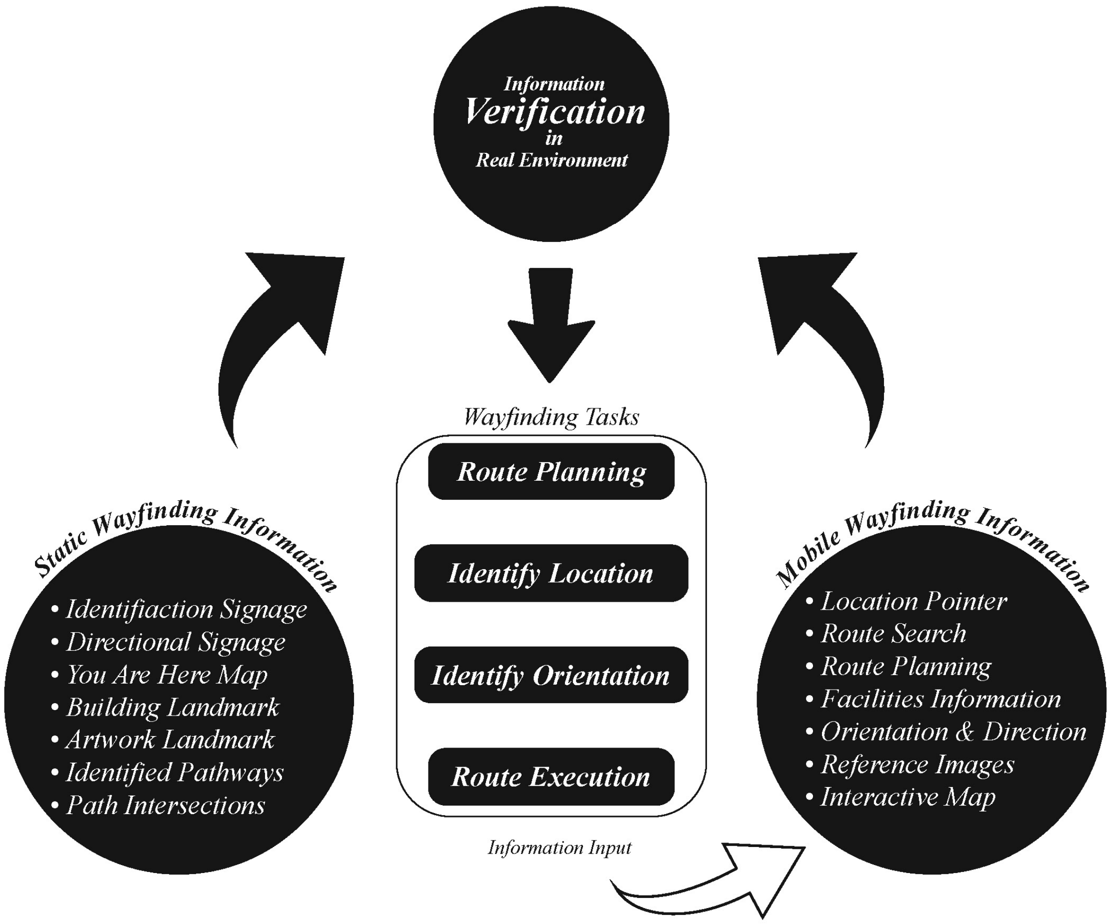


Figure 8.2 Information syntheses for wayfinding tasks

isolation. Like signage provide directional, identification and regulatory information. Whereas similar kind of information is also available in wayfinding applications but somewhat different manner. However, signage is good for getting the navigators' attention in the real environment but cannot efficiently guide them about the location and orientation. On the other hand, the wayfinding applications can deliver a larger volume of wayfinding information but cannot effectively gain the users' attention due to several factors mentioned in the previous chapters.

Therefore, it is recommended in the proposed wayfinding framework that an information synthesis should be considered to design the real environment wayfinding information to reduce the information processing and cognitive load effectively. A theoretical explanation has been presented in a diagram in Figure 8.2. This theoretical framework has consisted of the three fundamental stages involving information sources, wayfinding tasks and environmental validation through the information synthesis.

8.4.1 **INFORMATION SOURCES**

The mentioned theoretical framework explained the importance of wayfinding information sources in starting the different wayfinding tasks as well as in the information validation while performing these tasks. The environmental information can be accessed through two primary mediums, i.e., static and mobile wayfinding. The detailed introduction and comparison of these systems are as follows:

8.4.1.1 ***STATIC WAYFINDING INFORMATION***

As the name suggests, the static wayfinding information is consisting of those mediums which are somewhere placed permanently in the real environment to aid the navigators in finding their way. The static information can be delivered through signage, (You Are Here) maps, digital information kiosks, building landmarks, artistic landmarks, well-identified pathways, roads, intersections, the shape of roads, shape of buildings and other distinguishing features related to that. The signage can accommodate limited wayfinding information but is always visible for most viewing angles. Map information through you are here maps is also quite helpful in planning the route and understanding the environmental knowledge. However, it requires a great cognitive effort to understand your own position as well as the validation of the acquired information in the real environment. Building landmarks are quite efficient in letting one understand one's location and orientation due to its potential visibility range in the real environment.

On the other hand, the artistic landmarks are quite efficient in delivering the localised information covering the smaller areas. The shape of roads, intersections, shape of buildings and other environmental features can act as environmental landmarks to reorient the navigators in the real environment. In this aspect, the environmental knowledge gained from the initial planning through reading maps is quite essential to use the static wayfinding information efficiently.

There are several pros and cons for static wayfinding information systems. The benefits may include permanent visibility, information validation not required, well-identified, less confusing and real-time presence. However, they are compromised on viewing angles, limited information volume, difficult to update or change the information, and they can be unnoticeable if placed in the high environmental homogeneity.

8.4.1.2 ***MOBILE WAYFINDING INFORMATION***

The other source of environmental information is mobile wayfinding information which is mentioned in Figure 8.2. The mobile wayfinding information consists of many wayfinding aids, including but not limited to personal devices, mobile devices, PDA's and other location-enabled digital devices. The significant information content which can be gathered from the mobile wayfinding information sources consists of location pointers indicating current position, route searching, planning, interactive maps, reference images, facility information and orientation identification. These devices gathered the individual user-based information using different technologies like GPS and beacon-based systems to provide context-aware information. The significant benefits of mobile wayfinding information are that it can incorporate a larger volume of information, provide interactive information, and be updated on a real-time basis.

The larger volume of information in mobile sources is theoretically quite good as navigators can access this information anytime. However, it also requires a good number of cognitive efforts to reach the desired information through app navigation. The digital interface is of quite an importance in affecting the user's ability to reach the required wayfinding information. The digital application navigation is also quite dependent on the user's familiarity with the technology and mobile devices.

8.4.2 ENVIRONMENTAL VALIDATION

The environmental validation is the confirmation of the cognitive map and the information acquired from different wayfinding aids and spatial settings. In figure 8.2, the environmental validation is of critical importance. The wayfinding information gathered from mobile information sources and static information sources are processed inside the human brain and afterwards helps in building up the cognitive map. The cognitive map of information needs a specific validation in the real environmental settings. If this information is not being validated in the real environment, then the cognitive processing is constantly going to search out the relevant clue from the surroundings.

A very simple example can explain this phenomenon. A wayfinding task has been planned from point A to Point B, starting point and the destination point, respectively (Figure 8.3). The gathered information described a landmark on a decision point. Once the navigator is at that decision point, he needs to validate whether this decision point is correct as he learned it from the wayfinding information. This verification can be done if he is able to see the described landmark in the real environment. Afterwards, he can align his location and orientation as per the learned information. Environmental validation is quite necessary to complete the wayfinding tasks effectively.

8.4.3 WAYFINDING TASKS

The third phase of the proposed theoretical framework consists of wayfinding tasks. The wayfinding tasks are quite different in terms of information requirements based on their type of activities. The fundamental wayfinding tasks identified in the previous literature and mentioned in this thesis's initial chapters are as follows. *Route planning, identify location, Identify orientation, and Route execution.* The wayfinding information requirement would be quite different as all the mentioned tasks have different nature of activities. The segregation of these tasks has already been established in the literature as an effective way of performing the wayfinding. The information required for these wayfinding tasks and their interrelationship has been delineated in Figure 8.3. The figure explains the complete wayfinding process along with the wayfinding tasks in detail.

The figure also explains the type of information and when it is required to perform the requisite task.

8.4.3.1 *ROUTE PLANNING*

Planning is crucial while performing the wayfinding tasks, especially inside those spatial settings that are hard to remember due to visual homogeneity. In this wayfinding task, complete planning is required by the navigators from the starting point to the final location. Route planning is majorly done using digital or paper maps, complete route information, environmental aids and where to look it for. Once the information is provided, the navigator starts building up a cognitive map to understand the route and potential decision points for effective wayfinding.

8.4.3.2 *IDENTIFYING LOCATION*

Location identification is also considered an essential wayfinding task. The identification of location is not only helping the navigators to understand their current position but also can help them for validating the further planning of the route. In the cognitive map, the navigators need to understand the covered and remaining route to validate wayfinding information. Also, the correct identification of the navigator’s current position can reduce the cognitive load, bringing wayfinding efficiency.

8.4.3.3 *IDENTIFYING ORIENTATION*

During or at the start of the journey, the identification of one’s orientation is as important as the current location. The orientation information allows the users to understand their current position and to help them whether to continue in this direction or not. This wayfinding task is quite tricky if the environment is visually similar or cluttered with different aids like advertisements on roads and public spaces. In these areas, environmental validation is necessary to proceed further; however, it is not possible with the correct identification of one’s location and orientation.

8.4.3.4 *ROUTE EXECUTION*

The fourth and final wayfinding task is route execution. Once the navigator acquires the relevant information regarding route planning and identifies the correct location and orientation, the route can be executed confidently towards the destination. Route execution can be compromised if the cognitive map and environmental validation are not matching correctly. Once the route has been executed, all the tasks mentioned above can be repeated as per the need of the navigator. All the wayfinding tasks have been presented in the relevant sequence as being practised by most of the navigators.

8.5 WAYFINDING INFORMATION REQUIREMENT

Wayfinding is a complete journey from a starting point to a destination. It involves many stages ranging from the starting point, walking, decision points and the destination. During this process, several types of environmental and wayfinding information are required to reach the destination efficiently. In the previous literature, all the stages have been described in detail; however, the wayfinding information requirement during all the stages have not been discussed holistically. Our proposed wayfinding information requirement framework has tried to develop a complete delineation of the information required during the wayfinding process. In figure 8.2, the concept of information synthesis has been introduced. From that theoretical framework, a complete information synthesis and information requirement framework has been formulated. The suggested framework has been suggested based on the findings of this thesis (Figure 8.3). The several stages of the wayfinding process, along with the information requirement, has been discussed in detail as follows.

