An Exploration and a Participatory Study Toolkit: Identifying the Relationship between Pavements and Older Pedestrians

A Thesis Submitted for the Degree of Doctor of Philosophy

By

Lulu Yin

Department of Design

College of Engineering, Design and Physical Sciences

Brunel University London

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Abstract

Walking is the most regular activity for older people to keep healthy and is a popular means of transport for seniors doing their daily errands. Pedestrian pavements play an important role regarding the quality of walking among older people, whereas poorly designed or badly maintained pavements may pose challenges to walking. An empirical study was conducted in London with 41 senior residents aged 60 and over. It aimed to identify hazardous factors of the pavement, explore the behavioural and physical impact of pavement hazards on older people and gather the elders' requirements for improving the pavement. A mix of qualitative methods and quantitative methods collaborating interviews, observations, cultural probe, and questionnaires were used to collect data. Qualitative analysis encompassing transcription, coding, and categorising and statistical analysis, assisted by the use of software, were applied to examine the data. The study outcomes show that hazardous pavement factors were made up of poor pavement conditions and pavement obstructions categorising broken conditions, uneven surfaces, narrow pavements, slippery obstacles, parked vehicles, overgrown plants, and so on. These factors could increase the risk of falling to the participants, cause physical burdens to the participants and limit their walking and view. The participants had to adapt their walking behaviour or gait patterns to avoid the hazardous factors. For example, they often adopted cautious steps, walked slowly, stepped aside, gave way to other people, adjusted their pace, or stopped walking to mitigate the walking risk caused by pavement hazards. Regarding minimising those accident-prone conditions and creating a safe and comfortable walking environment for older pedestrians, the participants came up with suggestions for improving the pavement. Wide and flat pavements, clean paved surfaces free from obstacles, and a pedestrianised pavement with well-maintained and uniformly designed street amenities were found to be mostly requested by the participants.

The empirical outcomes have been translated into a map-based toolkit to enable researchers, namely local councillors, urban planners, neighbourhood designers, and road engineers, to have a better understanding of the relationship between pavements and older adults and to further explore the study topic through a participatory study with older adults as the participants. In the participatory study, users can use the tool to identify hazardous factors of pavements and their impact on walking in the study participants and to propose recommendation to enhance the walking environment based on a printed map of a local pavement environment. As to the outputs of the study, plenty of analysable data which are systematically categorised by the tool will be provided to researchers. Then, researchers can prioritise problems with the pavement, analyse the significant walking behaviour associated with the pavement hazards and make improvements in the pavement. The toolkit has been evaluated by target users in interviews and workshops with questionnaires applied to collect feedback. According to the user feedback, the tool encouraged elderly participants to actively share their views and to generate ideas in a group activity. Also, the tool enabled researchers to conduct an efficient group study, to develop their work with new knowledge and to create an assessment report and design guidance for the age-friendly pavement environment.

Keywords: pavement condition, pavement obstruction, older adult, walking, toolkit, participatory study

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Definition of terms

Age-friendly: This includes outdoor spaces, buildings, transportation, housing, social participation; respect and social inclusion; civic participation and employment; communication and information; and community support and health services that are beneficial and friendly to older people (WHO, 2007a; Handler, 2014).

Accessibility: Accessibility in the context of this research refers to an accessible environment that shall be safe, comfortable, and free from environmental threats to enable older people to live active, independent and high-qualified life (Healthyageing.eu, 2018). The accessibility of the environment would be fulfilled by collaborating with multiple aspects of urban planning including transport, housing, social participation, community services, outdoor spaces, and public buildings (Healthyageing.eu, 2018)

Older pedestrians: Pedestrians are people who are walking rather than driving (Oxford Dictionaries | English, n.d.), and people older than 60 are defined as older adults (Un.org, n.d.). Therefore, older pedestrians in this study are defined as older adults who are above 60 and are able to conduct the walking activity in outdoors.

Pavement environment: For this research, the pavement environment is defined as the three-dimensional walking space including the walking environment on pavements and conditions of paved surfaces.

Walking environment: This includes the indoor and outdoor environments where people can carry out their walking activity. The outdoor walking environment is associated with street management, traffic, safe routes, mixed priority routes, shared paths and spaces, and mixed-use places (Sinnett *et al.*, 2011).

Walking behaviour: According to Mohamaddan, Case and Loon (2012) and Mohamaddan (2013), walking behaviour can be studied by measuring the walking distance, walking time, walking information and walking experience. The study focuses on the impact of pavements on the walking process of older pedestrians. So the walking behaviour mentioned in the study particularly means older adults' behavioural changes in walking and their gait patterns.

1 Introduction

This chapter introduces the background of this research, its aim, questions, objectives and scope and outlines the chapters and structure of this thesis.

1.1 Research background

The senior population is large and continually growing all over the world (He, Goodkind and Kowal, 2016). According to European Economic Commission (2018), people aged 65 and above will be 29% of the whole population in 2070 and those aged 80 and over will make up 13% of the world population. Colby and Ortman (2015) reported that the percentage of the US population aged 65 and over is predicted to be 98 million in 2060, which is twice of that in 2014. In the European Union, the population of people aged 65 and over in 2070 will be higher than in 2016 (European Economic Commission, 2018). There are 15.3 million people in the UK aged above 60, 11.8 million people above 65, 1.6 million people aged 85 or over, and over half a million people were 90 years old or older in 2017 (Office for National Statistics, 2017). The population of older people (aged 60 and over) in the UK is expected to continuously increase for the next few decades (Clarkson *et al.*, 2013).

Older people can maintain their capacity to live longer and independently through a healthier lifestyle and being engaged in regular physical activities (Musselwhite and Haddad, 2010; Kerr, Rosenberg and Frank, 2012; NICE, 2018). Leslie *et al.* (2005), Lockett and Willis (2005) and the CDC (2007) identified that walking was the most common, basic, active, inclusive, accessible and regular activity for older people (aged from 60 to 90) to do every week. Daily walking benefits cardiorespiratory health and general strength and decreases arthritic pain (Kerr, Rosenberg and Frank, 2012). In addition, walking is regarded as the most effective means of travel for older people, especially for those who live in cities and want to be less reliant on driving (Hine and Grieco, 2003; Fisk *et al.*, 2009; Shrestha *et al.*, 2016). Van Cauwenberg *et al.* (2012) found that the largest group of people that preferred walking for their daily commute were older than 60. Transport for London (TfL, 2016a) reported that senior residents (aged over 65) in London usually walk for daily errands at least two or three times a week.

1. Introduction

As walking outdoors is important for older adults, The Older People's Commissioner for Wales (2013) emphasised that public areas must be age-friendly so that it would be easier for older people to walk outdoors and remain engaged with society. Pavements have been identified as an indispensable component for a pedestrian-friendly environment (Tan, 2015; Age UK, 2019). Pavements must accommodate mobility requirements of older people, encourage older adults to lead a healthy and active life, make them involved in communities, and enable their walking activity to be safe and comfortable by preventing the risk of falls (Public Health Agency of Canada, 2015; Mateo-Babiano, 2016). Gallagher *et al.* (2010) indicated that clear pavements without obstacles, such as ice, snow, or overgrown bushes can encourage older adults' walking. Mateo-Babiano (2016) found that walking could be satisfied and encouraged by continuous pavements, evenly paved surfaces, wide pavements, and adequate lighting. Nevertheless, the poor quality of pedestrian environments can hinder the walking activity of elderly people (Beard *et al.*, 2009; Lin and Moudon, 2010). Badly paved surfaces, narrow pavements, potholes, grating, curbs and commercial boards, and street installations, such as bins, have been identified as environmental hazards that make people less likely to go outdoors (Michael, Green and Farquhar, 2011).

Many studies have indicated that the quality of pavements and pedestrian infrastructure play a key role in building an age-friendly environment and influencing walking quality and walking rate of older adults. However, they do not fully explain the specific impact of poor pavement condition on walking among older people or show a clear relationship between walking, older adults and the pavement environment. This study aims to clarify the relationship by identifying hazardous factors of pavements and their effect on older pedestrians, understanding walking in older adults and exploring age-friendly design guidance on pavements according to the walking needs of older people.

Grant *et al.* (2010) and Bindels *et al.* (2014) found that understanding older people's concerns and views can make their needs more likely to be identified and help build walkable environments. Wennberg, Phillips and Ståhl (2017) agreed that it would be crucial to include older people's knowledge and perspectives in exploring the impact of outdoor environments, and they suggested finding out a way for older adults to participate in the process of shaping their environment. Therefore, a toolkit has been developed to provide a participative process for older pedestrians to share their experiences of walking behaviour and their requirements to improve the pavement facility with local councillors, urban planners, neighbourhood designers or road engineers. With the participation of older people through the use of the tool, researchers can collaboratively identify problems with pavements, recognise the impact of the environmental hazards and co-develop solutions for improvements.

1.2 Research scope: aim, questions, and objectives

London has been chosen as the research area because it is the capital of the UK which has a large number of senior population and ageing group. Also, pavements in this urban area come in various types including wide or narrow paving areas and new or old paving materials (Camden Council, n.d.; DfT, 2007; IHBC, 2018). Also, London authorities often undertake new projects for an age-friendly city to ensure a safe and accessible environment for senior residents (Watson, 2014; Age UK, 2018). To undertake the study in London, the study topic can be fully understood, and the research questions can be answered by plenty of relevant and representative evidence. Therefore, the primary data collection for this study samples the population of senior residents in London and investigates the pavement environment in the region. The study aims to identify pavement hazards by investigating all possible issues in the pavement environment including obstacles caused by paved surfaces and problematic characteristics in the environment. Mitra, Siva and Kehler (2015) showed that poor pavement conditions were often caused by climatic factors rather than the weather itself. Therefore, problems with the pavement caused by weather elements are also regarded as hazards, however, the climate itself is excluded from this research. Physical behavioural changes in walking is one of the main focuses of this inquiry and it covers walking patters, gait patterns, and other behavioural factors emerged in the walking process on the pavement. This study will collect data from elderly adults who are older than 60 and able to engage in walking activities, even though they had some ageing declines in their body. The group of people above 60 has been identified as older adults by many institutions, such as the UN (Un.org, n.d.), and 60 has been widely used as the minimum age for selecting senior participants in many studies (Spirduso, Francis and MacRae, 2005; Clarkson *et al.*, 2013; Lockett and Willis, 2005; Van Cauwenberg *et al.*, 2012). So, the age range is also adopted by the study to scope elderly participants.

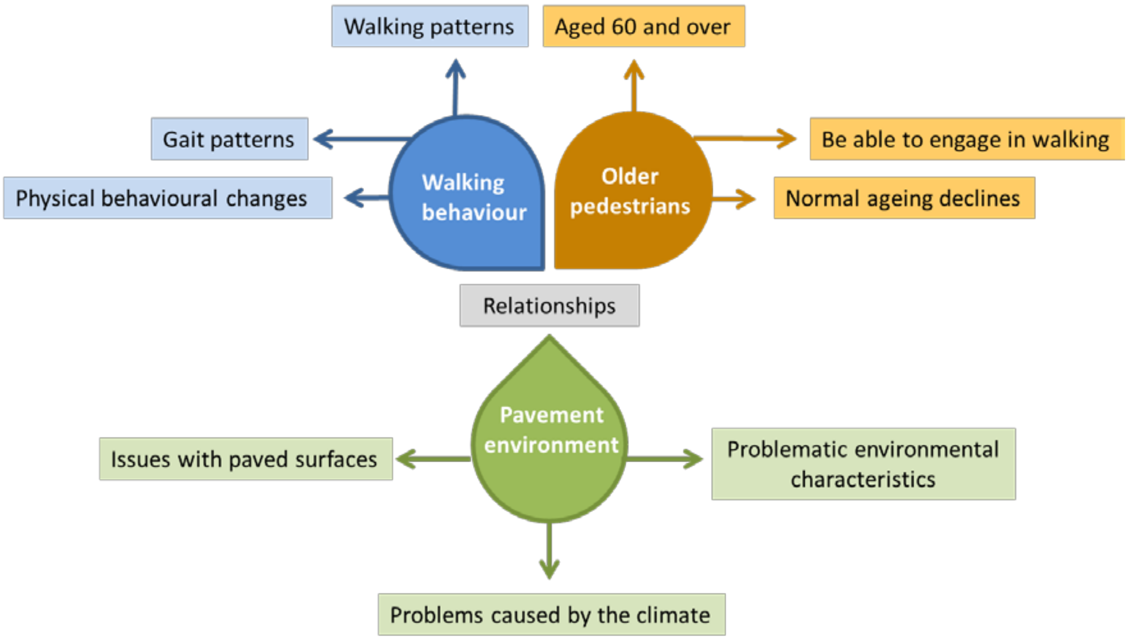


Figure 1-1. The research scope.

1.2.1 Research aim

This research aims to identify hazardous factors of pavements and their impact on older pedestrians and seek improvements on pavements concerning walking experience, perspectives, and needs of older adults.

1.2.2 Research questions

RQ1: What pavement factors are hazardous to older pedestrians?

The first question was made to explore what factors of the pavement environment can be regarded as hazards to older pedestrians.

RQ2: What is the impact of pavement hazards on older pedestrians?

The second question intends to investigate why pavement hazards are identified as threats to elderly pedestrians and how they affect walking among older adults.

RQ3: What are the requirements of older pedestrians for the pavement environment?

This question looks into walking needs of older pedestrians and their concerns and requests to pedestrian pavements in order to identify improvements in the pavement.

RQ4: How to involve older adults in the process of developing pavements in their neighbourhood?

The last question aims to find out a way or method for people who work on urban environments or transport environments to develop pavements to satisfy older people's walking ability and needs.

1.2.3 Research objectives

To seek answers to the research questions, this research has five objectives to be achieved:

RO1: To analyse relevant studies on walking among older people, ageing changes in walking, outdoor built environments and approaches and guidance of pavement development, and to review participatory research process and tools.

RO2: To identify hazardous factors of pavements and their adverse impact on walking in older pedestrians.

RO3: To explore older pedestrians' walking behaviour associated with the pavement hazards, and to collect their requirements for an age-friendly pavement environment.

RO4: To review tools that could be used to foster idea generations, group interaction and effective research activities.

RO5: To translate the results of the empirical study into a toolkit for researchers to investigate pavements and improve the pedestrian environment for older adults.

RO6: To develop the toolkit by collecting various expertise from an evaluation study with stakeholders from different fields.

1.3 Outline of the thesis

Figure 1-2 shows that this thesis is implemented in five research stages and 8 chapters consisting of six studies adapted form a book of Blessing and Chakrabarti (2009): literature review in research clarification stage, descriptive study I (DS-I) in exploratory stage, prescriptive study I (PS-I) and descriptive study II (DS-II) in idea generation stage, prescriptive study II (PS-II) and descriptive study III (DS-III) in development and evaluation phase. The clarification of this research is found in Chapters 1, 2 and 3 to describe the background of this study, identifying research gaps and opportunities and clarifying the research questions and the methodology. Chapter 4 discussed DS-I, which is an empirical data collection used to seek answers to research questions 1, 2 and 3. To answer RQ 4, Chapter 5 described an idea generation study (PS-I) which is used to generate a primary concept of the toolkit. In addition to Chapter 5, DS-II, in the form of an expert interview, was used to review the primary design of the toolkit. Based on the primary concept, a design development stage (PS-II) was undertaken to further develop the toolkit. An evaluation study, DS-III, was carried out to test the toolkit with users. Both PS-II and DS-III are divided into two sections which are discussed separately in Chapters 6 and 7.

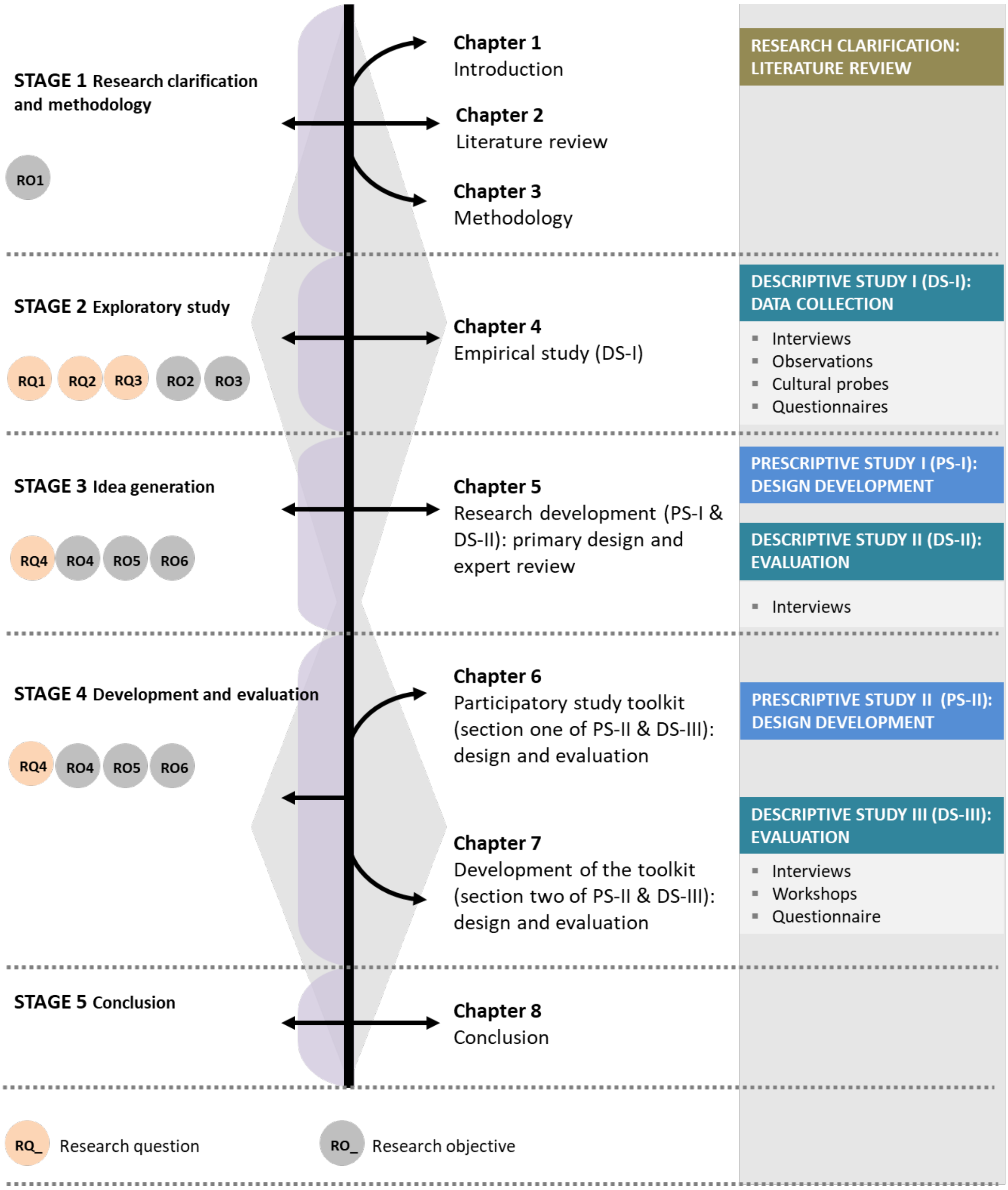


Figure 1-2. Outline of the thesis.

Chapter 2 Literature review

Chapter 2 describes a review of older people's walking purposes and benefits in outdoors. It also analyses the impact of ageing declines and poorly-built environments on older adults and their walking activity. Additionally, this section explores inclusive, walkable, accessible and age-friendly environments and seeks guidelines for building pedestrian-friendly pavements. It also discusses the participatory process and activities and tools of co-design and user-centred design. Finally, the chapter explains the research gap and motivation of this study.

Chapter 3 Methodology

Chapter 3 introduces the methodology applied for this research and explains the reason for choosing different research approaches and methods for the study. This chapter presents a research plan with a specific description of different studies and explains the paradigm of this research by specifying the study strategies and techniques adopted in different phases. Additionally, sampling methods and ethical issues are discussed in this chapter.

Chapter 4 Empirical study (DS-I)

This chapter describes an empirical study referred to descriptive study I (DS-I) which was a data collection that investigated hazardous factors of the pavement environment and their impact on walking in older pedestrians. The study also identified older adults' requirements for the pavement. Four techniques including interviews, observations, cultural probes, and interview-based questionnaires were used to collect data from older adults based in London. From the results, the study found that poor pavement conditions and pavement obstructions were identified as hazardous factors of pavements. They could increase the risk of falling, cause body pain and limit walking and view of older adults and induce changes in elderly people's walking patterns. To mitigate the hazardous factors and adverse impact of the pavement, an age-friendly and pedestrianised walking environment with well-maintained paved conditions free from any obstacles should be built for older people.

Chapter 5 Research development (PS-I & DS-II): primary design and expert review

Chapter 5 introduces Prescriptive Study I (PS-I) which was conducted to create an initial *design support* which is a toolkit based by conceptualising the outcomes of the empirical study. The toolkit comprised of a database and 16 locating marks. It was reviewed by eight experts invited from diverse fields, but which were relevant to the content of the tool. An interview was carried out enabling experts to share their comments on the inputs, content, design, application, outputs, and development of the toolkit. According to the interview results, the tool was novel and original. However, the usability and usefulness of the tool should be improved considering the needs of users. Therefore, the study decided to redesign the tool for researchers to deeply explore data based on their expertise and needs in a participatory study with older adults being involved as participants.

Chapter 6 Participatory study toolkit (section one of PS-II & DS-III): design and evaluation

Chapter 6 describes the development of a participatory study toolkit created based on the results of the previous evaluation study (DS-II). The redesigned toolkit would serve researchers who work on environment-development, such as local councillors, road engineers, and urban designers, to assess and improve pavements through group studies with older adults being involved as participants. The tool enables researchers to identify problems of pavements and their impact on older pedestrians and to construct a better pedestrian environment for older adults and allows elderly participants to share their views and generate ideas. Five mini workshops (DS-III) were conducted to request target users to test the toolkit from the aspects of usability, usefulness, effectiveness, and efficiency. An observation and two questionnaires were additionally employed to observe user behaviour and collect user feedback. According to the testing, users were able to arrange a group study using the toolkit to identify pavement hazards and associated walking behaviour and requirements of older adults. However, the information and instruction of the toolkit should be clarified, and the design and usability should be improved.

Chapter 7 Development of the toolkit (section two of PS-II & DS-III): design and evaluation

This chapter discusses a new version of the toolkit modified based on the results of the last evaluation. The revised toolkit has made several changes in its components, design, and utility to encourage more group discussion and idea generation. The new tool was evaluated by researchers in interviews and by elderly users in workshops to fully and deeply explore their views. A demonstration was used to assist researchers with the self-study of the toolkit and the workshop was filmed to record extra information. In addition, questionnaires were adopted to record users' comments. The new toolkit received more positive feedback compared with the reviews of the previous design, however, it still needs to be developed with further modifications in usability. The toolkit was finalised with an improvement in design and specifications, and it was named W-KIT which can be accessed via a website https://yinlulu07.wixsite.com/wkit.

Chapter 8 Conclusions

The contributions to new knowledge and implications of this research are indicated in this chapter. The chapter concludes the whole research project by responding to the research theme and questions and highlighting significant findings. A participatory study toolkit is designed based on the study findings to investigate pavement hazards and develop an age-friendly walking environment for older pedestrians. The outcomes of this research extend the knowledge of pedestrian environments and walking among older adults. Additionally, the study contributes to end-user-involvement studies, urban development, age-friendly cities, and tool design. In future, the study topic will be explored more by including different samples and research techniques and toolkit will be developed for broader users.

2 Literature review

This section aims to clarify the relationship between elderly people and the built environment by analysing related studies. The review of the literature has sought older people's purposes of physical activities and walking as well as benefits of walking outdoors. It has also identified the internal impact of ageing in terms of changes in walking patterns and the external influence caused by outdoor built environments on older pedestrians. In addition, the literature review examines related guidelines for designing pedestrian-friendly pavements. Theory and tools of human-centred design, participatory design and co-design were also researched and analysed in this section in order to seek a better way for older adults to communicate and share their needs and walking experience with people who work on pavement development.

2.1 Walking in older adults

Data from Age UK showed that around 25% of the UK population would be aged over 65 by 2040 (Office for National Statistics, 2013). Older adults, especially those who have retired, often have plenty of time for physical activities (Strath, Isaacs and Greenwald, 2007). Participating in regular physical activities can contribute towards a positive impact for the body and mind, and thereby enabling older adults to live independently even as they age (Kerr, Rosenberg and Frank, 2012; NICE, 2018). Studies have shown that walking is an easy and affordable activity and it is more likely to prevent people from injuries in comparison with other exercises (Rosenberg, Sallis and Norman, 2014). Additionally, older people show more confidence in walking as compared to other physical activities (Newsom *et al.*, 2004). Therefore, walking has become the main physical activity adopted by older people for health benefits. Ormerod *et al.* (2015) found that almost 98% of older British adults undertook at least one fitness activity to maintain their long-term health, and the most common activity was to go outdoors as often as possible. The focus groups (participant aged from 60 to 90) of Lockett and Willis (2005) identified walking as the most common activity, and more than half of their participants (a total of 13 seniors) walked regularly every week. Senior residents (aged over 65) in London usually walk at least two to three times a week or once a week for diverse purposes, such as for exercise, shopping, and other errands (TfL, 2016a). Eyler *et al.* (2003) also found that up to one in three of people aged over 65 years walked regularly for leisure.

2.1.1 Benefits of walking

Regular walking has significant advantages for older people concerning their physical condition (Brookfield, Thompson and Scott, 2017). Walking prevents obesity, diabetes, and high blood pressure (Sinnett *et al.*, 2011). Murphy *et al.* (2007) indicated that walking could help people increase their diastolic pressures and reduce their body mass index, including weight and fat. Simonsick *et al.* (2005) found that elderly people, especially females, could enhance their walking ability, walking speed, stability and lung function by walking for a reasonable distance (around 6 kilometres) every week. The chances of death in older people from any causes could decrease by 50% if they walk at least one mile every day (Clifton, Livi Smith and Rodriguez, 2007). Walking can also increase the cognitive ability for older adults and can positively contribution to mental health (Prohaska *et al.*, 2009; Wood, Frank and Giles-Corti, 2010). Outdoor physical activity could make older adults become active and more independent for their health and wellbeing (Curl, 2016; Cheng, Tyler and Holloway, 2014). Daily walking can increase the level of social participation and make older people connect more closely to their society (Gosselin and Laforest, 2008).

Walking is regarded as a good way to travel especially when people who live in the city are aiming to reduce their reliance on driving (Fisk *et al.*, 2009). Walking is also regarded as the most sustainable and age friendly mode of transport (Kim, Choi and Kim, 2011; Mateo-Babiano, 2016). Elderly people especially when they age over 75 were found to walk more rather than to take the public transport for short trips (Fiedler, 2007). According to Van Cauwenberg *et al.* (2012), up to 35.9% of their subjects (aged 60 or older) reported that they chose walking more often for daily trips rather than travelling by other means. Hine and Grieco (2003) and Shrestha *et al.*, (2016) also found that the smallest number of car drivers among all age groups are older people; and walking is the main form of transport for them. In the UK, the Road Safety Research Report commissioned by the Transport of London stated that 40% of short trips among all ages were conducted by walking (Dunbar, Holland and Maylor, 2004).

Walking also brings multiple benefits to the community and the neighbourhood. Blacklock, Rhodes and Brown (2007) confirmed that extending the level of walking activity could make a remarkable increase in the economy, environment and social function of cities. According to Litman (2003), walking could also reduce the cost of transportation by improving the access for people who have given up driving and could promote social interaction in the neighbourhood. Sinnett *et al.*, (2011) indicated that well designed walking environments could reduce societal and economic costs on health issues, and improve social interaction, social capital and promote the older adults' sense of security in the neighbourhood.

2.1.2 The impact of ageing declines on walking

When people grow old, their walking performance can sometimes be impacted by the increasing physical weakness of their body (Spirduso, Francis and MacRae, 2005). Older adults have reduced flexibility and strength or may have impaired vision, weaker bones as well as other age-related deterioration (Saftari and Kwon, 2018). These age-related changes can influence their walking speed and performance (Newman *et al.*, 2003). Studies have shown that the ageing leg extension power and muscle strength can have a significant relationship with the walking speed of older adults (Rantanen and Avela, 1997; Mänty *et al.*, 2012; Manini, 2013). Lauretani *et al.* (2003) and Watsford, Murphy and Pine (2007) also provided evidence showing that the decreased function of the respiratory muscles through ageing could potentially reduce their walking ability, speed, and distance. In addition, walking speed is also limited by the declining strength in elderly people's quadriceps and ankle dorsiflexion which make them produce shorter strides and a slower velocity when stepping (Menz, Lord and Fitzpatrick, 2003; Rose and Gamble, 2006).

These age-associated decrease in the walking performance and gait patterns can cause instability and imbalance and increase the risk of falling in older people (Schrager *et al.*, 2008; Pirker and Katzenschlager, 2017). Most falls were found by Talbot *et al.* (2005) that occurred in older people when they were walking and most injuries were caused by falls. In many countries, falls are the main cause of injuries to older people aged 65 and above. In England, around 30% of people aged 65 and over fall and injure themselves every year and the risk of falling and fall-related fractures increases exponentially as people age (GOV.UK, 2018).

2.2 Hazardous impacts of poor environmental factors

2.2.1 The impact on walking behaviour

Compared to the physical decline of ageing adults, the walking environment can have greater implications for older adults (Patterson *et al.*, 2014; Mateo-Babiano, 2016). Changes in gait patterns and walking behaviour of older pedestrians have been found to be influenced by some hazards in the walking pavement (Kovacs, 2005; Caetano *et al.*, 2016). These include uneven pavements, parked cars, tactile paving, curbs, overgrown shrubs, and inappropriate street facilities and furniture (Nilsagård *et al.*, 2009; Newton *et al.*, 2010). People often choose to step over or step aside from obstacles on the road (Kovacs, 2005), or they adopt more cautious gaits, shorter step length, or a slower walking speed when they encounter uneven and slippery surfaces or other barriers (Chang *et al.*, 2017). Also, they usually adapt their gaits and widen their strides to keep balance and stable on slopes (Merryweather, Yoo and Bloswick, 2011). Sometimes, older adults stop walking or have to step onto the road when walking on broken or uneven pavements, or when they face other pedestrians on a narrow pavement (Gallagher *et al.*, 2010; I'DGO, 2010; Brookfield, Thompson and Scott, 2017).

2.2.2 The impact on walking experience

The design of pavements and infrastructure designed for pedestrians may either increase or decrease the walking speed and the quality of walking (Kealey *et al.*, 2005; Fisk *et al.*, 2009; Clark, Scott and Yiannakoulias, 2014). The width and gradient of pavements are one of the most common factors that impacts on people's walking behaviours (Kim, Choi and Kim, 2011). In the survey by Iversen (2010), the walking space which is mainly defined by the pavement width was found to have the most detersive effect on the speed of walking. Nilsagård *et al.* (2009) and (Newton *et al.* (2010) corroborated that the evenness of pavements, parked cars, tactile paving, curbs, benches, greenery and toilets impacted the walking experience and behaviours of elderly people. Irregular pavements could make people feel tired, and a busy footpath or a muddy road could challenge people's walking and make them feel difficult to move (Merryweather, Yoo and Bloswick, 2011; Patterson *et al.*, 2014). In addition, older participants in the study conducted by Day (2008) identified that commercial boards, shop boards, stalls, rubbish bins, overgrown trees and broken streetlights could be seen as environmental barriers that made older people feel uncomfortable and inconvenienced (Muraleetharan and Hagiwara, 2007).

2.2.3 The risk of falling

These hazardous factors could increase the risk of falling in older people (Strath, Isaacs and Greenwald, 2007). More than 50% of falls reported by elderly people over the age of 65 occurred outdoors (Bergland, Jarnlo and Laake, 2003). Nyman *et al.* (2013) found that most falls of older adults were induced by the absence of well-built pavements, sloping surfaces and road obstructions. Li *et al.* (2006) and Zamora *et al.* (2008) observed that steps, identical surface colours, street furniture and poorly-lit areas also contributed to a large percentage of falls among elderly people. In addition, missing manhole covers or covers which are broken or slippery have become one of the main causes of falls, slips and trips (Devon County Council, 2016). Uneven and slippery surfaces could make older people lose their balance and fall (Dunbar, Holland and Maylor, 2004; Day, 2008). According to the report of falls in outdoors by Lai *et al.* (2009), more than three quarters of the falls or trips caused by unevenness and nearly half of the falls were related to slippery obstructions and one third of the falls occurred when the two hazards are on the same surface. Day (2008) found that older people's balance and stability of steps could also be impacted by stepping aside advertising boards, bins and street stores.

In terms of fall-related injuries, the study by Gillespie *et al.* (2009) revealed that 50% of injuries among older adults were caused by falls. James *et al.* (2009) also found that around 80% of patients in a Jamaican hospital had fractures caused by falls in built environments. The majority of the patients were aged 65 or older who had more injuries in their legs and arms (ibid.). In Canada, 85% of elderly patients were injured because of falls or trips and there were 67% of hospitalizations with orthopaedic injuries (Newsom *et al.*, 2004). Falls and fall-related injuries also increase the death rate and make older people less confident or independent (NICE, 2013). According to Rubenstein (2006) and WHO (2007b), nearly half of injury-related mortalities in elderly people were caused by falls, and 31% of these were contributed by environment-related hazards. Older people who have experienced fall-related injuries could be more likely to have a fear of falling when walking outdoors (Gyllencreutz *et al.*, 2015). The anxiety of falling could hinder older adults, especially senior females, to undertake outdoor activities (Sjögren and Stjernberg, 2010; Peel, 2011).

In addition, falling also increases healthcare costs and associated burden. For example, people in the UK who fall on the pavement are allowed to claim compensation ranging from £1500 to £31,000 from the NHS (LawOnTheWeb.co.uk, n.d.). The compensation policy increases financial pressure on healthcare organisations and the government. NHS spends £4.6 million every day due to fall-related issues, and the organisation has been estimated to spend more than £2.3 billion every year which includes £15 million on general injuries and £1.7 billion on hip fracture for patients who fall and hurt themselves (Anderson, 2008; Ageuk.org.uk, 2010).

2.3 Age-friendly outdoor built environments

An age-friendly place environment is not just limited to older people but also for everyone to feel safe, comfortable and secure in their neighbourhoods (Age UK, n.d.). Outdoor spaces and transport amenities are the most essential factors for an age-friendly environment (Age UK, n.d.). The age-friendly city needs to improve the accessibility and street environment with more resting areas and better facilities and to clean obstructions in streets (Mackett, 2014). According to the WHO Age-friendly Cities Guide, pavements in an age-friendly neighbourhood should provide wide, smooth and even surfaces with lower curbs, and without obstructions such as slippery surfaces, parked cards or trees (WHO, 2007a).

2.3.1 Walkable environments

Walkable environments are friendly to older people as they enable people to walk for diverse purposes, such as for reaction, and enable people to reach their intended destination in a safe and comfortable way (Cerin *et al.*, 2011; Ariffina and Zaharib, 2013). Owen *et al.* (2007) found that the index of walking rate and distance were more significant in high-walkable neighbourhoods. People are active of going out to do more physical activities (including walking) and more engaged with societies in high-walkable environments than in low-walkable areas (King *et al.*, 2011; Winters *et al.*, 2015). The proximity of commercial and mixed-used areas are main walkable factors that increase walking rate (Joh, Nguyen and Boarnet, 2012). Other walkable features include short to medium length blocks, safe crossings, street-oriented buildings, comfortable and safe places for waiting, safe spaces, or visible parking functional, street furniture and special pavement (Choi, 2012).

2.3.2 Inclusive environments

An inclusive environment also provides everyone with a safe, accessible, convenient and easy environment in view of mobility needs of diverse groups, including disables and older adults (Gardiner and Theobald, 2018). It makes senior adults' activities easier by allowing them to access and use the environment according to their requirements without extra effect (CABE, 2006). According to Manley (2016), designers and civil engineers should provide appropriate resting places and seats and create clear landmarks and signage for building an inclusive environment. In addition, inclusive pavements should be more accessible for different types of pedestrians and various activities (Burton and Mitchell, 2007). Environmental obstacles such as steeps, steps, uneven surfaces, slippery surfaces, poor lighting and inadequate signage should be avoided (CEM, 2010).

2.3.3 Accessible environments

Accessibility is a key feature for an age-friendly, inclusive and walkable environment (Kilby and Smith, 2012). To improve the accessibility, a built environment shall have paved, flat, smooth and wide walking paths with good lighting and adequate seats to improve the quality of life for local residents (Chaudhury et al., 2012). Additionally, designated footpaths, an integrated system of pedestrian traffic areas, and a clear layout and connected streets can contribute to a more accessible walking environment and foster the frequency of walking (Cao, Handy and Mokhtarian, 2006; Joh, Nguyen and Boarnet, 2012).

In summary of the studies, pavements have been found to be one of the most essential components of building age-friendly environments. By improving the quality of pavements, senior residents could be more active in walking with less risk of falling occur to them (Tomalty and Haider, 2009). For example, wide and smooth pavements and plentiful pedestrian facilities make older people tend to undertake more walking activity (Burton, 2012). The focus group conducted by Gallagher *et al.* (2010) showed that walking could be encouraged if the pavement is clear without obstacles, such as ice, snow or overgrown bushes.

2.4 Guidance and approaches for pavement development

2.4.1 Guidelines created by other studies

Several studies have provided recommendations to build pedestrian-friendly environments. For example, the Nottingham City Council (2016) launched a transport programme to support sustainable transport modes such as to integrate cycling and building accessible infrastructure. I'DGO (2010) developed *The Design of Streets with Older People in Mind* by forming design guidelines based on older adults' needs and UK transport documentations to concern almost all features of pedestrian environments, such as pavement materials, pavement levels, tactile paving, seats, bus stops, and signage. They recommended that street furniture or facilities should be built and maintained regularly to avoid becoming redundant. Oxley and Hern (2016) and Burton and Mitchell (2007) established guidelines for improving the accessibility, comfort, and security of pavements. They suggested that pavements should be well maintained and be clean, flat, non-slippery and two metres wide minimum. To make the pavement safe and available for end-users, Hass-Klau (2015) additionally introduced a concept of pedestrianisation that suggests pavements to be pedestrianised by providing wide footpaths, removing obstacles, building more sharing and green spaces and using appropriate paving materials, such as small bricks or *York stones*.

2.4.2 Guidance developed by the UK government

Documents published by the UK government offer a more comprehensive and official view of pavement plans and road design regarding pedestrian needs. The *Manual for Streets* published by the Department for Transport (2007) provides substantial information about improving the quality of pavements that considers the needs of different road users. The *Pedestrian Comfort Guidance for London* created by the Transport for London (2010) provides urban planners with specific and consistent strategies for designing pedestrian-friendly pavements. The *Streetscape Guidance* (TfL, 2016b), which was recently updated by the Transport for London, provides more insights into pavement design with targeted approaches concerning different aspects of the pavement environment. In summary of those government publications, pavements must be wide, solid, durable, walkable and comfortable and be low–risk to reduce falls. Also, pavements must be designed with a good drainage system and de-cluttered by reducing parked cars, overgrown trees, unnecessary furniture or obstacles.