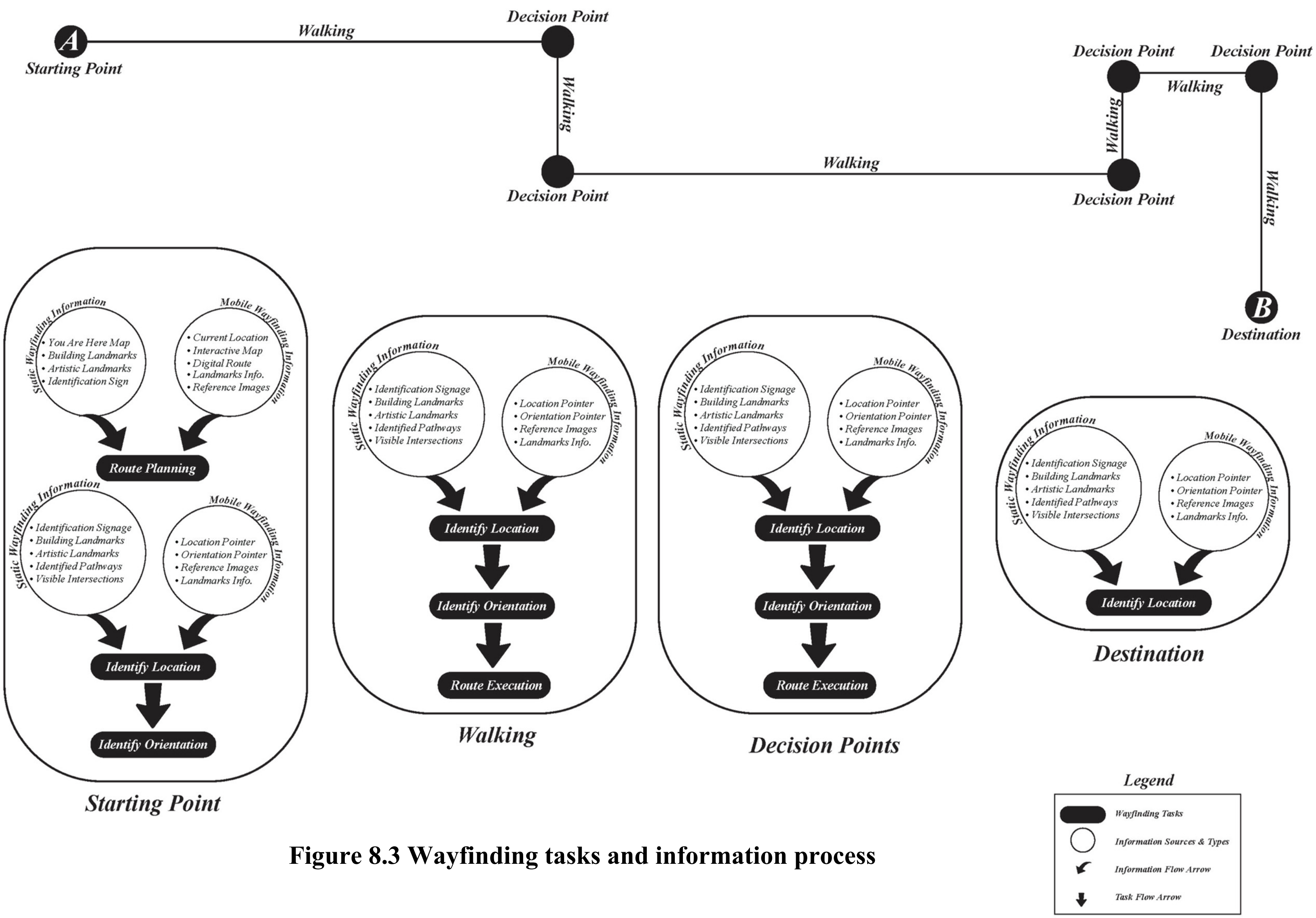


Figure 8.3 Wayfinding tasks and information process

8.5.1 STARTING POINT

The first stage of the wayfinding process is the start of the journey. At this point, certain information has been required by the participants to perform various wayfinding tasks. In figure 8.3, the information requirements have been carefully delineated. The first wayfinding task is route planning. At the starting point or before starting the actual journey, route planning is essential to finding the destination. This becomes of most importance when the spatial settings are illegible and hard to memorise. For this route planning task, synthesized information gathering has been proposed from the mobile and static information sources. The interactive map, digital route estimation, and location pointer are of critical importance from the mobile information sources, interactive map, digital route estimation, and location pointer. Whereas the static information sources can be quite helpful if the provided information has you are here maps (YAH) and identification signage. By synthesizing the mentioned information from both sources, navigators plan their route to find the destination.

Along with route planning, the task of identifying the current location is essential to locate yourself correctly in the planning phase. The location and orientation pointer from mobile information sources are of great importance for location identification and correct self-orientation. However, in many situations where spatial congestion is present, like in complex institutional environments, the location and orientation pointer does not work correctly. Also, they show sometimes misleading information, which confuses the navigators while route planning or performing other wayfinding tasks. Owing to this, a synthesised approach has been proposed in the current framework for location identification. From static information sources, identification signage, landmarks, pathways, and visible road intersections are the critical sources for secondary information. The information synthesis can provide the basis for information validation in the real environment and efficiently guide the navigators.

8.5.2 WALKING

The next stage of the wayfinding process after route planning is the walking activity. During this activity, the information requirements for the navigators have been changed. When a navigator is walking, he requires location identification on the go and orientation to resume the current activity. Also, there is little time to look for the environmental cues during walking as they pass by quickly. Owing to this, those environmental aids can be helpful for the navigators, which are easily noticeable, require less effort to identify and deliver the information within a limited time. For this reason, a synthesised information requirement has been proposed during the walking activity. The mobile information can provide the location and orientation information by using real-time tracking; however, in the case of inaccurate tracking, the real environment aids can be quite beneficial.

It was quite evident from our studies that navigators spend more time navigating the mobile information during walking as it was continuously there with them. In addition to that, mobile wayfinding applications can accommodate more wayfinding information than the real-time environment, which gains the attention of the navigators during walking. The static wayfinding information, identification signage and landmarks have been proven more influential in guiding the navigators than the other factors. However, in our framework (figure 8.3), we have proposed that if pathways and intersections are planned to attain the navigator's attention, they can also be of great use. Once the location and orientation have been identified during the walking activity, the navigators continue executing their next wayfinding stages.

8.5.3 DECISION POINTS

During the wayfinding process, the most critical stage is decision points. Decision points, along with several definitions, have been discussed in the previous chapters. The basic understanding regarding the decision point is that it is a point on the planned or exploratory route where a navigator needs to decide on the current location, orientation and continuity of their journey. It can be road or pathway intersections, fused pathways, roundabouts or fused walkable areas. In other words, it can be treated as a mediatory point somewhere in the whole journey. The information required at this point should be helpful in identifying location, orientation, and further planning of the route.

In our proposed framework, we have delineated the required information from mobile and static information sources. However, as per our studies, the navigators tend to experience some difficulties while entirely relying on mobile information sources. They have faced difficulties in realising their current positioning and orientation due to several factors. These factors include but are not limited to the crowd influences, visibility conditions, visual clutter in the real environment and inaccuracy of the mobile tracking system due to spatial complexity. The findings have also been discussed in study 4 of this thesis. The navigators, therefore, more relied on the real environment validation. Furthermore, the major helpful information aid was identification signage and reference images from static information and mobile information, respectively. However, for both information types, synthesis was instrumental rather than relying on one information source.

8.5.4 DESTINATION

As depicted in figure 8.3, explaining the journey from point A to point B where A is the starting point and B is the destination point. The destination point is the end stage of a wayfinding process. At this stage, the most critical factor was to identify the destination. So, the information which can easily identify the destination may be influential at this stage of information requirement. As per the literature and our study findings, several information sources have been delineated in our proposed framework. Location and orientation pointer are necessary to identify that journey has been finished. In addition to that, reference images of the destination are also critical to familiarise the navigators in advance visually. At the same time, identification signage and other landmarks are necessary to identify the destination. According to our findings, the navigators relied more on the identification signage in the real environment synthesizing with the reference images provided by the mobile information. However, several issues have been caused due to the difference in viewing angle and the time of picture taken. The proposed theoretical framework explained the concept of wayfinding information synthesis and the information requirements while performing the different wayfinding tasks.

In the next chapter, a study has been performed to validate the findings of the current framework for further applications by information designers and users. The current framework in figure 8.3 has suggested the contribution of mobile and static wayfinding aids in directing the users while performing wayfinding tasks. The complete framework suggested a detailed information requirement plan for the users; however, the location and orientation identification are the most important part of the whole framework. Therefore, in the next chapter, the information requirements for location and orientation identification have been validated at decision points. This validation can be useful to understand the basic concept of the suggested framework which utilises this location identification repeatedly during all the four stages of wayfinding tasks presented in figure 8.3.

CHAPTER 9: VALIDATION STUDY FOR INFORMATION SYNTHESES & TYPES FOR WAYFINDING TASKS IN COMPLEX ENVIRONMENT

9.1 OVERVIEW OF THE CHAPTER

This chapter introduces a validation study for the proposed theoretical framework for wayfinding information syntheses and the types of wayfinding information required by the navigators in the complex environment. The location and orientation identification at the decision points have been planned to be validated from the proposed wayfinding synthesis model. The identification of one's location and orientation are very influential in all the wayfinding tasks as presented in the previous chapter. The whole framework validation would require an enormous amount of time and effort. Owing to this, the effectiveness of environmental information syntheses has been validated in this study. The validation study tried to validate the said parameters in the simulated situation to investigate the effectiveness of the proposed model. The findings have a strong influence in developing the information guidelines for the requisite designers and guiding them to improve the institutional wayfinding system.

9.2 INTRODUCTION

Wayfinding tasks require an intensive cognitive effort and the ability to gather environmental information from different resources and find the destination. This task becomes more intensive if the environmental settings are more spatially complex, homogeneous and difficult to remember. Owing to this, after several studies on human wayfinding behaviour and performance. A comprehensive wayfinding framework has been developed. The said framework presented the idea of wayfinding information syntheses by using mobile/portable information with static wayfinding information systems. The framework also proposes different information requirements for various wayfinding stages and for performing different wayfinding tasks. The proposed findings require a comprehensive study to validate the suggested information requirement. The proposed findings stated different information requirements while performing various wayfinding tasks as presented in the previous chapter. The wayfinding tasks including starting point, walking, decision points and destination require the participants to gather the information from environmental sources and utilise them for identifying their current location and orientation. This location identification further helped them to devise further wayfinding strategies and actions. From the presented wayfinding framework in figure 8.3, the location and orientation identification has been considered very influential in all the wayfinding tasks. Therefore, in this study, an experiment has been designed to validate the proposed wayfinding framework. Owing to this, two hypotheses have been designed to validate the influence of environmental information and user syntheses behaviour.

Hypotheses: **H1:** Reference images of wayfinding information, if provided with user matched angles and synthesized with the real environment, can increase the wayfinding performance.

H2: Façade reference images of building landmarks can be less effective than the user matched angle images for increasing the wayfinding performance.

A validation study has been conducted based on the suggested wayfinding information requirement using wayfinding performance as a standard metric. Twenty-seven male university students have participated in the study. The study has been performed using a desktop-based virtual reality setup. The participants have performed five wayfinding tasks, each within an unknown institutional complex environment. Based on the hypothesis, the participants were analysed for their performance. The developed hypotheses were based on the proposed theoretical framework and have been proven right. The suggested information requirement increased the participants' performance by taking less time.

9.3 METHOD

This validation study was aimed to investigate the effectiveness of the proposed theoretical wayfinding information requirement framework in real-time environmental settings. From the said framework, self-location identification has been identified as the significant and most repeating factor. Therefore, this factor was tested in the validation study with the variety of different information settings provided to the navigators. Owing to this, a desktop-based virtual reality experiment has been designed using 360º panoramic images of the real institutional environment. Participants need to perform five wayfinding tasks each, and their performance has been measured by the time taken and the count of errors. The experiment was performed in three stages pre-experiment questionnaire (sense of direction), wayfinding tasks, post-experiment interview for ascribed actions. All the participants who participated in the experiment were inducted from a reputed higher education institution from Hong Kong. For this study, the data has been recorded in the form of the Likert scale, screen recording and voice recording for the experiment and interview, respectively.

9.3.1 PARTICIPANTS

The participants were invited from a very reputed higher education institute situated in the city centre of Hong Kong. All the participants were informed via a participant induction poster requiring male Chinese participants with a specific limitation on age group (18 to 35). Only male participants were invited to the experiment to avoid gender differences while performing wayfinding tasks as predicted from the previous literature as well as in our studies. Literature and our studies also supported the cultural influences on human wayfinding behaviour. For that reason, only Chinese participants were invited to conduct the experiment. The participants were informed before about the desktop-based virtual reality experiment. All the participants were quite aware of the computer basics. In addition to that, trial wayfinding tasks were also designed to familiarise themselves with the experimental setup. In total, twenty-seven participants took part in the experiment and performed five different wayfinding tasks each. However, the data of two participants were disqualified to maintain the overall quality.

Participants were also required to report the Santa Barbara Sense of Direction Scale (SBSDS) before starting the experiment, along with the questions related to the usage of wayfinding applications. Before starting the experiment, the complete procedure of trials and actual experiment has been explained to the participants, and they were given a five-minute practice time. A consent form has been signed by the participants for taking part in the research study, and they were given a cash incentive for their cooperation. Requisite ethical approval (APPENDIX I) has been obtained from the relevant authorities, and special precautionary measures have also been taken due to the COVID-19 pandemic.

9.4 DATA COLLECTION

The current experiment has been segregated into three major segments. The first segment has been consisted of collecting data related to the participants' sense of direction and their prior experience of using wayfinding applications. In the second phase, the desktop-based virtual reality experiment has been performed after a brief demonstration and practice session. The third phase was about the explanatory interview from the participants explaining the reason for choices and ascribed actions. The data has been recorded and analysed quantitatively and qualitatively wherever deemed necessary.

9.4.1 PRE-EXPERIMENT

On arrival, all the participants were asked to sign their written agreement to participate in this research study, and their acquired data can be shared on public forums. After that, the participants were asked to report the sense of direction scale to measure their spatial ability. The Santa Barbara Sense of Direction Scale (SBSDS) (Hegarty *et al.*, 2002) has been used in many studies and found quite effective in measuring spatial ability. In the said questionnaire, participants were also asked about their prior usage of wayfinding applications, i.e., Google Maps. The questions asked from the participants have been presented in Table 9.1. The first two questions were related to the usage of wayfinding applications, whereas the remaining questions have been taken from the Santa Barbara Sense of Direction Scale (SBSDS). The questions from SBSDS have been presented in the Likert scale, having strongly agreed and strongly disagreed on the poles. The data has been recorded using the online service of Microsoft Forms.

Table 9.1 Pre-experiment questionnaire

Sr.	Questions
Wayfinding Applications	

Sr.	Questions
	Do you use wayfinding applications?
	What applications do you use for wayfinding?
Santa Barbara Sense of Direction Scale	
Q1	I am very good at giving directions.
Q2	I have a poor memory for where I left things.
Q3	I am very good at judging distances.
Q4	My "sense of direction" is very good.
Q5	I tend to think of my environment in terms of cardinal directions (N, S, E, W).
Q6	I very easily get lost in a new city.
Q7	I enjoy reading maps.
Q8	I have trouble understanding directions.
Q9	I am very good at reading maps.
Q10	I do not remember routes very well while riding as a passenger in a car.
Q11	I do not enjoy giving directions.
Q12	It is not important to me to know where I am.
Q13	I usually let someone else do the navigational planning for long trips.
Q14	I can usually remember a new route after I have travelled it only once.
Q15	I do not have a very good "mental map" of my environment.

9.4.2 EXPERIMENT

The wayfinding experiment has been designed to evaluate the participants' information requirements while performing the wayfinding tasks. As proposed in the previous chapter, the wayfinding information synthesis suggested the concurrent use of mobile and static wayfinding information. This experiment simulated the suggested environment and required the participants to perform wayfinding tasks using the desktop-based virtual reality system. After completing the initial questionnaire regarding their spatial ability and usage of wayfinding applications, they were introduced to the experimental procedure. Researchers demonstrated the experimental procedure with the trial setups in front of the participants. Participants were also given five minutes to practice the method for identifying their location and explore the environment using a desktop-based virtual reality system. The participants were given five different and unknown locations inside the educational institution. They could take their time in identifying their location. Once the task is completed, they were directed towards the following location by the researchers.

9.4.2.1 ***EQUIPMENT***

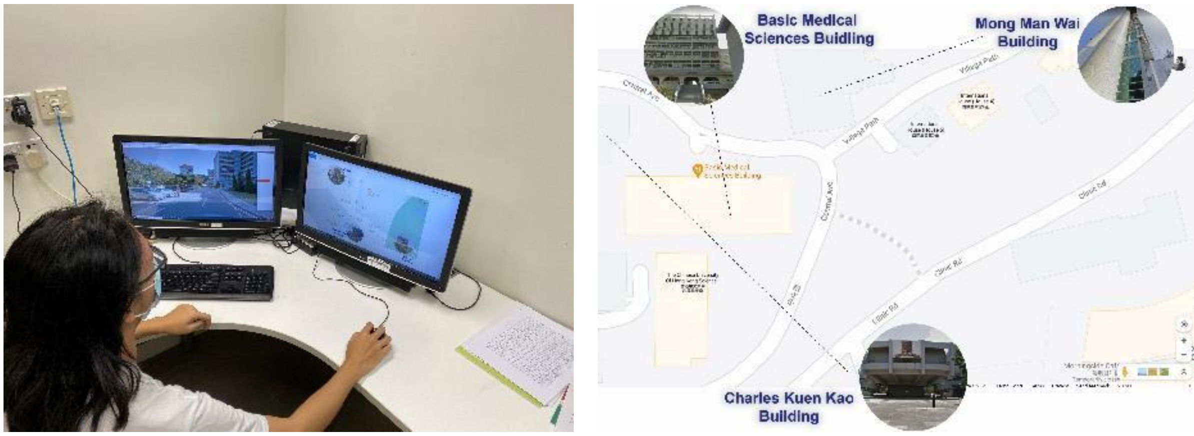


Figure 9.1 Experimental setup in design lab

The experiment has been conducted using the HP desktop (Core i7, 5th gen, dedicated graphics memory 8 Gb) and dual monitor screens having a screen resolution of 1920x1080. Both monitors were attached to a single computer as an extended display in addition to the main one. One screen has been used as a mobile information display, and the other has been simulated as a 360^{o} panoramic virtual environment. The panoramic images from an educational institution have been downloaded from google maps with relevant API's. The panoramic images have been converted into a 360^{o} spherical navigable environment using a cloud-based virtual tour software known as LAPENTOR. For the mobile information, the maps have been created using Adobe illustrator 2021 and Adobe Photoshop 2021. The participants can view all the directions using a mouse pointer and zoom in and out to see the details in the real environment. Similarly, for the mobile information, the zooming and panning options were also added to see the details.

9.4.2.2 ***DESIGN***

The experiment has been designed with a clear objective, and independent and dependant variables have been defined accordingly presented in Table 9.2.

Table 9.2 Experiment variables

Independent Variable with sub features	Dependent Variables
Types of wayfinding information: • Written information • Landmark information • Reference images of identification signage	• Time taken for task completion
Viewing angle of a reference image • Viewing angle matched with actual info. • Regular viewing angle	• Number of errors during the task completion
Signage • Visible • Not Visible	

<u>*Controlled Factors:*</u> During the whole experiment, certain factors have been controlled to prevent confounding elements. These factors have been delineated in Table 9.3. The factors start with the lighting conditions of the experimental settings, which have been kept to daylight time. The amount of information has been kept constant with an equal amount of information throughout all the conditions. The provided map has provided the information for a selected diameter as presented in the table. Walking speed, path and asking directions were considered confounding in the previous studies of this thesis. In response to that, these factors have been kept constant in the virtual environment for a reliable causal relationship among the type of information and the participants' performance. The most critical parameter has been balanced, which is the different difficulty levels of the testing environment. The Latin square method has been used to balance this bias.

Table 9.3 Controlled factors during the experiment

Factors	Measures
Lighting conditions	All the locations will be presented with daylight without glares on wayfinding information.
Amount of info.	Every map provided with three pieces of information (signage/reference image or both).
Map details	The provided map has been taken 100m diameter of the presented location.

Factors	Measures
Visual conditions	Visual conditions kept clear. i.e., no smoke, fog, or visual clutter.
Walking speed	No walking is required as all the participants will be at decision points only.
Asking directions	Being virtual experiment participants cannot ask for directions from anybody.
Walking path	No walking is required as all the participants will be at decision points only.
Language barriers	All the required information will be presented in English and Chinese language.
Cultural differences	Only Chinese participants have been invited.
Gender differences	Only Male participants have been invited.
Latin square	Balancing location difficulty has been done using the Latin square method of order 5 to reduce the bias.