2.4.3 Tools and approaches for pavement development

Additionally, some applications and tools have been created to assess and monitor the quality of pavements by collecting feedback from pedestrians. For example, the *Audit checklist* designed by Curl *et al.* (2016) is used to evaluate risk factors of pavements among pedestrians. It includes a list of poor conditions and street obstructions that allows pedestrians to indicate problems with the pavement from the list. Based on the checklist, researchers can deliver a report and solutions to the identified problems. The *Pedestrians Environment Review System* (TfL, 2006) is a walking audit tool that assists researchers to gain a better understanding of the pedestrian environment by identifying pedestrian needs and particular factors that can be improved. The *FixMyStreet* is a map-based App designed by MySociety that allows British residents to report road problems with their neighbourhoods using photographs and descriptions (FixMyStreet, n.d.). The *FixMyStreet* has been widely recommended and used by many UK councils, such as the Oxfordshire County Council and Buckinghamshire County Council. The App assists in quick decision making as it shows each hazard in a specific site and displaying them on the map so that local authorities know where prior construction work takes place and to calculate hazardous landmarks (see Figure 2-1). Jelks *et al.* (2018) developed a mapping toolkit, the *Proctor Creek Citizen Science Application*, to be used in smart devices for people that can report hazards caused by dumping. Data collected by the application would be further analysed by ArcGIS Online and presented on an interactive map (ibid.).

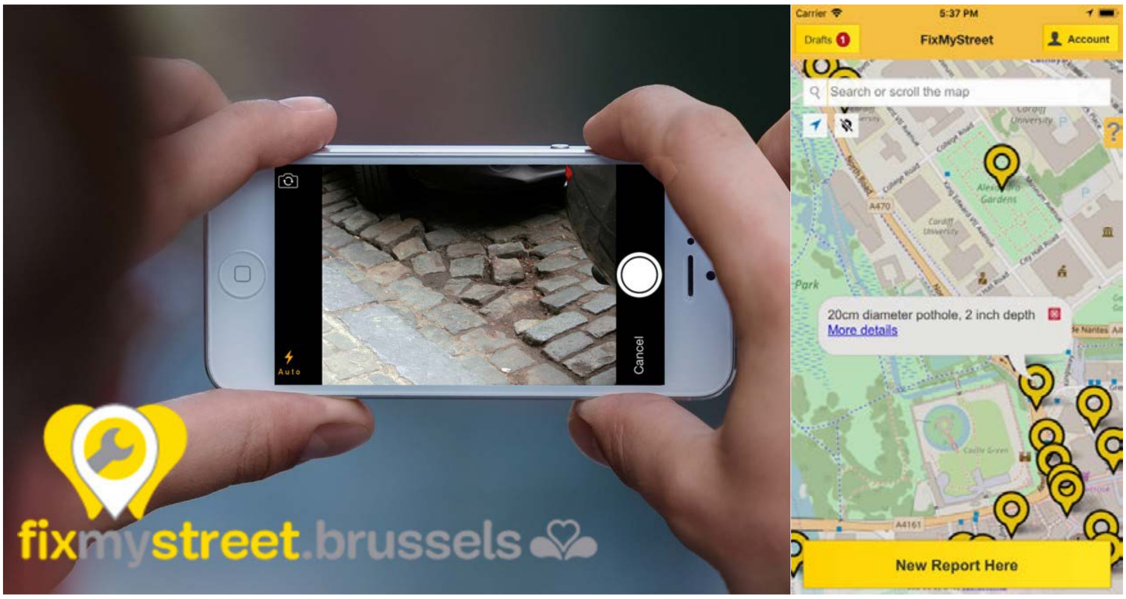


Figure 2-1. FixMyStreet design by MySociety (FixMyStreet, n.d.).

Local authorities in the UK provides a platform which is more widely used by residents to monitor pavements in their community (London Borough of Hillingdon, n.d.). Each authority offers an official website enabling people to report problems with local roads and pavements anywhere or anytime via the website (see Figure 2-2). Based on their reports, local councillors can compile and analyse the information and find the most severe cases before deploying construction work.

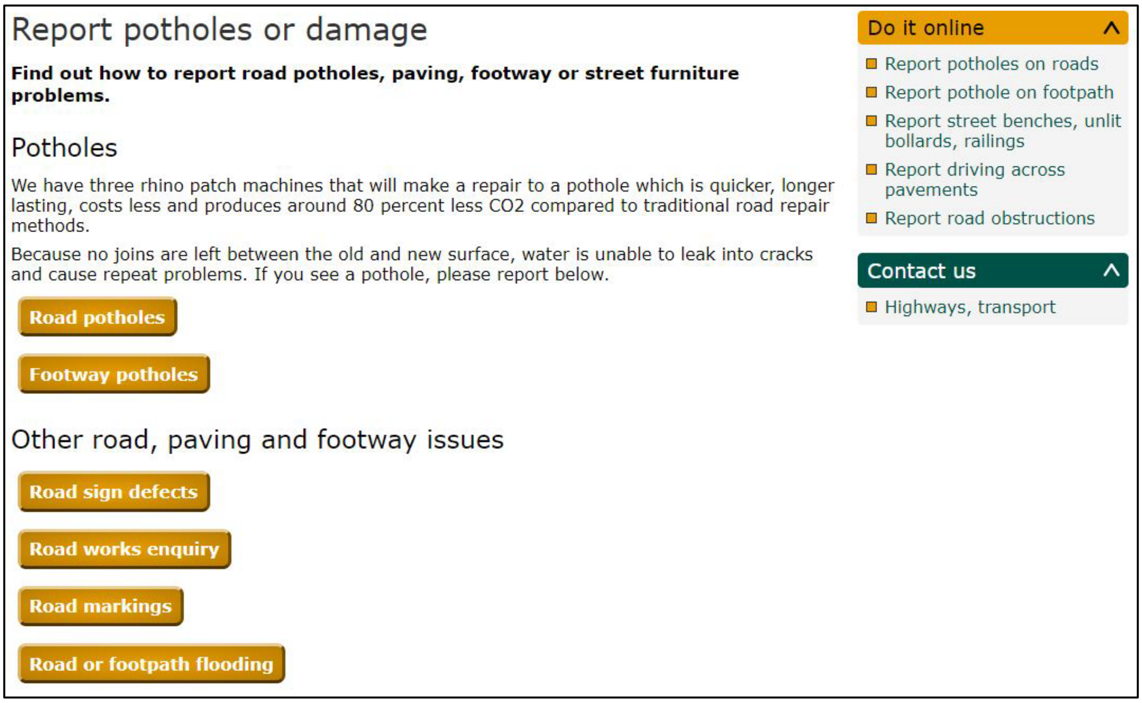


Figure 2-2. An example of the report page set up by the UK local authority (London Borough of Hillingdon, n.d.).

2.5 Participatory design processes and human-centred design methods

Older people are encouraged to be more active to participate in developing age-friendly environments (WHO, 2018). Including older people in the process of shaping their environment can make their needs and the impact of built environment be understood deeply (Wennberg, Phillips and Ståhl, 2017). Therefore, some of the guidelines discussed in the last section have been created based on pedestrian needs. Some of the applications were designed to help the public engage with researchers, such as urban planners, in terms of monitoring pavement conditions and reporting problems with the local pavements. However, few of them have fully identified or understood the walking need of senior adults or provided a direct and two-way communication between older pedestrians and specialists who develop pavements.

The participatory design can enable end users to join the design team to be the equal group members to communicate needs and share experience (Sleeswijk Visser, Van Der Lugt and Stappers, 2007; Millard *et al.*, 2010). Co-design is one of the most effective method used for collaborative research and co-creation that enables users as well as all other stakeholders to work with the design team together to identify problems and develop design solutions and to share insights and ideas with each other (Thedore and Alexiou, 2018). The co-design process shall include representatives from diverse groups in the study and respect all participants' ideas (NCOSS, 2017). It shall use activities and conversations to engage participants' knowledge, ideas and experience and shall test interactively the solution developed by the co-design team (ibid).

Participatory studies are also often conducted in human-centred design process to allow design teams or research groups to have more knowledge about the needs, contexts, behaviours and emotions of people they design for (Madpow, no date). Human-centred design can help specialists develop a better understanding of the empathy for human perspectives by including stakeholders in all steps of the design process (Ellen Macarthur Foundation, 2016). Observations, interviews and conversations are the most common methods used in the user-centred design to analyse people's behaviour and facial expressions and understand people's perspectives, experience and concerns (Giacomin, 2012; Townson, n.d.).

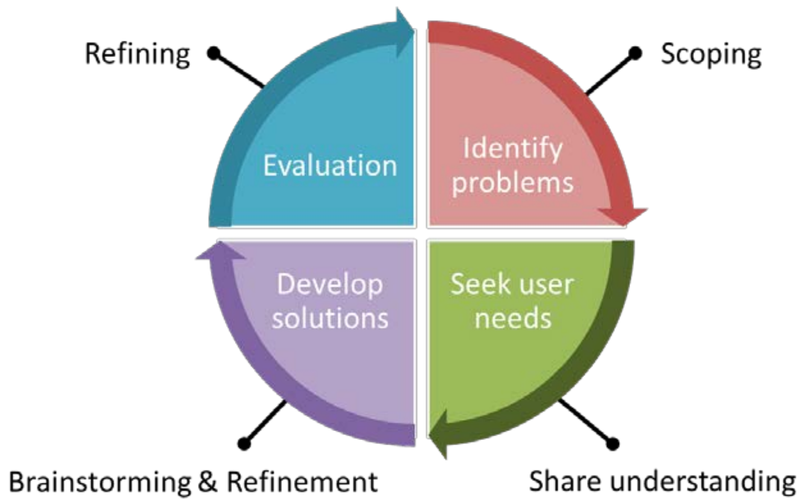


Figure 2-3. A simplified visual map of the design process adapted from Millard et al. (2010) and Usability.gov (n.d.).

The process of the participatory design is a problem-solving process which requests the specialist team and users to initiate a project by looking at problems and main issues that users are facing with and identifying user needs (Design Council, 2005; Millard *et al.*, 2010; Usability.gov, n.d.). Based on the problem exploration, the specialist group would be able to generate a solution quickly according to the user needs and to refine the solution by collecting user feedback in the evaluation stage (ibid.).

2.5.1 Tools for participatory study, user-centred design and co-design

Many tools have been created in order to assist researchers and designers to undertake a participatory research, user-centred design and co-design study in a more effective way. The next section will discuss some participatory research tools to understand how they are structured as well as their benefits and drawbacks.

2.5.1.1 Participatory mapping

Participatory mapping is a common tool used to investigate problems with a community or a neighbourhood with locals in a more flexible and creative way (Parcitypatory.org, 2018). It can visualise information of a local environment, display the needs of residents and enable different groups of stakeholders to locate the most severe problems (ibid.). Map-based presentations can assist researchers to make quick decisions and create relevant policies based on according to outputs of the map and perspectives and the needs of the local community (ibid.). Participatory maps are usually used in workshops conducted by researchers to interact with groups of participants recruited from locals (Baker and Smith, 2014). The maps usually shows roads and significant landmarks around a location or focuses on main components of a built environment when the map size is limited (ibid.).

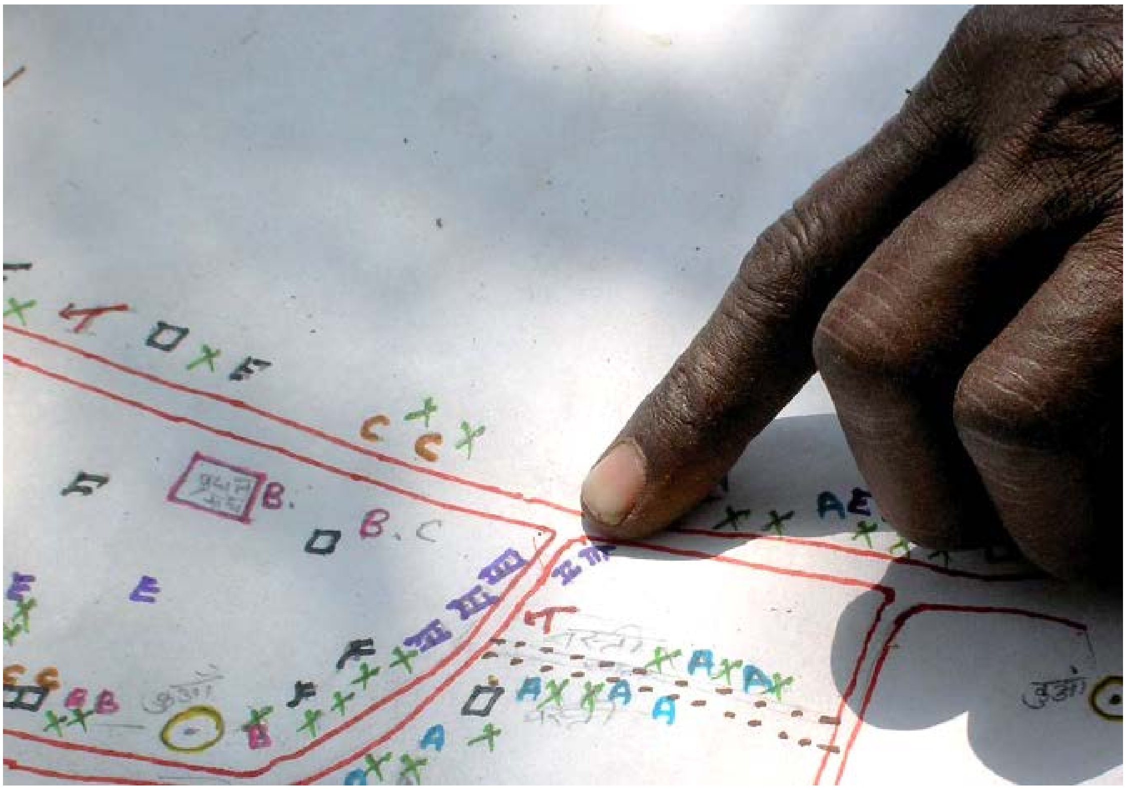


Figure 2-4. An example of the participatory map (Parcitypatory.org, 2018).

2.5.1.2 The Design Kit

The Design Kit created by IDEO (IDEO.org, 2015) groups various traditional and innovative design research activities, such as group interview, co-creation, visual map, and role playing, for designer to conduct human-centred and collaborative design. The Design Kit describes and explains how to recruit participants for different studies, what steps for each study and what materials should be used (ibid.). It also assists designers to engage and interact with participants and provides suggestions to encourage more insights shared and more ideas generated (ibid.). The Design Kit includes plenty of tools used in different stages of the human-centred design, while not all of them are used on the participative process. The study only focus on the tools used for participatory activities. According to Table 2-1, participatory activities between design teams and users referred by the Design Kit are grouped into two sections, Inspiration and Ideation. In the Inspiration group, Conversation Starters, Extremes and Mainstreams, Card Sort and Peers Observing Peers are tools that mainly explore issues and people's perspectives to problems, seek different use cases, hacks, and design opportunities to design concepts. Inspiring tools, such as Collage and Draw it, helps researchers to understand people's thinking, value and needs related to the design theme and expand participants' ideas. In addition, Group Interviews can be used to collect diverse opinions from a large group and identify the most beneficial and inclusive solution. For idea generation, the Design Kit provides many suggestions helping design researchers and participants develop a design solution in different design stages. Brainstorm can be used when co-design teams plan to generate design ideas, and they can further discuss and create a design solution in Co-Creation sessions. Role Play assists designers to evaluate the design solution by asking participants to play different roles to experience the design solution. Notebook, cards, camera and post-it notes are the most common materials requested by the Design Kit for co-design or collaborative activities.

Table 2-1. Participatory activities included in Design Kit (IDEO.org, 2015).

Design Kit	**Participatory activity**	**Description**	**Things to be prepared**
Inspiration	Conversation Starters	It helps encourage creativity by demonstrating design ideas to users and asking them to describe their opinions.	Pens, notebook
	Extremes and Mainstreams Designing	It suggests including extreme users in the process of designing a solution to make the solution inclusive and to seek different use cases, hacks, and design opportunities.	Pens, notebook
	Card Sort	Using cards to demonstrate ideas and make participants sort them according to preference.	Cards
	Peers Observing Peers	Designers are the observer in this activity asking participants to report issues and perspectives using camera, pens and paper, observing the way they undertake the report	Pens, paper, camera, art supplies

		and seeking significant findings.	
	Collage	To understand people's thinking, value and needs related to the design theme by asking participants to make collages using magazine and paper.	Pens, paper, glue, magazines
	Draw It	Draw something to initiate the activity and ask people to draw their thoughts and ideas that are inspired by the sketch or by a topic or description.	Pens, notebook
	Group interview	The group interview is useful to collect diverse opinions from a large group and to identify most beneficial solution.	Pens, paper, camera
Ideation	Brainstorm	Ask participants illustrate ideas on Post-its and display them and keep encouraging to generate concepts in a more open way.	Pens, Post-its, a large sheet of paper or whiteboard
	Co-Creation Session	Cooperate with people to discuss and create a design solution.	Pens, Post-its, paper, a place to meet
	Role Playing	To evaluate a design solution by asking people to play different users to experience the design solution.	No necessary.

2.5.1.3 Service Design Tools

Likewise, Service Design Tools produced by Tassi (2009), is an on-line repository that offers many activities and tools for co-design and user-centred design to create better services. As the repository serves the design of a service system, more scenario-based activities and fun toolkits are involved in the depository. Table 2-2 shows that some tools such as LEGO, Issue cards and Affinity diagrams, can help design researchers understand problems, identify relationships and the significance in the problems and seek new criticalities and design opportunities. Motivation matrices, Storytelling and Character profiles enable design teams to have a better understanding about the user needs by allowing stakeholders to share their desires, interests and suggestions and by enabling participants to share and describe their distinctive characters. With the use of the toolkits, designers can explore a better design solution (a service system) and build a close connection with different stakeholders or users. Design games, Group sketching and Rough Prototyping are other effective tools to encourage idea generation and concept sharing based on visual information. They help simulate a service design and foster interactions in the design process using tangible prototypes. Other toolkits, such as Constructive interaction, Wizard of OZ, Service prototypes and Experience prototypes, can foster user test by making participants experience prototypes of a service system, and make participants be more active to share views and feelings. Table 2-2 provides a summary of the tools produced by Roberta Tassi (2009).

Table 2-2. Toolkits of Service Design Tools made by Roberta Tassi (Tassi, 2009).

Service Design Tools	**Description**	**Material**
LEGO serious	It is an experiential process to enable participants to share ideas and enable designers to identify design opportunities.	Common LEGO
Design games	Design games can drive user's participation and idea generation and connect different thoughts in a playful way.	Game supplies
Role play	Participants simulate a service experience by acting different user groups to play the same scene repeatedly.	Prototypes
Group sketching	Participants from diverse backgrounds to simply sketch up ideas and share the concepts.	Paper and pens

Issue cards	Cards present issues through an insight, a picture and a drawing or a description to assist participants to understand problems and assists researchers to identify new criticalities and opportunities.	Cards
Rough Prototyping	To visualise ideas, simulate a service design and foster interactions in the design process using tangible materials.	Prototype
Affinity diagram	Participants generate ideas regarding a problem or a goal and show them on Post-its or small cards, and then, they identify the relationships and significances in the affinity map with researchers.	Post-its, stickers or small cards
Motivation matrix	To include stakeholders in each section of a service system and allowing them to share their needs and interests. Accordingly, to explore design solutions and connection between different stakeholders.	Motivation matrix with its column headers are stakeholders and row headers are components of a service system
Mind map	It is a map starts with a problem or an idea and develops with relevant insights presented using words or drawings. It shows correlations between each insight clearly.	Paper and pens
Storytelling	Storytelling enables design researchers to communicate ideas using sketches and allows stakeholders to put in their suggestions.	Paper and pens
Character profiles	Participants share and describe their distinctive characters enabling design team to build up a profile of them for share.	Paper and pens
Constructive interaction	Participants to speak out their feelings and thoughts when testing a service design for design researchers to record results. The study can be	Prototypes

	more effective and nature if different users test and speck loud together.	
Wizard of OZ/ Service prototype/ Experience prototype	Observing and seeking perception and experience of users and interaction between users and a service using prototypes. Specific physical touchpoints are suggested to use in the experience prototype.	Prototypes

2.6 Summary

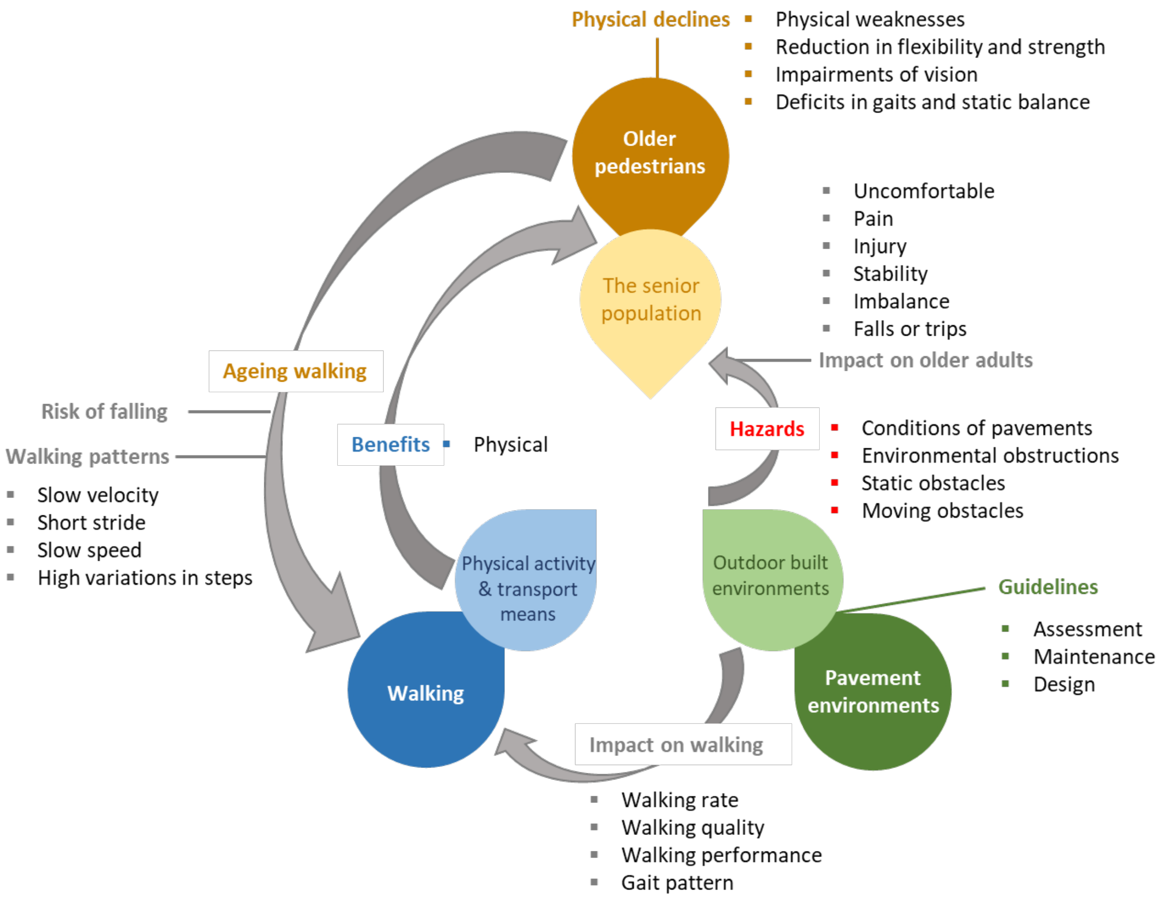


Figure 2-5. Systematic analysis of the research background.

This chapter provides a systematic analysis of the research background by reviewing relevant literature where there is a close relationship between the elderly population, physical activities and outdoor built environments. On this basis, the study emerged correlations among older pedestrians, walking and pavements (see as summarised in Figure 2-5). In summary, walking is the most common and the main transportation for older people to remain healthy and for their daily errands. Walking has many benefits to older adults in physical and mental aspects. Regular walking can improve health conditions and walking ability and performance of older people and enable them to engage with the society and live independently. However, age-related decline in older people, such as reduction in their balance, can affect their gait pattern, limit their walking and make them less likely to go out. However, when compared to natural ageing, the outdoor built environment has a much stronger impact on walking rate and walking patterns of older people. Poor quality and hazards of pavements can affect the safety and quality of walking and cause falls or fall-related injuries. Conversely, age-friendly environments that are walkable, inclusive, accessible and safe for older people can encourage senior adults to undertake more outdoor activities. Pavements have been identified as an indispensable component of an age-friendly environment. Pavements in good condition can enhance walking rate and allow older people to undertaken a safe and comfortable walking. Therefore, a large number of guidelines for pavement construction have been created to capture the needs of older people and to prevent them from the risk of falling. In addition, some interactive applications have been used for residents to monitor and report the quality of pavements. Based on the literature review, the next chapter outlines an empirical study to continue investigating factors of pavement environments that are regarded as hazardous by older people. The study would examine the walking behaviour of older pedestrians and the risks that they face with in poor pavement environments in order to explore more impacts of pavement hazards. In view of older people, the study would also analyse the relationship among ageing weakness, walking pattern and the pavements. In addition, the study would collect older pedestrians' requirements for pavement enhancement in order to complement guidance for building age-friendly environments.

Furthermore, the inclusion of older people has a great impact on building a sustainable community and making policies for age-friendly cities (Buffel, Phillipson and Scharf, 2012). Involving road users in environment development can also improve outdoor infrastructure and mitigate unnecessary costs or unaccepted design (Kujala, 2003; Ormerod *et al.*, 2015). Therefore, although some methods have been used to seek needs of road users, a more inclusive and participatory tool has to be developed using design interventions. It should enabling older adults' walking experience, walking needs and perspectives as well as hazardous impact of pavements on them to be fully understood and regarded by professional groups of pavement development. The toolkit would also help research groups understand the relationship between pavement environments and older pedestrians by exploring problems with pavement and their correlation with walking in older adults and work out improvements according to older people's needs. Materials of participatory study, co-design and user-centred design, such as maps and cards, would be adopted to develop the toolkit. Rather than asking researchers to prepare study suppliers on their own, the toolkit would provide diverse components to assist researchers to engage with participants (older people), encourage idea generation and group discussion. Chapter 5, 6 and 7 describes how the toolkit is designed, developed and tested on expertise and user feedback.

3 Methodology

3.1 Introduction

This chapter provides a critical review of the research purpose and introduces the design research methodology adapted from a book of Blessing and Chakrabarti (2009) which presents the setting of the studies at each stage. It also discusses specific approaches and techniques adopted by the study to find the answers to the research questions. Additionally, the chapter explains the sampling and ethics of the doctoral research.

3.1.1 Research purpose

According to Gary (2018), the research purpose can be defined as one of four types: (1) exploration, (2) description, (3) explanation, and (4) interpretation. The exploratory study aims to explore what is happening in a phenomenon by asking questions about it; the descriptive purpose depicts a picture of a phenomenon under a natural process; an explanatory research looks to explain why and how a phenomenon happens rather than asking what the phenomenon is; and the interpretive study explores the experiences of people and their perspectives on the experiences (Gray, 2018). This research was defined as an exploratory study as it would explore problems with pavements and walking and seek why and how those issues were caused. The study aims to investigate what factors of pavements can be recognised as hazards, describe the impact of the pavement factors on the walking behaviour of older adults and identify the requirements of elderly people regarding pavements. It also intend to find a way to assist people who work on pavement development, such as local councillors, road designers, and urban planners, to maintain and develop pavements with the participation of older adults.

3.2 Research Methodology

This section describes a sophisticated research plan of conducting the study to seek research answers. Many methodologies are available to structure a study plan, such as constructionist methodology or interpretivisit methodology (Kara, 2017). Constructivist methodology shows a purpose of finding the truth and meaning from the interaction between people and the world (Gray, 2004). Interpretivisit methodology can assist researchers to interpret human actions and a social phenomenon within a specific context according to people's subjective perspectives, understanding, and explanations on their behaviour (Matthews and Ross, 2010). The two methodologies would be helpful to seek the relationship between older pedestrians and pavements by investigating older people's walking experience in their neighbourhoods.

However, there will be a design development involved in the study as a toolkit has to be created to answers RQ4. Therefore, a research plan that covers the whole design process would be more appropriate for the study rather than the positivist methodology or constructionist methodology. Many methodologies from design could be used by the study such as Doing Research in Design (Crouch, 2012) and Design Research (Laurel, 2003) which provide many cases of design studies. However, none of them explains the design research using a systemic structure like the *Design Research Methodology (DSM)* proposed by Blessing and Chakrabarti (2009) does. The DSM framework can help the doctoral study to clarify the design process regarding the objectives, inputs, and outputs of each stage in the process. It also provides a number of criteria of developing a *design support* and suggests appropriate methods of evaluating the *design support* with end-users.

3.2.1 Research strategies and research approaches

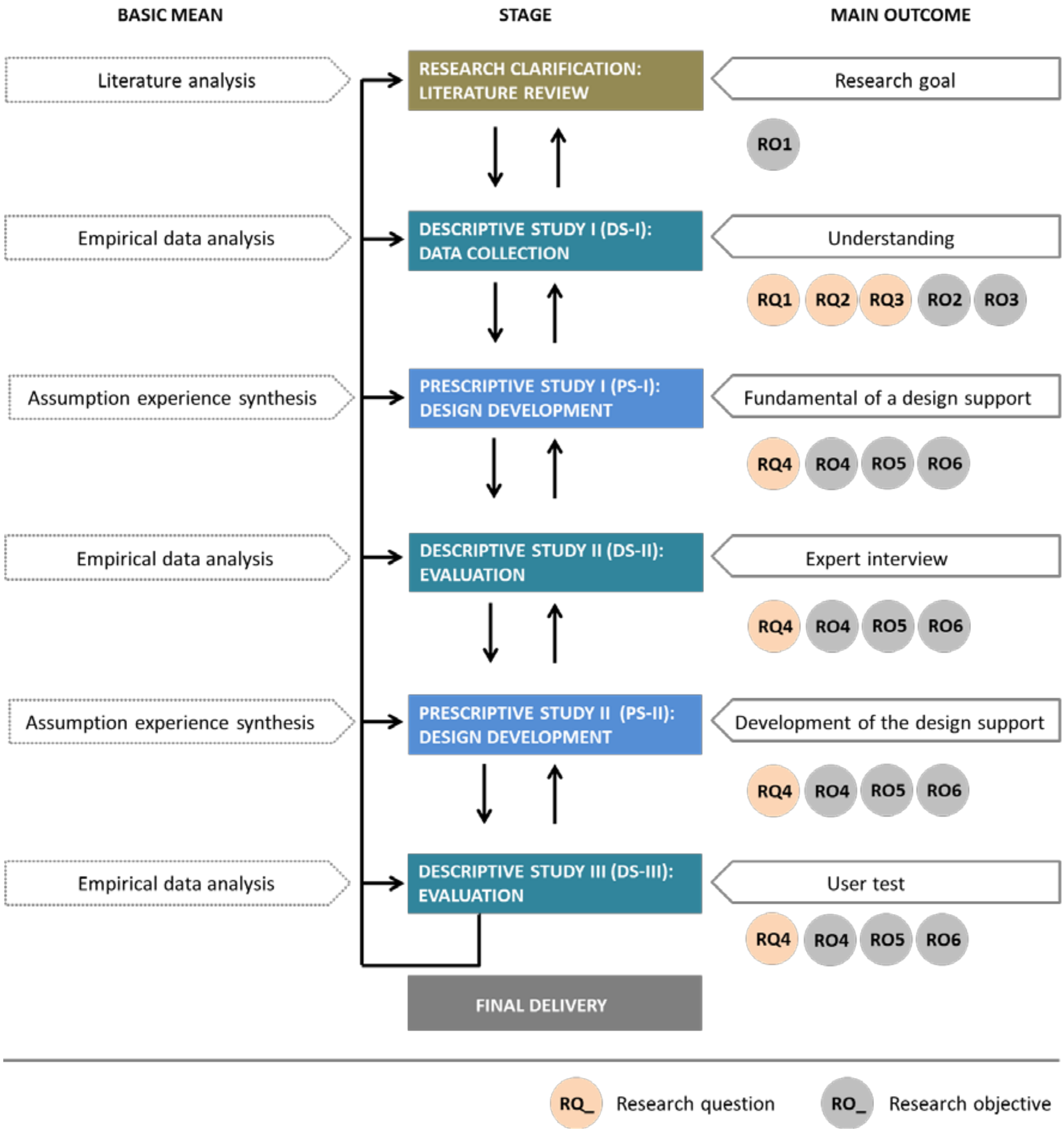


Figure 3-1. The research methodology, adapted from Design Research Methodology (Blessing and Chakrabarti, 2009).

A methodology mode was adapted from the DSM framework for the study to identify research tasks at the early stage, to understand and improve the existing situation, and to eventually create and develop a better design (Blessing and Chakrabarti, 2009). It divided the study process into six stages: research clarification (RC), descriptive study I (DS-I), prescriptive study (PS-I), descriptive study II (DS-II), prescriptive study II (PS-II), and descriptive study III (DS-III) (see Figure 3-1). The research clarification is presented in the literature review (Chapter 2) to clarify research gaps and motivation by reviewing other relevant studies. Descriptive study I is an empirical data collection conducted to seek answers to research questions 1, 2 and 3. The design process and development stage of a participatory toolkit is described in prescriptive study I and prescriptive study II. Descriptive study II is an expert interview to review the primary design of the toolkit created in perspective study I. Descriptive study III is an evaluation process which has two sections to test different versions of toolkit developed in prescriptive study II with target users. The RC stage (research Clarification) was implemented by reviewing and analysing literature to find existing evidence and indications to support the hypothesis, aim, questions, and focuses of the study. In addition to the literature review, the goals and tasks in each stage of the study were clarified. In DS-I (descriptive study I), knowledge about pavement environments and walking among older adults as well as relationships between pavements and older pedestrians were complemented by new evidence. DS-I was conducted to identify patterns of pavements and older pedestrians' walking as well as their relationship by exploring the walking experience and walking behaviour of older adults. Grounded theory has been found to be useful to investigate a research area where the theoretical view is unclear or absent (Robson and McCartan, 2015). Therefore, it was used to carry out DS-I and build new theoretical knowledge based on the empirical data collected by DS-I. The use of grounded theory was an iterative process (Gilbert, 2008). It requests a preliminary data collection to be conducted in the first section and a more focused data collection to be done in the next section. Therefore, DS-I was broken down into two sections and the first section adopted an inductive process to initially form theoretical views using the empirical data. The inductive section assists researchers to build new knowledge and to reveal patterns that exist between different variables (Gray, 2004), and it usually collects and analysed data using qualitative methods, such as interviews and observations. Then in the second part of DS-I, a deductive study was conducted to further identify significant findings among the data obtained in the first section and to clarify relationships between the qualitative data patterns using a quantitative method (Kumar, 2012). More details of the grounded theory of the study will be discussed in Chapter 4.4.

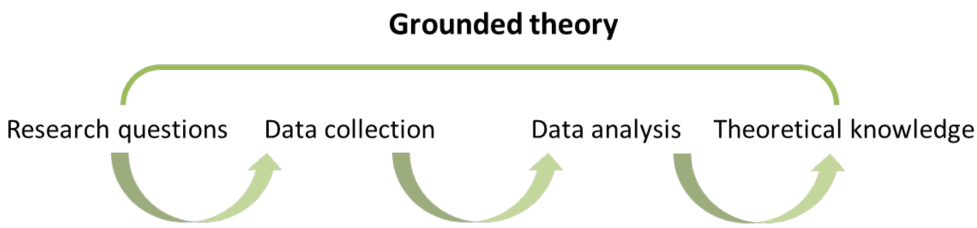


Figure 3-2. Grounded theory, adapted from Glaser (2013).

Based on the results of DS-I, the study proposed a toolkit in PS-I (Prescriptive Study I) stage to answer RQ4. The tool was designed for road engineers, urban planners, and pavement designer, to explore pavement conditions and their correlation with older adults. The concept was then reviewed by several experts in DS-II (descriptive study II) for a deductive motivation to explore user action and user experience of the toolkit. From DS-II, the study gained comments on the content and use of the tool, expertise in explicated the influential factors of creating a toolkit and design criteria and suggestions on the future development of the tool. Following the study, the tool was redesigned to a better toolkit in PS-II (Prescriptive Study II) to serve a participatory study which enables researchers (e.g. urban planners) to assess and improve pavements with senior adults being involved as participants. Another descriptive study (DS-III) of two evaluations was done to test the usability, effectiveness, efficiency, and usefulness of the new toolkit with its end-users.

3.3 Research methods

This project is also a mixed research bringing together qualitative approaches and quantitative techniques (Gilbert, 2008). Qualitative methods are often used to collect people’s thorough perspectives, to acquire insights into problems and to identify a phenomenon that has not been studied (Flick, Kardoff and Steinke, 2004). Quantitative research methods are used to explain a phenomenon by collecting data in a numerical process (Muijs, 2011). It helps to determine possible occurrences and identify the strength of the relationship between variables (Muijs, 2011). By combining qualitative methods and quantitative methods, the study topic can be better understood, the research questions can be interpreted with rigor and research answers can be fully identified (Wisdom and Creswell, 2013).

According to Punch (2014), the combined method has four design models including triangulation design, embedded design, exploratory design, and explanatory design. Triangulation is a single-phase study allowing qualitative and quantitative data to be collected at the same time; the embedded design requires one research method to play a supportive or a secondary role to the other method in a study; the explanatory design usually includes quantitative methods in the first phase and qualitative methods in the second phase; and exploratory design allows researchers to collect qualitative data before getting quantitative data (Punch, 2014). The mixed research was made up of an exploratory mode and triangulation mode. DS-I employed the exploratory design mode which combines a qualitative data collection and a triangulation study. Qualitative methods were first used by DS-I to fully understand what problematic factors with the pavement environment and how the problems affect older pedestrians. Following this, the triangulation study supported and verified the identified qualitative information with a more extensive sample. The data collected in the two stages were discussed together to interpret the same phenomenon, thereby to gain a better understanding of the study topic. DS-II was a qualitative study which aimed to in-depth investigate the interviewees’ extensive and exact information and ideas about the toolkit. DS-III adopted the triangulation mode to test the toolkit with target users. The qualitative methods enabled user actions and significant phenomena to be observed and enabled the toolkit to be tested properly in a real context, and the quantitative methods made the qualitative evidence comparable and the prior matters identifiable.