Experiment Parameters: During the whole experiment, certain factors have been controlled to prevent confounding elements. These factors have been delineated in Table 9.3. in addition to that, specific metrics have been devised to measure the performance of the participants. The first metric was the time taken to complete the respective wayfinding task, along with the number of errors they have made while pointing out their current location and orientation on the map. The detailed parameters and metrics have been presented in Table 9.4.

Table 9.4 Experiment metrics and pre-requisites

Experiment Parameters	
Metrics	• Time taken for task completion • Number of errors during the task completion
Task	Identify Location & Identify Orientation on the provided map
Participants	Total 25 (Chinese), Male
Pre-Requisite	Participant consent form, Briefing of participant instructions, Usage of Google Maps, Santa Barbara Sense of Direction Scale, Virtual reality practice session to ensure a similar level of familiarity

9.4.2.3 *LOCATIONS & CONDITIONS*

The experiment has been performed using the virtual location of a reputed university in Hong Kong. All the participants have never visited the said university campus before, and they were not familiar with the environmental settings of the said campus. All the selected locations have been carefully selected while keeping in mind certain elements. The complexity of the selected location can be an influential factor in affecting the participant's performance and for the increased number of errors. Specific parameters have been devised to cater to this issue before selecting the real-life location for our virtual experiment. The parameters have been presented in Table 9.5. In total, four parameters have been considered significant based on the literature and performed studies. The number of buildings in the experimental settings for each task has been kept constant to five. In addition to that, pathways, building shapes and the number of intersections were also considered to be essential and kept constant for a uniform complexity throughout the experiment.

Table 9.5 Location complexity parameters

Location	**Complexity parameters**			
	No. of buildings in view	Pathways (Visible or fused)	Building shapes (Same or distinctive)	Intersection type (no, 3-way, 4 way)
L1	***5***	***Visible***	***Distinctive***	***2 ways***
L2	***5***	***Visible***	***Semi distinctive***	***3 ways***
L3	***5***	***Visible***	***Distinctive***	***3 ways***
L4	***5***	***Visible***	***Distinctive***	***3 ways***
L5	***5***	***Visible***	***Distinctive***	***3 ways***

After selecting the locations based on the above parameters, experimental conditions have been devised. During the experiment, there were two screens, one for the map information and the other for the 3d virtual environment, as depicted in Figure 9.1. To develop the experimental conditions, a combination of three independent variables have been devised consisting of the type of information, viewing angle and the visibility of the said information. Out of 24 different combinations, four combinations have been selected as the experimental conditions. To measure the effectiveness of the change of information, a basic set of combinations has also been selected named as condition 1. The details of experimental conditions have been presented in Table 9.6, where certain symbols have been used to depict the information. In the mentioned table, certain symbols have opted, i.e., landmark (L), signage visible (S_1), signage not visible (S_0), landmark with façade view (L_F) and landmark with matched or user perspective view (L_M).

Table 9.6 Experimental conditions

	Real Environment Information	Map Information
Condition 1	Landmark + Signage not visible ($L + S_0$)	Signage Visible (S_1)
Condition 2	Landmark + Signage not visible ($L + S_0$)	Landmark Facade view, Signage Visible ($L_F + S_1$)
Condition 3	Landmark + Signage not visible ($L + S_0$)	Landmark Matched view, Signage Visible ($L_M + S_1$)
Condition 4	Landmark + Signage visible ($L + S_1$)	Landmark Facade view, Signage Visible ($L_F + S_1$)
Condition 5	Landmark + Signage visible ($L + S_1$)	Landmark Matched view, Signage Visible ($L_M + S_1$)

Based on the conditions mentioned above, five locations have been prepared and used for the pilot testing. In the pilot testing, it has been observed and mentioned by the participants as well that may be the environmental settings can influence the wayfinding performance. Owing to this, the Latin Square method has been applied to balance the effect of environmental settings. After applying this design balancing method, five balanced settings have been developed (APPENDIX II), consisting of five environmental settings in each category. The balancing of environmental settings and information conditions have been presented in Table 9.7. Twenty-five participants have been presented with these balanced settings so every balanced setting have been utilised by five participants. Therefore, the analysis will solely depict the effect of information change on the wayfinding performance.

Table 9.7 Latin square balance of environmental settings

Balanced settings 1	L1-C1	L2-C2	L3-C3	L4-C4	L5-C5
Balanced settings 2	L1-C2	L2-C3	L3-C4	L4-C5	L5-C1
Balanced settings 3	L1-C3	L2-C4	L3-C5	L4-C1	L5-C2
Balanced settings 4	L1-C4	L2-C5	L3-C1	L4-C2	L5-C3
Balanced settings 5	L1-C5	L2-C1	L3-C2	L4-C3	L5-C4

9.4.2.4 *PROCEDURE*

Participants have been invited to the Asian ergonomics design lab for taking part in the wayfinding virtual reality experiment. The experiment has been designed with five wayfinding tasks having a variance of wayfinding information. Participants have been asked to report their consent regarding personal data while using standardized consent forms. After that, participants were requested to be seated in front of the desktop-based virtual reality setup. The participants were asked about their prior experience using wayfinding applications, i.e., Google maps, apple maps. After that, to measure their spatial ability, the Santa Barbara Sense of Direction scale has been presented to the participants.

There were four environmental settings have been prepared for the participants to practice and acquaint themselves with the mechanics of the experiment. The experimental procedure, along with the practical examples, have been demonstrated to each participant. Once they feel comfortable, they can practice themselves for 2-3 minutes. The wayfinding tasks require the participants to locate their location and identification on the map. For this purpose, participants could practice so that it cannot be a factor of delay and affect the participant's performance in any way. After completing the practice session, participants were given the actual balanced environmental settings to identify their location and orientation on the map. Every environmental setting has been oriented towards the real North; however, true north was never mentioned on the map information, so the participants cannot guess the orientation information from here. During the experiment, a video recording device has been placed to record the participants' actions. Once the task has been completed by the participant, the researcher was responsible for changing the next location information for both, i.e., map information and real environment information.

After completing all the tasks, the participants were invited for a short explanatory interview for their actions during the experiment. During the interview, they were asked about the most used information sources and why they have relied on them. In addition to that, the participants were also asked about their desired strategy of searching the way in an unfamiliar environment, especially when the environment is spatially complex and hard to memorize. The data for this experiment has been collected in the form of video footage, which has been analysed afterwards using requisite methodologies.

9.4.2.5 *DATA ANALYSIS*

The collected data has been in the form of video recordings. All the video recordings have been analysed carefully using different methodologies. The wayfinding task time has been observed from the recordings and noted down for every participant and every task. In addition to that, if the participants have made an error while performing the experiment, then it also has been recorded. Based on the hypotheses mentioned earlier in this chapter, specific statistical techniques have been considered relevant to analyse the data. All the information conditions have been recorded in the form of time taken. So, the statistical mean and standard deviation of time taken for each condition was considered appropriate for the initial finding of participants' performance. Before applying any further statistical analysis, the data were checked for normal distribution using Shapiro Wilk's test of normality. The data were further analysed using the Related-Samples Wilcoxon Signed Rank test after being found as a non-normal distribution. The said test was also used for the combination of conditions which has been further explained in the results section. To find out the relationship between spatial ability and the participant's performance, Kendall's Tau correlation test has also been considered appropriate.

9.5 RESULTS

The results of the current validation study have provided interesting insights regarding the proposed wayfinding information framework. The proposed wayfinding framework suggested the wayfinding information synthesis while finding the way in an unknown environment. In this validation experiment, the participants' wayfinding performance was recorded with the change of information conditions. The performance has been measured using the time taken and the total number of errors while performing the wayfinding tasks. The overall time taken, and the number of errors has been presented in Table 9.8.

Table 9.8 Wayfinding tasks performance

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SBSD S scale	3.8	5.73	4.93	4.6	3.6	5.73	5.53	3.33	2.4	5.07	4.33	5.13	5.67	5.13	2.27	6	3.6	3	5.8	5.87	2	4.07	4.4	5.27	4.4