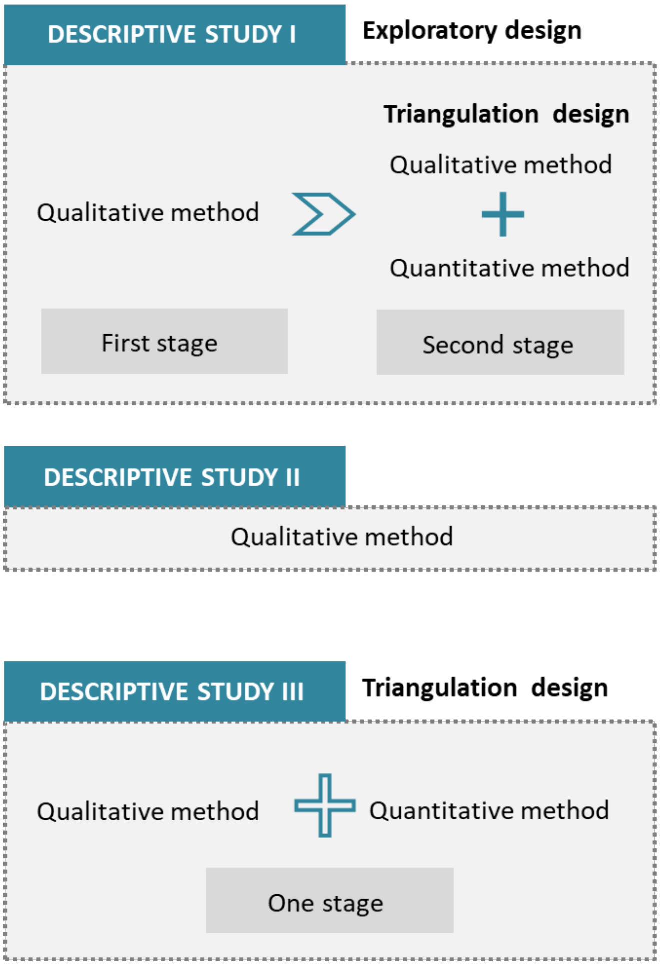


Figure 3-3. Research methods, adapted from Punch (2014).

3.4 Research techniques

This section further describes the qualitative methods and quantitative techniques in details. Several qualitative research instruments including interviews, observations, and cultural probes were used to collect information according to the research questions from a focused sample in DS-I. The interviews and observations were chosen because they were the most common qualitative methods used to explore and fully understand people's feeling, views, experience, and behaviour (Silverman, 2011; Coe *et al.,* 2017). Also, the cultural probe was employed because it can provide an opportunity for participants to self-report covered issues (Collins, 2010). Using them together in DS-I can guarantee all possible findings to be identified rather than using a single qualitative method (Frost, 2013). Additionally, a questionnaire was adopted along with an interview in DS-I to provide more evidence of the qualitative data and verify the study findings with a larger sample in a quantitative way (Kayama *et al.*, 2016). In the developing process of this research (DS-II and DS-III), interviews and workshops plus short questionnaires were employed as they could allow users' needs and interests of the tool and their impact on design to be studied (Taylor-Powell and Renner, 2009).

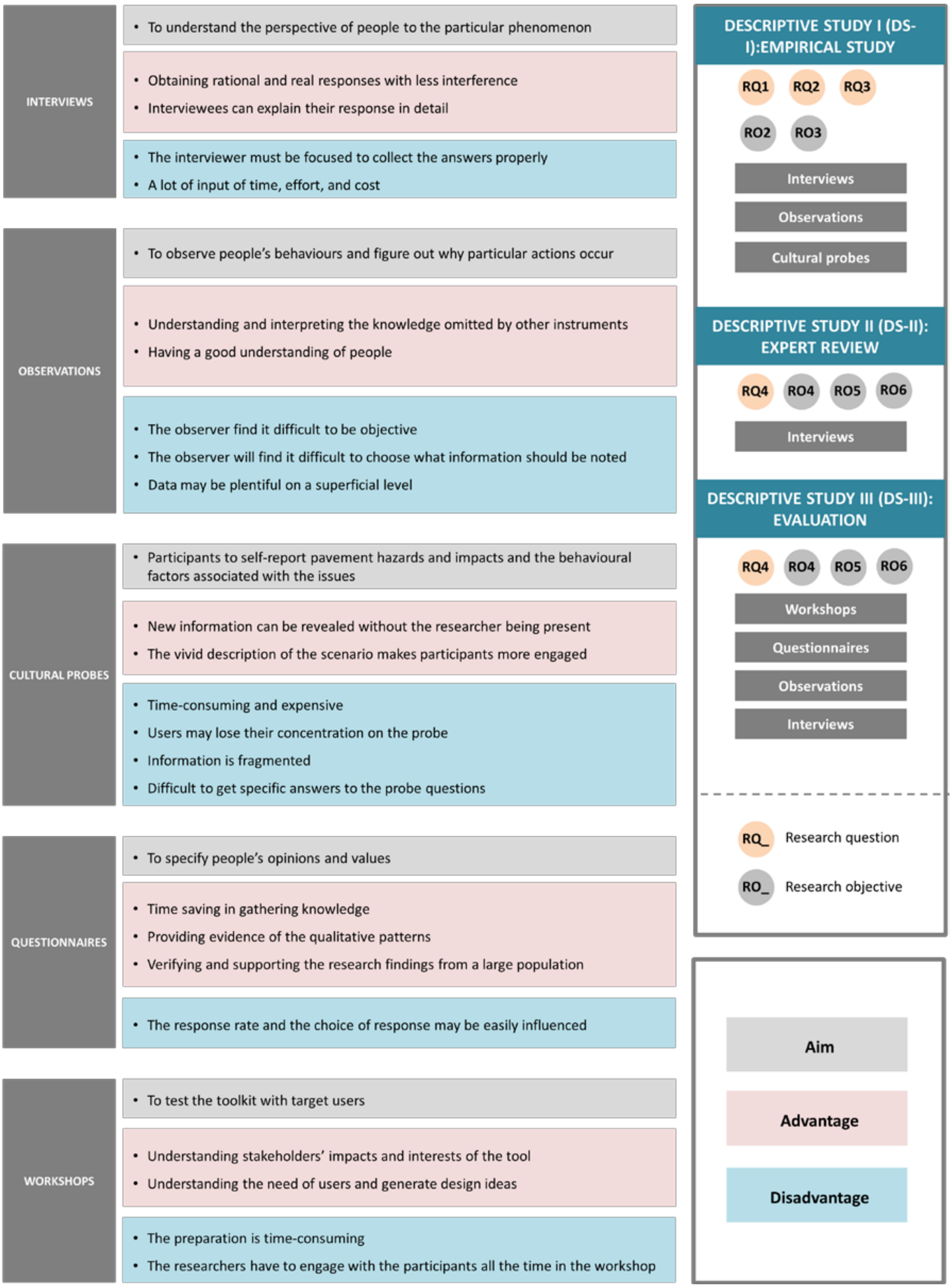


Figure 3-4. Techniques of the data collections.

3.4.1 Interviews

In view of the participation of elderly people, qualitative interviews (Silverman, 2011) were the primary choice for the study because the method can ensure older people's answers to be expanded and their perspectives to particular phenomena such as falls on pavements to be explored in-depth (Opdenakker, 2006). To be more specific, interviews were used in DS-I to find out older peoples' views on pavements and hazardous impact of the pavement and to explore older adults' walking behaviour. The interviews were also adopted by DS-II and DS-III to investigate users' perception and comments on the toolkit. The interviews were semi-structured and carried out face-to-face so that interviewees could give rational and real responses and provide explanations of their answers (Punch, 2014).

The interview questions were composed based on a review of contemporary studies and findings. They covered both closed-ended and open-ended questions to seek diverse answers. Closed-ended questions make interviewees' answers be identified in a specific scope and be comparable than those to open-ended questions (Reja *et al.*, 2003). Open-ended questions allow interviewees to explain their response in details and assisted interviewers to collect more information by encouraging interviewees to think about their answers (Mathers, Fox and Hunn, 1998).

3.4.2 Observations

According to Coe *et al.* (2017), observations are an appropriate method for researchers to understand and to interpret the nonverbal and paralinguistic knowledge that are omitted by other instruments (Marshall and Rossmann, 2011). Observations were then applied in DS-I to further study the walking behaviour and pavement hazards identified in the interviews. Observations were also applied in DS-III along with workshops to look at user behaviour of toolkit users. There were two workshop studies conducted in DS-III. The first workshop was observed by a non-participant observer (Sapsford, 2006) who had no interaction with the tool users to figure out critical problems without influencing their exercise. Unlike the first workshop, a participant observation was carried out with elderly users of the toolkit in the second part of DS-III to have a closer understanding of the user experience of the toolkit (Punch, 2014).

In the observation process, observers may find it hard to be objective and, therefore, have difficulty in choosing what information shall be detected or recorded (Matthews and Ross, 2010). Also, the observed data may be plentiful on a superficial level and the result of observations may be less analysable if all information are recorded (Matthews and Ross, 2010). To cope with the matters, all potential evidence was recorded in the observations and they were analysed carefully regarding the study topic and objectives using the coding method.

3.4.3 Cultural probes

Cultural probes known as diary studies allow participants to self-report information omitted by other methods (Collins, 2010). In a study by Adkins *et al.* (2012), user-reported perception has been found to be a strong method to explore the relationship between neighbourhood environments and walking. Therefore, in DS-I, a cultural probe was designed for older adults to self-record problems with pavements as well as walking factors associated with the problematic elements in order to reveal covered evidence. In line with the suggestions by Collins (2010), the cultural probe kit provided a diary book for participants to note down phenomena and opinions and offered a disposable camera for them to photograph significant issues.

Even though the cultural probe can be applied to study people’s everyday life, designing a cultural probe kit is time-consuming and expensive (Murphy, 2006). Also, some users can easily lose their concentration with the probe (Murphy, 2006), and hence they may not finish the diary book properly within the stipulated time. Additionally, data gathered by cultural probes may be difficult to analyse to get specific answers as the information can be fragmented and confusing (Gaver *et al.*, 2004). Due to the disadvantages, the study was expanded by a longer time for the participants to complete the survey and the data was carefully transcribed and coded in the analysis stage with the help of Nvivo.

3.4.4 Workshops

Workshops, as mentioned early, were chosen by the evaluation phase of the toolkit (DS-II and DS-III) because they are recognised as a method of exploring the impact of a design projects and interests of the stakeholders to the project (Rail Safety and Standards and

Board, 2008). Westerlund (2007) agreed that workshops could be commonly used to understand the needs of people in generating design ideas, and people could make more appropriate judgements about a design concept in workshops. However, time can be an apparent limitation in organising workshops as special facilities and materials have to be prepared for the activity, and participants may be difficult to remain engaged or active throughout workshops (Maheshwari, 2012). To mitigate those issues, the study adopted recommendations by Taylor-Powell and Renner (2009) to prepare workshops and used questionnaires to boost additional discussion at the workshops. Workshops are usually carried out with multiple sample sizes (Rail Safety and Standards and Board, 2008). As discussed early, workshops were widely conducted in DS-III. In the first section of the evaluation (DS-III), a workshop with five mini groups individually consisted of two elderly participants and one researcher were organised to look into user needs, user behaviour, and user experience plus the interaction between the two the elderly participants and researcher. A larger workshop done with eight elderly participants was carried out in the second section of the evaluation (DS-III) to examine if they could use the toolkit to conduct a group study properly.

3.4.5 Questionnaires

As indicated early, this research used mixed research methods to collect data in DS-I and DS-III. In DS-I, qualitative data had been collected by interviews, observations, and cultural probes. DS-III also explores the users' feedback by conducting workshops and observations. To take a further step into research answers, this study specified the participants' opinions and qualitative values by developing measurable and statistic data (Punch, 2014). The questionnaire used by DS-I aimed to gather more knowledge, provide evidence to the qualitative patterns identified by the other qualitative methods and evaluate and support research findings with a larger population (Kendall, 2008). The questionnaires employed by DS-III were used to measure end-uses comments on the toolkit.

Questionnaires are an effective instrument to collect data, however, the response rate of questionnaire can be influenced by many factors, such as the design, wording, and ethical issues in the questions (Robson and McCartan, 2015). The questionnaires in this research tried to minimise these potential matters by following a guidance adapted from a study of Gilbert (2008), Creswell (2009), and Walliman (2011b). According to the guidelines, questionnaires provided a logical structure and accurate information, and questions were simple and precise to ensure correct answers to be given by respondents (see Chapter 4.3.1).

3.5 Data analysis methods

The qualitative and quantitative data was analysed by different approaches to clarify research answers and specify research findings.

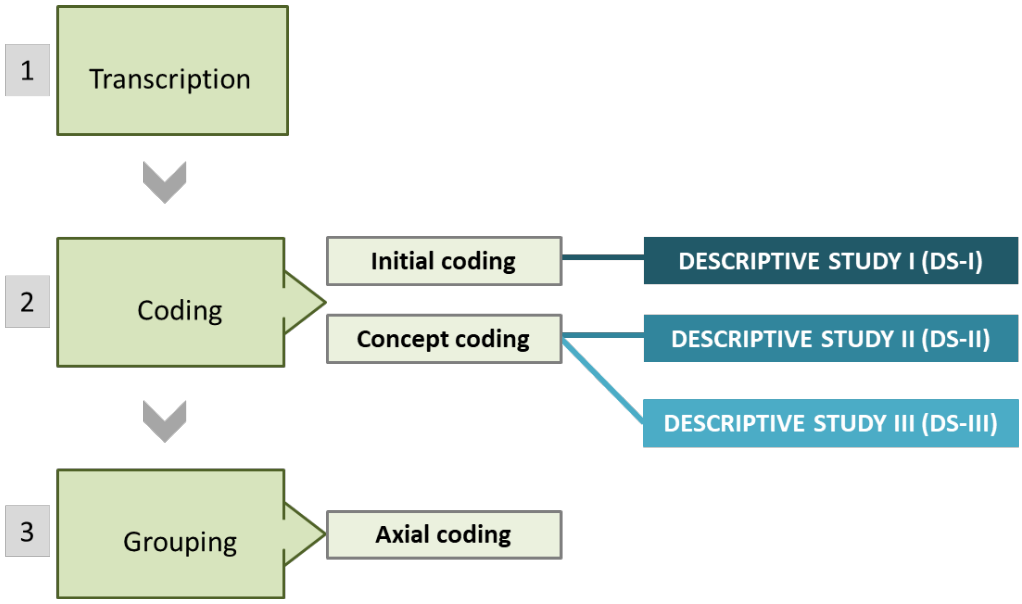


Figure 3-5. Qualitative analysis, adapted from Saldaña (2016).

One of the key challenges in using qualitative methods is that they generate substantial data (Bryman, 2016). Therefore, it is essential to generalise and integrate the qualitative data before explaining and comparing the results. Figure 3-5 shows that the analysis process of qualitative data had three phases including transcription, coding, and grouping adapted from (Cho and Lee, 2014). The original qualitative data was first filtered and transcribed so that it could be analysable and detailed for the further analysis (Bailey, 2008). In the transcription, participants' social talking which was irrelevant to the study topic was not translated, however, associated visual information obtained from the observations were recorded and transcribed into writing materials. In the coding process, the transcribed data, according to Bryman (2016) and Miles, Huberman and Saldaña (2013), were turned into fragments and labelled by words or short phrases and ultimately were classified into groups so that correlations between different patterns to be elucidated by studying these generated groups (Walliman, 2011a). For the qualitative analysis, the research questions and objectives played a key role in defining the codes and categories, and NVivo as a tool of CAQDAS (computer assisted qualitative data analysis) was used to assist in managing the substantial information (Lewins, 2001).

According to Saldaña (2016), data can be coded by different methods together to analyse a complex phenomenon. The qualitative information collected in the descriptive study (DS-I, DS-II and DS-III) was coded in two stages. Data obtained in DS-I was analysed by initial coding (Saldaña, 2013) at first, and data gathered in DS-II and DS-III was studied by concept coding (Saldaña, 2016) essentially. The initial coding enables the primary data of DS-I to be fully analysed to emerge all variables. The data were detached and broken into small parts to reveal their relationships and were coded openly to detect all possible theoretical directions at this stage. However, DS-II and DS-III received a large number of visual data and narratives and the data had to be defined and explained with a more specific concept. Therefore, concept coding was used as it makes the data be coded by shorter phrases which reflects a broader meaning of the original information or phenomenon (Saldaña, 2016). Axial coding, also known as categorising, was adopted in the second stage of all the qualitative analyses to organise the fractured data analysed in the first round to create meaningful concepts. According to Blair (2015), the initial codes of the same topic were brought together in the same category based on their attributes or questioning themes in the axial coding process. Also, the axial coding could identify the relation between the categories and their sub-items.

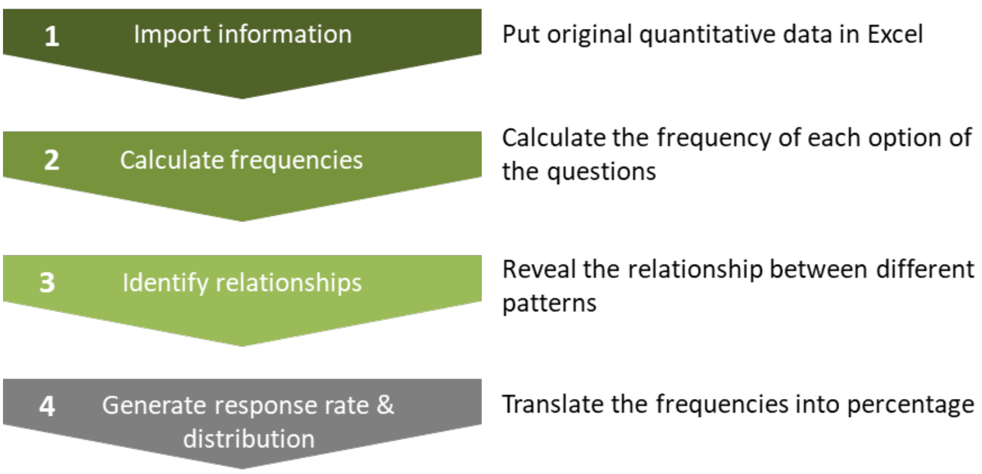


Figure 3-6. Quantitative analysis of the data collected by the empirical study (DS-I).

Quantitative information obtained by the questionnaires used by DS-I, DS-II and DS-III was analysed by counting participants' answers to each question (Muijs, 2011). A small amount of data was gathered from DS-II and DS-II, so it was easy to manually count and categorise them. However, a large amount of quantitative data was collected in DS-I. Then, Excel was adopted to calculate and analyse the evidence. To analyse the DS-I questionnaire, the original data (answers to the questions) were first imported into Excel to calculate the frequency of each option of the closed-ended questions. Based on the frequency analysis, Excel revealed significant issues and relationships between different data patterns in the cross-sections of the horizontal and longitudinal lines of its matrices (Guerrero, 2010). Those frequencies were displayed as percentages to demonstrate a more significant comparison between among the answer groups to the same question.

3.6 Sampling and ethics

Sampling assists researchers in reducing the time and effort spent on getting consistent and unbiased measurements of the population under the study (Sapsford, 2006). The study aimed to explore a new topic from a focused population and to develop a toolkit for particular groups to use. To avoid the monotony in data collections, purposive sampling strategy was used to ensure diverse evidence explored from the focused sample and to guarantee participants to be recruited from various ages and occupations with different expertise (Martínez-Mesa *et al.*, 2016). In consideration of the available resources and research plan, this enquiry employed different sample sizes for different studies, and a list of backup participants was prepared in case someone might be absent from the study (Robson, 2015).

Table 3-1. The sample size and criterion of different data collections

Study	Research methods	Sample size	Criteria
DS-I: section one	Interviews, observations, and cultural probes	9 older adults	• Participants are aged 60 and able to walk
DS-I: section two	Interview-based questionnaires	32 older adults	• Participants are aged 60 and able to walk

DS-II: expert interview	Expert interview	8 experts	• Participants have relevant knowledge about built environments, the mobility of older adults, and tool design • Participants are helpful to develop the toolkit
DS-III: evaluation study one	Testing the tool: workshops	10 older adults	• Participants are aged 60 and able to walk
		5 researchers	• Participants' work is related to the content of the toolkit • Participants are potential users of the toolkit
DS-III: evaluation study two	Testing the tool: workshops and an interview-based study	8 older adults	• Participants are aged 60 and able to walk
		8 researchers	• Participants' work is related to the content of the toolkit • Participants are target users of the toolkit

The empirical study (DS- I) intended to explore older adults' walking experience and behaviour associated with pavement hazards. The sampling of this study was 41 which accorded to the standard sampling (20 to 50) of a qualitative study (Marshall *et al.*, 2013). They were selected from older people who were able to engage in walking, even though they may have some ageing declines. As explained in Chapter 1.3, the minimum age of the subjects was set at 60 as people at this age were usually scoped as older adults. Because of the research scope and question sets, family members and the dwelling, race, gender, and previous occupation of the participants were not regarded in this research. Then, the perspective and walking experience of older people were explored in DS-I, and the need, behaviour, and experience of the elderly users of the toolkit were investigated in DS-III.

The sample size of qualitative interviews can be ranged from 5 to 90, and a large sample size is usually used to represent the whole target population and a smaller sample allows individuals to share their ideas from various aspects (Blair and Conrad, 2006). Therefore, during the development of the design concept (DS-II), eight experts were invited in the individual interviews to give practical and related suggestions to the initial concept of the toolkit. Experts were chosen with their speciality, profession, and contributions being associated with the research topic or helpful to develop the toolkit (Libakova and Sertakova, 2015). Therefore, the background of the experts covering built environments, accessible environments, ageing studies, inclusive design, and tool design. The experts from the studies of outdoor environments helped the tool to clarify what information would be useful and important for road designers and what use task of the tool could be. The expertise from the design experts focused on user preferences, user needs, and user experience of the toolkit. The scholars in inclusive design and ageing studies gave more comments on the future development of the tool regarding the physical condition of older people.

In DS-III, the toolkit was tested by two user groups respectively was elderly users and researchers. The elderly users were sampled from the same research population of the empirical study that were aged 60 and over and able to engage in walking. The researchers were selected as they had acquired relevant knowledge or research interest in terms of the study topic (Creswell and Plano Clark, 2017). Seven early-stage researchers, four experienced researchers, one designer, and one local councillor were recruited to test the toolkit. They worked on built environments, highway and pavements, architectural design, inclusive design, ageing mobility, tool design, and neighbourhood maintenance. They were selected because their work was related to the content of the toolkit and that they would be target stakeholders or users of the tool. In the study, they shared opinions on both advantages and disadvantages of the toolkit regarding its information, design, usability, usefulness, and efficiency from different standpoints. In addition, they indicated that the toolkit was conducive to them to apply in their work and the data collected by the tool was able to be expanded.

This research was approved by Research Ethics Committee of Brunel University London to recruit participants for data collections. Participants were given an information sheet and a consent form before doing the study. They were also given the right to withdraw from the research at any time for any reason. Their name was coded in numbers, and other identifiable characteristics were covered up to ensure anonymity. In addition, participants' personal information was documented confidentially and kept in a private PC and a locked cabinet to safe guard their personal information.

3.7 Summary

This chapter describes a scientific system (a design methodological proposal) explaining the approaches, strategies, methods, and sampling of the study and discussing how the new knowledge of this study were built and verified. This research is an exploratory study that seeks hazards of the pavement environment and their relationship with older pedestrians and builds theoretical perspectives based on the findings. The doctoral enquiry was carried out through a mix of qualitative methods and quantitative methods plus a combination of a deductive process and an inductive action using interviews, observations, cultural probes, workshops, and questionnaires. In the following chapters, the research questions will be answered by different studies (DS-I, DS-II, DS-III, PS-I, and PS-II), and the objectives, design, samplings, data collections, and data analysis of the study will be explained with more details.

4 Empirical study (DS-I)

4.1 Introduction

This chapter introduces an empirical study (DS-1) set up to investigate the relationship between pavement environments and older pedestrians by identifying hazardous factors of the pavement and walking behaviour of older pedestrians. The study intends to answer the research question RQ1, RQ2 and RQ3:

RQ1: What pavement factors are hazardous to older pedestrians?

RQ2: What is the impact of pavement hazards on older pedestrians?

RQ3: What are the requirements of older pedestrians for the pavement environment?

The study also aims to implement the research objectives RO2 and RO3:

RO2: To identify hazardous factors of pavements and their adverse impact on walking in older pedestrians.

RO3: To explore older pedestrians' walking behaviour associated with the pavement hazards, and to collect their requirements for an age-friendly pavement environment.

The study comprised two parts with 41 participants recruited from London. Nine of them participated in the first part, and 32 were the subjects of the second-part. The participants were in the age group of 60 and over and they were able to complement walking in outdoors. The study used both qualitative and quantitative methods to collect data. The first part of the study was carried out to gather the participants' opinions of the pavement environment as well as their walking experience. Interviews, observations, and cultural probes were used in this part to collect resourceful presentations and interpretations of pavement hazards with qualitative evidence (Gray *et al.*, 2014). The data was transcribed, coded and categorised to identify significant phenomena and patterns as well as the relationship among the data patterns. The results of part one showed that hazardous factors of pavements included poor pavement conditions and obstructions. They could pose a risk of falling or discomfort to the participants or cause changes in the participants' walking behaviour. The qualitative results and relationship between pavements and older adults were further investigated in part two using an interview-based questionnaire (Muijs, 2011; Ravitch and Carl, 2015). The quantitative data gained by the questionnaire was statistically analysed to show the response rate of the participants, to verify the qualitative data patterns, and to prioritise findings of the study.

4.2 Section one of the study

4.2.1 Participants

The study recruited older adults from the Brunel Older People's Conference Group affiliated with the Brunel Institute for Ageing Studies. The group was chosen as a resource of getting participants because the group members had a prominent level of co-operation with research projects and they were voluntary to be involved with academic activities. The participants were invited by a letter with an information sheet inside introducing details of the study to ensure that they would know about the tasks that they had to do and the rights they were given in the study. Nine participants consisting of five females and four males who met the sampling criterion voluntarily took part in the study. As Table 4-1 shows, the participants ranged from 71 to 90. All participants were retired and seven of them did not drive, so walking and public transportation had become their main travel methods.

Table 4-1. Participant demographics (n=9 people)

Gender	Age band	Occupation status	Driving or not
Female (n=5)	60-69 (n=0)	Retired (n=9)	Driving (n=2)
Male (n=4)	70-79 (n=3)	Semi-retired (n=0)	Non-driving (n=7)
	80-89 (n=5)		
	≥90 (n=1)		

4.2.2 Methods

Table 4-2. Method of the data collection

Data collection method	Duration	Tool	Result
Individual interviews	45 minutes	An interview booklet	Interview scripts

Observations	Minimum 60 minutes for two days (minimum 30 minutes for per day)	An observation notebook Camera	Observation notes
Cultural probes	5 days	A diary book Camera A pen	A report of daily walking

The study used a set of methods including interviews, observations, and cultural probes to investigate the walking experience of the participants and their opinions on the quality of pavements. This combination assisted the participants to understand the study questions, and hence give valid data (Hussein, 2009). Also, the collaboration of different qualitative methods can provide abundant insights to a complicated study topic and can complement the deficiency of study results worked out by a single qualitative technique (Frost, 2013). The interview was first conducted to have a broad view on the participants' perspectives of pavements and walking activities. The observations were used following the interview as that the knowledge found in the interview could be further explained during walking in real-world pavement environments. Cultural probe was a more complicated method than the interview and observation as it needed to be completed by the participants themselves. Therefore, the cultural probe was applied last after the participants had a better awareness of the study topic from the interview and observation. The research data was recorded through interview scripts, observation notes, and probe reports, and significant phenomena were also photographed.

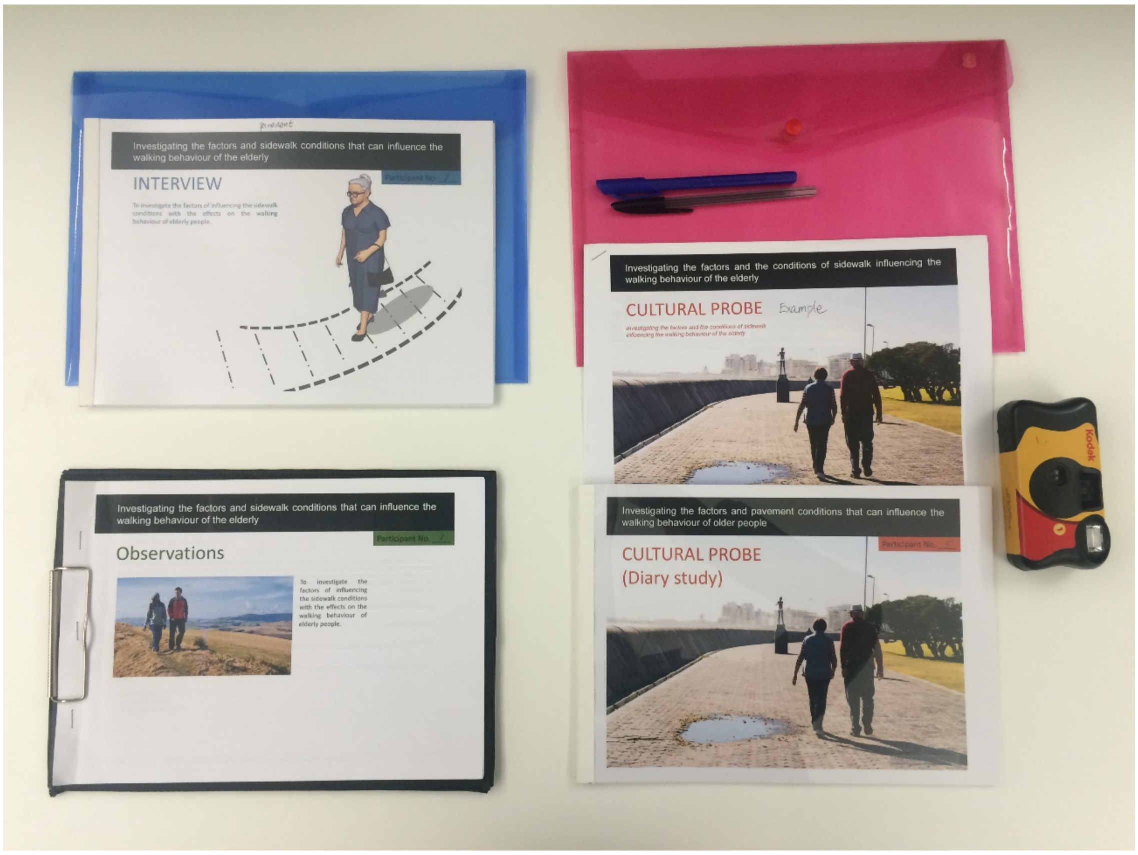


Figure 4-1. Research instruments of the study.

4.2.2.1 Interviews

According to the study process made by O'Leary (2010), there were four stages to conduct an interview: (1) planning the interview, (2) developing the interview questions, (3) conducting the interview, and (4) analysing the data. In the preparation stage, the study identified who the participants would be, where and when the interview would take place, and how the interview could be carried out. The interview was then designed as a semi-structured interview conducted face-to-face with participants aged over 60 and were able to engage with walking. Considering the risk of travelling and physical conditions of the participants, the interview was carried out at participants’ home and each of interview took around 45 minutes. An interview booklet was supplied to present the queries for the participants, and it used many images of pavement conditions and walking situations to inspire participants with more ideas. Four primary questions were raised first to the participants ‘what factors of pavements can affect walking in older people?’, ‘how do older adults adjust walking behaviour when they encounter barriers on the pavement?’, ‘what difficulties could be caused by pavement hazards to older pedestrians?’, and ‘what are features of good pavement environments?’. The questions were designed by adapting the research questions RQ1, RQ2 and RQ3. Based on the main interview questions, an open-ended discussion was conducted to further explore specific explanations of the participants' answers.

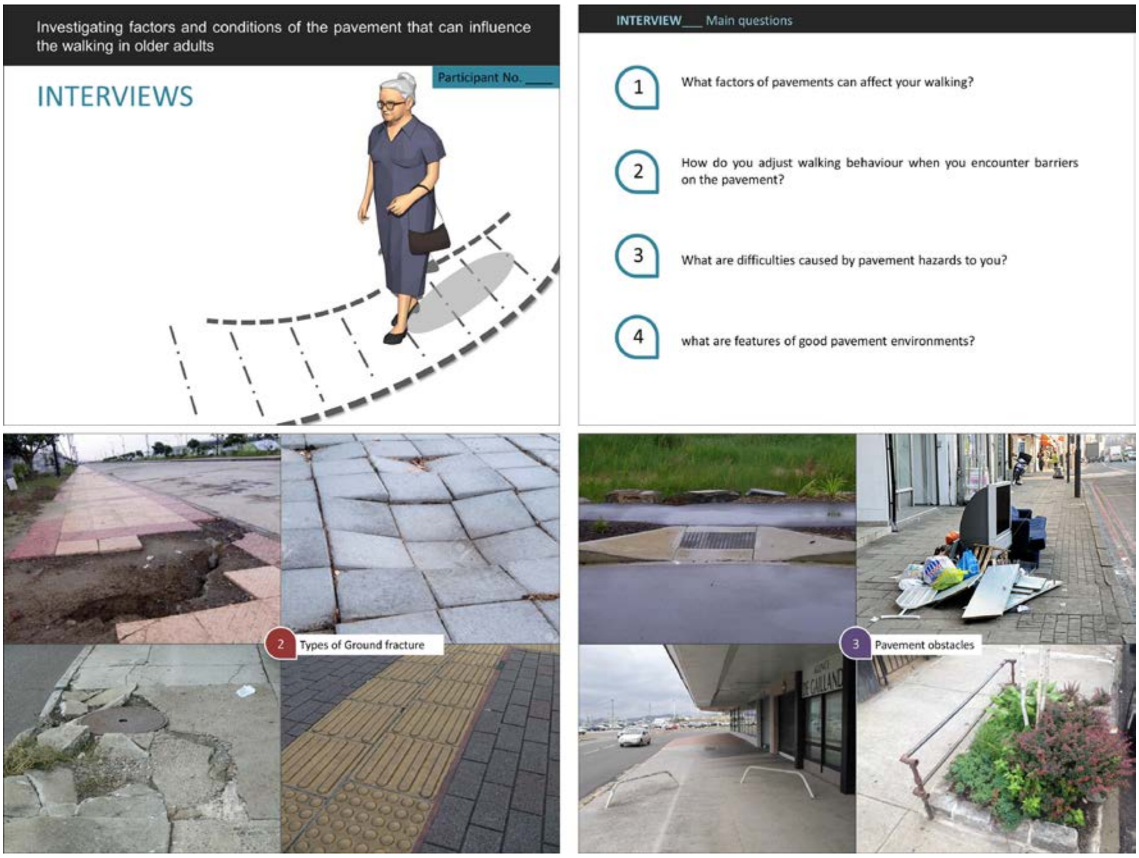


Figure 4-2. The interview booklet.

4.2.2.2 Observations

Based on the interview, a field observation was carried out to capture the phenomena and behavioural factors that the participants had described in the interview. According to O'Leary (2010) and Kara (2017), the study set the duration and location of the observation considering the elderly participants' walking condition and availability. In the study, the participants were requested to walk for 30 minutes minimum for a two-day observation in their neighbourhoods with an observer followed and to point out the hazards that they had ever encountered in the pavement environment. The participant observation allowed the observer to better understand the pavement environment and detect the occurrences and information that were neglected by the participants through the personal experience (Guest, Namey and Mitchell, 2013). Based on the review on the interview scripts and exiting studies (Kovacs, 2005; Gallagher *et al.*, 2010; I'DGO, 2010;

Chang *et al.*, 2017), the observation identified what walking patterns or environmental obstacles could be recorded. For example, slow and careful steps, ground fracture, and likely falls could definitely be noted down once they were found in the observation. In addition to the observation, five open-ended questions were asked to the participants to reflect on their walking experience. The questions were developed based on the interview questions, whereas, they were re-written in simpler sentences so that the participants could give answer without being distract from walking. The queries included:

1) Why do you choose to walk on the pavement?
    - To explore attractive elements of the pavement for older pedestrians.
2) What environmental factors of the pavement do you pay more attention to?
    - To identify influencing factors of the walking environment to older adults.
    - To investigate the good and bad impact of the environmental factors.
3) What conditions of the pavement do you pay more attention to?
    - To identify good conditions and poor conditions of the paved surface.
    - To investigate the impact of different conditions of the pavement.
4) How do you cope with pavement hazards during walking?
    - To explore older people’s walking behaviour and gait patterns triggered by pavement hazards.
5) Do you have any other comments on the pavement?
    - To expand elderly pedestrians’ perspectives on the pavement based on the walking experience.

Investigating factors and conditions of the pavement that can influence the walking in older adults

Participant No. ____

Observations

OBSERVATIONS

- The observation is semi-structured and conducted by a participant observer
- The location and time of conducting the observation are random and decided by participants
- The participant will answer several open-ended questions during the study
- A camera is used to record the observation

Observations_ Random questions

Participant No. ____ --Day 1

- Date:
- Locations:
- From _ _ : _ _ to _ _ : _ _

- Particular occurrences in the observation:
- Reflective notes (the observer's personal views)

- Why do your choose to walk on the pavement for the observation?
- What factors of the pavement do you pay more attention to?
- What conditions of the ground surface do you pay more attention to?
- How do you cope with the pavement hazards during walking?
- Do you have any other comments on the pavement?

Figure 4-3. Questions for the observation.

4.2.2.3 Cultural probes

In addition, a cultural probe kit was provided for the participants to self-report special phenomenon and pavement hazards exposed when they walked alone. According to Collins (2010), the probe pack offered a diary, disposable camera, and a pen. The diary book introduced the instruction of the study and ethical matters that the participants needed to be aware of. It also prepared six questions for the participants to finish every day based on their walking activities. The questions were consistent with the queries raised in the interview and observation concerning hazardous factors of pavements and older pedestrians' walking behaviour:

1) How long have you spent on walking today? (the approximate time)
2) How is the weather today?
3) Have any obstruction or pavement condition affected your walking behaviour or walking safety?
4) How did the obstruction or poor condition affect you?
5) Have you adjusted your walking behaviour due to the pavement hazards? What changes have you made in walking?
6) What else do you want to share?

The diary book also used illustrations of pavement conditions and difficulties in walking to assist the participants to understand the study topic so that they could give correct and relevant answers. In addition to the report, the disposal camera was prepared for the participants to record abnormal situations of the pavement and unusual occurrences. Current studies (Gaver *et al.*, 2004; Robertson, 2008; Schorch, Müller and Meurer, 2017) show that the cultural probes usually last from one week to several months due to the design of the study and sample size. As there were only nine participants in the study and they often walked for a short distance in neighbourhoods, the cultural probes demanded the participants to finish a five-day report within one month.