Info. Settings	***Locations & Time Taken (Number of Errors)***				
BS 1	*L1-C1* 2:02 (0)	*L1-C2* 0:33 (0)	*L1-C3* 0:38 (0)	*L1-C4* 0:29 (0)	*L1-C5* 0:25 (0)
BS 2	*L1-C2* 1:18 (0)	*L1-C3* 0:28 (0)	*L1-C4* 0:47 (0)	*L1-C5* 0:38 (0)	*L1-C1* 1:58 (0)
BS 3	*L1-C3* 1:00 (0)	*L1-C4* 1:35 (0)	*L1-C5* 0:53 (0)	*L1-C1* 1:05 (0)	*L1-C2* 0:58 (0)
BS 4	*L1-C4* 2:57 (0)	*L1-C5* 0:38 (0)	*L1-C1* 0:50 (0)	*L1-C2* 1:28 (0)	*L1-C3* 0:42 (0)
BS 5	*L1-C5* 1:06 (0)	*L1-C1* 0:51 (0)	*L1-C2* 1:13 (0)	*L1-C3* 0:44 (0)	*L1-C4* 0:33 (0)
BS 1	*L1-C1* 1:55 (0)	*L1-C2* 0:47 (0)	*L1-C3* 1:07 (0)	*L1-C4* 1:34 (0)	*L1-C5* 0:58 (0)
BS 2	*L1-C2* 0:51 (0)	*L1-C3* 0:40 (0)	*L1-C4* 0:24 (0)	*L1-C5* 0:18 (0)	*L1-C1* 0:48 (0)
BS 3	*L1-C3* 0:45 (0)	*L1-C4* 3:23 (2)	*L1-C5* 0:41 (0)	*L1-C1* 2:47 (0)	*L1-C2* 3:27 (1)
BS 4	*L1-C4* 1:25 (0)	*L1-C5* 0:47 (0)	*L1-C1* 0:53 (0)	*L1-C2* 0:36 (0)	*L1-C3* 0:53 (0)
BS 5	*L1-C5* 0:43 (0)	*L1-C1* 1:07 (0)	*L1-C2* 1:02 (0)	*L1-C3* 0:35 (0)	*L1-C4* 0:58 (0)
BS 1	*L1-C1* 4:57 (2)	*L1-C2* 1:17 (0)	*L1-C3* 1:44 (0)	*L1-C4* 0:43 (0)	*L1-C5* 1:03 (0)
BS 2	*L1-C2* 0:44 (0)	*L1-C3* 0:35 (0)	*L1-C4* 1:10 (0)	*L1-C5* 0:36 (0)	*L1-C1* 1:10 (0)
BS 3	*L1-C3* 0:56 (0)	*L1-C4* 1:43 (0)	*L1-C5* 1:10 (0)	*L1-C1* 2:22 (0)	*L1-C2* 1:08 (0)
BS 4	*L1-C4* 2:20 (2)	*L1-C5* 0:44 (0)	*L1-C1* 1:27 (0)	*L1-C2* 0:51 (0)	*L1-C3* 1:02 (0)
BS 5	*L1-C5* 0:42 (0)	*L1-C1* 1:37 (0)	*L1-C2* 4:03 (4)	*L1-C3* 0:33 (0)	*L1-C4* 0:51 (0)
BS 1	*L1-C1* 0:49 (0)	*L1-C2* 0:19 (0)	*L1-C3* 0:18 (0)	*L1-C4* 0:30 (0)	*L1-C5* 0:26 (0)
BS 2	*L1-C2* 1:17 (0)	*L1-C3* 1:23 (1)	*L1-C4* 2:17 (2)	*L1-C5* 0:32 (0)	*L1-C1* 2:43 (1)
BS 3	*L1-C3* 1:05 (1)	*L1-C4* 0:29 (0)	*L1-C5* 0:48 (0)	*L1-C1* 1:25 (0)	*L1-C2* 1:17 (0)
BS 4	*L1-C4* 0:27 (0)	*L1-C5* 0:15 (0)	*L1-C1* 1:16 (0)	*L1-C2* 1:11 (0)	*L1-C3* 1:13 (0)
BS 5	*L1-C5* 2:24 (1)	*L1-C1* 3:09 (0)	*L1-C2* 6:11 (1)	*L1-C3* 1:15 (0)	*L1-C4* 1:32 (0)
BS 1	*L1-C1* 3:22 (1)	*L1-C2* 0:55 (0)	*L1-C3* 1:21 (0)	*L1-C4* 0:21 (0)	*L1-C5* 1:02 (2)
BS 2	*L1-C2* 3:07 (2)	*L1-C3* 0:47 (0)	*L1-C4* 3:22 (2)	*L1-C5* 0:48 (0)	*L1-C1* 2:10 (0)
BS 3	*L1-C3* 1:17 (0)	*L1-C4* 0:58 (0)	*L1-C5* 1:30 (2)	*L1-C1* 0:37 (0)	*L1-C2* 3:20 (0)
BS 4	*L1-C4* 1:24 (0)	*L1-C5* 0:27 (0)	*L1-C1* 1:07 (0)	*L1-C2* 0:58 (0)	*L1-C3* 0:56 (0)
BS 5	*L1-C5* 0:32 (0)	*L1-C1* 1:33 (0)	*L1-C2* 1:21 (0)	*L1-C3* 0:45 (0)	*L1-C4* 0:55 (0)

Five balanced settings have been provided for all the twenty-five participants as mentioned in the table mentioned above, i.e., Table 9.8. All the conditions have a different set of information which affected their wayfinding performance. To investigate the differences in time taken for the respective conditions, a descriptive analysis has been performed using SPSS software. All the information conditions have been compared using the mean time taken for each condition for all the participants. As described in Table 9.9, the highest mean time has been taken for information condition one, followed by condition two, condition four, condition three and condition five, respectively. However, the time difference has suggested that participants have performed better in certain information conditions for completing the wayfinding tasks. However, a detailed statistical investigation is required to understand whether the time differences are statistically significant or not.

Table 9.9 Descriptive analysis

	Condition1	**Condition2**	**Condition3**	**Condition4**	**Condition5**
Mean	105.60	96.48	54.48	79.48	48.24
N	25	25	25	25	25
Std. Deviation	61.312	81.817	20.245	54.669	26.425

To compare the mean differences of the said information conditions, specific statistical tests have been instrumental. Based on this study, the data has been checked for normal distribution and found non-normally distributed. Owing to this, nonparametric tests for related samples have been considered suitable to compare the mean differences, i.e., Related-Samples Wilcoxon Signed Rank Test (Siegel, 1956). The said test has been applied to compare each information condition with other conditions and to investigate whether the statistical differences have been instrumental or not. The results showed some interesting facts because all the conditions were not statistically different from each other, contrary to the expectations from Table 9.9. The performance in condition 1 is statistically like condition 2, where the p-value=0.270, which is higher than the significant value *($p \leq 0.05$)*. Similarly, condition 1 with condition 4, condition 2 with condition 4, condition 3 with condition 5 are statistically like each other, having the p-value equal 0.113, 0.716 and 0.166, respectively, which is relatively higher than the significant p-value.

In addition to that, some of the information conditions have been considered statistically significant differences with each other depicting the performance variation. The p-value for condition 1 and condition 3 has been reported significantly where the p-value equals 0.000. Similarly, condition 1 with condition 5, condition 2 with condition 3, condition 2 with condition 5, condition 4 with condition 5 are significantly different from each other, having the p-values equal to 0.000, 0.026, 0.000 and 0.021. Although the mean time taken depicted in Table 9.9 suggested the performance variation, the statistical test suggested that some conditions are not statistically different. Moreover, the conditions mentioned in Table 9.6 have signage visibility and reference image information as key variables to understand the impact on wayfinding performance. Owing to this, condition 2 and condition 4 have been combined and compared with condition 3 and condition 5. In the combined conditions 2 and 4. the reference images have been presented in the façade view. Whereas, in conditions 3 and 5, the reference images have been presented in the matched perspective view. So, the above-mentioned statistical test can analyse that which information condition is significantly better than others.

Similarly, condition 2 and condition 3 have been combined and analysed with condition 3 and condition 4. In both condition combinations, the difference is of signage visibility in the real environment. In conditions 2 and 3, the signage is not visible in the real environment, whereas the other two conditions are vice versa. The related sample Wilcoxon test has been applied to investigate the relationship of information variance with the wayfinding performance. The combination of conditions 2 and 4 have been statistically significant with the combination of 3 and 5 in terms of wayfinding performance. This notion can be easily seen where the p-values are equals to 0.001, which is statistically significant *($p \leq 0.05$)*. For the condition combination of 2 and 3 with a condition combination of 4 and 5, the performance difference is not significant because the p-value equals 0.304.

In addition to that, participants' spatial ability has also been analysed with their wayfinding performance. The spatial ability can also be the confounding factor affecting the performance instead of the information variation in the static or mobile information. For that reason, the Santa Barbara sense of direction scale has been reported by each participant before starting the experiment to measure their spatial ability. The individual's spatial ability has been collated with the total time taken while performing the wayfinding tasks. As the data was non-normally distributed, Kendall's Tau test of correlation was considered suitable for this purpose. The relation between the participant's spatial ability and total time taken for the wayfinding tasks has not been significantly correlated, i.e., *(p-value=0.123)*.

After the experiment, all the participants were asked several questions related to their wayfinding experience and decision choices made during the experiment. All the participants have mentioned several essential wayfinding aids which were quite helpful for them while performing the wayfinding tasks. All the mentioned information sources have been transcribed and coded into generic categories. The information categories have been converted into a word cloud based on the frequencies mentioned by the participants. The word cloud of information sources has been presented in Figure 9.2 and Table 9.10. The preferred sources for information have consisted of the shape of road in real and map environment, road intersections, landmark reference images in the map information and building façade in the real environment. These sources have been presented respectively to the frequencies mentioned by the participants.

Table 9.10 Information types and frequencies

Sr.	Information Type	Frequency
1	Road Intersections	16
2	Shape of road	14
3	Reference Images	12
4	Façade design of the building	10
5	Map Information	9
6	Signage in real environment	8
7	Environmental natural features	5
8	Perspective matched images	4
9	Road name	2

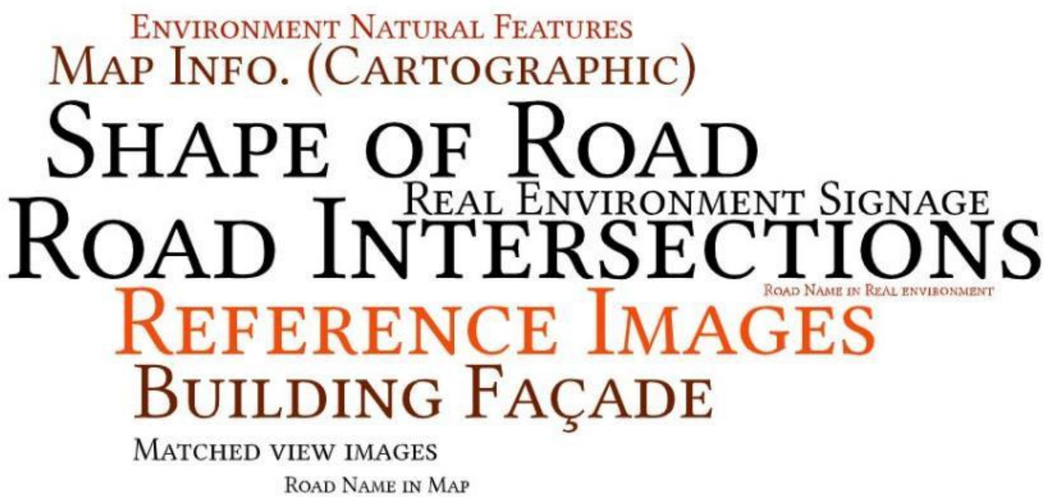


Figure 9.2 Word cloud of preferred information sources

9.6 DISCUSSION & CONCLUSION

The mean comparison of the information conditions and statistical differences have been influential in describing the factors which can affect the wayfinding performance of the participants. In Table 9.9, the overall mean comparison of information conditions clearly described that the wayfinding performance had been lowest with the information condition 1 followed by condition 2, condition 4, condition 3 and condition 5, respectively. However, the most effective and efficient information condition cannot only be found out by the mean comparison of the time taken for performing the wayfinding tasks. To see the overall performance distribution amongst all the participants, it was considered necessary to perform the Wilcoxon rank test for the mean comparison. The respective statistical test investigated the said argument in detail. In the previous section of this study, the hypothesis described that the match perspective reference images are more efficient in increasing the wayfinding performance than the regular façade reference images.

As the statistical test suggested, the performance (Time taken for task completion) of condition 1, condition 2 and condition 4 are somehow not significantly different from each other. This argument suggests that the information conditions presented in these three conditions almost have a similar impact on the participant's wayfinding performance. On the other hand, the performance (Time taken for task completion) of condition 3 and condition 5 are quite like each other but significantly more efficient than conditions 1, 2 and 4. In three conditions (1,2,4), reference images (façade view) were provided on the map information as described in Table 9.6. While in conditions 3 and 5, reference images in the map information were from the matched perspective instead of the façade view. The effect of the signage variable on performance is not significant, however, the effect of the viewing angle of a reference image on performance is significant. Users performed better if the reference images of environmental information provided in the map are of matched perspective instead of façade view.