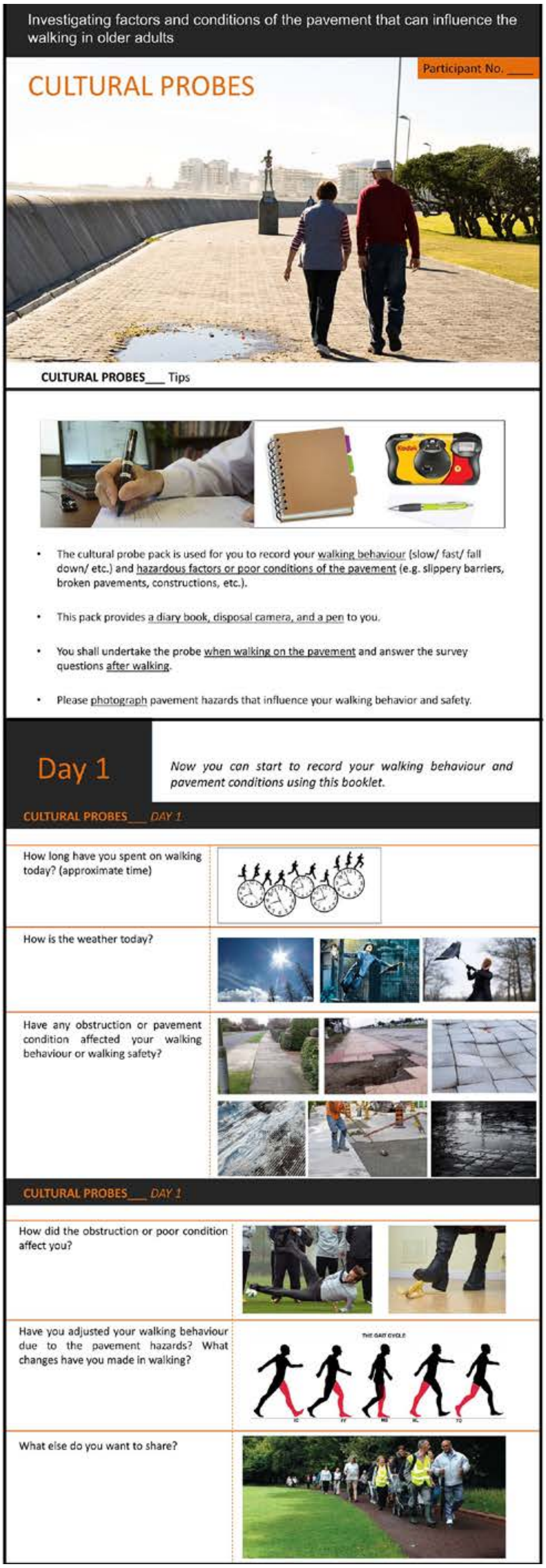


Figure 4-4. The booklet of cultural probes.

4.2.3 Analysis

Data collected by different research techniques in the same study can be analysed separately or cooperatively to interpret the same phenomenon (Frost *et al.*, 2010). As the study methods explored the same cases and information, several similarities were revealed in different datasets. Therefore, the interview scripts, observation notes, and participant reports were analysed separately but to be discussed together. The data were coded with the help of NVivo to manage the substantial and clutter information (Lewins, 2001). Qualitative analysis of transcribing, coding, and categorising were used to analyse the qualitative data. At first, the original data were transcribed to be more analysable before moving to the next stage to make patterns and meanings more easily identifiable (Blomkvist, 2011). Initial coding (Saldaña, 2016), also known as open coding, was used to label the data openly with themes at the beginning of the analysis. The qualitative dataset was coded into as many themes as possible so that all possible findings would be uncovered. For example of the initial coding, some phrases such as gaps between pavement bricks, little holes, poor and broken areas, damaged pavements, construction barriers, over hanging trees were regarded as pavement hazards and were coded as long as they were found to affect older people's walking adversely. Also, cautious steps, carful walking, and slow poses associated with the pavement hazards were coded as walking behaviour in this stage. The open coded data then demonstrated both anticipated and unexpected information, such as the mental impact of the pavement, and emerged similarities and differences between the data patterns. Afterwards, the preliminarily coded data were classified into 49 groups according to their themes. For example, fractures and missing slabs were classified into broken pavements, water and fallen leaves were grouped as slippery barriers, and overgrown bushes, trees and hedges were brought together into overgrown plants. By taking a further step, the groups were clustered into four larger categories according to their meaning in an axial coding process where the relationship between the category and their sub-codes were specified (Blair, 2015). The final groups were:

(1) factors of pavements that influence older pedestrians (including pavement obstructions and ground fractures)

(2) the impact of hazardous pavement factors comprising the risk of falling and limits on walking
(3) the walking behaviour of the participants combining situations of adopting cautious steps, walking slowly and so on
(4) factors of a good walking environment

In addition to the data analysis, photographs from the observations and cultural probes gave a visualised description of the pavement problems and indicated the factors that the participants mostly concern with in their daily walking activity in the pavement environment.

Figure 4-5. Photographs of pavement hazards in London taken by the participants for the cultural probe.

4.2.4 Results

Problems with the pavement were classified into 16 categories and they commonly resulted in falls, trips, or difficulties to the participants. The participants had to make changes in the walking behaviour, such as adopting cautious steps, stepping aside, or stopping, to avoid the hazards or the risk of falling. Contrary to the hazardous factors, features of a good pavement environment were described by the participants as well-organised plant, plenty of lights, and a wide pavement.

4.2.4.1 Hazardous factors of the pavement environment

Table 4-3. Pavement hazards found in section one of the study

Pavement hazard	**Reference (n=176)**	**Sub-theme**	
Slippery obstacles	n=32	Climatic conditions (rain/ snow/ ice) Puddles	Plants (Leaves, Moss) Paving materials
Plants	n=21	Overhanging or growing trees	Leaves Roots
Uneven pavements	n=17	Surfaces in different heights	Sunken surfaces
Rubbish	n=15		
Broken pavements	n=14	Gaps between paving bricks Hole in pavements	Missing slabs
Street infrastructure and furniture	n=12	Light Bus stops Cable boxes	Seats Metal barriers
Construction	n=12	Safety barriers Street buildings under construction	Road maintenance Repair equipment
Moving obstacles	n=11	Cyclists Skateboarders	Wheelchairs Scooters
Changes in paving level	n=9	Kerbs	Slopes
Parked cars	n=8		

Paving patterns	n=6	Different textiles Different colours	Different patterns
Street stores property	n=6	Tables and chairs Lamps	Advertising boards
Narrow pavements	n=5		
Tactile pavements	n=4	Slippery	Unevenness
No pavement	n=3		
Manhole covers	n=1	Uneven surfaces	

Hazards of the pavement were coded into 16 groups with 176 references. As Table 4.3 shows, slippery obstacles were mentioned to 32 times in the study and became the most significant issue in the pavement environment. This covered different slippery elements caused by climatic conditions, such as rain, snow, and ice, and other obstacles including liquid waste, leaves, and moss. Twenty-one references were relevant to plant issues contributed by overgrown trees (see Figure 4-6c), bushes, and tree roots, overhanging tree branches (see Figure 4-6a) and fallen leaves (see Figure 4-6h). Uneven paved surfaces were found to be caused by being built in inconsistent heights or built in sunken ground and they were mentioned 17 times by the participants (see Figure 4-7a). Following that, the distribution of waste issues included 15 references to be regarded as a significant hazard. Gaps and holes in the pavement (see Figure 4-7h) or missing slabs (see Figure 4-7e) were identified as typical features of broken pavements and they received 14 references from the analysis. Problems with street infrastructure and furniture were made up of poorly maintained or poorly-built light, bus stops, cable boxes, seats, and street barriers and they received 12 references in total. Likewise, construction obstacles were associated with 12 references and they grouped safety barriers, repair equipment, plant care, street buildings under construction and road maintenance (see Figure 4-6i: construction of street buildings; and 4-6s: pavement maintenance). Cyclists, skateboarders, wheelchair users, and scooters were defined as moving obstacles on the pavement and there were 11 references relevant with them. Changes in paving level, such as kerbs (see Figure 4-7i), steps (see Figure 4-7f), and slopes, were identified as problematic characteristics of the pavement by the participants and they received nine comments. Parked cars on the pavement were reported as a common hazard to older adults and they had eight comments from the participants. A smaller group of references (n=6) was associated with the design of pavement presentation consisting of confusing colours, textiles and patterns and street shops property, such as tables, chairs, and advertising boards. The narrow pavements and tactile pavements were also hazards to walking that associated with five references and four references respectively. In addition to pavement hazards, the absence of a pavement was mentioned three time by participants as it could put the participants in a dangerous situation when walking in the street. A participant also identified manhole or drain covers as a problem as he noticed that the covers could increase the risk of falling or tripping to older people.

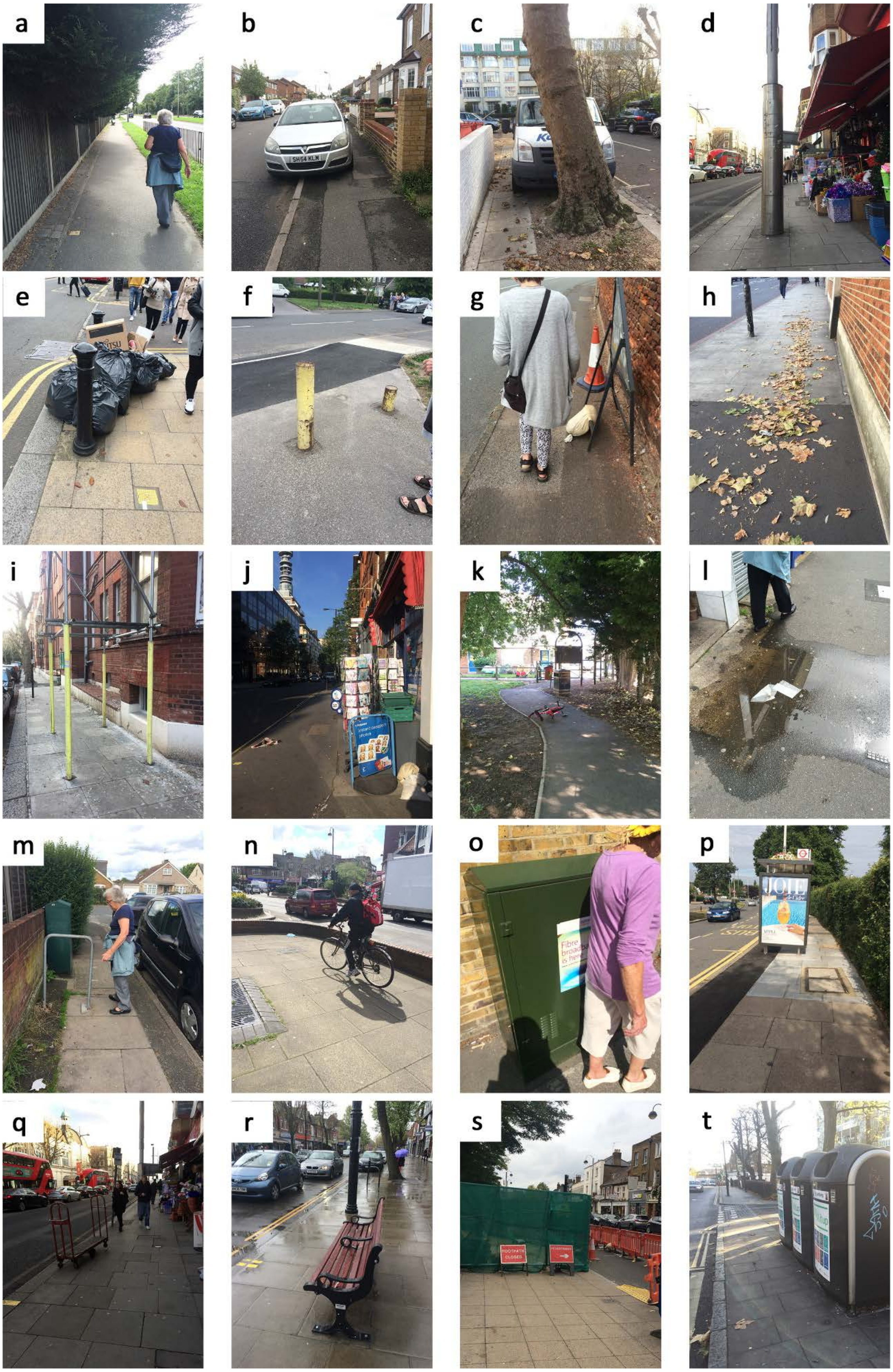


Figure 4-6. Pavement obstructions photographed in London.

Figure 4-7. Poor pavement conditions photographed in London.

4.2.4.2 Physical and behavioural impact of pavement hazards

The hazardous pavement factors were found to be the main cause of the negative impact on the participants reflecting in the risk and difficulty of walking and the limits on view and walking. For example, slippery conditions or broken paving bricks could cause falls and trips to the participants and fractured pavements could made the participants have difficulty in walking. The impact of the poorly paved conditions would be further increased when some barriers, such as water and leaves, covered paved surface. In that situation, the participants indicated that they could not see the pacing condition properly. Some factors affected the accessibility of the walking environment and limited walking in the participants. For example, poorly maintained or designed street amenities, parked cars, and street store property sometimes took up much space on the pavement making the participants feel that their movement was restricted.

Table 4-4. The impact of pavement hazards on walking among the participants

Impact on walking	Reference (n=12)	Relevant pavement hazard
The risk of falling	n=7	Climatic conditions Construction Broken pavements Cable boxes Kerbs
Physical burdens	n=2	Broken pavements
Limits on view	n=2	Street furniture (light) Leaves
Limits on walking	n=1	

In addition to the impact, poor pavement conditions could trigger changes in the walking behaviour of the participants. This study categorised 13 behavioural changes of the participants from the analysis. As Figure 4-8 shows, stepping aside was mentioned 12 times and became the most common walking pattern (Figure 4-9a: stepping aside from barriers). Cautious gaits (n=10) were another common behaviour pattern that adopted by the participant when they encountered pavement barriers, such as snow, uneven pavements, and broken surfaces. Walking slowly (n=10) was also often triggered by the hazards when the participants had to adopt a slower speed to negotiate the pavement conditions. Many participants (n=5, see Figure 4-9b and Figure 4-9d) were observed often walked outside of the pavement because of overgrown bushes, and some participants reported that they often shortened or lengthened their paces (n=4) due to hazardous conditions. In the situation of narrow pavements, the participants had to make room and give way (n=4) to other pedestrians. To avoid overhanging tree branches, they chose to lower their head (n=4) (see Figure 4-9e). Stepping onto the street (n=3) was an alternative change for the participants if the pavement was in a poor condition. One of them preferred to face the oncoming traffic when walking in the street. In addition to the results, some behavioural factors were specific to individual cases. For example, some participant chose to raise his/her legs higher, stop walking, or cross the road to the opposite pavement to cope with pavement hazards or unacceptable paved conditions, and one participant walked sideways in a limited walking environment.

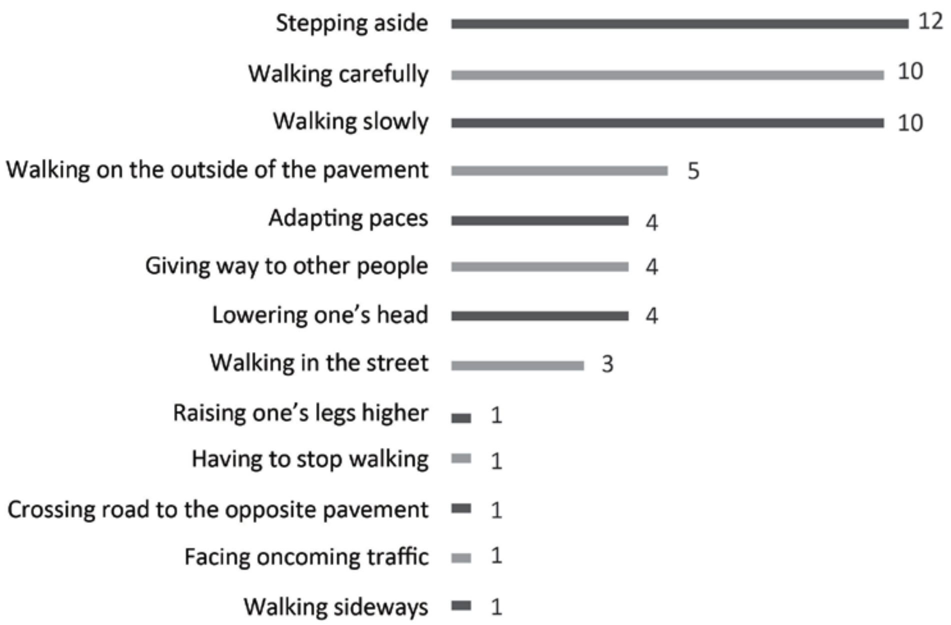


Figure 4-8. The behavioural changes in participants' walking (n=57 reference).

Figure 4-9. Examples of the behavioural factors.

4.2.4.3 Features of a good pavement environment

Table 4-5. Features of a good pavement environment

Feature	Reference (n=6)
Well organised plants	1
Plenty lights	1
More public seats	1
A wide pavement with an open view	1
Smooth paving surfaces	1
No parked cars on the pavement	1

Regarding the features of good pavements, the participants requested well-organised plants, plenty of lights and seats, a wide pavement with open view, fewer parked cars, and smooth paving surfaces, such as big slabs.

4.3 Section two of the study

After finishing the first data collection of the empirical study, it was found that some topics needed further explorations, the results needed verification, and the correlation between the identified patterns needed to be clarified. A questionnaire (Matthews and Ross, 2010) was designed to investigate those aspects using a larger sample size. The questionnaire was applied in an interview to encourage a wide range of responses and to obtain additional information of the participants' responses.

4.3.1 Design of the interview-based questionnaire

Table 4-6. Guidelines for designing questionnaires, adapted from Gilbert (2008) Creswell (2009) and Walliman (2011b).

Item	Recommendation
Purpose	• Obtain accurate information from respondents • Provide a logical structure to the questionnaire • Provide a standard form for recording responses • Facilitate data entry and processing during the analysis
Respondents	• Clarify the sample size of the questionnaire
Questions (How data can be assessed?)	• Consider the scale of the survey content • List the questions that needed by this study • Establish exactly variables that the survey wish to gather • Formulate the questions precisely to elicit the responses that are required • Questions should be simple and short • Questions must be pre-coded and allow alternatives with an 'other' category
Language	• Language must be unmistakably clear and unambiguous • Make no inappropriate assumption in the expression
Layout	• Think about the process of using the questionnaire

- Provide clear and professional presentation
- Minimise clutter of pages and question setting
- The front page should inform the respondents of the necessary information of the survey and ethical concern

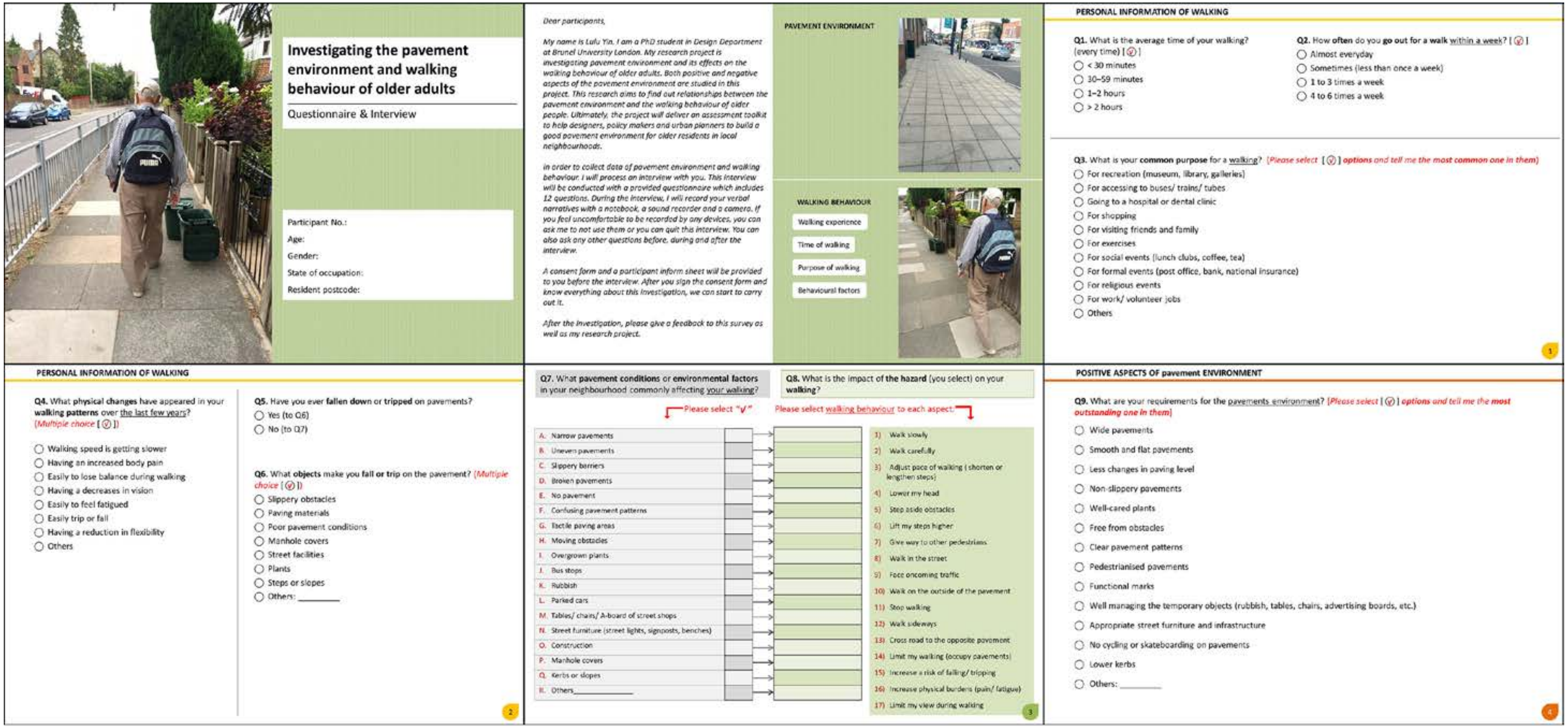
---

As interview-based questionnaires could be time-consuming and complicated (Coe, 2017), guidelines adapted from Gilbert (2008), Creswell (2009), and Walliman (2011b) were used to design the data collection. According to the guidance, questionnaires needed to have a logical and standard structure; the sample size of respondents must be clarified earlier to guarantee the completeness; questions had to be specific, short, and simple; the language of the questions needed to be carefully scripted to reduce ambiguity; and the layout had to be clear and professionally presented without clutter.

As discussed earlier, the questionnaire was used in an interview. The sample of a qualitative study has to be set in an appropriate size enabling significant data to be exposed to a great extent while to avoid repetition and irrelevant information (Mason, 2010). 20 to 50 subjects are often suggested as the standard sample size of a qualitative study (Marshall *et al.*, 2013), so this study selected a middle point of 30 participants to be the minimum of the sample size. The questionnaire included nine closed-ended questions consisting of three category questions and five listed questions. The category questions were single-choice questions that requested respondents to choose one answer from multiple options, and the listed questions were multiple-choice questions that provided a series of choices that allowed the respondents to have multiple answers (Gray, 2018). The questions were developed based on the findings of the previous data collection. They concerned the participants' preference of daily walking, looked into past falls of the participants, and inquired about hazardous factors of pavements and their impact on the participants' walking:

1. What is the average time that you spend on walking?
2. How often do you go out for a walk within a week?
3. What is your common purpose for walking?
4. What physical changes have appeared in your walking patterns over the last few years?

5. Have you ever fallen down or tripped down on pavements?
6. What factors make you fall or trip on the pavement?
7. What pavement conditions or environmental factors in your neighbourhood commonly affect your walking?
8. What is the impact caused by the hazards (you select) on your walking?
9. What are your requirements for the pavements environment?


Investigating the pavement environment and walking behaviour of older adults

Questionnaire & Interview

Participant No.:
Age:
Gender:
State of occupation:
Resident postcode:

Dear participants,

My name is Lulu Yin. I am a PhD student in Design Department at Brunel University London. My research project is investigating pavement environment and its effects on the walking behaviour of older adults. Both positive and negative aspects of the pavement environment are studied in this project. This research aims to find out relationships between the pavement environment and the walking behaviour of older people. Ultimately, the project will deliver an assessment toolkit to help designers, policy makers and urban planners to build a good pavement environment for older residents in local neighbourhoods.

In order to collect data of pavement environment and walking behaviour. I will process an interview with you. This interview will be conducted with a provided questionnaire which includes 12 questions. During the interview, I will record your verbal narratives with a notebook, a sound recorder and a camera. If you feel uncomfortable to be recorded by any devices, you can ask me to not use them or you can quit this interview. You can also ask any other questions before, during and after the interview.

A consent form and a participant inform sheet will be provided to you before the interview. After you sign the consent form and know everything about this investigation, we can start to carry out it.

After the investigation, please give a feedback to this survey as well as my research project.

PAVEMENT ENVIRONMENT

WALKING BEHAVIOUR
- Walking experience
- Time of walking
- Purpose of walking
- Behavioural factors

PERSONAL INFORMATION OF WALKING

Q1. What is the average time of your walking? (every time) [ ]
- ○ < 30 minutes
- ○ 30–59 minutes
- ○ 1–2 hours
- ○ > 2 hours

Q2. How **often** do you **go out for a walk** within a week? [ ]
- ○ Almost everyday
- ○ Sometimes (less than once a week)
- ○ 1 to 3 times a week
- ○ 4 to 6 times a week

Q3. What is your **common purpose** for a walking? *(Please select [ ] **options** and tell me the **most common one** in them)*
- ○ For recreation (museum, library, galleries)
- ○ For accessing to buses/ trains/ tubes
- ○ Going to a hospital or dental clinic
- ○ For shopping
- ○ For visiting friends and family
- ○ For exercises
- ○ For social events (lunch clubs, coffee, tea)
- ○ For formal events (post office, bank, national insurance)
- ○ For religious events
- ○ For work/ volunteer jobs
- ○ Others

1

PERSONAL INFORMATION OF WALKING

Q4. What **physical changes** have appeared in your **walking patterns** over the last few years? *(Multiple choice [ ])*
- ○ Walking speed is getting slower
- ○ Having an increased body pain
- ○ Easily to lose balance during walking
- ○ Having a decreases in vision
- ○ Easily to feel fatigued
- ○ Easily trip or fall
- ○ Having a reduction in flexibility
- ○ Others

Q5. Have you ever **fallen down** or **tripped** on pavements?
- ○ Yes (to Q6)
- ○ No (to Q7)

Q6. What **objects** make you **fall or trip** on the pavement? *(Multiple choice [ ])*
- ○ Slippery obstacles
- ○ Paving materials
- ○ Poor pavement conditions
- ○ Manhole covers
- ○ Street facilities
- ○ Plants
- ○ Steps or slopes
- ○ Others: ________

2

Q7. What **pavement conditions** or **environmental factors** in your neighbourhood commonly affecting your walking?

Q8. What is the impact of **the hazard** (you select) on your **walking**?

Please select "√"

Please select walking behaviour to each aspect.

A. Narrow pavements
B. Uneven pavements
C. Slippery barriers
D. Broken pavements
E. No pavement
F. Confusing pavement patterns
G. Tactile paving areas
H. Moving obstacles
I. Overgrown plants
J. Bus stops
K. Rubbish
L. Parked cars
M. Tables/ chairs/ A-board of street shops
N. Street furniture (street lights, signposts, benches)
O. Construction
P. Manhole covers
Q. Kerbs or slopes
R. Others________

1) Walk slowly
2) Walk carefully
3) Adjust pace of walking (shorten or lengthen steps)
4) Lower my head
5) Step aside obstacles
6) Lift my steps higher
7) Give way to other pedestrians
8) Walk in the street
9) Face oncoming traffic
10) Walk on the outside of the pavement
11) Stop walking
12) Walk sideways
13) Cross road to the opposite pavement
14) Limit my walking (occupy pavements)
15) Increase a risk of falling/ tripping
16) Increase physical burdens (pain/ fatigue)
17) Limit my view during walking

3

POSITIVE ASPECTS OF pavement ENVIRONMENT

Q9. What are your requirements for the pavements environment? *(Please select [ ] **options** and tell me the **most outstanding one in them**)*
- ○ Wide pavements
- ○ Smooth and flat pavements
- ○ Less changes in paving level
- ○ Non-slippery pavements
- ○ Well-cared plants
- ○ Free from obstacles
- ○ Clear pavement patterns
- ○ Pedestrianised pavements
- ○ Functional marks
- ○ Well managing the temporary objects (rubbish, tables, chairs, advertising boards, etc.)
- ○ Appropriate street furniture and infrastructure
- ○ No cycling or skateboarding on pavements
- ○ Lower kerbs
- ○ Others: ________

4

Figure 4-10. The interview-based questionnaire.

Figure 4-11. The participants in the interview-based survey (photographs have been permitted by participants).

4.3.2 Participants

Table 4-7. Participant demographics (n=32 participant)

Gender		Age band		Occupation status	
Female	59.4%	60-69	21.9%	Retired	68.8%
Male	40.6%	70-79	50.0%	Semi-retired	31.2%
		80-89	21.9%		
		≥90	6.3%		

32 older adults participated in the study and they were recruited from senior residents in London with the support of several social groups and associations. The requests for the participants on the age ($\geq$ 60) and walking condition (have the ability of walking) were the same as those in the previous study. The sample consisted of 19 females (59.4%) and 13 males (40.6%), and the most sizeable number of them were from the age group of 70-79 (50.0%) and the smallest group of the participants were aged over 90 (6.3%). Twenty-two participants (68.8%) were retired and the others were semi-retired (31.2%) as they were still doing a part-time job or working as a volunteer.

4.3.3 Analysis

All 32 participants completed the questionnaires correctly and there were no rejected entries. Results of the questionnaires were statistically analysed with the use of Excel to work out correlations between different data patterns and the response rate by calculating the respondents and responses to different options and questions (Kara, 2017). Interview scripts from the study were transcribed and classified according to their themes and meaning to make a specific interpretation on the quantitative results.

4.3.4 Results

The results of the study were in line with the findings from the previous data collection. It verified the previous findings and interpreted the correlation between pavements and older pedestrians. The analysis outcomes (see Table 4-8) show that the majority of the participants (43.8%) walked between 30 minutes to 59 minutes every time. Almost one-third of them (31.3%) walked for more than one hour, and some respondents (9.4%) walked more than two hours on each trip. More than three-quarters of the participants (75.0%) walked almost every day and only a few of them (3.1%) walked less than once a week. Common purposes for walking were going shopping (93.8%), accessing to public transportation (81.3%) and undertaking recreations (75.0%), social activities (71.9%), formal events (68.8%), and exercise (62.5%).

Table 4-8. Information of participants' routine walking activity

Walking characteristic	Category	N=32 participant (%)
Walking time (per trip)	< 30 minutes	15.6%

	30-59 minutes	43.8%
	1-2 hours	31.3%
	>2 hours	9.4%
Walking rate	Almost every day	75.0%
	1 to 3 times a week	6.3%
	4 to 6 times a week	15.6%
	Less than once a week	3.1%
Walking purpose	Shopping	93.8%
	Transportation	81.3%
	Recreation	75.0%
	Social activity	71.9%
	Formal errands	68.8%
	Exercise	62.5%
	Medical service	59.4%
	Visiting friends or families	50.0%
	Working	37.5%
	Religious events	37.5%
	Others	6.3%

68.8% of the participants stated that their walking speed was getting slower over the past few years. Almost half of the respondents (46.9%) indicated that they were more likely to trip or fall and there was a reduction in the flexibility of their muscles and joints. A significant number of the responses showed that the participants started to experience fatigue (40.6%) and body pain (37.5%) when walking, especially when they walked for a long distance. Some respondents also found that they had a decrease in their vision (28.1%) and balance (25.0%) and had difficulty in raising their feet (12.5%).

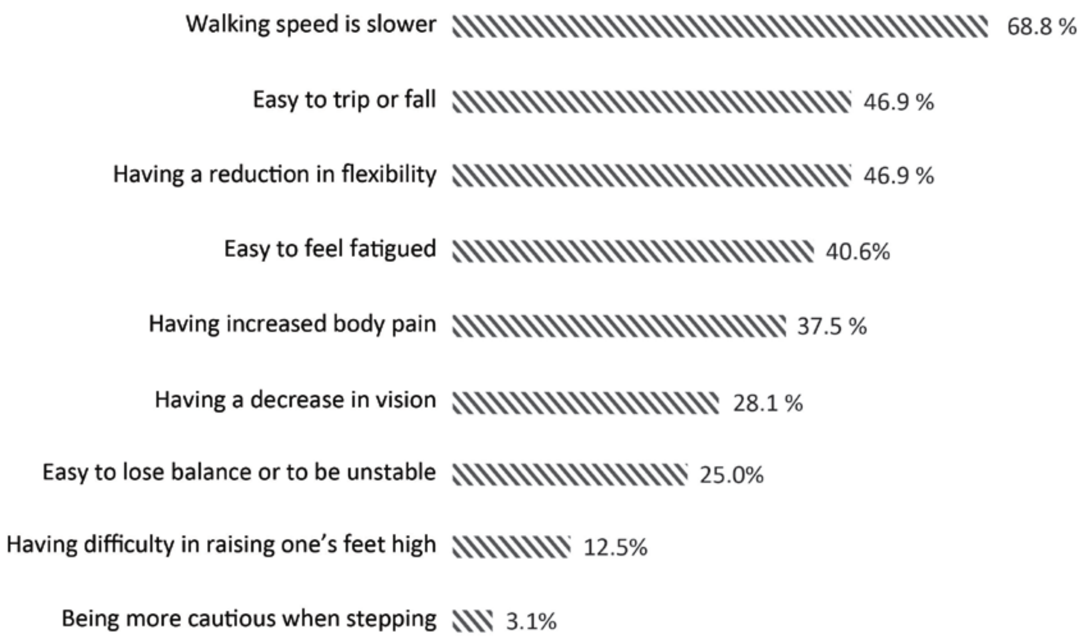


Figure 4-12. Physical declines in the participants (n=32 respondents).

4.3.4.1 Hazardous factors of the pavement

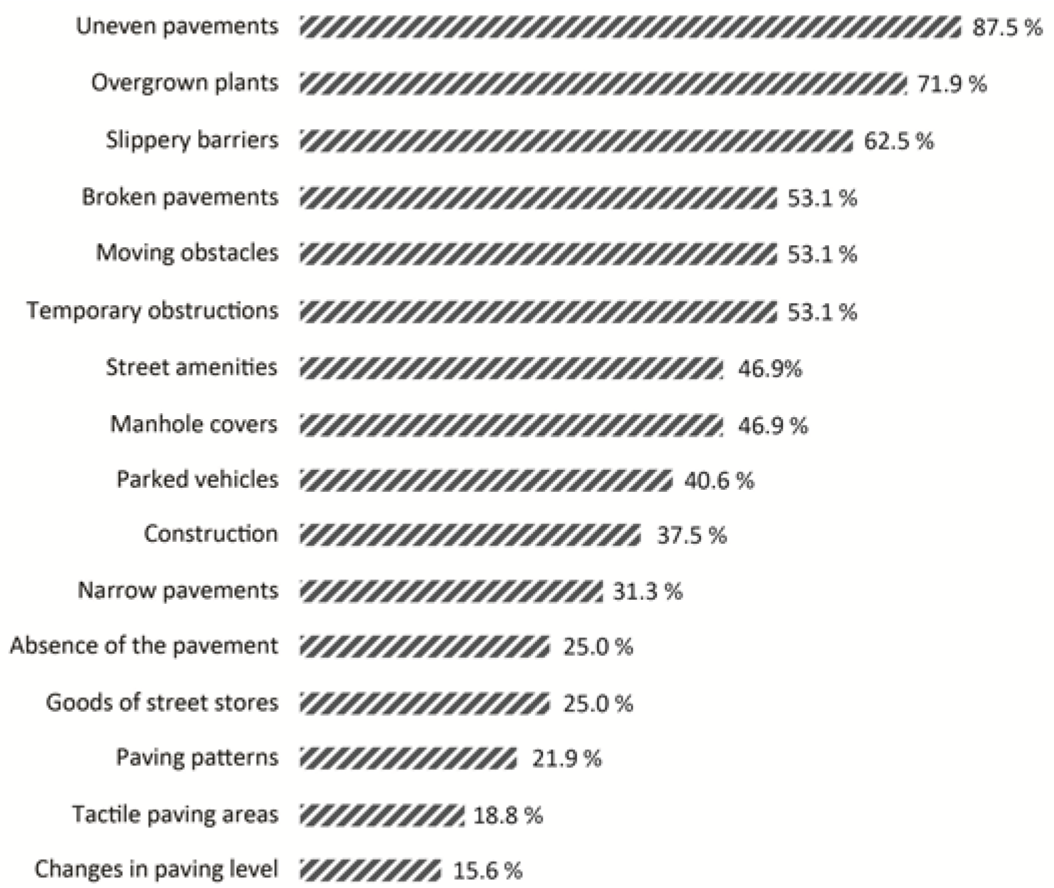


Figure 4-13. Pavement hazards (n=32 respondents).

Figure 4-13 displays that top-ranking pavement hazards identified by the interview-based questionnaire corresponded with the most significant hazardous conditions found in the previous study. The common high-ranking hazards were uneven pavements (87.5%), plants (71.9%), slippery obstacles (62.5%), broken pavements (53.1%), moving obstacles (53.1%), and temporary obstacles (53.1%), such as rubbish, the rubbish for collection, and personal belongings. In addition, poorly maintained or designed street amenities (46.9%), parked vehicles (40.6%), construction barriers (37.5%), and narrow pavements (31.3%) were an apparent issue to the participants in both of the studies. The absence of the pavement (25.0%) and street stores (25.0%) were regarded as detrimental elements by a smaller group of the participants, and inconsistent paving patterns (21.9%) and tactile paving areas (18.8%) were found to be hazardous factors of the pavement by few participants in the two studies. Different from the last study, manhole and drain covers (46.9%) became a more noticeable issue to the participants in this study while changes in paving level (15.6%) were less influential to their walking.

In the interview, the participants further explained why certain pavement factors were determined as hazards. Regarding the poor pavement conditions, they indicated that:

> "When encountering ice, especially black ice and water on the pavement, the road would be better for walking...uneven pavements are the main problem...the situation of fracture is dangerous…I don't like blind paths…slabs are always missing or broken…slabs in different heights cause the risk of trip…broken pavements usually come with the unevenness…the uneven condition is not easy to see as the slabs are all in the same colour…ponding is easy to stay on pavements…the road next to Ickenham bus station only gets a pavement on one side…I feel more difficult to walk on slopes when getting old...tactile footpaths make my feet sore…some small stones are easy to be broken by parked cars…tree roots break pavements… tree roots make pavements uneven…paving stones are a big problem, and they are knocked down by cyclists…parked cars are too heavy to damage kerbs…manhole covers can be uneven and sometimes missing."

Referring to the pavement obstructions, the respondents cited that:

> "I'm afraid that the overhanging trees could cut my face…parked cars make my walking inconvenient…I have to walk on the wrong side of the road or cross the road if the pavement is under construction…parked cars take half of the pavement in Uxbridge road…I got hurt by a cyclist before…people always take the rubbish out of their house early than the collection time…overhanging trees on the narrow pavement make a worse situation…pavements are narrow due to the bushes that grow out of providing houses…construction of road repair and provide house take up space of pavements…manhole covers sometimes come out from the pavement…Pield Heath Road and Hauliton Road that near to Hillingdon hospital are narrowed down by bus stops…public chairs make pavements narrower…it is not easy to get to bus stops when the council repairing the pavement…cyclists are terrible and they often cycle in a wrong direction on pavements…rolling skateboards is annoying and dangerous for us…I think the government chose wrong plants for the city and less cared the trees…construction barriers are usually put on the pavement earlier by road workers before they start to work."

4.3.4.2 The adverse impact of pavement hazards

Ninety-five responses (see Figure 4-14) were obtained from the multiple questions regarding the impact of the 16 pavement hazards. Approximately half of the responses (45.3%) confirmed that the poor pavement conditions increased the risk of falling or tripping. As reported by the participants (n=23) who had fallen over the past few years, 40 falls happened on the pavement and most of them were caused by poor ground conditions (82.5% in Figure 4-15) especially uneven pavements or broken surfaces. Also, the study found that plants consisting of the roots and leaves of trees made up a considerable number of historical falls (17.5% in Figure 4-15). Slippery barriers (e.g. ice and water) resulted in 10% of the falls and manhole covers caused 7.5% of the falls. Apart from that, the participants confirmed that hazardous factors of the pavement could limit their walking (24.2%) or view (16.8%). The study specified that the limits were often caused by parked cars, slipperiness, manhole covers, overgrown plants, or inadequate street amenities. In line with the previous outcomes, some comments

(13.7%) from this study also reveal that uneven surfaces, slopes, and slopes could increase pain and fatigue in older adults' body.

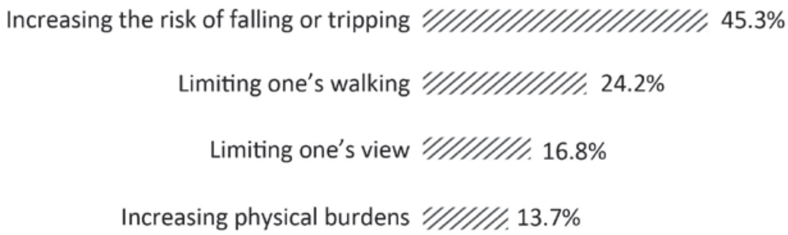


Figure 4-14. The adverse impact of pavement hazards on the respondents (n=95 responses).

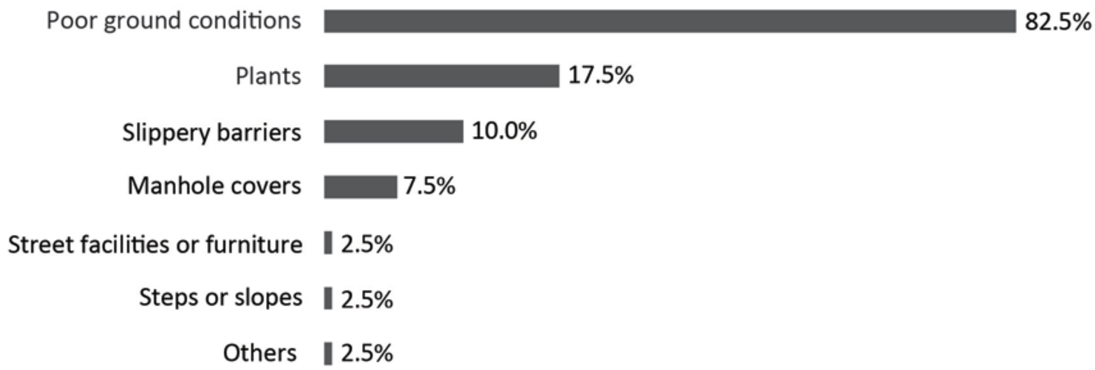


Figure 4-15. Causes of the respondents' historical falls (n=40 responses).

4.3.4.3 Behavioural changes of the participants

The study received 713 coded items from analysing the participants' responses to the 13 behavioural changes. Each walking behavioural pattern received a different amount of responses, and Figure 4-16 displays the percentage of the responses to each behavioural factor among the 713 coded items. The responses to each behavioural factors distributed differently in regard to the 16 categories of pavement hazards, and the results are shown in percentage in Table 4-9. Based on the analysis, the specific correlation between the 13 walking behaviour and each pavement issue were justified in this stage. As the results indicated in Figure 4-16, the most common behaviour of the participants were in paralleled with those detected by the last study, namely adopting cautious steps (18.4%), stepping aside (15.6%), adjusting paces (10.1%), walking slowly (10%), and giving way (9.7%). The respondents in this study were more likely to display such behavioural factors when they walked on poor pavement surfaces or when they encountered pavement obstructions. For example, Table 4-9 shows the responses to the walking behaviour 'stepping aside' (n=111) are mainly distribute in five pavement hazardous groups including temporary barriers (14.4% of the responses to stepping aside [n=111]), fractured pavements (12.6% of the responses stepping aside [n=111]), overgrown plants (11.7% of the responses to stepping aside [n=111]), parked cars (9.9% of the responses to stepping aside [n=111]), or slippery floors (9% of the responses to stepping aside [n=111]) existing in the walking environment. The behavioural factor 'giving way' contributed 69 responses to the 713 coded items, and Table 4-9 shows that participants adopted such behaviour when the walking space was limited by poorly planned street furniture (13% of the responses to giving away [n=69]), narrow paved width (10.1% of the responses to giving away [n=69]), or overgrown plants (10.1% of the responses to giving away [n=69]). In line with the previous findings, Figure 4-16 illustrates that stopped walking (7.9%) is also a main behavioural change in walking among the participants. According to Table 4-9, this behaviour received 56 responses and they mainly distribute in pavement hazards, namely slipperiness (16.1% of the response to stopping walking [n=56]), moving obstacles (12.5% of the response to stopping walking [n=56]), and parked vehicles (10.7% of the response to stopping walking [n=56]). As Figure 4-16 demonstrates, a minority of the responses presents that the participants could be forced to walk on the outside of the pavement (7.4%) when there were some obstacles occupied on the inside of the pavement. Table 4-9 specifies that common obstacles that often cause people to walk on the outside of the pavement are overgrowing trees (28.3% of the response to walking on the outside of the pavement [n=53]), temporary barriers (13.2% of the responses to walking on the outside of the pavement [n=53]), and inappropriate street amenities (9.4% of the responses to walking on the outside of the pavement [n=53]). Agreeing with the previous survey, Figure 4-16 shows few results of this study were associated with the situation of walking in the street (5.9%). However, stepping onto the street could be triggered by slipperiness, broken pavements, parked cars, and overgrown plants, and it was also a reasonable behavioural change to older adults when there was no pavement was available (see Table 4-9). In addition, Figure 4-16 shows that 5.6% of the participants' behavioural changes is related to the action 'crossing to the opposite road'. According to Table 4-9, overgrown trees (15.0% of the responses to crossing road [n=40]) and construction (12.5% of the responses to crossing road [n=40]) were verified in this stage that were more associated with the walking pattern. Lowering the head was found to be a rare behavioural change

(3.6% of the 713 responses shown in Figure 4-16) in walking. However, the study results shown in Table 4-9 indicates that lowering the head was a notable action related to overhanging tree branches (46.2% of the responses to lowering one's head [n=26]). Similar with the participants of the last study, the respondents of the interview-based questionnaire rarely raised their steps higher (3.5% of the 713 responses shown in Figure 4-16) to deal with pavement hazards. But, Table 4-9 shows that the participants could present this behaviour particularly on uneven surfaces (36.0% of the responses to raising one's legs higher displayed [n=25]). According to Figure 4-16, facing the oncoming traffic (1.7%) was confirmed as another uncommon behavioural. However, it was the most preferred choice for the participants when they walked in the street with no pavement built along with the road (66.7% of the responses for facing oncoming traffic [n=12]). The results shown in Figure 4-16 also verified that the participants barely walked sideways (0.7%) except when the walking space are were obstructed by overgrown plants. Table 4-9 shows that 40.0% of the responses to walking sideways (n=5) is associated with overgrown trees.

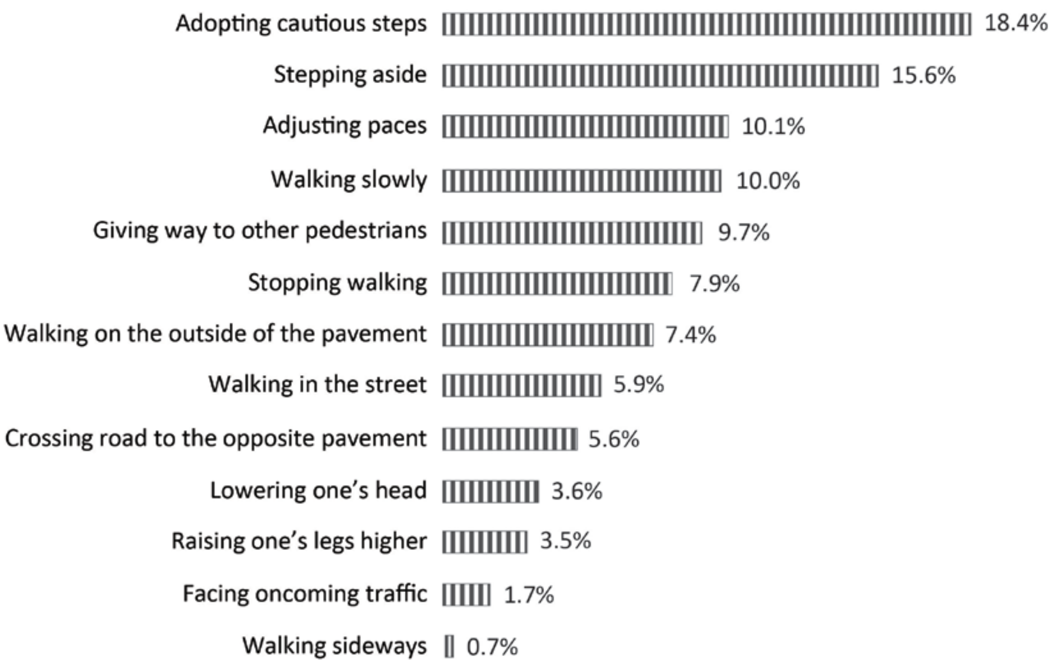


Figure 4-16. Behavioural changes of the respondents (n=713 reference).

Table 4-9. Specific relationships between behavioural factors of walking in the participants and pavement factors

n=response **%** = distribution of the responses to each walking behaviour in the pavement hazard	**Adopting cautious steps (n=131)**	**Stepping aside (n=111)**	**Adjusting paces (n=72)**	**Walking slowly (n=71)**	**Giving way (n=69)**	**Stopping walking (n=56)**	**Walking on the outside of the pavement (n=53)**	**Walking on the road (n=42)**	**Crossing to the opposite side (n=40)**	**Lowering one's head (n=26)**	**Raising one's legs higher (n=25)**	**Facing oncoming traffic (n=12)**	**Walking sideways (n=5)**
Uneven pavements	18.3%	8.1%	18.1%	16.9%	8.7%	8.9%	5.7%	4.8%	7.5%	26.9%	36.0%	0.0%	0.0%
Overgrown plants	7.6%	11.7%	8.3%	4.2%	10.1%	3.6%	28.3%	11.9%	15.0%	46.2%	12.0%	0.0%	40.0%
Slippery barriers	13.0%	9.0%	15.3%	15.5%	4.3%	16.1%	9.4%	16.7%	7.5%	11.5%	4.0%	8.3%	0.0%
Broken pavements	9.9%	12.6%	11.1%	9.9%	8.7%	5.4%	5.7%	14.3%	7.5%	7.7%	12.0%	8.3%	0.0%
Moving objects	3.8%	1.8%	5.6%	4.2%	8.7%	12.5%	1.9%	0.0%	2.5%	0.0%	0.0%	0.0%	0.0%
Temporary obstacles	6.1%	14.4%	4.2%	4.2%	10.1%	3.6%	13.2%	2.4%	7.5%	0.0%	12.0%	0.0%	0.0%
Street amenities	3.8%	8.1%	4.2%	7.0%	13.0%	7.1%	9.4%	7.1%	7.5%	0.0%	0.0%	0.0%	20.0%
Manhole and drain covers	6.9%	6.3%	9.7%	5.6%	2.9%	8.9%	7.5%	0.0%	2.5%	0.0%	12.0%	0.0%	0.0%
Parked vehicles	3.8%	9.9%	1.4%	2.8%	7.2%	10.7%	5.7%	11.9%	10.0%	0.0%	0.0%	0.0%	0.0%
Construction	5.3%	7.2%	5.6%	5.6%	4.3%	7.1%	3.8%	9.5%	12.5%	3.8%	0.0%	0.0%	20.0%
Narrow pavements	7.6%	0.0%	8.3%	8.5%	10.1%	1.8%	3.8%	2.4%	2.5%	0.0%	0.0%	16.7%	0.0%
Absence of pavements	1.5%	0.0%	1.4%	1.4%	2.9%	3.6%	0.0%	11.9%	10.0%	0.0%	0.0%	66.7%	20.0%
Shopkeeper's goods	3.1%	6.3%	1.4%	1.4%	4.3%	3.6%	3.8%	2.4%	5.0%	0.0%	0.0%	0.0%	0.0%
Confusing paving patterns	3.8%	1.8%	1.4%	2.8%	0.0%	1.8%	1.9%	4.8%	0.0%	0.0%	4.0%	0.0%	0.0%
Tactile paving areas	3.1%	0.9%	2.8%	4.2%	2.9%	0.0%	0.0%	0.0%	2.5%	0.0%	8.0%	0.0%	0.0%
Changes in paving level	2.3%	1.8%	1.4%	5.6%	1.4%	5.4%	0.0%	0.0%	0.0%	3.8%	0.0%	0.0%	0.0%

4.3.4.4 Participants' requirements for the pavement environment

This section gathered older pedestrians' concerns about an age-friendly and walking-friendly environment based on the positive features of a good pavement generalised in the previous study and other studies (I'DGO, 2010; Oxley *et al.*, 2016; TfL, 2016b). As Figure 4-17 presents, even though the narrow pavement was not a strong threat to the participants' walking, wide pavements were requested by the largest percentage of respondents (85.7%). Smooth and flat pavements were also requested by 78.6% of respondents. 75% of participants said pavements should be free from any obstacles including rubbish, parked cars, or moving dangers, such as cyclists or skateboarders. More than half the sample requested the street amenities to be well planned and well maintained (67.9% of the respondents) and expected fewer changes in paving level (60.7% of the respondents) and lower kerbs or no kerb along with the pavement (57.1% of the respondents). 46.7% of the participants required pavements to be built with non-slippery paving materials, and 39.3% of them suggested pedestrianising pavements, managing temporary obstacles, and using functional marks to highlight hazardous conditions of the pavement. Additionally, the respondents (10.7%) would like the pavement to be constructed with clear patterns, and some participants (7.1%) needed the tactile paving areas to be situated in an appropriate location. Also, a participant (3.6%) expected the pavement environment to protect older people from the traffic or building construction. According to the interview, the respondents added that:

> "Tarmacadam is good but it not easy to be maintained…even pavements especially in a busy area…rubber would be a good material for paving the pavement…uniformed policy for the pavements in the UK…paths to local locations shall be well maintained…I would spend more time walking on well-maintained and well-carded pavements…I prefer tarmac and small paving stones…good and flat surfaces…wider pavements will be lovely…Camden High Street already rebuilt pavements by changing big slabs to small stone…lower kerbs while the height is larger than 10 centimetres…use markings to separate roads, pavements and cycling lanes instead of paving kerbs… I like tactile footpaths…it is a good place to cross the road…make sure it is placed on a suitable area…pedestrianise the

pavements in shopping areas…separate the pavement space for different pedestrians…more suitable and well cared for plants…a cycling lane for cyclists…put a walkway separated from vehicles when conducting a construction."

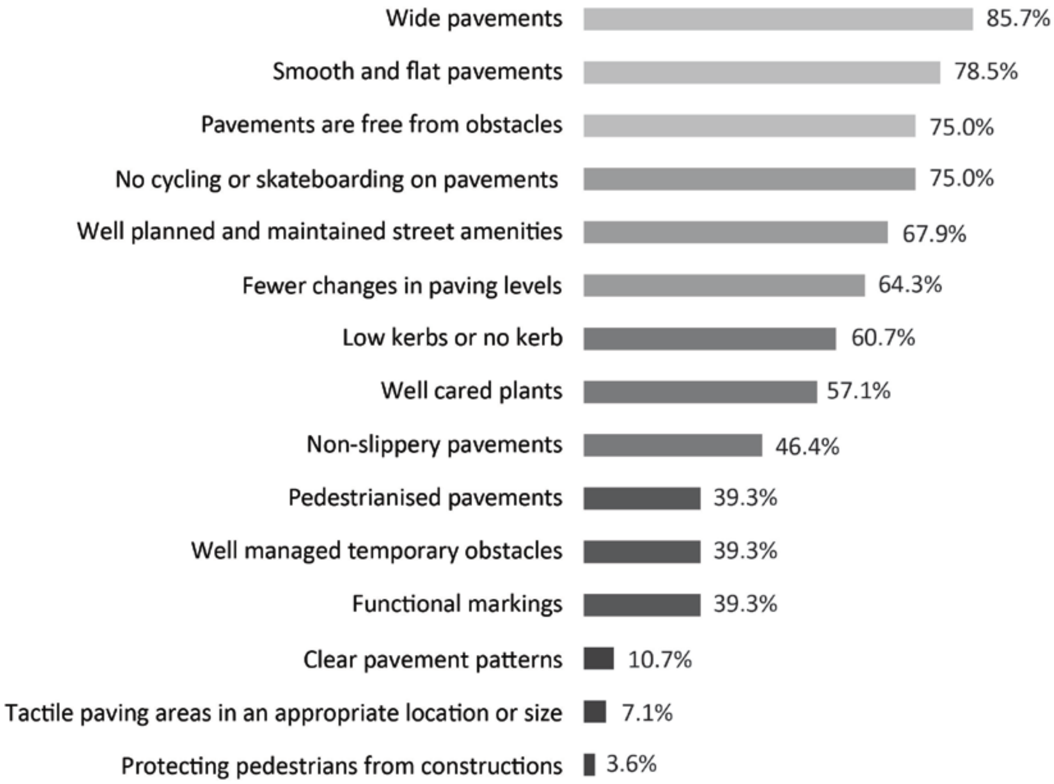


Figure 4-17. Requirements for the pavement environment (n=32 participant).

4.4 Discussion of the empirical results (DS-I)

To answer the research questions RQ1, RQ2 and RQ3, this study used interviews, observations, cultural probes, and an interview-based questionnaire to collect data from older pedestrians. It investigated hazardous factors of the pavement environment which could influence older people's walking and also identified the walking behaviour and walking needs of older pedestrians. As shown in Figure 4-18, poor pavement conditions and pavement obstructions contribute to hazardous factors of the pavement environment. They were regarded as problematic factors because they were found that have an adverse impact, such as an increase in the risk of falling, on older pedestrians. Then, elderly people had to make behavioural changes in their walking to deal with the hazardous factors and impact. It also found that ageing declines in the physical condition of older people could increase the adverse effect of the pavement problems and restrict participants' strategic adaptions in walking. To prevent the hazards and develop the age-friendliness of the pavement environment, the participants requested a pedestrianised pavement in well-maintained conditions that were free from any kinds of obstacles.

Figure 4-18. Framework of study findings.

4.4.1 Pavement hazards and their impact

Oxley *et al.* (2016) found that older people were mostly associated with the risk factors of injury-related falls in outdoor built environments. Poor pavement conditions were one of the most common threats to seniors' walking as they were more likely to induce falls (Li *et al.*, 2006; Curl, 2016; Yin and Pei, 2018). The study identified that uneven pavements, slippery barriers, and broken conditions were the main hazards resulting in falls or trips to older pedestrians as they often lifted their feet in a lower height (Wang *et al.*, 2016). Changes in level, which composed of kerbs, slopes, or steps, also stood out as a significant hazardous feature as it was also one of the causes of accidental falls. The CDC (2007) confirmed that most senior adults' falls occurred when climbing steps, and over half fall-related injuries were caused by walking on slopes. In addition, confusing paving patterns, which composes of discordant colours, textures, and materials, could make older people more easily fall on those poor pavement conditions as they made the hazards difficult to recognise. The study also found that stepped pavements could contribute to the risk of falling and made older adults have more difficulties in walking. Bloomberg *et al.* (2010) has found that steps could increase the risk and the fear of falling to older adults. Some falls could also occur due to manhole or drain covers which were wet or less maintained and raised slightly higher than the paved surface around them. A report of Devon County Council (2016) and a study of Willis (2017) provided evidence that slippery, broken or missing covers of manholes had become a common cause of fall-related injuries to pedestrians from all ages. According to a study of I'DGO (2010) in the UK, blind paths could make British seniors unstable and even fall or slips. This study confirmed that falls on blind pavements could potentially triggered by the unevenness and slipperiness of the tactile blisters. Additionally, overgrown plants and bushes could make older pedestrians fall (Marsden *et al.*, 2010) as fallen leaves could result in slipperiness and tree roots could become obstructions if they extend above the ground level.

In addition to the adverse impact, pavement hazards could initiate pain in the hip, ankles, heels, and feet of elderly people. The participants reported that they have increased pain in their body when walking on slippery and uneven pavements, and they felt tired when walking on slopes as they had to spend extra energy on the uphill. A study of

Bloomberg *et al.* (2010) has confirmed that the improper height of steps could easily deteriorate elderly people's climbing comfort. Apart from that, hazardous factors of the pavement could limited older adults' walking and view. In line with Chaudhury *et al.* (2012), narrow pavements were identified as a common issue to limit walking in older people. Overgrown plants, parked cars, and inappropriate street amenities, especially those on a narrow pavement, often blocked the walking path, and hence influenced walking in older pedestrians and limited them to view surroundings (Galanis and Eliou, 2011; TfL, 2016b). Likewise, abundant stalls, tables, chairs, and advertising boards of street stores could restrict older people's view and walking and reduce the accessibility of pedestrian environments by occupying the pavement. Inappropriately installed or maintained street lights, signs, cable boxes, bins, and bus stops could also clutter the walking space on pavements and result in difficulties of stepping. Ongoing construction was determined as a more prominent problem that reduced the pavement space and influence older pedestrians' walking. DfT (2007)reports that construction work always gives rise to pavement closures. In this case, older people were more likely to leave the pavement and to walk in the street. However, they felt unsafe to walk close to the traffic even though there was a temporary pedestrian path set on the carriageway to protect them from the passing vehicles. In addition, narrow paved width, uneven pavements, and the absence of the pavement could make older people walk on roadway and put them in a dangerous situation (I'DGO, 2010).

4.4.2 Walking behaviour of older pedestrians

Problems with the pavement could also cause changes to older adults' walking or make them adopt some behavioural patterns as a strategy to deal with walking hazards (Yin and Pei, 2018). This research identified that slow and cautious steps were the most significant walking patterns of older people when facing potential falling risks caused by slippery obstacles, manhole covers, broken surfaces, unevenness, and narrow pavements. Shkuratova, Morris, and Huxham (2004) and Kang and Dingwell (2008) found that the common way that people older than 65 adopted to maintain their balance was to slow down their pace and to walk carefully. The study additionally found that older adults sometimes raised their steps higher than usual to mitigate the risk of tripping caused by pavement obstructions especially uneven pavements. Stepping aside from obstacles on the pavement, which has been identified by Wall, Wrisley and Statler (2009) as a common behaviour pattern of older people, was also verified by the study as one of the notable actions for participants to cope with rubbish, fractured surfaces, overgrown vegetation, parked cars, or slippery surfaces in the pavement environment. Additionally, the research revealed that older pedestrians sometimes lengthened and shortened their steps alternatively when stepping over slippery surfaces. Weerdesteyn *et al.* (2005) have observed that older people, especially females, adjust their paces to improve their stability when walking on the surface in poor condition. Stop walking to observe unsafe or risky situations before deciding how to deal with them has been identified as a general behavioural pattern of older people by I'DGO (2010). Parked cars and moving obstacles on pavements, such as approaching cyclists, scooters, or skateboarders, were found to be the main elements to stop older pedestrians walking. Older people may also have to stop walking and give way to other pedestrians when the walking space is narrowed down or occupied by obstructions. If obstacles occupy the inside area of the pavement, older adults would walk on the outside of the pavement rather than stopping walking. However, this behaviour goes against older adults' will to walk inside to keep safe and to keep away from the passing traffic. In line with a study by Ariffina and Zaharib (2013), the study discovered that elderly people also chose to walk in the street if the pavement was poorly maintained, or the pathway ahead was blocked or there was no pavement available. However, stepping onto the street could make elders in a dangerous situation and be likely to be hit by a car (Lockett and Willis, 2005). Therefore, when walking in the street, most older adults prefer to face oncoming traffic so that they can detect potential dangers and stand aside from them timely (Luoma and Peltola, 2013). Lowering the head and walking sideways were another two strategic actions occasionally adopted by elderly pedestrians to cope with hazardous factors. The two behaviour patterns are unusual and have not been identified by other studies, however, the study found that they were easily triggered by overgrown trees, overhanding tree branch, and narrow pavements.

4.4.3 The impact of physical declines in older adults

The study found that ageing declines in older adults' physical conditions could amplify the adverse impact of pavement hazards. Older pedestrians' walking speed decreased by pavement problems could be further affected by the weakness in their leg extension power and muscle strength (Rantanen and Avela, 1997; Manini, 2013). Falls and trips caused by pavement obstructions could be additionally increased to senior adults due to the age-related loss in their balance and visual function (Schrager *et al.*, 2008; Pirker and Katzenschlager, 2017; Saftari and Kwon, 2018). Physical burdens on elderly pedestrians such as bodily pain and fatigue caused by the poor pavement condition could be aggravated more by ageing declines in seniors' body (Mänty *et al.*, 2012).

Ageing changes could also restrict older pedestrians' behaviour adopted to deal with hazardous circumstances (Yin and Pei, 2018). Age-associated changes in older adults' flexibility and posture make them have a difficulty in bending their knees (Oxley *et al.*, 2016). Also, bodily pain are gradually appeared in elders' neck, joints, and muscles with age can limit their action (Woodhouse, Liljebäck and Vasseljen, 2010). Therefore, elderly pedestrians may be unable to lift their legs higher to cope with the falling risk caused by slippery barriers and unevenness or to lower their head to avoid overhanging tree branches.

4.4.4 Recommendations for the pavement environment

Older people's concerns about an age-friendly pavement environment were compiled as a list of recommendations which were further discussed and clarified based on UK guidance of built environments (see Table 4-10).

Table 4-10. Recommendations to age-friendly pavements

Recommendation list	
1	Wide pavements that allow at least two pedestrians to walk together
2	Even and smooth pavement surfaces
3	Low kerbs (less than 10 centimetres in height if possible)
4	Non-slippery paving materials
5	Regularly maintained pavements
6	Fewer steps or slopes, or building the pavement on a small gradient
7	Tactile pavements are made in an appropriate size with better materials and built in an appropriate location
8	Well-maintained manhole covers

9	Clear pavement patterns in a uniformed design
10	Functional markings on the pavement to indicate hazardous conditions
11	Clean pavements that are free from obstacles, such as rubbish, parked cars, or cyclists
12	Well-maintained and appropriate plants for the pavement environment
13	Well planned and maintained street amenities designed in a coherent form
14	Pedestrianising the pavement for different road users
15	A well-defined pedestrian route separated from the construction or traffic

Many studies have specified that well-maintained pavements and wide footpaths are indispensable in assisting safe and easy walking (Newton *et al.*, 2010; Chaudhury *et al.*, 2012). The older adults in the study indicated that a wide pavement could prevent street amenities, trees, and stalls from turning into obstructions and could enable them to step aside from pavement obstacles easily (see Figure 4-19: a, b and c). To build a wide pavement, engineers can follow the rules of Cheshire County Council (2005) which recommend the pavement to be wide in 1000mm minimum. Or, the pavement width can be decided based on the pedestrian level that the larger pedestrian flow in the area, the wider pavement shall be provided (Kim, Choi and Kim, 2011). In line with Burton and Mitchell (2007), the study found that flat and smooth pavements could encourage older people to walk more often. To improve the evenness of pavements, the participants suggested well-maintained covers of manholes, tarmac pavement, big paved slabs, small and compact paving stones, and kerbs lower than 10 centimetres.

In parallel with I'DGO (2012) and TfL (2016b), few ramps and steps, pavement on a small gradient, and tactile path in an appropriate design and location were requested by the participants to prevent the risk of falling. Paving patterns were also required to enable older people to observe pavement hazards and unexpected changes in paving level. According to TfL (2016b), modular design, consistent patterns, and clear colours and layout enable pedestrians to perceive and cognise correct pavement conditions. Newton *et al.* (2010) also found that sharp and contrasting colours could draw older people's attention to changes in the floor surface, especially upcoming steps. The participants advocated that colour markings could also be a good idea of warning about hazards of pavement. The study found that TfL (2011) has regarded ground markings as a useful approach to highlight problematic pavement conditions, such as uneven and broken pavements or missing slabs (see Figure 4-19: d). However, the markings currently used by the UK government were confusing, inconspicuous and non-uniformed. A more readable demonstration in unified design could be developed to notify older people of hazardous pavement conditions.

The quality of walking in older people and pedestrian environments can be boosted through regularly maintained pavements which clean and brightly-lit and free from any barriers (Gallagher *et al.*, 2010; Buffel, Phillipson and scharf, 2012; Handler, 2014; Adams and Cavill, 2015). The participants recommended that temporary barriers, such as rubbish and puddles, to be clean up immediately, and slipperiness to be further avoided using anti slip and quick-drying paving materials. As to permanent obstacles, such as overgrown trees and inappropriate bus stops, plants shall be more adequately chosen by councils to avoid fallen leaves and be regularly trimmed by their owners to decrease the likelihood of overgrown issues (see Figure 4-19: e). Street amenities shall be well maintained and uniformly designed and built in an appropriate location on pavements to support a barrier-free walking environment (see Figure 4-19: f). According to Cheshire County Council (2005) and Mackett, Titheridge and Achuthan (2012), removing or grouping redundant street amenities can allow more pedestrian space, avoid pavement clutter, and enable clear sightlines along the pavement (Camden Council, n.d.).

The provision of pedestrianisation can play a vital role in improving the accessibility and walkability of built environments and enhancing the safety and comfort of walking (Cheshire County Council, 2005; Soni and Soni, 2016). Pedestrianised environments often prioritise pedestrians by having an isolated walking zone away from the traffic (DfT, n.d.). The study suggested that public pavements to be pedestrianised properly for roadside safety with a separate footpath for older adults, and a different lane for other road users, such as cyclists and scooter users (see Figure 4-19: g). Building pavements on both sides of the street (Cheshire County Council, 2005), and providing an independent walking path with safety barriers divided from construction can also enhance the accessibility of the pavement and protect older adults from walking in the street (see Figure 4-19: h).

Figure 4-19. Examples of the participants' requirements for an age-friendly pavement environment.

4.5 Summary

An empirical study consisting of two data collections has been done with 41 older adults recruited in London. It adopted an exploratory design of qualitative methods and quantitative methods comprising of interviews, observations, cultural probes, and questionnaires to collect data. The first data collection was conducted with nine participants using the qualitative techniques (interviews, observations, cultural probes) to fully understand about older people's perspectives on neighbourhood pavements and their walking experience and walking needs. Qualitative data analysis encompassing transcription, coding, and categorising was used to analyse data and it initially identified pavement hazards and their impact as well as the participants' behavioural changes in walking. In the second data collection, the findings were verified and the relationship between the qualitative patterns was specified using an interview-based questionnaire collecting data from a larger sample (32 participants). Excel was applied to calculate answers to the questionnaires, and the qualitative information obtained from the interview were transcribed and categorised to further interpret the outcomes of the questionnaire.

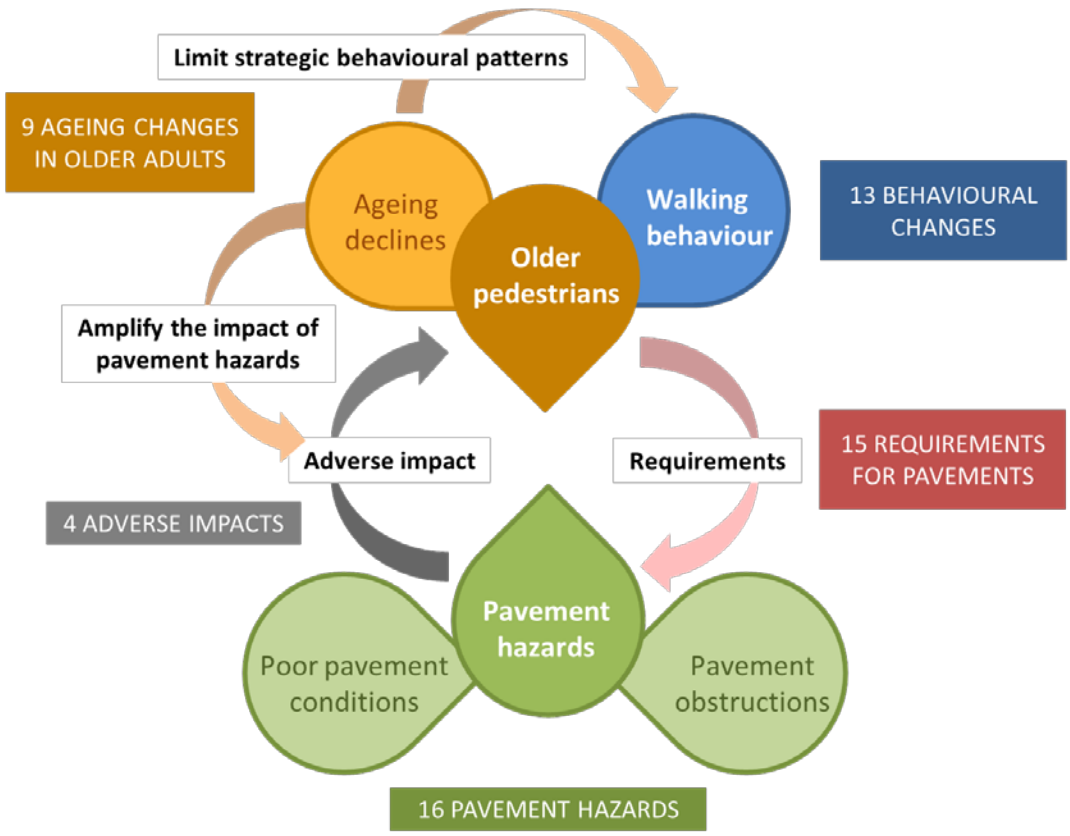


Figure 4-20. A framework of main empirical findings.

From the analysis, the relationship between the pavement and older adults was clarified by identifying significant problems with the pavement and notable walking behaviour of older adults and by seeking older people's requirements for pavements. Figure 4-20 categorised 16 pavement hazards and grouped them into poor pavement conditions, such as uneven surfaces, broken pavements, slops, and confusing paving patterns; and pavement obstructions, such as slippery surfaces, street amenities, cyclists and overgrown trees. These pavement hazards mainly lead to four adverse impacts on older pedestrians. For example, uneven pavements and sloping ground could increase the risk of falling and bodily pain to older adults. Cyclists riding on pavements and narrow pavements could limit older people's view or walking. Older people had to adapt their gait patterns or change their behaviour to deal with those hazardous issues. There were 13 behavioural changes in walking have been analysed in the study. For example, older people slowed down their walking speed, stepped aside or raised their legs higher to avoid uneven surfaces or slippery pavements. When overhanging tree branches extended into the pavement environment, elderly pedestrians lowered their head to walk through the area or walked on the outside of the pavement. However, as people age, their walking behaviour and performance could be influenced by ageing deficits in physical conditions (Webber, Porter and Menec, 2010). This study identified that nine physical declines in elderly people were significantly evident, and they could influence the walking behaviour of older people. For instance, the falling risk and physical burdens caused by pavement hazards could be more likely happen to older people due to ageing declines in older adults' vision and walking ability. The age-related bodily pain makes senior adults have difficulty lifting their legs or bending their neck to lower their head to cope with pavement hazards. Taking step further, this has created 15 guidelines on age-friendly pavement environments according to older people's walking behaviour and their needs. For example, an age-friendly pavement environment shall provide wide, clean and pedestrianised pavements with well-maintained and appropriate plants. These research results were compared with other studies such as guidelines from the UK urban or transport departments.

5 Research development (PS-I & DS-II): primary design and expert review

5.1 Introduction

This chapter introduces a transitional period developed from the primary data collection to the design concept of a research tool in response to RQ4 and to achieve RO4, RO5, and RO6:

RQ4: How to involve older adults in the process of developing pavements in their neighbourhood?

RO4: To review relevant guidelines and principles of product design, graphic design, and interface design.

RO5: To translate the results of the empirical study into a toolkit for researchers to investigate pavements and improve the pedestrian environment for older adults.

RO6: To develop the toolkit by collecting various expertise from an evaluation study with stakeholders from different fields.

Following the empirical study, perspective study I (PS-I) was carried out to explain how the findings of DS-I were applied to develop a toolkit and descriptive study II (DS-II) was undertaken to enable the toolkit to be review and developed by collecting expertise. The tool was designed to help researchers build an age-friendly walking environment and to have a better understanding of the relationship between pavement conditions and older pedestrians. The tool composes of a database and 16 locating marks. The database is used for researchers to recognise hazards of pavement environments and their impact on older pedestrians and to deal with the problems with practical solutions. The locating marks represent the pavement hazards identified in the empirical study, and they allow researchers to explore issues in the real-world pavement environment. Eight academics, who had an expertise in pedestrian environments, built environments, ageing studies, or design approaches, have been invited to evaluate the tool and to give suggestions on the future development of it. According to their feedback, the database presents new knowledge of the pavement and walking behaviour of older pedestrians based on the empirical study sampling senior adults. However, the tool needs to be improved to be more practical and useful regarding the needs of users.

5.2 Primary design concept (PS-I)

After the data collection, the research sough how the empirical findings could be practically used to encourage people who work on environment development to be more aware of the correlation between the walking environment and senior pedestrians. Additionally, it intended to give a chance for older people to be regarded in pavement projects. Many concepts including guidelines, checklist, methods, and tools were though of regarding the purpose. As it was difficult to decide a design format before further identifying user needs (Blessing and Chakrabarti, 2009), a toolkit consisted of a database and a group of locating marks collecting guidelines and checklist was developed on the outcomes and the theoretical framework obtained by DS-I (see Chapter 4.18). It enables users to have a systematic view of pavement hazards and their impact on older adults as well as elderly people's walking behaviour and walking needs to the pavement.

5.2.1 The database

As there had been a systemic database of the empirical findings created in last chapter, it was used directly by the toolkit to assist users, such as urban planners and city designers, to get knowledge of pavements and walking behaviour, to develop pedestrian environments, and to maintain pavement quality. The database was made up of a brochure and a card pack. The brochure was divided into five sections incorporating descriptions, checklist, and guidelines of (1) the background of the study, (2) introduction to the toolkit, (3) older people's preference of daily walking, (4) hazards of pavements, (5) older people's walking behaviour and past falls, and (6) improvements in the pavement.

The card pack includes 16 single cards representing the 16 pavement factors categorised in DS-I. Cards are widely used in design toolkits, such as YangoCards designed by Deng, Antle and Neustaedter (2014), VizitCards made by (He and Adar, 20170 , and TilesCards created by Mora, Gianni and Divitini (2017), as they can describe complex concepts in a more effective way and display theoretical knowledge to practical guidelines and insights. The card pack was created to explain the specific relationship between each pavement hazard and older pedestrians by clarifying the characteristics and problematic impact of the issue and presenting behavioural changes and requirements of older people associated with the hazard.