As an overall discussion, the results can be summed up to the statement i.e., (performance of Condition 5 = Condition 3 > Condition 4 = Condition 2 = Condition 1). This relationship has proved the mentioned hypothesis about the reference images. In addition to that, two of the information conditions (2,3) have no signage visibility in the real environment, whereas the conditions (4,5) have visible signage in the real environment. To further investigate whether signage visibility can significantly affect the wayfinding performance, the two sets of conditions have been combined, as stated in the results section. The results enunciated that conditions 3 and 5 is statistically better than conditions 2 and 4; however, conditions 2 and 3 have no significant performance differences with conditions 4 and 5. This notion can be influential in proving that reference images if matched with the user's viewing perspective, can increase the wayfinding performance. This argument has been consistent with the previous study (Cheung, 2006), where image information performed better in navigation tasks. However, regarding the façade images or matched perspective images, no information has been studied before in the literature.

In addition to that, 3D models of landmarks or as a piece of reference information can also be influential, as presented in the previous studies (Shelton and Hedley, 2004; Klatzky *et al.*, 2008; Hoe *et al.*, 2017). However, the presented 3D models have a very different view compared to the user's human eye view. Owing to this, 3D models would be able to perform like the façade images as depicted in our study. A similar study (J. Xia *et al.*, 2008) has also described that images of particular landmarks from eye level are influential in enhancing orientation and navigation performance. The wayfinding performance in our study was not affected by the visibility of identification signage in the real environment. The signage visibility was considered important in synthesizing the map and real environment information, however, participants considered reference images of landmarks more important while combining the two information sources.

Although the studies (Gibson, 2009; Oyelola, 2014) suggested that the identification signage are extremely useful in the public spaces for identifying the potential destination, however, in our study, due to the presence of mobile map information, the identification signage in the real environment was considered less important. Because in the map information, it is quite difficult to validate the information in the real environment just by seeing the identification signage. Maybe it can give the idea of location proximity; however, it cannot give the exact direction and orientation in the real environment. After performing the experiment, the participants mentioned their preferred wayfinding information sources as per their practice and comfortability.

As depicted in Figure 9.2, the most preferred information source is the shape or patterns of the road. This finding has been considered consistent with the previous studies (Hölscher *et al.*, 2009; Carlson *et al.*, 2010; Wolbers and Hegarty, 2010) where the shape of the road was quite influential for the participants to navigate themselves in the real environment. In addition to that, the road intersections are also considered to be very influential while performing the wayfinding tasks. Our finding has also been consistent with the previous studies (Asher *et al.*, 2013; Clarke, Elsner and Rohde, 2013). However, in both information aids, the intersection is also a decision point for a wayfinding task, i.e., either to continue in the same orientation or need to change it. After that, the reference images of landmarks are also considered to be very important in guiding the navigators. However, in the previous studies (Cornell and Greidanus, 2006; Omer and Goldblatt, 2007), the role of landmarks in wayfinding have been investigated. In our study, the reference images to identify the landmarks in a real environment have been investigated and found effective while performing the wayfinding tasks.

The wayfinding information in the real environment (static) and in the mobile platforms is helpful in the wayfinding aids when the environment is not complex. For the complex, congested institutional public environment, these information aids are not effective enough to guide the navigators. Owing to this, an information synthesis of static and mobile wayfinding information is required to inform the navigators effectively also for the validation of provided information in the real environment. For information synthesis, only the role of landmarks reference images and signage visibility have been validated for this study. The reference images with the matched perspectives of the user's view are more efficient than the reference images of the building façade.

On the other hand, the signage visibility in the real environment has no significant influence on participants' wayfinding performance. It is also recommended to validate further the proposed wayfinding theoretical framework for different parameters mentioned in the framework. The wayfinding information synthesis for static and mobile information can be proven efficient in comparison to the existing wayfinding strategies, especially for complex and illegible environments. In the next chapter, comprehensive conclusions have been discussed based on the findings of this thesis. Future works along with the thesis limitations have also been discussed in the next chapter to further direct the readers regarding the requirements for wayfinding system design.

CHAPTER 10: CONCLUSION AND FUTURE WORKS

10.1 OVERVIEW OF THE CHAPTER

The current chapter discusses the key findings of the said thesis consisting of the type of environmental settings, user-related differences in behaviour, different types of information, wayfinding information aids and the proposed idea of wayfinding information synthesis. This chapter also discusses the limitations of the presented studies along with the theoretical contributions of the current studies. After that, some future research directions will be discussed, which can further enhance the findings of this thesis. The future directions will help the readers to understand the extent of the said project if combined with the potential technological advancements.

10.2 KEY FINDINGS

The key findings for this research thesis include several factors related to the spatial environment and its quality, user-related differences and behaviour, and the wayfinding information and its types. In this thesis, several research studies, including human participants, have been conducted to investigate the factors and propose a new wayfinding framework for the effective delivery of information to navigators.

10.2.1 COMPLEX ENVIRONMENTS

The spatial environments have been consisted of buildings, walking areas and landmarks in indoor and outdoor spaces. These spaces possess several qualities; however, for wayfinding, the environment needs to be legible for the navigators. The public spaces, especially institutions situated in the central urban areas with congested spatial planning, have been transformed into complex, illegible and homogenous spaces. These spaces are hard for the navigators to memorise and recall during the wayfinding tasks. The homogeneity of the environment makes it even more complex, which is the usual case for public sector universities, hospitals, malls and other congested public spaces. This thesis highlighted the differences between regular and complex environments for wayfinding and described that the wayfinding strategies which have been proposed in the previous literature are not efficient enough to cater for the wayfinding problems of modern-day environments. These environments become more complex after the extension of spaces with poor planning and mostly based on the already defined and available space. This thesis also contributed towards the metrics for identifying the complex environments and recommended well-thought wayfinding strategies to mitigate the navigation issues and made the whole environment efficient for all types of users.

10.2.2 CULTURAL & INDIVIDUAL DIFFERENCES

This thesis investigated the differences related to the navigators while performing wayfinding tasks. In our study, two cultures being the representatives of collectivists and individualists, have been studied to investigate the cultural differences. Several cultural differences, including the design of information, information volume, and type & coding preferences, have been identified. The identified differences have suggested that the existing wayfinding aids, especially the written aids, have potential limitations in terms of language understanding as well as in attracting the users' attention while doing the wayfinding tasks. Users from different cultures can understand similar information at different levels because of their cultural influences. Similarly, the wayfinding behaviour while performing the real-time and virtual wayfinding tasks also varied because of the said influences. In the previous literature, it has been evidently expressed that there is a need for culturally consistent wayfinding aids in complex environments; however, no theoretical framework has been proposed with special consideration of cultural and individual-related differences.

Several individual-related differences, including age, gender, education, profession, spatial ability and spatial familiarity, has also been investigated in our studies. Spatial familiarity, gender and spatial ability have been influential, whereas the remaining factors have little or no influence on the wayfinding performance. This notion suggests that in complex environments, the overall performance for wayfinding tasks may only be affected if the navigators have visited that before they are too good at finding their way. The individual-related differences have also suggested that the existing wayfinding techniques and information aids are not efficiently enhancing the wayfinding activity, especially if the navigators are unfamiliar with the environment.

10.2.3 INFORMATION AIDS, TYPE & VOLUME

Wayfinding information can be delivered by utilising various environmental cues and purposely designed aids to help the navigators in wayfinding. These aids are majorly of two types consisting of static and mobile wayfinding aids. In static wayfinding aids, all those aids are included, which are present in the real-time environment, i.e., signage, kiosks, landmarks, pathways, intersections. In the mobile wayfinding aids, the information can be delivered by GPS devices, smartphones, beacon-based devices and using RFID. In our studies, a thorough investigation has been conducted in real-time environments and virtual environments. Users have depicted the differences of preferences in the wayfinding information and designs. Collectivists prefer minimal, colour-coded and symbolic information in signage along with more reliance on gaining the information from a passer-by. On the other hand, individualists prefer more detailed, thorough and less colour-coded information for the real environment; also, they preferred to avoid social contact for obtaining the wayfinding information.

Identification signage, mobile devices and building landmarks have been preferred by the navigators. Whereas the optimised information volume has been varied across cultures and spatial familiarity. Navigators also suggested improving the existing wayfinding information and process in the complex public institutions as they are not efficient in guiding the way with ease.

10.2.4 WAYFINDING BEHAVIOUR

In this thesis, some of the studies have also been performed by the users in the real environment of a complex university environment. Participants were asked to perform various wayfinding tasks inside the campus to observe their potential behaviour. As suggested by the preliminary studies, there was a significant difference of behaviour in obtaining wayfinding information, preferred sources of information and wayfinding strategies amongst different cultures, gender, spatial familiarity levels. The participants have faced difficulties in the real environment due to the presence of extreme homogeneity in the spatial settings. Collectivists performed slightly better than the individualists because of their social interactions with the passer-by. The former group relied more on the real environment information rather than the provided digital devices; also, they have preferred the interesting landmarks and intersections to guide them during the tasks.

Gender also played an essential role in our studies, where females performed with a slight poor performance in comparison to males. The initial starting time for planning the wayfinding task has been quite long for females as well as they took longer time on decision points as well. Most of the participants tried to validate the provided information gained in the planning phase of the wayfinding tasks in the real environment; however, they could not do so because of several factors mentioned in the previous chapters. Spatial familiarity was also influential in the participants' performance, as the familiar navigators took less time obtaining environmental information.

10.2.5 **INFORMATION SYNTHESIS**

As per our investigations, the static wayfinding aids were not efficient enough independently to deliver the wayfinding information to the navigators because of the cultural and individual-related issues. While on the other hand, mobile wayfinding information also has several factors making it less efficient as an independent source of wayfinding information. In our real environment study, it has been observed closely that participants gained some of the information from mobile sources and YAH maps at the start of their wayfinding task, which is the planning phase. After gaining that information, they continuously tried to validate the information from both sources; however, they were not quite successful. This factor can be explained by this notion that in the previous literature, less or no consideration have been given to the synthesis of information during wayfinding tasks. A study (Jeffrey, 2017) suggested that static wayfinding aids can never be replaceable by digital or mobile wayfinding aids due to their potential benefits in the near future. According to the study, researchers have anticipated that maybe in future, both types of wayfinding systems should synthesise the information and worked for hand in hand to facilitate the navigators during wayfinding in complex environments.