The content of the database is displayed using infographics and figures as they were found to be the best approach to visualise messages for easy communication and understanding (Chen, 2010; Smiciklas, 2012; Dewan, 2015). Colour coding was applied to distinguish different sections of the database to guide users to follow up the information. More details of the database can be found in Appendix VI.

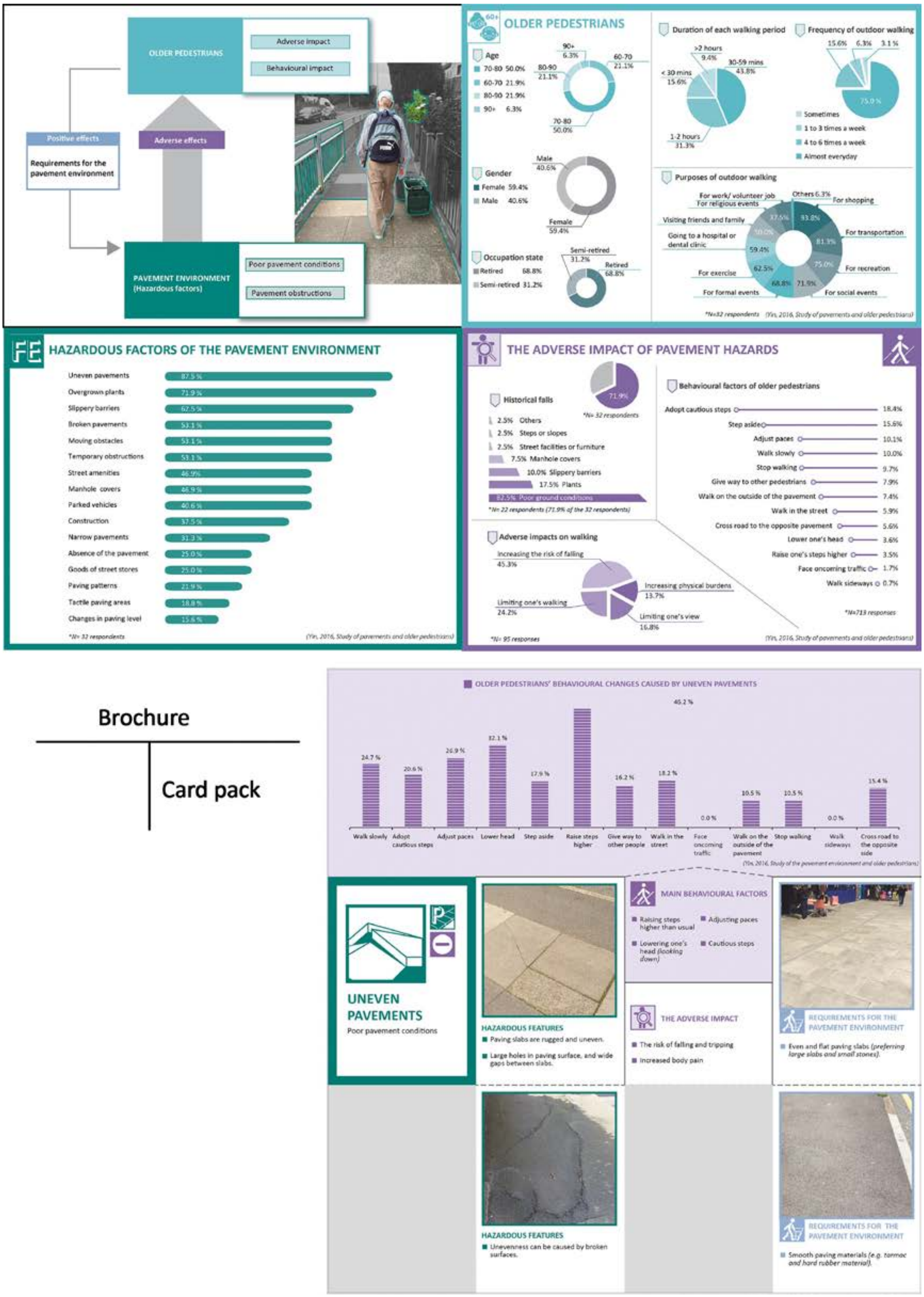


Figure 5-1. The database: the brochure and the card pack.

5.2.2 Locating marks

The tool also enabled researchers to undertake a map-based assessment using 16 locating marks with older pedestrians included. The locating marks made by symbolising the typical characteristics of the pavement factors identified by DS-I. They were designed according to the guidelines built by Adîr, Adîr and Pascu (2014). Therefore, the locating marks were presented in by simple, relevant, distinctive and legible symbols, and colour coding was employed again to keep a coherence in design. Maps would be used because a map-based presentation allows decisions to be made effectively by demonstrating localise environmental factors in a context (Dennis and Carte, 1998; Meyer and Filliat, 2003; Ziegler *et al.*, 2014). Also, mapping can foster the participatory and interactive process to include local people in developing their community (Lienert, 2019). For example, Harava (Sitowise, n.d.), which is a simple integrative map-based survey tool, helps city planners to make effective and sustainable decisions of building a better living environment in regard to resident needs. However, Ziegler *et al.* (2014) found that map-based exercises can only be practical by using a specific and locally associated map. As researchers may use the tool to investigate different pavement environment, it is not possible to provide a physical map presenting a fixed location. Therefore, this tool would require researchers to prepare a customised map rather than providing a map to them. The map should be printed in a proper scale size displaying the names of regional roads, landmarks and buildings clearly.

To conduct the map-based study, researchers are recommended to recruit older adults from the local neighbourhood to carry out the study individually. Using the locating marks, researchers will ask participants to pinpoint hazards of pavement environments on the map. Next, the researchers will record the number of hazardous locations and note what the type of the hazards, how many of those hazards exist in the pavement environment, and how many participants repeated the same issue. Based on the map-based presentation, researchers can prioritise significant issues by calculating the repetition of each hazard and work out solutions. After the assessment, researcher can further analyse the map-based results using the information presented by database.

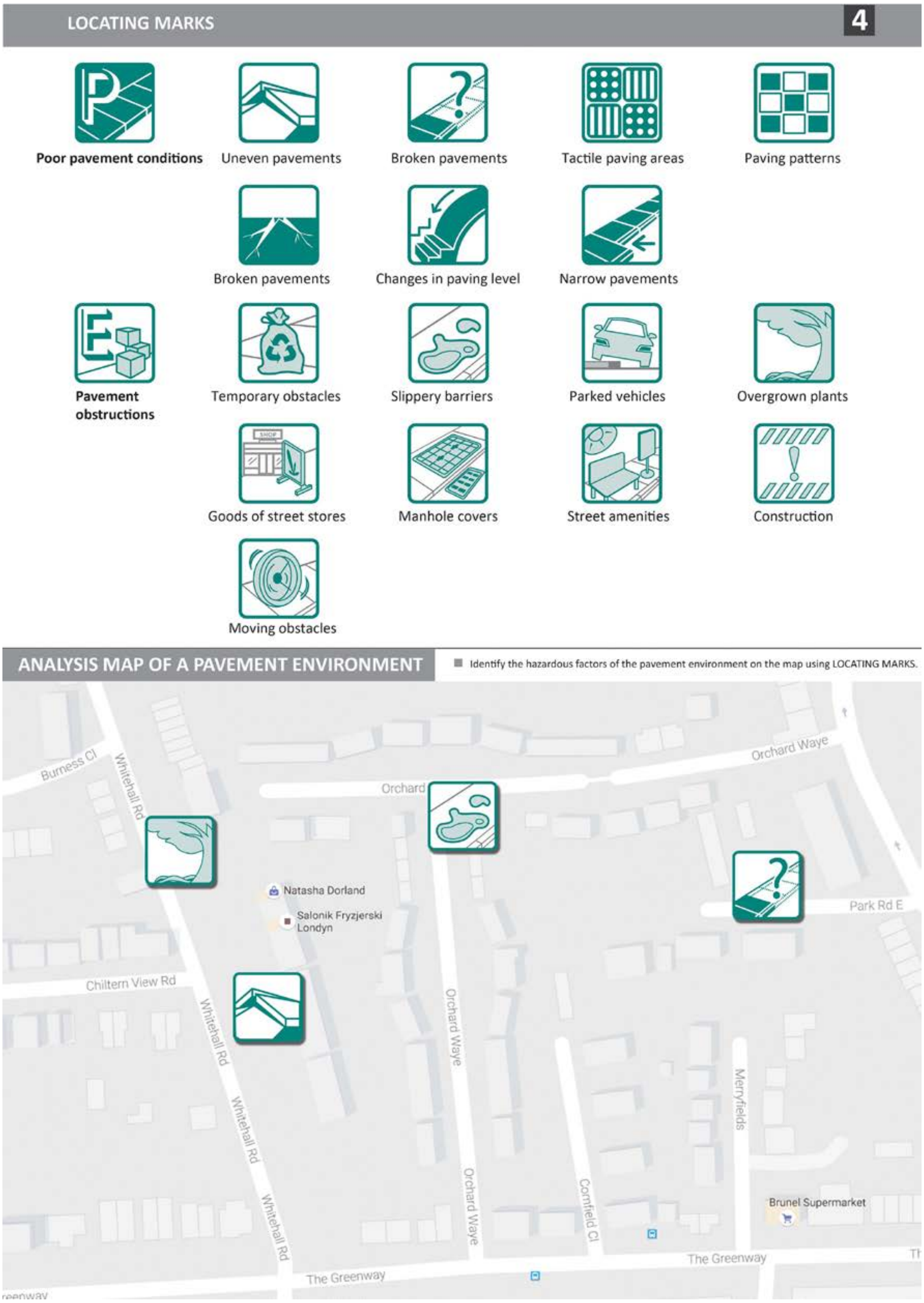


Figure 5-2. The map-based assessment conducted by locating marks on a 1:5000 map (a print of Google Maps).

5.3 Expert interview (DS-II)

The toolkit was an initial concept and many aspects of it needed to be reviewed and clarified with expertise from various fields before being further developed. An expert interview was conducted with eight experts to evaluate the content and design of the tool and seek its potential development. User interviews are mostly adopted to develop a design solution (Stenmark, Tinnsten and Wiklund, 2011), and the participation of experts assist the study to receive more reasonable, authoritative, correct and skilful comments (Libakova and Sertakova, 2015). The interview was carried out individually so that the experts could share deep views on the tool without being interfered by other participants (Guest, Namey and Mitchell, 2013). IDEO (2011) provides guidelines of how to prepare an expert interview step by step for the design research. According to the guidance, the study was designed by:

1. Selecting the experts associated with the study;
2. Providing information to the experts prior to the interview to let them know the query range, tasks, and duration of the interview;
3. Being flexible to question the experts and avoid the similar and repeated views;
4. Thinking of the questions expected in the study and paying attention to the extra information.

5.3.1 Participants

The experts were invited according to their education, expertise, and work experience that related to the study topic (Libakova and Sertakova, 2015). Eight experts who were scholars working in higher-education organisations were selected for the interview and they had made a remarkable contribution in both related academic and industrial areas. Some of them also had an influence on the policy and decision-making of the built environment. In this case, they were able to judge the content, design, usability, and usefulness of the toolkit and give recommendations for the tool from a professional angle.

As Table 5-1 shows, the experts were from four different professional domains including ageing studies, built environments, public transportation, and design field. Expert 1 worked on physical and psychological reactions of older adults in the built environment. He was invited because he had knowledge of walking among older adults and expertise of the relation between walking and physical environment, whereby he could help to examine the content of the tool. Expert 2 was involved in projects of maintaining and assessing the quality of highways and pavements, and he could give more comments on the section of pavement hazards and the map-based study. Expert 3 was skilled in design thinking, product development, and social innovation. So, she was invited to evaluate the tool from the aspect of design and user behaviour. Experts 4 focused on measuring the accessibility of the built environment for older people, the disabled, and wheelchair users. Expert 5 worked on people's behaviour in the interactive environment and the influence of street lighting on travel behaviour. So, the two experts were included as they could share more insights with environmental factors and impact on the walking activity of older pedestrians. Expert 6 developed inclusive toolkits for designers to learn about the ability and mobility of the senior population and people with disabilities. She could test the toolkit based on her research knowledge of older people's physical behaviour and conditions. Expert 7 specialised in person-environment interactions and the decision-making of built environments. Expert 8 concentrated on policy analysis, accessibility, travel behaviour, and public transport planning. So, the reason of inviting the last two experts was that they might be interested in find out if the tool could clarify the relationship between pavements and older pedestrian or if the tool could assist with the development of built environments and transport environments.

Table 5-5-1. Experts in the interview (n=8 people)

Domain	Profession
Ageing studies (n=1)	**Expert 1** – Impacts of the built environment in the physical and psychological aspects of older people
Built environment (n=3)	**Expert 2** - Performance and design of highway and pavement **Expert 5** - Lighting and interactive environments **Expert 7** - Person-environment interactions and decision making

Transport (n=2)	**Expert 4** - Accessibility of the built environment for the disable road users **Expert 8** - Travel behaviours, public transport system and accessibility of the build environment
Design (n=2)	**Expert 3** - Design thinking and social innovation **Expert 6** – Inclusive design toolkit

5.3.2 Methods

In line with Blessing and Chakrabarti (2009) and the CDC (2011), the tool was evaluated by discussing their input, exercises, outputs, and outcomes. Meanwhile, the experts were asked to test if the tool components were efficiently used, or if the tool provided a clear introduction and proper supports, or if it could meet the users' needs. Based on the objectives, the interviews raised ten open-ended questions to the experts:

1. Does the concept present clear, specific, or useful content (information)?
2. What is your comment on the design of the components?
3. What is your feedback about the usability of the tool?
4. Will you apply the components to your work?
5. How will you use the database or locating marks?
6. Which material is the most useful?
7. What aspects of the concept needs to be improved?
8. Who else could be interested in the components (potential users)?
9. What other information can the tool provide?
10. Do you have any other suggestions for the tool?

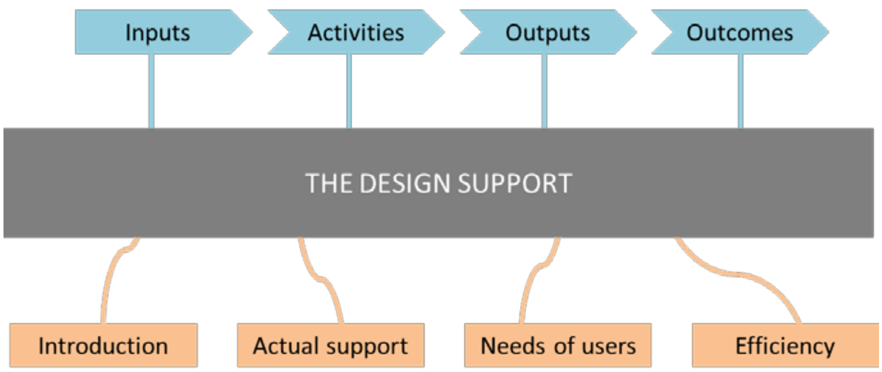


Figure 5-3. Criteria of the initial evaluation, adapted from Blessing and Chakrabarti (2009) and CDC (2011).

5.3.3 Analysis and results

The experts' comments were taken down by a recorder and a notebook. The original scripts were transcribed and encoded with the use of NVivo. The coding process was made up of two phases including concept coding and axial coding. Concept coding allows the original data collected from the interviews to be fully coded into small fragments according to the meaning of the information, and axial coding can further classify the coded evidence based on the similarities and differences among the data (Saldaña, 2016). Therefore, concept coding was adopted to initially code the information before the data was entered into the axial coding. In the concept coding phase, extensive concept words or phrases namely 'graphic design', 'presentation', and 'decision makers', were generalised based on the interview answers to code the collected data. The coded evidence was further categorised into seven groups of 'information', 'design', 'stakeholders', 'utilisation', 'components', 'application', 'stakeholders', and 'suggestions' in the second stage of coding (axial coding). Relations between the sub-categories found in the first coding stage and the core categories identified in the second coding section were elaborated in the coding process where significant phenomena could be interpreted (Benaquisto and Given, 2018).

Table 5-2 shows that 175 references were identified in the study and they were classified into seven categories comprising 46 nodes for 'information', six nodes for 'design', 14 codes for 'utilisation', 17 codes for 'components', 19 references for 'applications', 20 references for 'potential users', and 53 codes for 'suggestions'. The largest amount of codes was associated with the content of the tool and the recommendations for the toolkit while the least comments were given on the design of the tool.

Table 5-2. Results of the expert interviews (n=175 reference)

Category	Reference	Sub-category	Reference
Information	n=46	Positive	n=20
		Negative	n=26
Design	n=6	Layout	n=2
		Graphics	n=3
		Presentation	n=1
Utilisation	n=14	Positive	n=2

		Negative	n=12
Components	n=17	Card-pack	n=5
		Locating marks	n=12
Application	n=19	Contributions	n=12
		Limitations	n=7
Potential users	n=20	People who involve in designing or planning environments	n=12
		Decision makers	n=3
		Others	n=5
Suggestions	n=53	Information	n=24
		Usability	n=13
		Design	n=13
		Format	n=3

5.3.3.1 Information

Both positive (n=20) and negative feedback (n=26) were given by the experts concerning the information on the tool. All experts found that the database provided useful and specific information and clarified the relationship between pavements and older pedestrians based on older people's perceptions. They felt that the database was the most useful material for them to look into details about pavement hazards and their impact on older people according to the priorities indicated by infographic. Also, the card pack described a more specific relationship between different pavement hazards and older pedestrians. The experts commented that:

> "I think the tool provides useful information depending on who are the users…it is a good level to show information to people who are building the pavements…the study provides clear data based on the participants' perspectives…it shows a lot of specific content, especially the cards…the study and information are very useful and the original analysis and descriptions are good…it does provide useful information especially in the identification of hazards…it explains each feature of the pavement and gets further sights from elder people…some of the methods are quite interesting and I will focus on the technical things or physical texting…because as a

> designer, that would be very important information to understand the real perception of the pavement users, especially the venerable road users."

On the other hand, six experts, except Expert 5, reported that the rich information influenced the usability of the toolkit, and the relationship among the components was unclear. The negative feedback on the content were that:

> "I think it's (information) too rich…maybe too much information for some users who are not interested in all contents…I'm not sure how this [behaviours] particularly related to the pavement…It seems that they [users] have to digest the complicated information, but they only want to identify the hazards and get universal solutions…to establish a relation between different sections would be challenging…the information is clear on its own but together it needs a clear order…the information is quite hard to understand and very hard to apply…the per cent of negative features need to be explained…if you want to collect someone's perception very quickly, there is probably too much information."

5.3.3.2 Design

Regarding the design of the concepts, three aspects including the layout (n=2), graphics (n=3), and presentation (n=1) were evaluated by the experts. Expert 1 and Expert 3 said that the layout was poorly designed, the connection between each component was confusing and the infographics were complicated, and hence 'the arrangement must be streamlined and in an order…the navigation of it needs to be improved.' Even so, the other experts held a different view that they felt the design was consistent and it assisted them to use and to engage with the components. For example, they indicated that 'the design is brilliant and very good…the arrangement of each section is good…the connection of each section works…that really logical…really makes sense…the form of pins and map is quite engaging…the infographic in general looks attractive but you just need to make sure people can understand it'.

5.3.3.3 Utilisation and components

Some interviewees (Expert 2, 4, 5, 7 and 8) indicated that the tool was relatively easy and the whole view was effortless to follow. Regarding using each part of the toolkit individually, the experts gave more positive feedback. According to their feedback, the card pack (n=5) and locating marks (n=12) were the most important materials and they were more useful and original. Those experts indicated that:

> "all of the parts are useful, and the most important part is the database [database] to give a big picture to users…the card is useful in providing information…the card is quick to summarise the negative features of pavements, and useful for people who don't understand the environmental issues…the map is useful to highlight the areas where there are hazards…the analysis map is fun…the analysis map is more useful to deliver the study findings or for different users to generate ideas."

In contrast, using all components together as a whole toolkit was confusing, and it made experts spend more time to figure out the rationale of the tool. The negative reviews on the usability from Expert 1, 3 and 6 included that:

> "the concept needs to explain what to do with each component…I'm not sure how could we use it [map] with the database to inform the thing like what we are going to do…the card is easy to use, however, the rest of the parts as I said are hardly to be used purely because they may not practical in pavement design...the map is too 'noisy' and took me a long time to understand the process…I think it is useful to show the relationship, but I just think it's hard for people to follow the order."

5.3.3.4 Applications

The experts found that the components could be useful for people to conduct a research on pavements, plan built environments, investigate problems, and work out the issues. Expert 2, 4 and 5 showed more interests in the tool and they would apply it in their work and recommend it to other users. Their opinions showed that:

> "the translation of the information would lead or influence the decision process…for urban designers, you can use it to talk with the community…they probably use the materials with residents together to do something…it would be a tool to help people to do co-design…the results of this study have a potential to be applied in master student's projects…I would use it as a teaching tool to get students to think…as a way of a stimulation tool for them to observe people by following the guideline or suggestions…the concept is very good for academic papers… if you want to do research with the locating marks, it is brilliant and very detailed…I would use the map and cards if they have a digital version…The database is useful for learning about pavements, however, it needs to find a correct area to apply…I would mention it to people who are urban or environment designers…it needs to be developed a little bit further, but it has some potential."

However, Expert 6 and Expert 7 were sceptical of the concept in conveying practical outputs or the decision making. The explanation of their views was that:

> "we could use the marks to highlight the hazards but how can we make decisions with them…I'm not sure what can be done with the existing factors".

5.3.3.5 Potential users

Regarding the potential users or stakeholders (n=20), all experts came to an agreement that people involved in the environmental design and planning would certainly employ the tool to build pavements and transport environments, to construct pedestrian places and to develop communities and cities (n=12). Decision makers (n=3), such as local councils, might also be interested in the identification of negative problems with the pavements. Other people (n=5), such as academic researchers, students, and people who were unfamiliar with the pavement, could be alternative users using the tool for reference or adopting it as a study tool to explore neighbourhoods.

5.3.3.6 Suggestions

The experts also gave varied suggestions on the tool regarding its disadvantages and possibilities. Most ideas were generated regarding dealing with the plentiful information (n=24) and improving the usability (n=13) of the toolkit. The experts advised that the tool should be simplified by reducing the information, dividing the database (the brochure and card pack) into small parts and clarifying the connection between each component. To be more specific, they indicated that:

> "you don't want to give people too much information because, as a tool, you want to give information as little as possible…you can provide some information in a booklet and if people want to read it, they can read it, if they don't want to read it, then they can choose, they don't need to use it…not everyone would be interested in what are the theoretical findings behind the database…if you want people to analyse the relationship, do you want them to know that [information of the relationship]? If not, can we take that out as a resource...if you put the information together, it may be confusing…that is why you can break them down into smaller parts which make it clear and easy to use…I think the idea of cards is very interesting but it would be better if you separate the positive features and negative features…you can just have one card that helps you to think about like 'moving objects' what are those about…you don't have to put a lot (information) on one card…I think by breaking it down, perhaps to have more cards that may make it easier."

Additionally, the experts recommended that some content of the tool had to be explored more in terms of improving the usefulness of the tool. The tool should include more comprehensive information for users to know what it is about, what users could do with it, how to use it, and why it is important for users. The relevant suggestions from the experts were:

> "the study should provide more practical guidelines with more details…how do people know what the most important thing is and how to cover that in their work…if you give this [the toolkit] to road designers, they want to know

> how can they make the pavement better to older people…they need to know the whole story… I think having a clear summary to tell the things you want to say...and then that would make it easier to read through…identify all potential problems would be useful in raising users' interest in the concept."

The layout, design, and colour (n=13) should also be revised to enhance the usability and effectiveness of the tool. For example, the experts argued that:

> "green is a colour that is very difficult to recognise, especially for older adults…also green is usually a positive colour while you use it for representing negative features of pavements…think about your colour coding…in terms of the content, that should be clear in an order…in terms of the flow, it should be better…the proposal [database] would combine key features of those sections and make one tool and make the connection better…the marks of the map should be more simple and neutral."

In addition to the design idea, the tool could be developed to an investigation toolkit concentrating on the main content of pavements and walking behaviour, and it could offer more options for people to use it flexibly according to their needs and preferences. For example, Expert 6 expressed that:

> "if you want to go further, there should be more options for the users to design the pavement or prioritise different features…I think you may want to design a tool that people may make some changes on it…maybe you can allow people to edit it."

The rest of the advice were given to the format of the toolkit (n=3). Expert 2 suggested developing the tool with a digital map to collect real-time information about pavement hazards from a large population and to show results in time. Nonetheless, Expert 3 argued that a physical form would be more efficient for a cooperative study with local residents and allow users to use a customised map. She explained that:

> "it is not easy to put everything in a digital way…the physical thing that helps to do collaborate things, such as co-design. It doesn't mean everything has to be digital…digital thing is very difficult to do analysis unless you have a big

screen...but you can print it on a big map if you want to do analysis…I think this can be good for idea generation…the users can print it on their own, how big or how small they want it to be.”

5.4 Discussion

According to the study results, the tool was an original design and it provided plenty of views from a new angle as there was a lack of approaches using a sample of older pedestrians to study physical outdoor built environments based on a map. According to Mallery *et al.* (2012) and Peters (2016), the participation of elderly people can expand researchers’ understanding of study topics and trigger new ideas. The tool offered a better understanding of seniors’ perceptions of the pavement that helped users to think about what the impact of the pavement would be and what they could do with it. The card pack and locating marks individually received more positive comments from the experts as the two materials were found to be useful for experts to generate ideas and to identify pavement hazards and their correlations with older pedestrians. Many card-based tools, such as VizitCards designed by He and Adar (2017) and Tiles made by Mora, Gianni and Divitini (2018) have identified that cards were effective materials for idea generation and brainstorming. Most experts agreed that the design format and colours were well used to organise different sections. However, the connection between each section of the tool was confusing, whereby it was suggested to be optimised by coding the tool materials with different colours. Colour coding allows different parts of the toolkit to be more distinct from each other and enables users to better identify particular items (MacDonald, 1999; Opara and Cantwell,2013). The information and indications of the tool were also the main points that influenced and limited the usability of the toolkit. The tool provided superabundant information which were useful for people to learn about the study topic; however, it was time-consuming to understand all of the information in a short time. To improve the usability of the tool, the database should be broken down into smaller sections with little data presented in each part. On the other hand, although there was a mass of information given to users, the experts felt that additional explanations of the infographics and checklist shown by the database and the map-based assessment needed to be further explained. Additionally, experts indicated that key messages and instruction were absented from the tool making them confused about how to use the tool to conduct a study. In parallel with Cassidy and Ball (2018), essential information namely objectives, rules, function, tasks, and output of the tool had to be clarified to assist users with the data collection and data analysis. In addition to the improvement, a digital tool was recommended by an expert for an efficient use. However, older people could be more likely to resist an online digital application as they have more difficulties in using digital technology (Van Cauwenberg *et al.*, 2012) and they are afraid of making mistakes or releasing their personal information via internet (Knowles and Hanson, 2018). In view of the elderly users, it has decided the tool would remain a physical prototype in future. An expert explained that a physical tool could make the co-study between researchers and older adults easy and flexible by using a printed and customised map.

As to the usefulness and application of the toolkit, the experts found that the database might be less helpful or effective for experienced engineers or urban designers to make decision or to generate ideas. However, they saw the potential development of the tool from the idea of the map-based study. They suggested developing the tool to a map-based investigation tool to allow researchers to go further in exploring problems, seeking new findings, analysing data, dig into evidence, and developing outcomes according to their preference and professions. Target researchers of the toolkit could be people who engage in designing, planning and maintaining pavement environments, such as urban planners, pavement designers, road engineers, and local councillors. In addition, although the map-based study enabled researchers to make quick decision, researchers were unsure about how to further develop and explain the results of the map-based. They suggested that to have older people fully involved in the process of identifying problems and creating solutions using different parts of the toolkit, so that they could understand the needs, walking experience, and walking hazards of senior adults and interpret findings with more specific details (Minkler, 2005).

5.5 Summary

This chapter described how a tool was initially developed based on the results of the empirical study. It aimed to encourage people who were pursuing the design, planning and maintenance of built environments to better understand the relationship between the pavement environment and older pedestrians. The tool comprised a database and 16 locating marks. The database included a brochure and a card pack with plenty of information about pavement issues and their effect and the walking behaviour and walking needs of older pedestrians presented. The locating marks allowed researchers to do a map-based assessment with older pedestrians locating hazardous factors of the pavement on a customised and localised map prepared by researchers themselves. The tool was then reviewed by eight experts regarding the usability, design, information, and potential advancement of the components. According to the expertise, the tool was useful and it provided rich data and novel findings on pavement conditions and their impact on walking in older adults. Also, it allows researchers to learn about the study topic based on older people’s opinions, walking experience, and concerns for the pavement. Nevertheless, the information was too heavy and principles of the tool and the connection between different parts were unclear. Additionally, the tool was less useful or effective for experienced users to come into decisions or ideas. However, it could be developed to a map-based investigation toolkit helping users to look into desirable data deeply and to expand their work with the tool outputs. The next chapter will give a more specific introduction to the further development of the toolkit.

6 Participatory study toolkit (section one of PS-II & DS-III): design and evaluation

6.1 Introduction

This chapter continues to identify the answer for RQ4 and carry out RO4, RO5 and RO6 by describing how the primary design concept was developed to a participatory study toolkit in section one of prescriptive study II (PS-II) and how it was tested by users in the first stage of descriptive study III (DS-III).

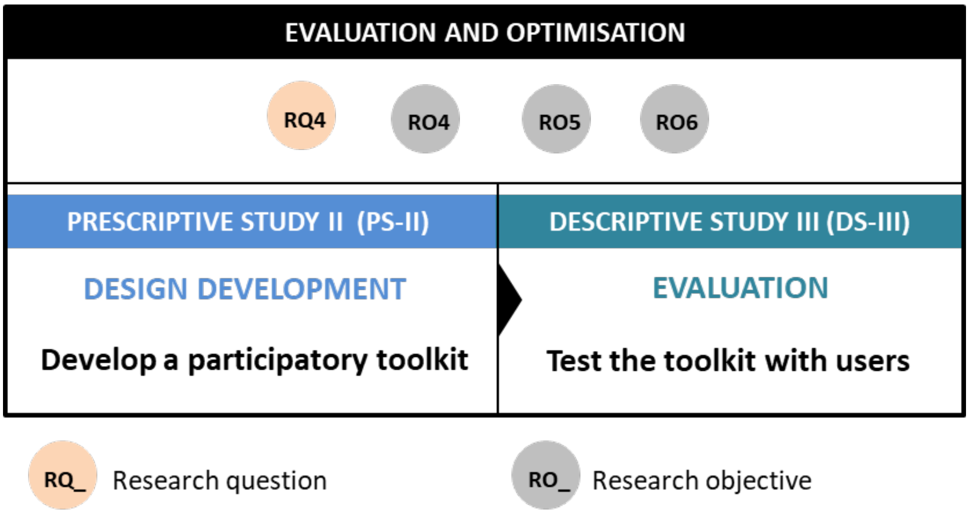


Figure 6-1. Aim of prescriptive study II and descriptive study III.

Based on the feedback from the scholars in the last study (in Chapter 5), the toolkit has been refined to assist researchers who are involved in planning pedestrian environments to assess and improve pavement environments for older pedestrians regarding their walking needs. The researchers can use the tool to arrange a group study with older adults being involved as study participants. In the study, the tool allows users to look into problems with pavements, identify the hazardous impact of the pavement, and explore older people's walking patterns associated with pavement hazards and come up with recommendations to improve the quality of the pavement. Several draft versions of the toolkit have been created to visualise the toolkit, and the latest design has been tested by target users in five workshops examining the usability and efficiency of the tool. Each workshop was undertaken by a researcher with two elderly participants. There were five researchers and ten participants recruited to the study. In addition, the study adopted purposive sampling to ensure diverse user needs and problems with the toolkit could be identified. The researchers were assembled from a higher education organisation, and they pursued a project regarding the built environment, inclusive design, or ageing mobility that were associated with the content, design, and output of the tool. The elderly participants were made up of ten London residents who were older than 60 and familiar with local pavement environments. Based on the workshop, an observation was carried out to monitor user actions; and an evaluation questionnaire was given to the researchers and participants to collect their feedback on the toolkit. The response rate of the questionnaires was calculated by counting the answers to each option of the questions, and additional qualitative information was discussed to further explain the questionnaire result.

The feedback from the workshops showed that the toolkit was easy to learn, the information was extensive and relevant to real problems with the pavement. The tool enabled the users to identify significant problems and solutions based on the data collected from older people. The result of the study conducted by the toolkit presented many similarities with the previous findings (DS-I). The researchers could develop their works, create a report of the pavement, deliver design guidelines for the pavement and further examine significant issues based on the study outcomes. However, the tool was requested to be improved regarding the design, instruction and connection between different sections. Also, the efficient interaction between users needed to be built up by the toolkit.

6.2 The rationale of the toolkit

To design the tool appropriately, a specific guidance of designing the tool was adapted from the findings and expertise obtained in DS-II (expert interview):

a. The tool shall be easy to use.
b. The tool shall be well-organised regarding colour and layout.
c. The tool shall deliver its main message and shows information in a proper way.
d. The tool shall enable users to know what they can do and how to do it.
e. The tool shall provide an efficient method to collect data.
f. The tool shall ensure users do appropriate exercises.

g. The tool shall assist users to identify problems and get solutions.
h. The tool shall enable the collected data to support researchers in their field and to expand researchers' knowledge.

The toolkit would provide an efficient way for researchers covering local councillors, urban planners, environment designers and pavement builders to conduct a study of hazardous factors and impact of the pavement environment. The study would be carried out based on a customised map of local pavements prepared by researchers. The map should be printed out in an appropriate scale (e.g. 1:2000 or 1:5000) and size (e.g. A2 or A1) to zoom in a specific pavement environment so that participants can localise hazards in correct sites on the map and researchers could conduct focused work on pavement development. Senior adults had to be involved in the study as participants to expand the meaning of data and to enhance researchers' understanding of the study topic. Therefore, the toolkit aimed to foster a participatory study (Massimi, Baecker and Wu, 2007) to allow older people to share their walking experience and perspectives on pavements. Perttula, Krause and Sipilä (2006) and Shih *et al.* (2009) found that more ideas could be generated between people when they share their individual opinions in a group. Therefore, the study will be conducted with a group of participants using the tool. The group shall include the maximum of six senior adults who have to be aged over 60 and able to engage in walking. The size of a focus group usually range from six to twelve (Guest, Namey and McKenna, 2017), and a mini group of six is easier to organise and to make participants feel more comfortable in group discussion (Krueger and Casey, 2015).

6.3 Version 1 of the participatory study toolkit

According to the discussion of the last chapter, version 1 continues developing the card pack and locating marks created by the initial design as well as the map-based assessment. In this way, the materials and exercise were found to be similar with those of a board game which usually provides dices, cards, boards, standpoints, and roles for users to play a map-based game (Kwiek *et al.*, 2007). Board games have been used as a research strategy for a group of people to effectively share and generate ideas in a more playful and easier way (Kultima *et al.*, 2008; Slegers and Duysburgh, 2015). Therefore, the design, principles, and rules of board games were adopted to create version 1 of the participatory study toolkit. In addition, the presentation of version 1 was created using suggestions of Kurniawan and Zaphiris (2005) on developing an interface for older adults that request designers to provide a simple, clear and coherent layout. Finally, version 1 was formed by consisting of a card pack, six handbooks, and six recording cards using white and black as background colours.

6.3.1 The card pack

The card pack offers 16 pavement cards demonstrate the 16 pavement hazards and their sub-categories classified in DS-I using photographs and descriptions. Almost all the pictures were obtained from the observation of the empirical study while the conditions that were not captured from the study were illustrated by online references. The cards can be used by researchers as a reference or can be employed to engage participants in the collaborative process and to foster group discussion and idea generation (Brandt and Messeter, 2004; Hornecker, 2010). More details of the card pack can be seen in Appendix VII.

Figure 6-2. The card pack: pavement cards.

Figure 6-3. The presentation of pavement cards.

6.3.2 Handbooks

Cards are usually the most essential part of a board game as they can encourage people to generate more ideas (Hornecker, 2010), thereby cards were adopted by version 1 for participants to indicate their answers and opinions in the study. The handbook was designed as a card set and there are six handbooks separately designed in a colour (see Figure 6-4). Each handbook collects (see Figure 6-5) two role cards in two genders and 63 stripe cards formed based on the findings of the empirical study (DS-I). The stripe cards are classified into five topics according to the empirical results, namely 1) Poor pavement conditions (seven factor cards and three customised cards); 2) Environmental obstacles (nine factor cards and three customised cards); 3) Negative effects of the pavement factor (four factor cards and three customised cards); 4) Behavioural changes of participants (13 factor cards and three customised cards); and 5) Recommendations for coping with the hazardous factors (15 factor cards and three customised cards). Card group 1 (pavement conditions) and card group 2 (environmental factors) were designed based on the previous locating marks used by participants to pinpoint problems with the pavement on a map. Card groups 3, 4 and 5 were grouped by three thematic icons, and their cards were coded so that researchers can record study results effectively. Also, the customised cards are offered in order that users can manifest new ideas. All stripe cards are inserted in the handbook and able to be pulled out by participants (see Figure 6-6).

To use the handbook, participants need to indicate their name, age, and gender on the role card so that researchers can further analyse the study results according to the personal information of the participants. Then, they start to identify hazardous factors of the pavement, point out their behavioural factors caused by the hazards and give suggestions to prevent the pavement from the issues. Participants shall indicate their ideas by displaying the corresponding stripe cards on the map. These cards must be placed in specific areas where the pavement hazards exist in the real world. Following that, researchers can identify significant findings and prioritise pavement issues and design solutions by calculating the amount of different card groups on the map.

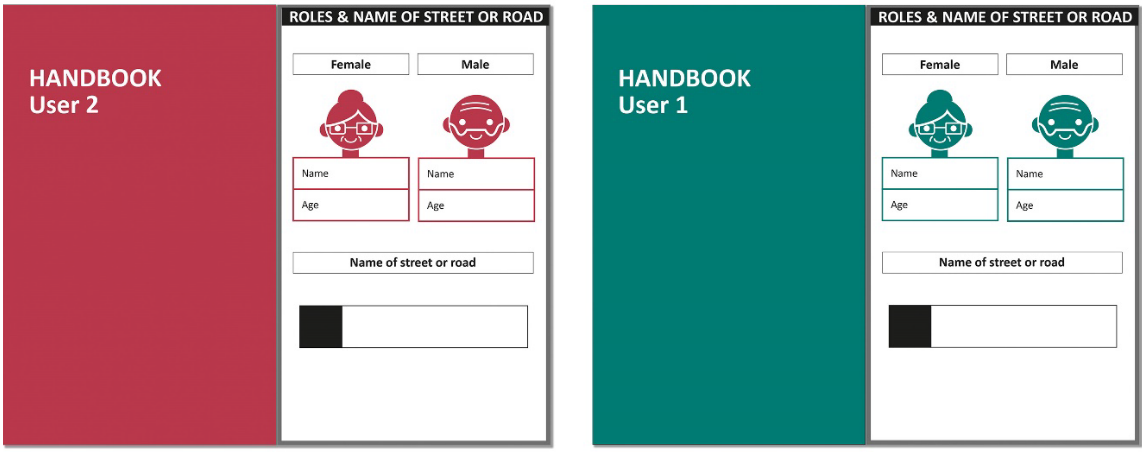


Figure 6-4. Handbooks for study participants.

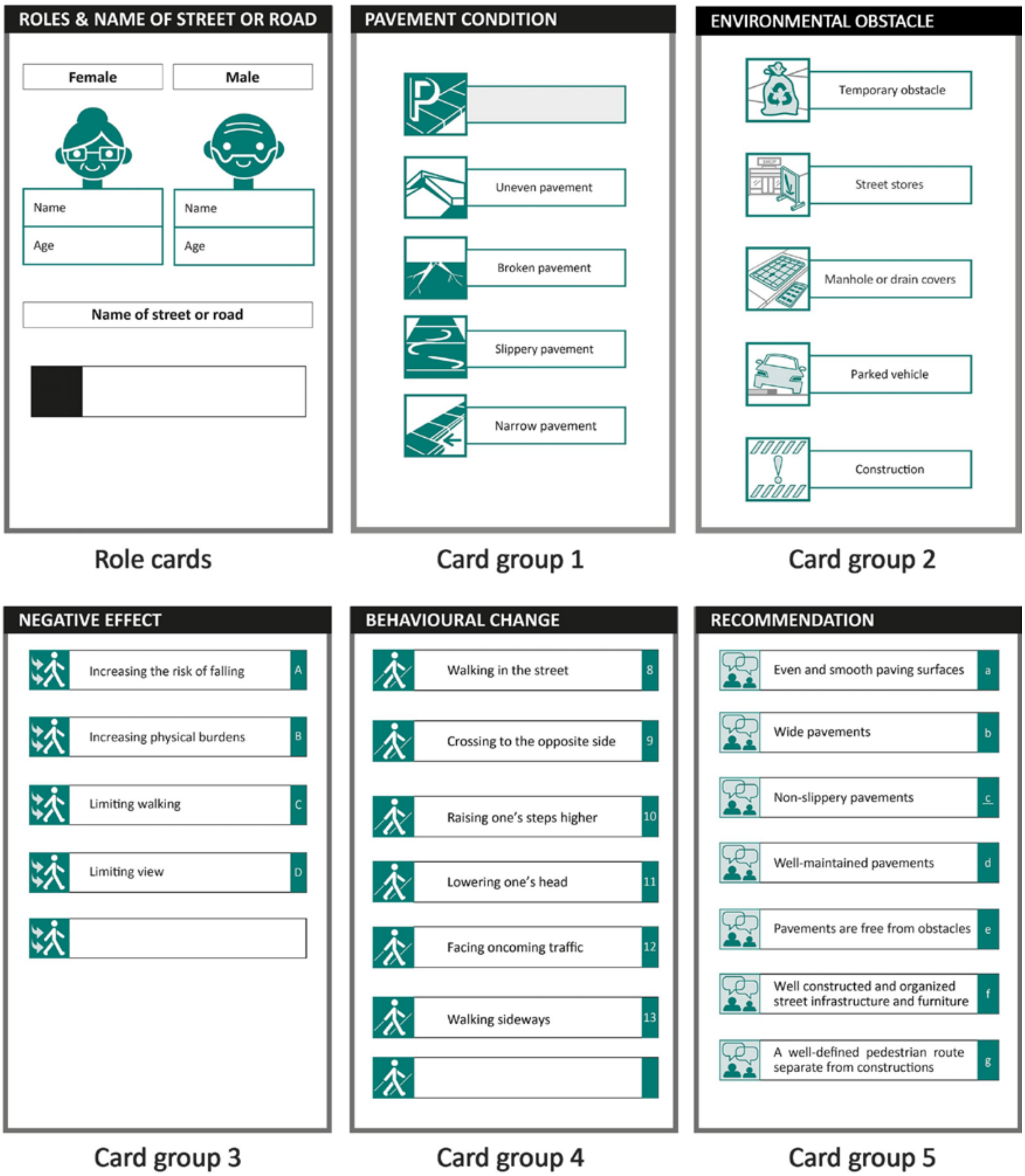
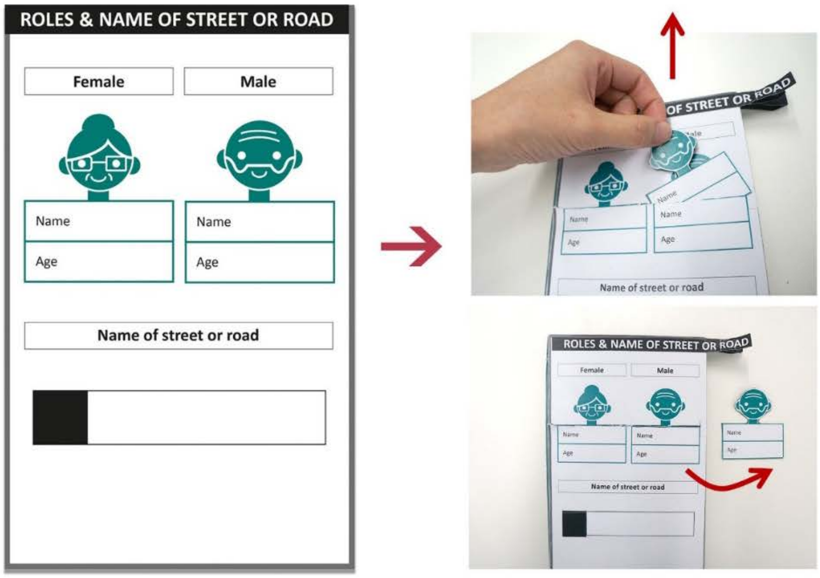


Figure 6-5. Content of the handbook.



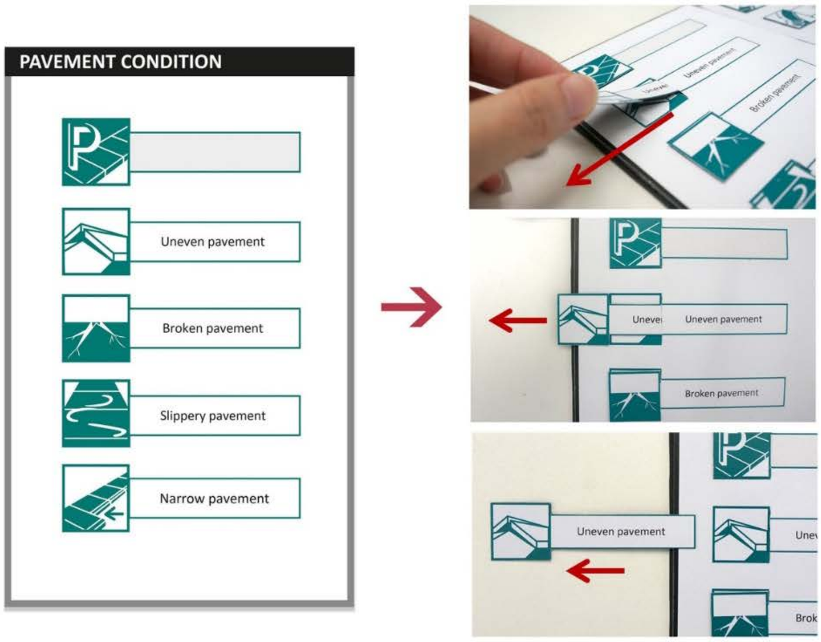


Figure 6-6. Use of the handbook.

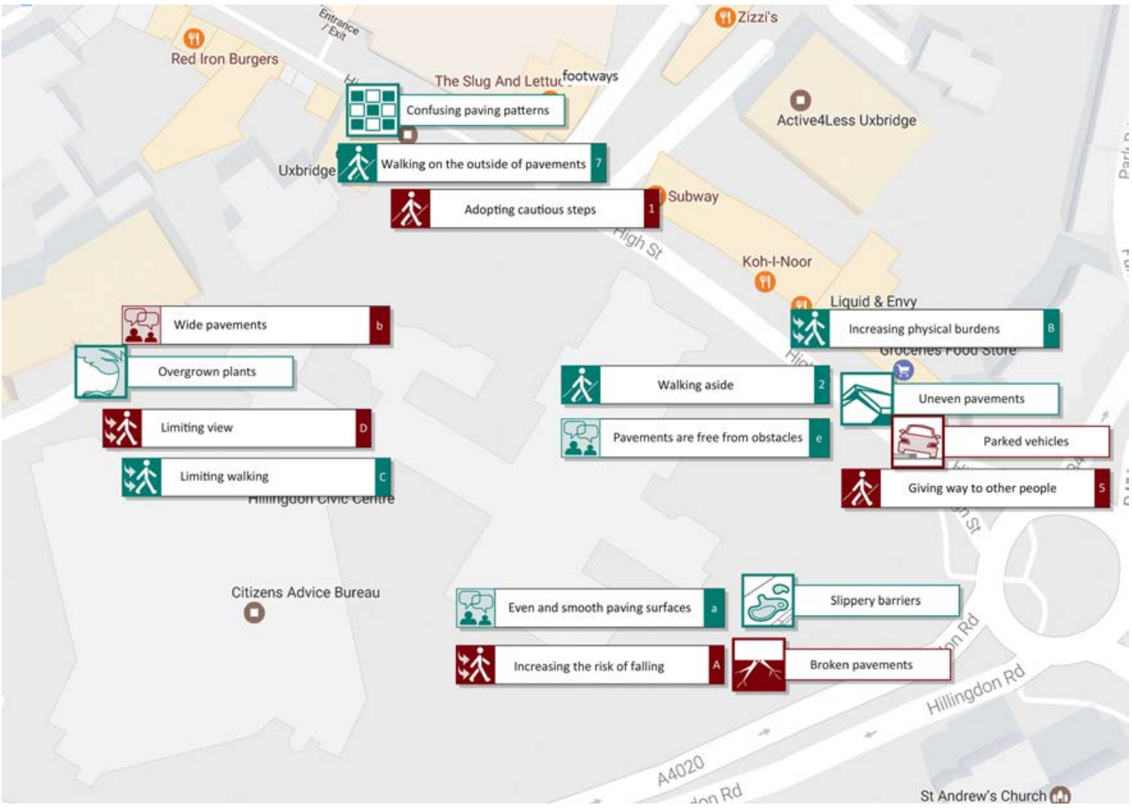
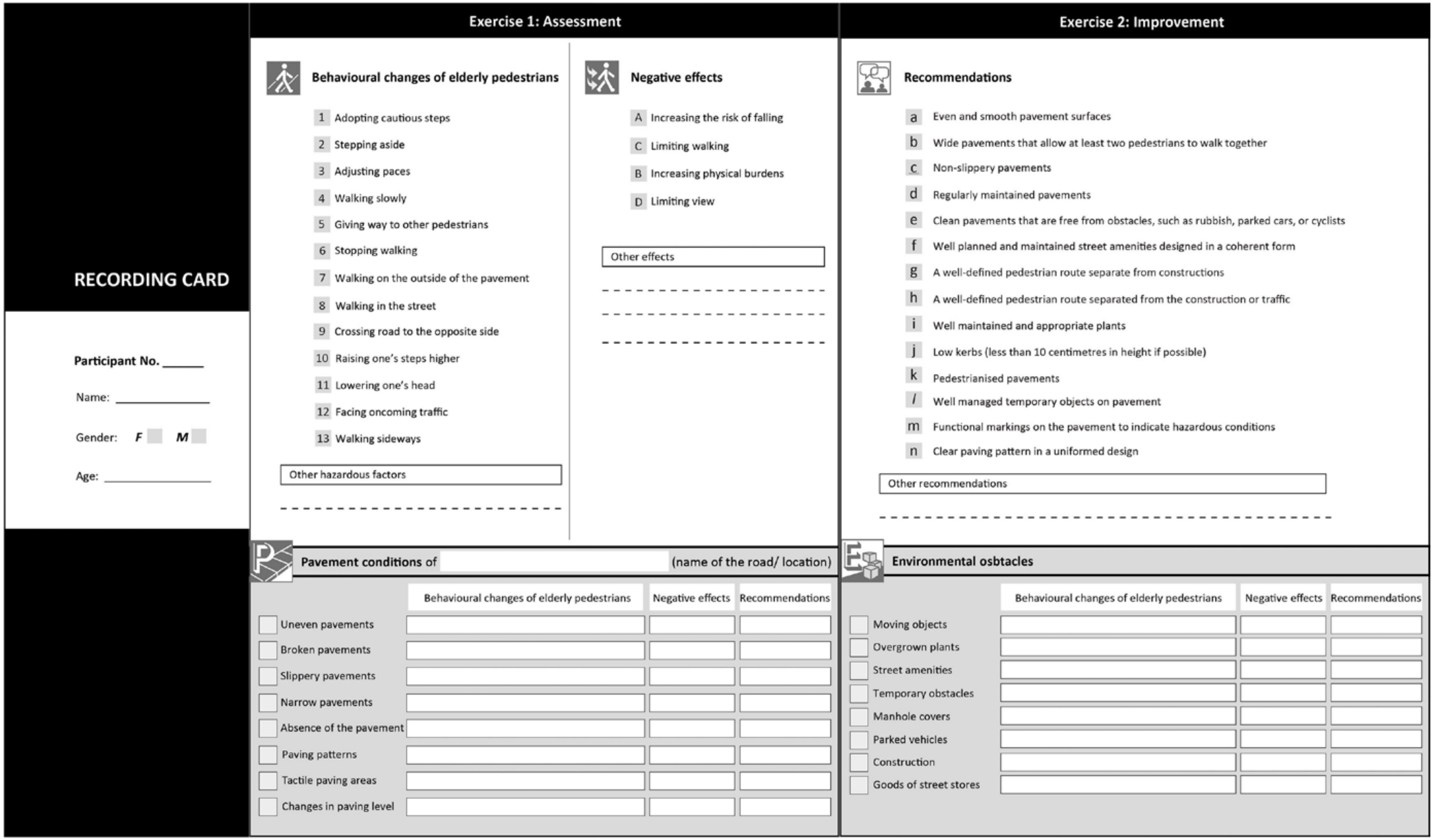


Figure 6-7. The map-based assessment conducted by the stripe cards on a 1:5000 map (a print of Google Maps).

6.3.3 Recording cards

There are six copies of the recording card and each of them is used by researchers to compile an individual participant's information and responses. The more participants in the study, the more copies of recording cards need to be used. Figure 6-8 shows that the recording card has five sections that are in parallel with the card categories of the handbook including personal information and behavioural changes of participants, identified pavement hazards and their effect and suggested recommendations for dealing with the issues. Researchers can obtain those data according to participant demographics (shown on the role card), the stripe cards shown on the map and findings and insights revealed by the study.



RECORDING CARD

Participant No. ______

Name: ______________

Gender: F ☐ M ☐

Age: ______________

Exercise 1: Assessment

Behavioural changes of elderly pedestrians

1 Adopting cautious steps
2 Stepping aside
3 Adjusting paces
4 Walking slowly
5 Giving way to other pedestrians
6 Stopping walking
7 Walking on the outside of the pavement
8 Walking in the street
9 Crossing road to the opposite side
10 Raising one's steps higher
11 Lowering one's head
12 Facing oncoming traffic
13 Walking sideways

Other hazardous factors

Negative effects

A Increasing the risk of falling
C Limiting walking
B Increasing physical burdens
D Limiting view

Other effects

Exercise 2: Improvement

Recommendations

a Even and smooth pavement surfaces
b Wide pavements that allow at least two pedestrians to walk together
c Non-slippery pavements
d Regularly maintained pavements
e Clean pavements that are free from obstacles, such as rubbish, parked cars, or cyclists
f Well planned and maintained street amenities designed in a coherent form
g A well-defined pedestrian route separate from constructions
h A well-defined pedestrian route separated from the construction or traffic
i Well maintained and appropriate plants
j Low kerbs (less than 10 centimetres in height if possible)
k Pedestrianised pavements
l Well managed temporary objects on pavement
m Functional markings on the pavement to indicate hazardous conditions
n Clear paving pattern in a uniformed design

Other recommendations

Pavement conditions of ____________ (name of the road/ location)

	Behavioural changes of elderly pedestrians	Negative effects	Recommendations
☐ Uneven pavements			
☐ Broken pavements			
☐ Slippery pavements			
☐ Narrow pavements			
☐ Absence of the pavement			
☐ Paving patterns			
☐ Tactile paving areas			
☐ Changes in paving level			

Environmental osbtacles

	Behavioural changes of elderly pedestrians	Negative effects	Recommendations
☐ Moving objects			
☐ Overgrown plants			
☐ Street amenities			
☐ Temporary obstacles			
☐ Manhole covers			
☐ Parked vehicles			
☐ Construction			
☐ Goods of street stores			

Figure 6-8. The recording card.

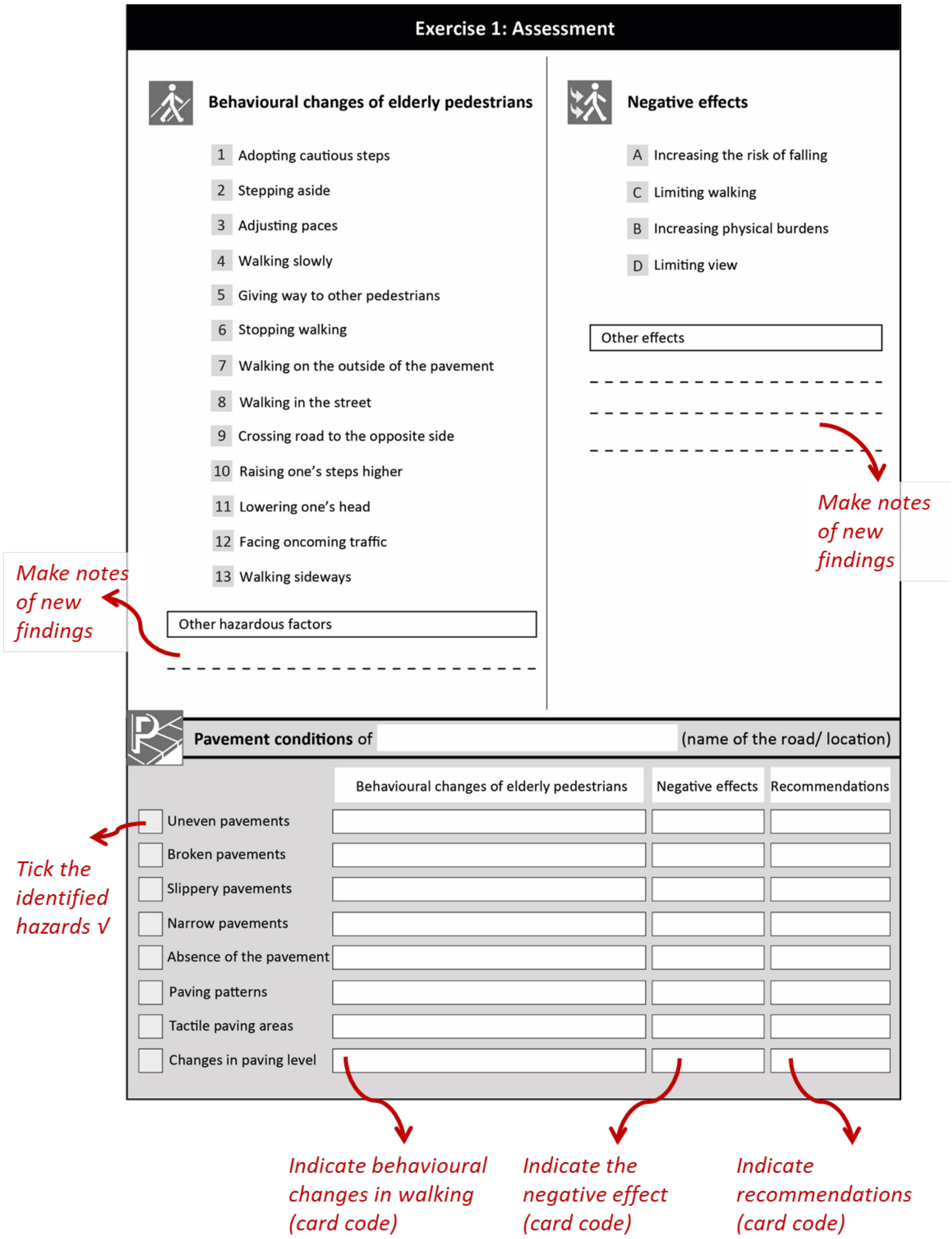


Figure 6-9. Use of the recording card.

6.4 Use of version 1

To use version 1, firstly, researchers would prepare a map to show a pavement environment and recruit participants from the residents in the area (see Figure 6-10). With the card pack, participants can start to think about the study topic and their missions and tasks. Then, researchers give the handbooks to the participant and ask them to indicate their name, gender, and age on the role cards. In the next stage, participants identify and locate hazards of the pavement on the map using the stripe cards of pavement factors. Based on their choices, they go on to indicate the impact of the identified pavement hazards, reporting behavioural changes caused by the hazards, and proposing recommendations to mitigate the pavement issues using relevant stripe cards. Finally, researchers write down the demographics of participants, the stripe cards presented on the map and extra findings.

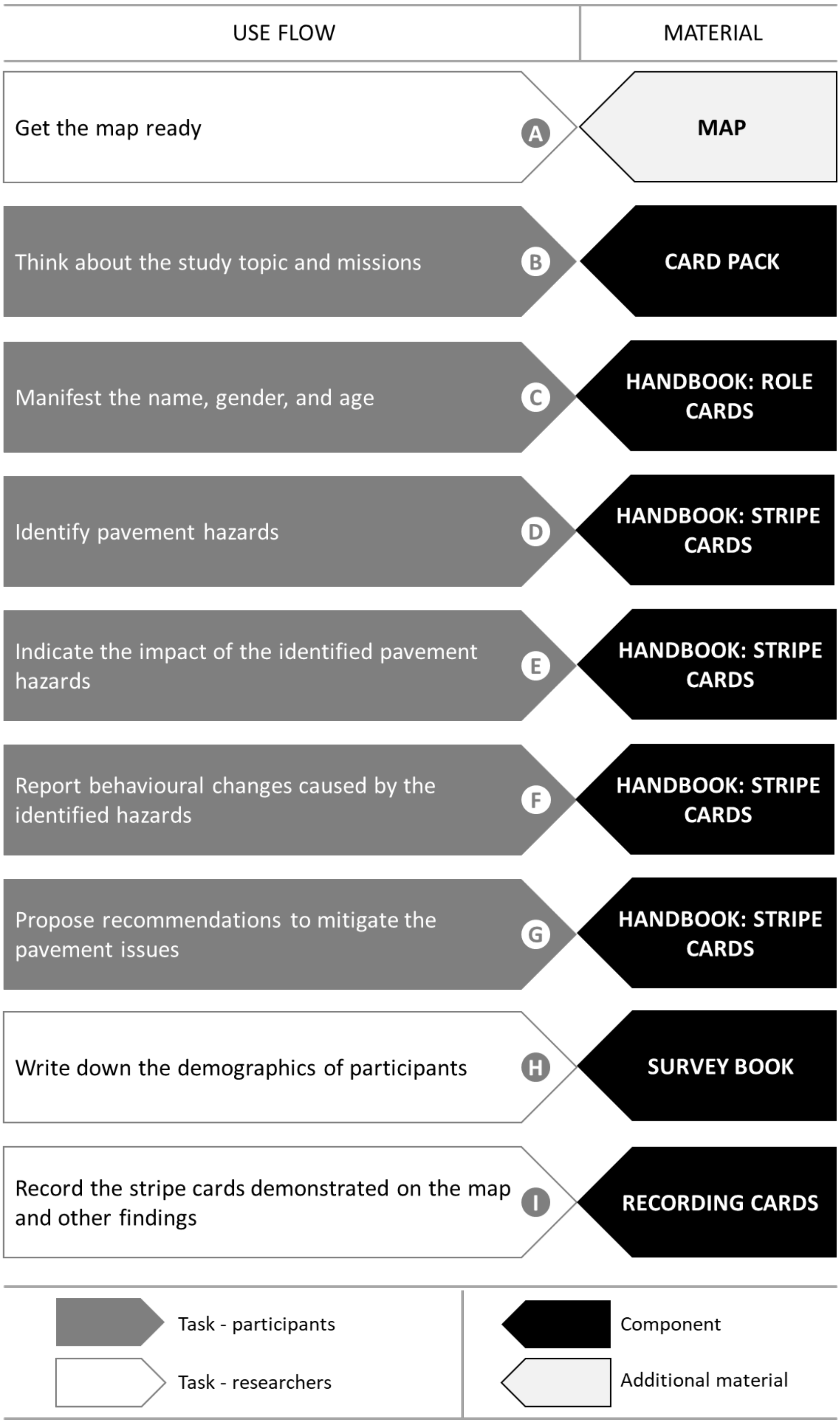


Figure 6-10. Use of the version 1.

6.5 Improvements in the toolkit

After producing the prototype, it found that version 1 had to be simplified and revised. Too many stripe cards were included in the version that made them difficult to be organised. Also, having such an abundance of cards displayed on the map cluttered the presentation of the map-based results (see Figure 6-7). To avoid the issue, the card groups of the handbook were developed into a participant survey book made up of three matrices. The strips cards of groups 1 and 2 were converted into the column header and strips cards of those card groups 3, 4 and 5 were turned into row factors of the matrices. Therefore, the column header of the three matrices are always the 16 pavement hazards while row factors of each matrix represent the impact of pavement hazards, older pedestrians' behavioural changes caused by pavement hazards, and improvements in the pavement. Comparing with the card-based presentation, data collected by a matrix can be interpreted and described more easily, and cross-sections of matrix rows and columns can better emerge the relationship between different data patterns (Corbin and Strauss, 2015). Also, rather than using a mass of stripe cards to present ideas, matrices could allow participants to indicate their responses by simply ticking associated cells.

In addition to the changes, the previous recording cards were combined into a single recording cards to enhance the efficiency of grouping and comparing study results. As version 1 requests researchers to compile data from survey books to the recording card, the recording card was designed using the same matrices of the survey book to keep consistency in formats of the two materials. However, each matrix row in the recording card was divided into six portions to assist researchers to group the data from different participants and also to distinguish their answers within the same category.

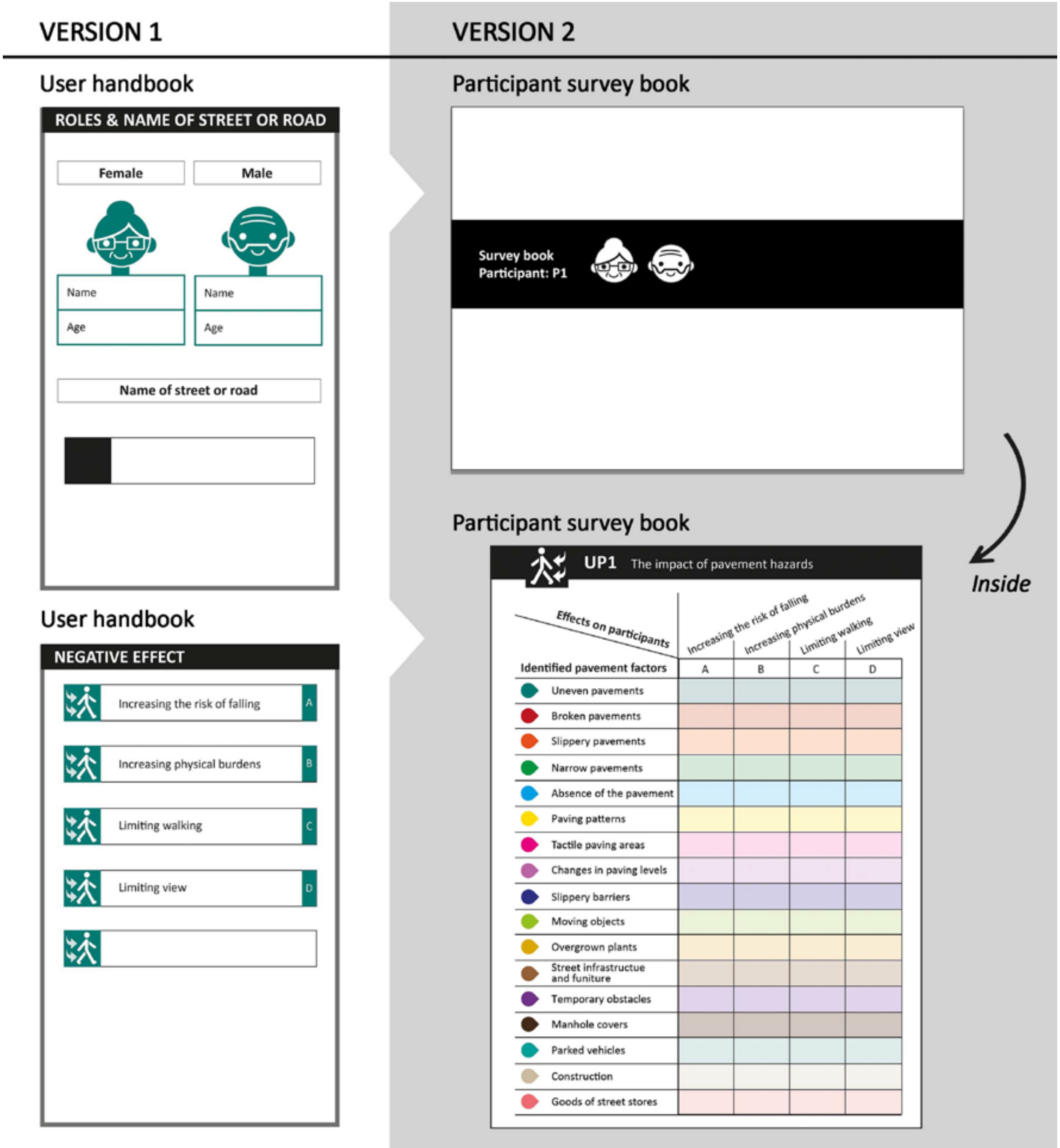


Figure 6-11. Changes between version 1 and version 2.

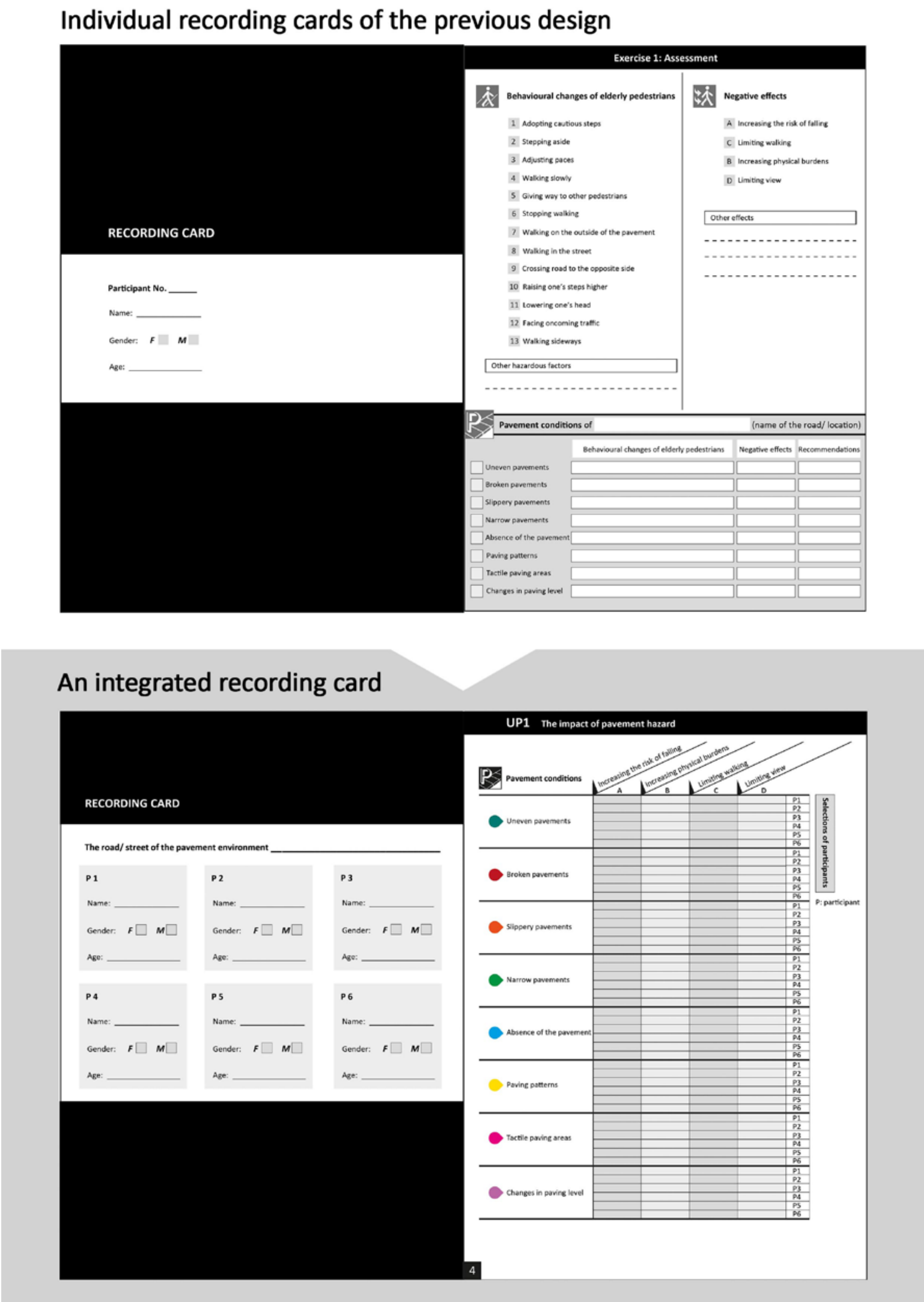


Figure 6-12. Individual recording cards were changed to an integrated recording card.

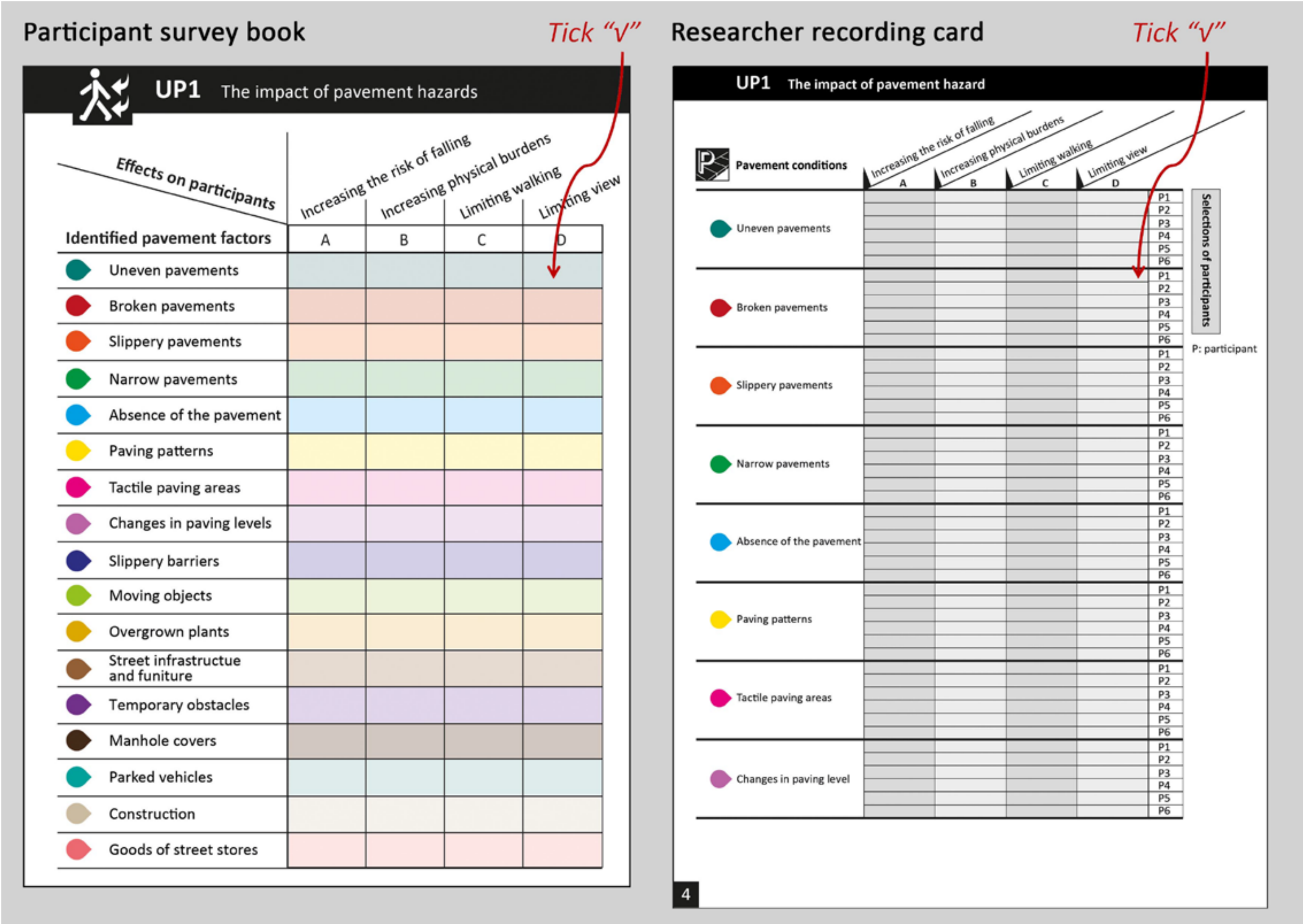


Figure 6-13. Use of the survey book and recording card.

6.6 Version 2 of the participatory study toolkit

Figure 6-14 shows that version 2 encompasses 16 pavement cards, six user-packs for participants separately including 16 locating pins and a survey book, and materials for researchers including a recording card and 16 landmarks. The pavement cards are kept in the same design as the previous version and the locating pins were developed based on the former locating marks. The locating pins for each participant are labelled by a participant number so that users know which problems are identified by which participants. Every 16 locating pins correspond with the 16 landmarks representing the pavement hazards listed by DS-I, and each category is coded by a colour. The locating pins are used by elderly participants to locate hazards of pavements on a map and the landmarks are used by researchers to highlight significances among the identified issues. Specific content of the components could be found in Appendix VIII.