As per the findings of our research and the research study (Jeffrey, 2017), it was much needed to develop a theoretical framework for synthesising the wayfinding information by having both information sources together. In this thesis, a complete wayfinding framework with auto guided navigation systems have been proposed. Which further elaborates the information syntheses in the cognitive part. Owing to this, a wayfinding information syntheses framework has also been proposed with the information requirements for different wayfinding tasks. This theoretical framework has also been validated afterwards for some of its recommendations due to the potential restrictions of time.

10.3 THEORETICAL CONTRIBUTION

Several theoretical wayfinding models have been proposed in the previous literature discussing related issues like human behaviour, information types and cognition. The first comprehensive model in the wayfinding literature for human wayfinding in an urban environment was proposed in a research study (Gopal and Smith, 1990). This proposed conceptual representation discussed the cognitive processes of a navigator in an urban environment. The model majorly described the cognitive processes, including the role of long term and short-term memory. The role of motor structures, including the environmental influences on human cognition, has been discussed in detail. In addition to this framework, another framework has been proposed in a study (Timpf *et al.*, 1992) which majorly described edges and vertex and their levels of abstractions during wayfinding. In this conceptual model, there are three significant levels of abstractions, i.e., planning level, instructional level and driver level. This wayfinding model discussed the wayfinding while driving, planning of the highway structures and their related issues. The information requirements have been very briefly described in this model for the above-mentioned three levels of abstractions.

Moreover, another study (Chen and Kay M Stanney, 1999) proposed a comprehensive wayfinding model for navigation in virtual environments. In the proposed model, the wayfinding process has been defined with clear and objective stages, including cognitive mapping, decision-making, and decision executions. Also, in the wayfinding model, several information requirements have been laid down necessary for the navigator to perform the wayfinding tasks in the virtual environment efficiently. The influences of navigational tools have also been proposed; however, major consideration has been given to virtual navigation. In reference to this model, another conceptual model (Li, 2006) has been proposed discussing the human and environmental interactions. This model is described in the shape of a triangle having the environment as a dynamic source of information, whereas the individuals are responsible for the cognitive processes and spatial abilities. On the third end, there were mobile devices which are responsible for being an effective source of information having position and orientation-based technologies. In all the three mentioned sides, the interaction of information has been practised by the navigators, whereas the environment and the mobile devices are the active sources of wayfinding information. In addition to this model, another study (Li and Willis, 2006) explained this information interaction model in detail by providing the behaviour of interaction. The interaction between individual and environment is influenced by the current location of the navigator.

Similarly, the interaction between individual and mobile devices are influenced by the interfaces of the mobile device as well as the type of information presented. Moreover, the interaction between mobile devices and the environment is influenced by the representations of the environment. This study also proposed the conceptual model of context-aware interactions based on the current findings.

A study (J. Xia *et al.*, 2008) has proposed a framework for wayfinding processes based on the differentiation of cognitive maps. The study represented two wayfinding processes, one with the partial or no cognitive map and the second one with the completed cognitive map. The model represented the different information requirements and the complete wayfinding process. Which also described the tangible entities, non-tangible entities, decision-making process and the wayfinding actions. The significant differences between the two proposed frameworks were during the wayfinding actions. The framework suggested some additional wayfinding information and validation requirements during the wayfinding actions and decision-making processes in the model with partial cognitive maps. In addition to that, the model has partially proposed some details based on the use of landmark utilities and the influence of landmarks on building up cognitive maps. In addition to that, another study (Lu and Bozovic-Stamenovic, 2009) has studied some socio-spatial perspectives in wayfinding and proposed a model based on the cultural influences on the wayfinding behaviour. The model proposed four major parameters in wayfinding consisting of human cognitive ability, wayfinding performance (search patterns), relational patterns of a setting and culture. The model described that cultural influences could affect human cognitive ability. At the same time, the wayfinding performance can be affected by the human cognitive abilities as well as the intelligibility of the settings. The four staged model briefly discussed the general influences on wayfinding behaviour.

A study (Giannopoulos *et al.*, 2014) has suggested a wayfinding decision model involving a three-staged iterative cycle process. The model has three major stages having environmental model, instructions model and user model. In the environmental model, the two categories have been described as independent and dependent models, whereas in the user model, spatial abilities, cultures and personal preferences have been described. In addition to that, in the instructions model, types of information have been described as pictorial, verbal and auditory information. Another study (Luo, 2018) has proposed a model for habitual wayfinding, which has been defined based on the studies performed in academic libraries. The model describes the wayfinding process and identifies another critical factor of travel habit in the whole process, which can affect the decision-making process while performing the wayfinding tasks. All the proposed wayfinding models have been proposing different phases of the wayfinding process. However, none of the models have been proposed based on the holistic approach of wayfinding, it's information requirements and the application in complex environments.

In our proposed framework in Figure 8.1, a comprehensive wayfinding framework has been proposed incorporating the holistic approach. This approach involves the human senses, information requirements, information influences, environmental influences, individual-related influences, cognitive processes, and wayfinding actions. The framework also suggested the incorporation of wayfinding information syntheses while designing the wayfinding systems for complex environments. The concept of information syntheses has been further explored in Figure 8.2, which describes the contributions of static and mobile wayfinding information and user validation in the real environment. This model has been further explained in Figure 8.3, describing each wayfinding phase with actions along with the requisite information requirements by the users if the environmental settings are too complex and illegible for the navigators. This theoretical contribution will not only help the designers to design and propose some effective wayfinding systems as well as it will help the researchers to dig more in synthesising the wayfinding information in other complex public institutional environments.

10.4 LIMITATIONS

In the first two studies related to wayfinding behaviour and preferences, the sample size was adequate for the statistical tests for each group; however, the sample has been taken from the population of Hong Kong and Pakistan to represent the individualists and collectivists cultures, respectively. For more accurate findings, it has been advised to gather data from more cultures so that the existing findings can be further validated from the sample population taken from the different countries. In the remaining studies where cultural differences need to be studied, the sample population has been taken from these two countries to maintain the control on confounding factors. However, for the remaining studies, the sample size has been kept near twenty-five to thirty participants. Which is considered to be an adequate sample size in the previous wayfinding studies (Meng and Zhang, 2014; Manganelli, 2016; Lin, Cao and Li, 2019); however, the larger sample size in the wayfinding experiment can further strengthen the findings.

In our studies, all the participants have been invited from the university campus; therefore, they were mostly students of different degree levels. Most of the participants were within the range of 18 years to 35 years. Owing to this, no significant age differences have been recorded in our wayfinding experiments. It has been considered a limitation due to the pandemic; many participants outside of the university settings were afraid to come for the experiment. However, it has been suggested that participants from larger age groups should also be inducted to perform wayfinding experiments, especially in complex environments, for further interesting insights. During the wayfinding experiments, several confounding factors have already been controlled to prevent the participants from other influences. However, in the real-time wayfinding experiment performed in study 3, this has been considered a little challenging. Owing to this, further validation study has been performed in the virtual reality-based environment to validate the findings and information suggestions proposed in the theoretical framework.

In the real and virtual environment wayfinding experiment, only university settings have been used. These settings have been taken as an ideal example of the complex environment of a public institution situated in the middle of the urban areas with the scarcity of space. However, it has also been suggested that the findings from the university settings can further be applied to public hospitals, malls and travel terminals with a bit of change in the information requirements depending upon the environment.

10.5 **FUTURE WORK**

This work proposes a novel approach for understanding the relationship of complex environments, wayfinding information and user behaviour. Most of the users of public institutions are digital natives and require the up-gradation of traditional wayfinding approaches. Further research is needed to understand the users' information requirements in complex environments, especially context-aware information. Several tools have been identified and utilised for aiding in wayfinding tasks like beacon-based devices, positioning devices and smartphones; however, the wayfinding information content for this generation is yet to be explored in detail. Future wayfinding devices propose a strong dependence on augmented reality devices; however, these devices still require requisite information for the respective audience to effectively deliver the content. From our theoretical framework, it can evidently be seen that the information syntheses and environmental validation, whether doing it by augmented reality or by human cognitive process, still need further investigation to improve the wayfinding systems. The current information syntheses practices are needed to be explored in a variety of environments with a variety of cultural samples to understand human behaviour regarding their respective processes. It has also been recommended that traditional wayfinding aids should be re-explored with a synchronised approach within mobile information. Because the auto guided navigation systems still needed human validation in the real environment as human wayfinding behaviour suggested so. Our proposed framework presented a holistic understanding of the wayfinding issues in modern and complex environments and presented the relevant suggestions to mitigate the confounding influences, which opens new dimensions for future researchers to investigate it further.

APPENDIX I: ETHICAL APPROVAL FOR RESEARCH

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

To	Luximon Yan (School of Design)
From	SIU Kin Wai Michael, Chair, Departmental Research Committee
Email	sdmsiu@ Date 29-Nov-2018

Application for Ethical Review for Teaching/Research Involving Human Subjects

I write to inform you that approval has been given to your application for human subjects ethics review of the following project for a period from 03-Dec-2018 to 01-Jul-2021:

Project Title:	University Campus Navigation: A Cross Cultural Study of Signage Understanding in University Campus Navigation Design Using VR Technology
Department:	School of Design
Principal Investigator:	Luximon Yan
Project Start Date:	03-Dec-2018
Reference Number:	HSEARS20181122003

You will be held responsible for the ethical approval granted for the project and the ethical conduct of the personnel involved in the project. In case the Co-PI, if any, has also obtained ethical approval for the project, the Co-PI will also assume the responsibility in respect of the ethical approval (in relation to the areas of expertise of respective Co-PI in accordance with the stipulations given by the approving authority).

You are responsible for informing the Human Subjects Ethics Sub-committee in advance of any changes in the proposal or procedures which may affect the validity of this ethical approval.

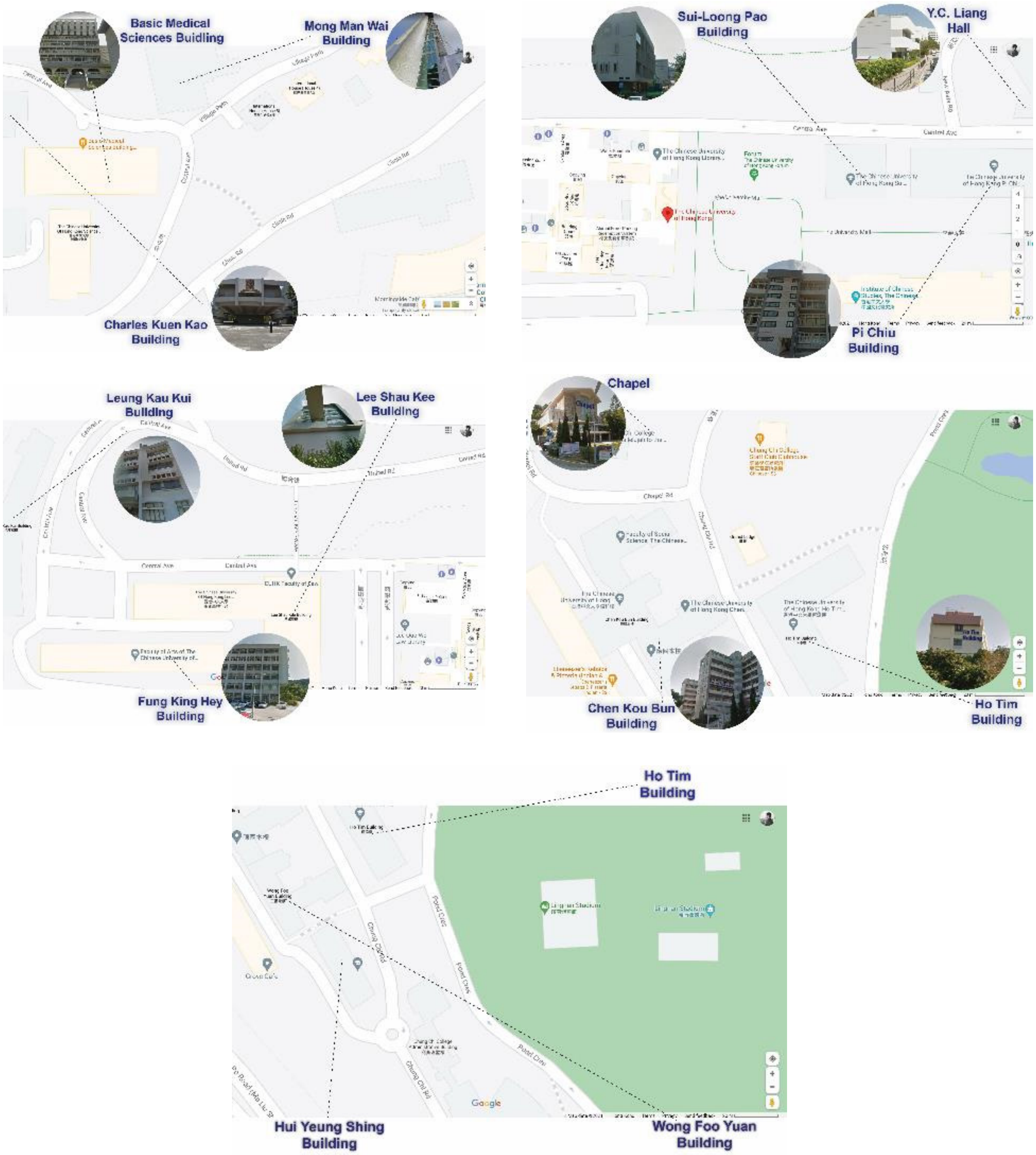
SIU Kin Wai Michael

Chair

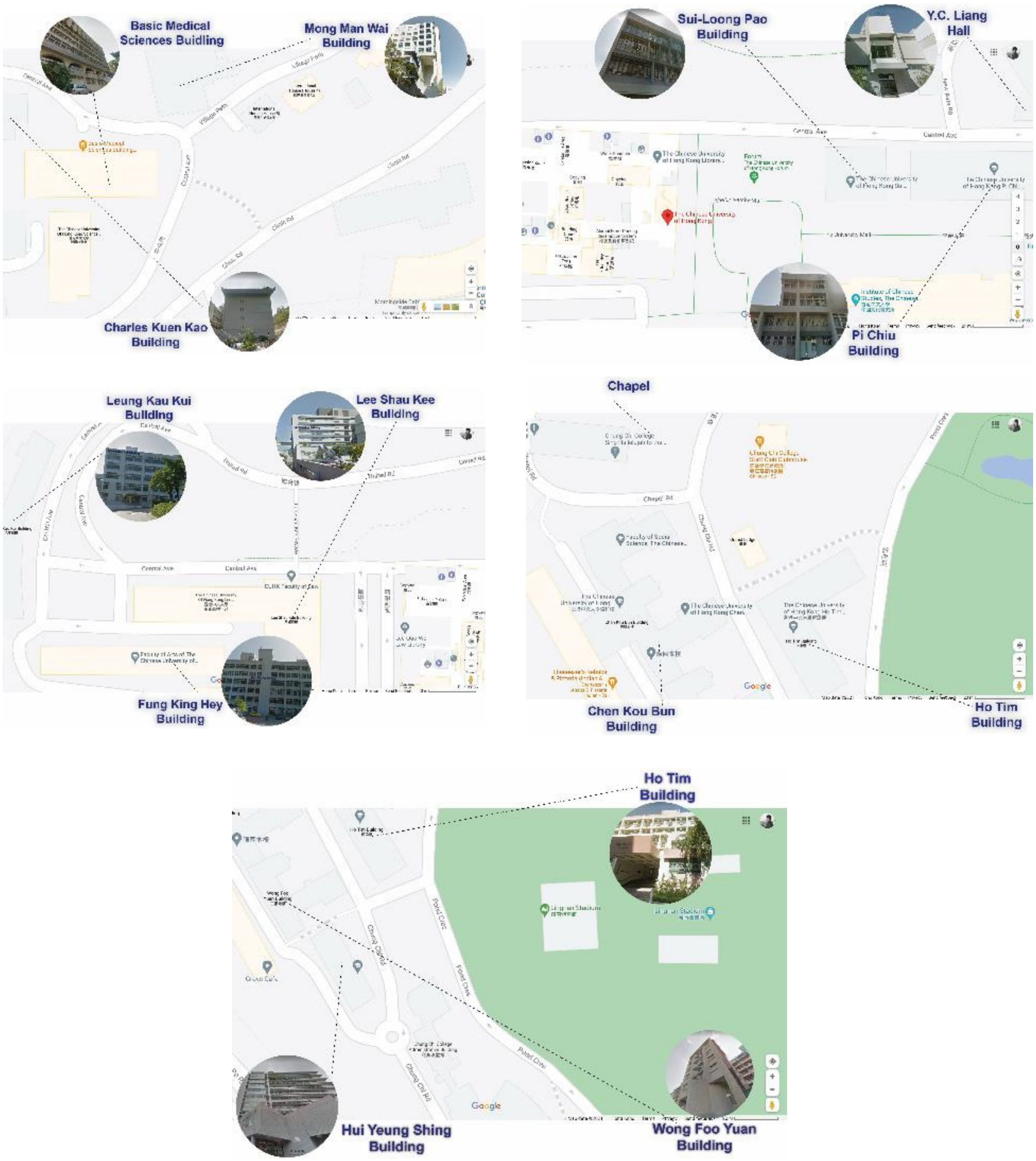
Departmental Research Committee

APPENDIX II: BALANCED SETTINGS

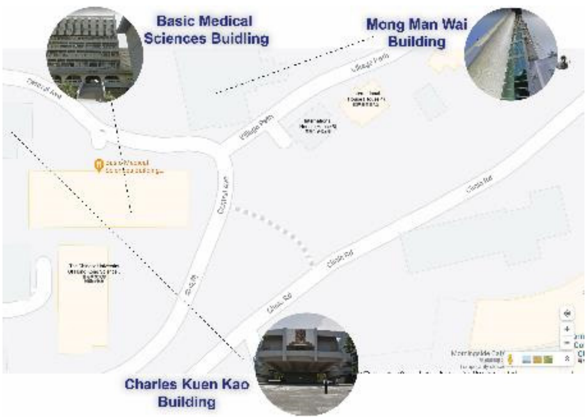
Balanced Settings 1

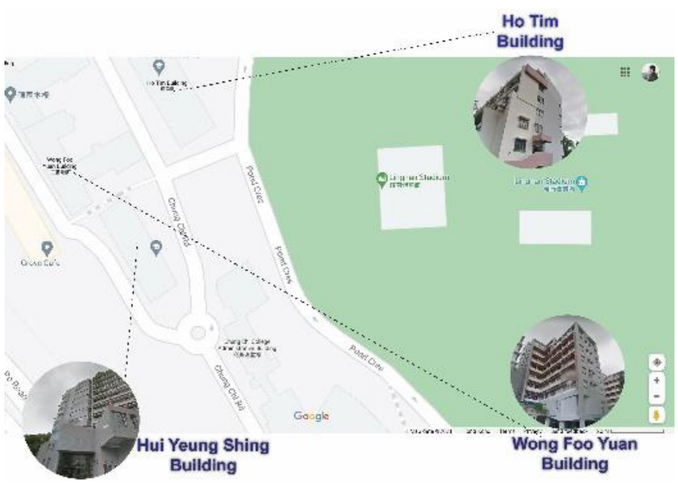


Balanced Settings 2

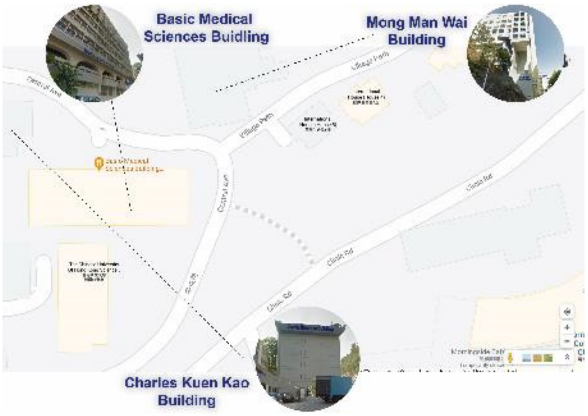


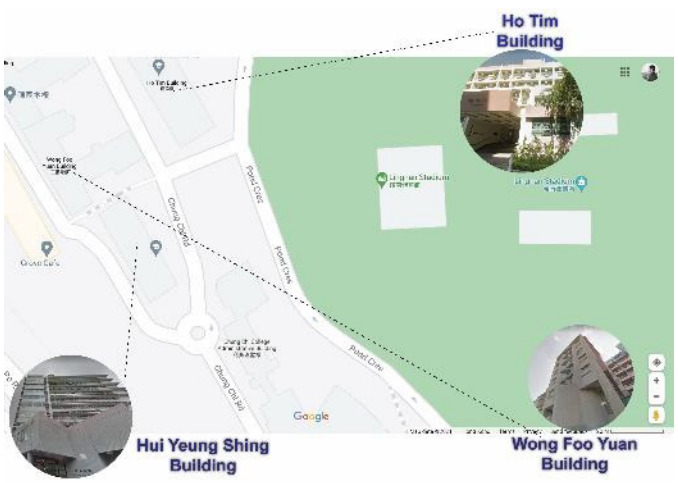
Balanced Settings 3





Balanced Settings 4





Balanced Settings 5

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