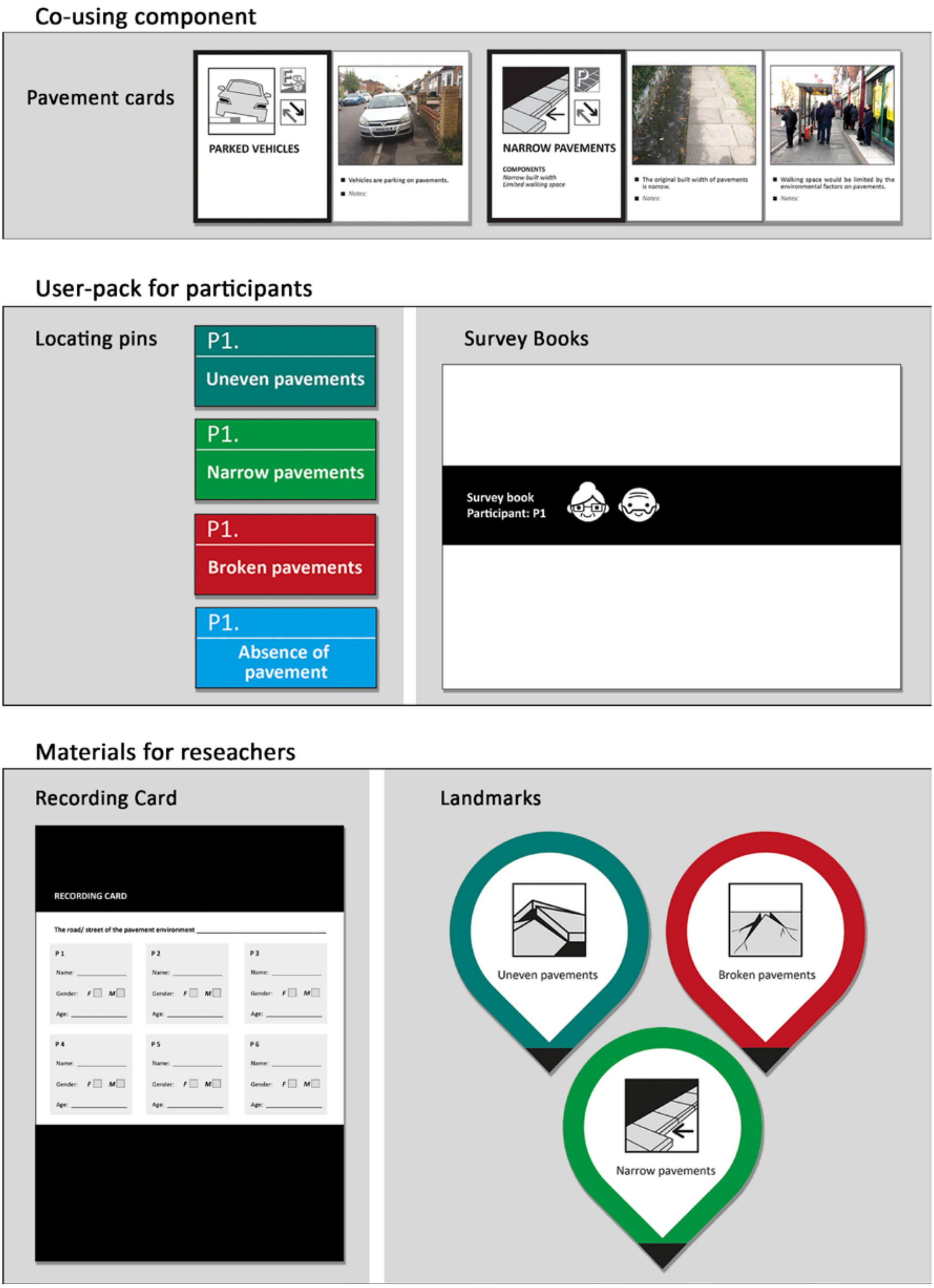


Figure 6-14. Components of version 2.

6.6.1 Use of version 2

Version 2 allows users to undertake two exercises, namely a map-based assessment and the pavement improvement. Figure 6-15 displays that researchers need to prepare a pavement map and to distribute locating pins and survey books to participants at the beginning of the participatory study. Then, they note down the participants' name, gender, and age and the location of the pavement environment on the cover page of the recording book. After that, researchers conduct the map-based assessment starting with the pavement cards. They shall ask participants to read through the pavement cards and discuss if any hazards demonstrated by the pavement cards exist within the pavement environment. If so, participants use the locating pins to position those issues on the map and have a group discussion to further explain their answers. Based on the group conversation, researchers highlight significant factors among the identified pavement hazards using landmarks (see Figure 6-16). Following that, participants indicate in the survey book the negative effect and behavioural impact caused by the highlighted issues. In exercise two, participants also need to suggest recommendations to deal with the pavement problems in the survey book. Finally, researchers use the recording card to group and organise the data obtained by all the survey books.

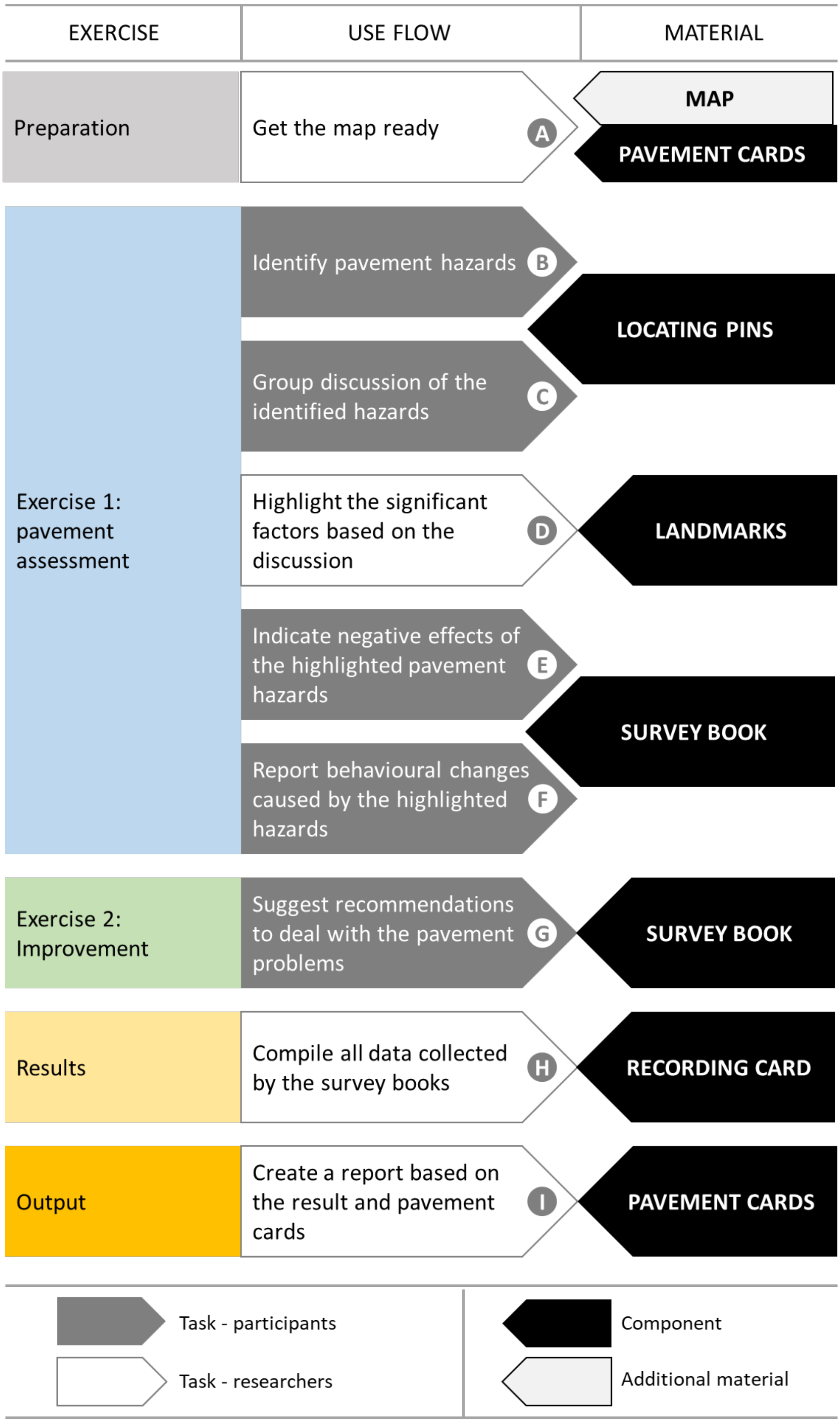


Figure 6-15. Use of version 2.

Figure 6-16. The pavement assessment conducted by the locating pins and landmarks on a 1:5000 map (a print of Google Maps).

6.7 Testing of version 2

Version 2 was tested to examine if it could assist users with a participatory study. Also, according to Blessing and Chakrabarti (2009) and CDC (2011), the study aimed to evaluate if version 2 could be easy to learn or to use or if it could communicate information accurately, enable users to do exercises properly, assist researchers with their work or satisfy the need of users.

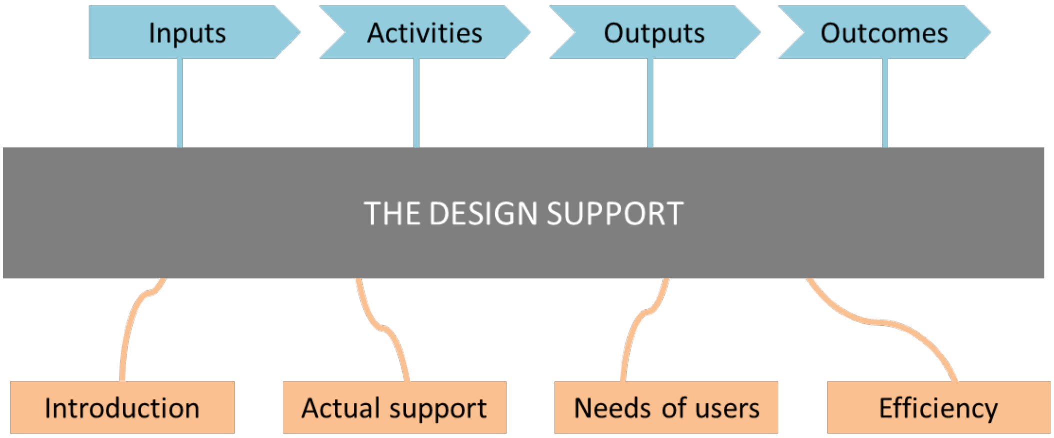


Figure 6-17. Criteria of the evaluation, adapted from Blessing and Chakrabarti (2009) and CDC (2011).

6.7.1 Participants

As the toolkit would be tested from the content, design, usability, usefulness, and efficiency aspects, the purposive sampling (Patton, 2009) was used to recruit participants from different fields to ensure diverse comments to give. Five early-stage researchers who separately from inclusive design, built environments, design tools, and ageing mobility were assembled for the evaluation. Their study was highly relevant to the content of the toolkit, and they could assist with the development of the toolkit. In the case, they might be interested in the tool and might be potential users. When recruiting elderly participants, the purposive sampling was also adopted to ensure the study equally included elderly participants from different genders and ages. Ten older adults consisted of six females and four males aged between 60 and 82 were selected for the testing. They were chosen because they were living in or around the location of the pavement environment studied in the workshop, thereby they were familiar with the pedestrian environment and were the shareholders of the environment maintenance and construction in the area.

All participants were divided into five groups individually made up of one researcher and two elderly participants. The five small teams were set instead of arranging a large group (e.g. a group of two researchers and six participants) because smaller groups allow study topics to be explored in-depth especially when participants have extensive experiences to share (Anderson, 1990, cited in Dilshad and Latif, 2013).

Table 6-1. Groups of the workshop

Workshop	Researcher	Participant (gender/ age)	
Group 1	Inclusive design	Female/ 71	Male/ 75
Group 2	Built and transport environments	Female/ 78	Male/ 76
Group 3	Design tools	Female/ 60	Male/ 69
Group 4	Mobility of senior adults	Female/ 73	Female/ 77
Group 5	Built and transport environment	Female/ 82	Male/ 75

6.7.2 Method

Workshops are common methods adopted in many studies (Chung and Hahn, 1999; Hamilton, Mitchell and Yli-Karjanmaa, 2002; Carlsson-Kanyama *et al.*, 2008) to develop a design tool and to identify users' interests and the impact of a design solution (Rail Safety and Standards and Board, 2008). This study arranged five workshops to proceed with a group study following the user instruction using a 1:2000 map created based on Google Maps. During the study, user actions and significant phenomenon, such as the improper use of the toolkit, were observed. After testing version 2, the participants were asked to summarise their feedback in a questionnaire.

Scale questionnaires are commonly used in many studies (Giladi *et al.*, 2000; Hills and Argyle, 2002; Martínez-Lavin *et al.*, 2003) to measure users' feedback. Dolnicar *et al.* (2011) concluded that five- or seven-point Likert scores are unstable and time-consuming in some cases. Also, five-point scales are usually used to collect various answers from a large population, so it would be less effective with a smaller sample (Murphy, 2012). by Jacoby and Matell (1971) found that three-point Likert scales were able to allow results to be retestable, reliable, and valid. Therefore, three-point answers included 'Yes', 'No' and 'Neutral' were employed by the questionnaire. 'Yes' represents the 'agreement', 'No' means the 'disagreement', and 'Neutral' indicates that participants would neither agree nor disagree. The questionnaire was designed in two types separately for the researchers and elderly participants. The two questionnaires had six shared questions: (1) Is the toolkit easy to use; (2) Is the toolkit efficiently designed; (3) Does the toolkit include the information that you expect; (4) Does the toolkit enable you to indicate your ideas; (5) Were the objectives of the exercises achieved by the toolkit; and (6) Did you obtain new knowledge from using the toolkit. In the questionnaire for the researchers, three more inquiries were asked regarding the usefulness and output of the toolkit: (7) Does the toolkit enable you to collect and compile the data quickly and easily; (8) How do you interpret the output of the toolkit; and (9) What will you do with the results of the investigation. Questions (1) to question (7) were closed-ended questions, and questions (8) and question (9) were open-ended queries. A blank space was given below each closed-ended question for the users to provide a sensible and expanded explanation for their answer.

Figure 6-18. Use of the locating pins and landmarks on the 1:2000 map.

6.7.3 Analysis and results

Both advantages and disadvantages of version 2 were discussed in the workshops, and the study revealed some problems with the tool regarding its use, design, and layout.

Each workshop was carried out within one hour with all tasks accomplished, and the questionnaires were completed with all questions answered. The frequency of the options ('Yes', 'No', and 'Neutral') to the closed-ended question were calculated, and the open-ended answers as well as extra qualitative data were transcribed and coded and categorised into different topics.

6.7.3.1 Results of the questionnaires

Table 6-2. Results of the questionnaires (n=response)

Respondent (5 researchers and 10 older adults)		Yes (n=71)	No (n=6)	Neutral (n=18)
Shared questions	**1. Is the toolkit easy to use?**	9	0	6
	Researchers:	3	0	2
	Participants:	6	0	4
	2. Is the toolkit efficiently designed?	11	2	2
	Researchers:	5	0	0
	Participants:	6	2	2
	3. Does the toolkit include the information that you expect?	11	0	4
	Researchers:	3	0	2
	Participants:	8	0	2
	4. Does the toolkit enable you to indicate your ideas?	9	3	3
	Researchers:	3	0	2
	Participants:	6	3	1
	5. Were objectives of the exercises achieved by the toolkit?	12	1	2
	Researchers:	4	1	0
	Participants:	8	0	2
	6. Did you obtain new knowledge from using the toolkit?	15	0	0
	Researchers:	5	0	0
	Participants:	10	0	0

<table>
<tr><td rowspan="3">For the researchers: only</td><td>7. Does the toolkit enable to efficiently compile the data quickly and easily?</td><td>4</td><td>0</td><td>1</td></tr>
<tr><td>8. How do you interpret the output of the toolkit?</td><td colspan="3" rowspan="2">• Making comparison between results
• Further probe the findings
• Creating a checklist or guideline
• Applying the result in self-works
• Using the tool with other stakeholders</td></tr>
<tr><td>9. What will you do with the results of the investigation?</td></tr>
</table>

Table 6-2 shows that the majority of the answers to questionnaire were ‘Yes’ (71 Yeses) which meant that the users generally agree with the design, content, outputs, and usability of version 2. Nine users (three researchers and six participants) agreed that version 2 was easy to use. Two researchers among them said that ‘the tool was straightforward’ once they learned how to use it, and the other elderly participants indicated that the ‘map was clear with the addition of tabs’, and the toolkit was ‘simple to understand’, ‘well explained’ and ‘all laid out very well’. However, it was complicated to entre information repeatedly in several matrices. Four senior adults pointed out that the guidance of version 2 was not clear and they ‘had to think quite hard about it’. They even ‘did it (the exercises) wrong at first’ with the confusing instructions. An elderly person also felt that some matrix factors, such as the ‘limiting walking’, should be further clarified by the toolkit to avoid confusion, and the researchers advised that the connection between different materials and study tasks should be clarified. Also, a researcher proposed that a digital format could be easy and effective to use.

When analysing the answers to questions 2 and 3, 11 users (five researchers and six participants) were found to agree that version 2 was well designed with full information provided. The elderly participants said that the tool was ‘good to have both visual [pins and landmarks] and written responses [survey books]’. They agreed that version 2 detected the elements that ‘related to all real hazards’. The researchers also reported that:

> "the information was good and extensive, the 'list of features [pavement factors] is very comprehensive…plenty of options that seem to address all potential issues…the recommendation list was very good for this application (tool)…all the questions are related to elderly people and questions were picked carefully for their age".

Regarding questions 4 and 5, most users were satisfied with the process of carrying out the participatory study using the tool (24 Yeses). The users commented that they were able to identify hazards and indicate their ideas with the toolkit as it included problems that truly exist in the real world. Additionally, it listed the actions the older adults had to do when they met the problem areas and provided improvements in the pavement. However, two elderly users found 'it was quite difficult to identify various problematic areas' using the insufficient locating pins, and 'not all negative features or impact were included'. A researcher felt that it could be better to explore all the pavement hazards identified by the locating pins rather than focusing on the ones highlighted by the landmarks only. Two researchers suggested the tool to include the psychological impact of the pavement and to involve disabled people in the study.

As for question 6, all users (five researchers and ten participants) became more aware of the pavement and the walking behaviour of older pedestrians after using the toolkit. Two researchers said that 'it expanded the understanding regarding the relationship between older adults and pavements' and 'it helped to understand the needs of elderly people and gave an idea about future maintenance planning'. The answers to question 7 showed that four researchers felt the tool 'was easy and quick' to compile the data in the recording card, whereas, another researcher found that the recording card was not efficient enough for use.

Regarding the output of version 2 (questions 8 and 9), some researchers would compare the study results based on the participants' personal conditions and give more explanations to the findings according to their profession. For example, a researcher commented that 'I will try to compare the participants' answers with each other and relate their answers to each one's bodily strength, health, and conditions. Some researchers would apply the data in their work or create design guidance based on the outcomes. One researcher indicated that he would 'make a checklist or guideline for designing inclusive environments for older people but also for as many people as possible'.

6.7.3.2 Significant phenomena revealed by the observation

The observation revealed specific user patterns of the toolkit and found that the elderly participants interacted very little with each other or with the researchers during the study (see Figure 6-19). This action occurred because the participants were too concerned about completing their survey books. To avoid the situation, researchers can try to engage with the participants and encourage the group discussion by raising follow-up questions based on the data collection (Owen and Noonan, 2013). However, the observation also found the researchers had less time to talk to the participants as writing down data in the recording card consumed more time of the study.

Figure 6-19. Users use version 2 to undertake a group study.

The results of the survey books and recording card showed that some incorrect entries were made by the elderly participants when they were presenting their responses in the matrices. For example, some of them easily ticked the options in wrong cells or gave answers to the pavement hazards that were not identified by the study (see Figure 6-20). The other participants were found to adopt additional actions to avoid that mistake. For example, they marked on the identified hazards in the column header of the matrices so that they could know exactly where to indicate their options in matrix rows (see Figure 6-21).

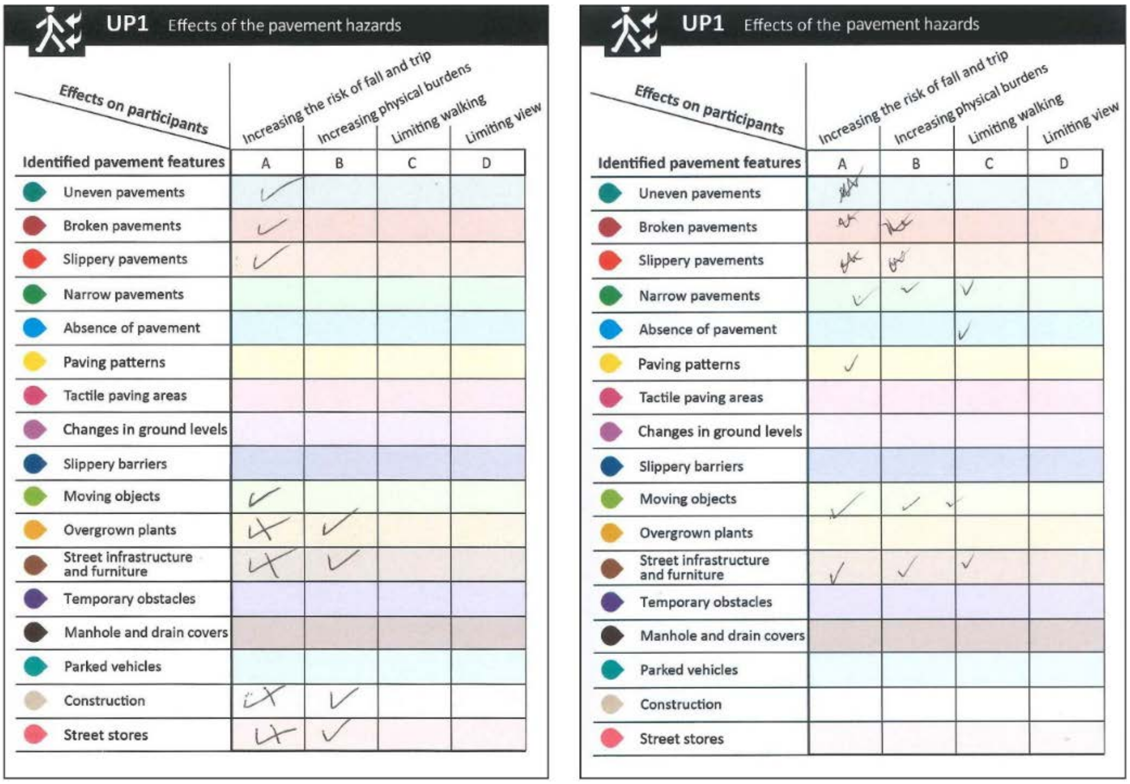


Figure 6-20. Mistakes of using the survey book.

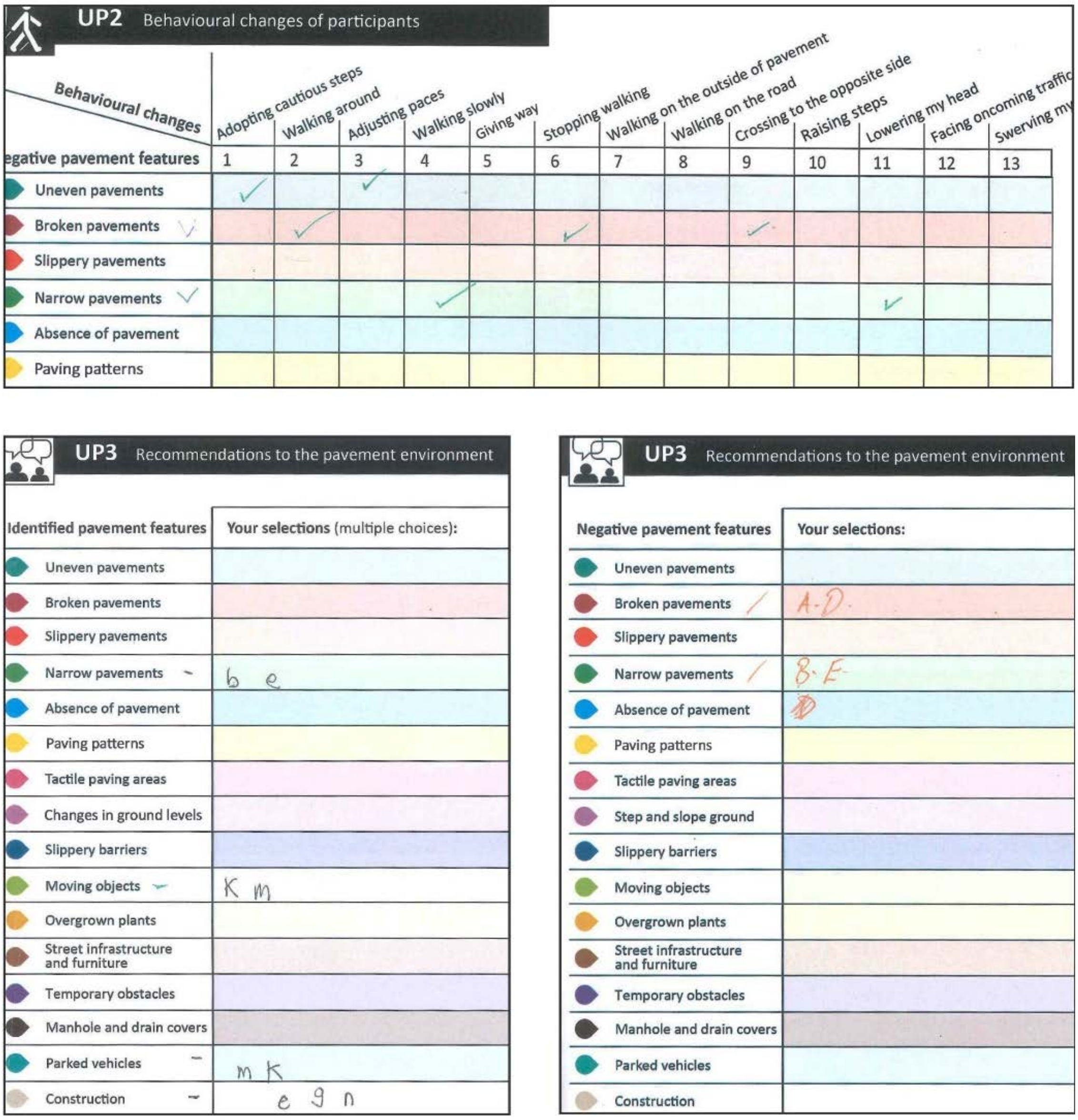


Figure 6-21. Additional actions adopted by the users to avoid wrong entries in the survey book.

6.7.3.3 Analysis of the data collected by version 2 of the toolkit

After the workshop, the study analyses the data collected by the recording card and found that the study results had many similarities with the previous findings of the empirical study (DS-I). For example, the most significant hazards identified by both studies were uneven surfaces and broken pavements. Also, both studies found that street amenities, parked cars, and the changes in paving level had a stronger influence on older adults. However, different from DS-I, overgrown plants and slippery barriers were recognised as minor pavement problems by the toolkit in the workshop.

Table 6-3. Pavement issues identified by the participants using version 2 of the toolkit (S=Significant factor)

Pavement hazards	Group 1	Group 2	Group 3	Group 4	Group 5
Uneven pavements	√	√ (S)	√ (S)	√ (S)	
Overgrown plants		√	√		
Slippery barriers		√ (S)	√		
Broken pavements	√ (S)	√ (S)	√ (S)		
Moving obstacles	√	√	√ (S)		√
Temporary obstructions			√ (S)		
Street amenities		√	√ (S)		√ (S)
Manhole or drain covers			√ (S)	√	
Parked vehicles			√ (S)	√ (S)	√
Construction		√	√		√
Narrow pavements	√ (S)		√		√
The absence of pavements			√		
Street stores		√		√	√
Paving patterns	√				√
Tactile paving areas				√ (S)	
Changes in paving level		√		√ (S)	√ (S)

In line with the empirical study (DS-I), data gathered by the toolkit showed that uneven surfaces, slippery barriers, and broken pavements were identified as the main reasons for falls or trips (see Table 6-4). Narrow pavements and street amenities often limited walking in the elderly participants, and parked vehicles were a main obstruction that blocked the participants' view. Also, pavement furniture, the unevenness, and narrow pavements were major elements that could increase physical burdens (e.g. fatigue and pain) to the elderly participants of the workshop.

Table 6-4. The impact of pavement hazards clarified by the participants using the version 2 of the toolkit (n=elderly participant)

Pavement factors	Increasing the risk of falls or trips	Limiting one's walking	Limiting one's view	Increasing physical burdens
Uneven pavements	n=4	n=2	-	n=3
Overgrown plants	n=1	n=1	n=1	n=2
Slippery barriers	n=4	n=3	-	n=1
Broken pavements	n=4	n=2	-	n=1
Moving obstacles	n=4	n=2	n=1	n=3
Temporary obstructions	n=1	n=1	n=1	n=1
Street amenities	n=2	n=3	n=1	n=4
Manhole or drain covers	n=2	n=1	-	n=2
Parked vehicles	n=1	n=2	n=3	n=3
Construction	n=2	n=2	n=1	n=3
Narrow pavements	n=2	n=3	n=2	n=4
The absence of pavements	n=2	n=2	-	n=1
Street stores	-	n=1	n=1	n=1
Paving patterns	n=1	-	-	-
Tactile paving areas	n=2	n=1	-	n=1

Changes in paving level	n=1	n=2	-	n=1

Table 6-5 shows a closer association between each pavement factor identified by the toolkit and the walking behaviour of older people. Some of the findings were relatively consistent with the results of DS-I. For example, the elderly participants of both studies were more likely to step aside from obstacles, such as overgrown plants, broken surfaces, temporary barriers, and other obstructions caused by the street stores on the pavement. Slippery obstacles, uneven pavements, and narrow pavements particularly made the older adults walk carefully and slowly or adjust their pace regularly. Both of the two participant groups had to give way to other pedestrians on narrow pavements, walk outside of the pavement due to inappropriate street amenities, and step onto the street because of the absence of the pavement. However, ‘raising legs higher’ as one of the most significant behavioural factors identified by DS-I was not regarded as a common strategic behaviour by the participants of the workshops.

Table 6-5. The relationship between pavement hazards and walking behaviour explored using the version 2 of the toolkit (n=elderly participants)

n=participants	**Adopting cautious steps**	**Stepping aside**	**Adjusting paces**	**Walking slowly**	**Giving way**	**Stopping walking**	**Walking on the outside of the pavement**	**Walking on the road**	**Crossing road to the opposite side**	**Lowering one's head**	**Raising one's legs higher**	**Facing oncoming traffic**	**Walking sideways**
Uneven pavements	n=4	n=5	n=5	n=6	n=2	n=2	n=2	n=2	n=2	n=2	n=1	n=1	-
Overgrown plants	-	n=3	-	-	n=2	n=2	n=1	n=2	n=1	-	-	-	n=2
Slippery barriers	n=6	n=3	n=5	n=5	n=2	n=4	n=2	n=2	n=2	n=3	-	-	-
Broken pavements	n=3	n=5	n=4	n=3	n=2	n=3	n=2	n=2	n=3	n=2	-	-	-
Moving objects	n=1	n=1	n=1	n=1	n=3	n=4	-	n=2	n=2	-	-	n=1	n=2
Temporary obstacles	n=1	n=2	n=1	-	n=2	n=1	n=2	n=2	n=1	-	-	-	n=1
Street amenities	n=1	n=5	n=1	n=2	n=3	n=3	n=4	n=1	n=3	-	-	-	n=2
Manhole and drain covers	n=3	n=3	n=2	n=2	n=2	n=2	n=2	n=2	n=2	n=2		--	-
Parked vehicles	-	n=3	n=2	n=3	n=2	n=3	-	n=3	n=2	n=1	-	n=2	-
Construction	n=1	n=3	n=1	n=2	n=2	n=3	-	n=2	n=2	n=1	-	-	n=1
Narrow pavements	n=3	n=2	n=4	n=5	n=5	n=2	n=2	n=5	n=4	n=5	-	n=2	-
Absence of pavements	n=1	n=1	n=1	n=1	n=2	n=1	n=1	n=3	n=1	-	-	n=2	-
Street stores	n=1	n=3	n=1	n=1	n=2	n=2	n=1	n=1	n=1	-	-	-	-
Confusing paving patterns	-	-	-	-	-	-	-	-	n=1	-	-	-	-
Tactile paving areas	n=2	n=1	n=1	n=1	-	-	n=1	-	-	n=2	-	-	-
Changes in paving level	n=1	n=1	n=1	n=2	-	-	n=1	n=1	n=1	n=1	-	n=1	-

6.7.4 Discussion

According to the user feedback, version 2 of the toolkit was fairly precise and easily understandable, and colours were well used to categories pavement hazards. It demonstrated a good layout and served its purpose. It allowed researchers to conduct a participatory study in the general duration (1 to 2 hours) of a focus group study. Version 2 assisted researchers to identify problems with the pavement and explore the walking adaption of older people to the hazards, and it provided possible solutions to the pavement problems using a recommendation list. Even though one researcher found that the association between older pedestrians and pavement issues was slightly ambiguous, all of the other researchers felt that this relationship was well-demonstrated by version 2. The result could be further analysed by using the new information which was emerged from the group discussion or by additionally probing the responses of the elderly participants. On the other hand, some elderly participants requested extra information provided by version 2 besides the original content as they need the tool to cover a full view of all concerns. For example, they would like to include matters of road crossing, information about psychological aspects, and rules for cyclists and car drivers. But the users should know that the toolkit was not designed for studying those aspects. The researchers argued that the use of the components was confusing and the links between each section of version 2 were unclear. They suggested the use of colour coding to distinguish different parts of the tool. Colour coding can boost users' understanding of the toolkit and improve the usability of the toolkit (Keller *et al.*, 2006). One researcher preferred a digital format as he believed that the digital version would be easier and more efficient to collect data and compare the study results. However, a digital toolkit could hugely limit the idea generation or creation and a paper prototype for older people would be more helpful in ideations (Blakeman and Taylor, 2017). Therefore, the future version of the toolkit would still be produced in a physical format.

Regarding the specific materials of the tool, the instruction and matrices were confusing for some users and this caused them to make mistakes at the beginning of the study, thereby the tool should explain more about the column and row factors and topic of the matrices. The locating pins enabled the researchers to find out key hazards by exploring how many participants identified pavement issues on the map and why they regarded those as threats, thereby they were referred to be the most useful component by the researchers. However, the pins were less useful to the elderly participants as each participant's pins only allowed he or she to identify every pavement hazard in one site once on the map. So, not all hazardous locations could be pointed out by the insufficient pins. The survey book assisted the elderly participants to give quick answers in the matrices, however, this made the senior adults less likely to think about or expand on their responses or share their opinions. As observed in the workshop, even though version 2 aimed to promote a group study, some participants did not cooperate with others or with the researcher well in generating or discussing ideas due to the design of the survey book. The recording card was efficient, easy, and quick to compile the data from the survey books. The analysis of the data collected by the recording card showed that version 2 allowed the researchers to obtain rigorous results from the participatory study. The outcome of the study was in accordance with the previous findings of DS-I which had been discussed and compared with evidence worked out by other studies. The findings assisted quick decision-making and expanded the users' knowledge of the study topic. The researchers would dig out more insights to the behavioural factors of the participants, develop future work with relevant findings, and improve the pedestrian environment with participants' desires.

6.8 Summary

This chapter has described version 1 and version 2 of the participatory study toolkit, followed by the analysis of an evaluation study. Version 1 and version 2 allowed anyone who designs and maintains the condition of pavements, such as environment designers, urban planners, and road engineers, to use them for a research purpose to identify hazardous factors and their adverse impact based on walking experience and perspectives of older adults using a printed map of a localised area. Both two version allow researchers to conduct a group study with the maximum of six older adults as participants. Version 1 was made to determine the content, form, and other design features of the toolkit and many problems with the use and design of the tool were revealed by the draft prototype. Therefore, the toolkit was modified to version, which is version 2, consisting of five components including pavement cards, locating pins, survey books, landmarks, and a recording card to assist users to assess and improve pavements. The pavement cards help elderly participants to better understand the content of the tool and to generate more ideas. Also, they can be used by researchers to interpret the data in the stage of analysis. The locating pins are used by participants to position pavement hazards on the map, and the landmarks were designed for researchers to highlight significances among the locating hazards. Based on the map-based exercise, the survey books allows participants to report the impact of the significant hazards and give suggestions to solve the problems. Following that, researchers can use the recording card to write down study findings and to group data from all the survey books. Version 2 was evaluated in five mini workshops and each of them contained one researcher and two participants. They were asked to give comments on the design, content, layout, use, exercises, and outputs of the tool. In the workshop, user action was observed and user feedback on the tool was collected by questionnaires. According to the results of the testing, version 2 was simple, and it enabled the users to explore problems and make decision quickly based on the outcomes of the participatory study. However, further improvements in the instruction, use flow, connections, and layout should have to be made foster the usability of the tool.

7 Development of the toolkit (section two of PS-II & DS-III): design and evaluation

This chapter describes the revised version of the toolkit (version 3) which was developed based on version 2 to improve the usability of the tool, encourage more group interaction and assist users to bring out more ideas. According to the feedback of the last testing, several modifications to the components and layout of the tool have been made in version 3. In addition, version 3 clarified the instruction and tasks of users and applied colour-coding to improve the usability and the connection between different parts. Version 3 has been tested by elderly users and researchers separately in workshops and an interview-based study. The workshops were conducted to determine if version 3 could promote more group interaction or if elderly participants could accomplish a group study properly. The workshops and user behaviour of the elderly participants were filmed, and a questionnaire was used to collect reviews of the users. The interview-based study aimed to find out if researchers could learn and use version 3 on their own by being assisted by a demonstration video. Eight researchers who were the potential users of the tool and who could give appropriate feedback on the tool participated in the study. According to the new testing, most participants felt that the version 3 was easy to learn and to use. The tool allowed them to have a comprehensive view of pavement hazards and walking in older adults that accorded with real-world situations. The researchers indicated that version 3 offered them a new opportunity to arrange a group study with older pedestrians, and they could expand their work based on the outputs of the tool. However, version 3 still presented some disadvantages in the design aspect that restricted the group study. Therefore, a final version of the toolkit called W-KIT further amended based on the results of the evaluation is delivered by the study.

7.1 Improvements in version 3

In the last testing, the researchers suggested that it would be better to explore the impact of all pavement issues identified by the locating pins rather than studying on the ones highlighted by the landmarks only. Then, the biggest change of the version 3 was to abolish the landmarks while to keep the locating pins. In this case, it ensures researchers to investigate all problems with the pavement and enables those issues to be identified in specific locations. Secondly, the personal survey books were replaced by group survey cards to encourage more group discussion. Each matrix of the survey book was turned into a pie chart to ensure that all users could read the information from different angles. The row factors of the matrices were developed into the segments of the pie charts. There were three pie carts generated based on the three matrices and they would be respectively used to explore the adverse impact of pavement hazards, older adults' walking behaviour caused by the hazards, and recommendations for the pavement. Another change was made in the locating pins as the elderly participants of the previous evaluation found that the locating pins limited them in positioning a pavement hazard in various areas. Therefore, the pins were redesigned into mini cards to allow a pavement problem to be positioned in more than one site. According to the layout of the survey cards, the mini cards were also made in a round shape to be keep consistency in design. In addition, the pavement cards were modified with the colours adopted by the mini cards to improve the connection between the two components. The instruction used illustrations to communicate the information so that messages would be easy and quick to perceive and remember for users (Dewan, 2015). More details of the changes between version 2 and version 3 can be found in Figure 7-1.

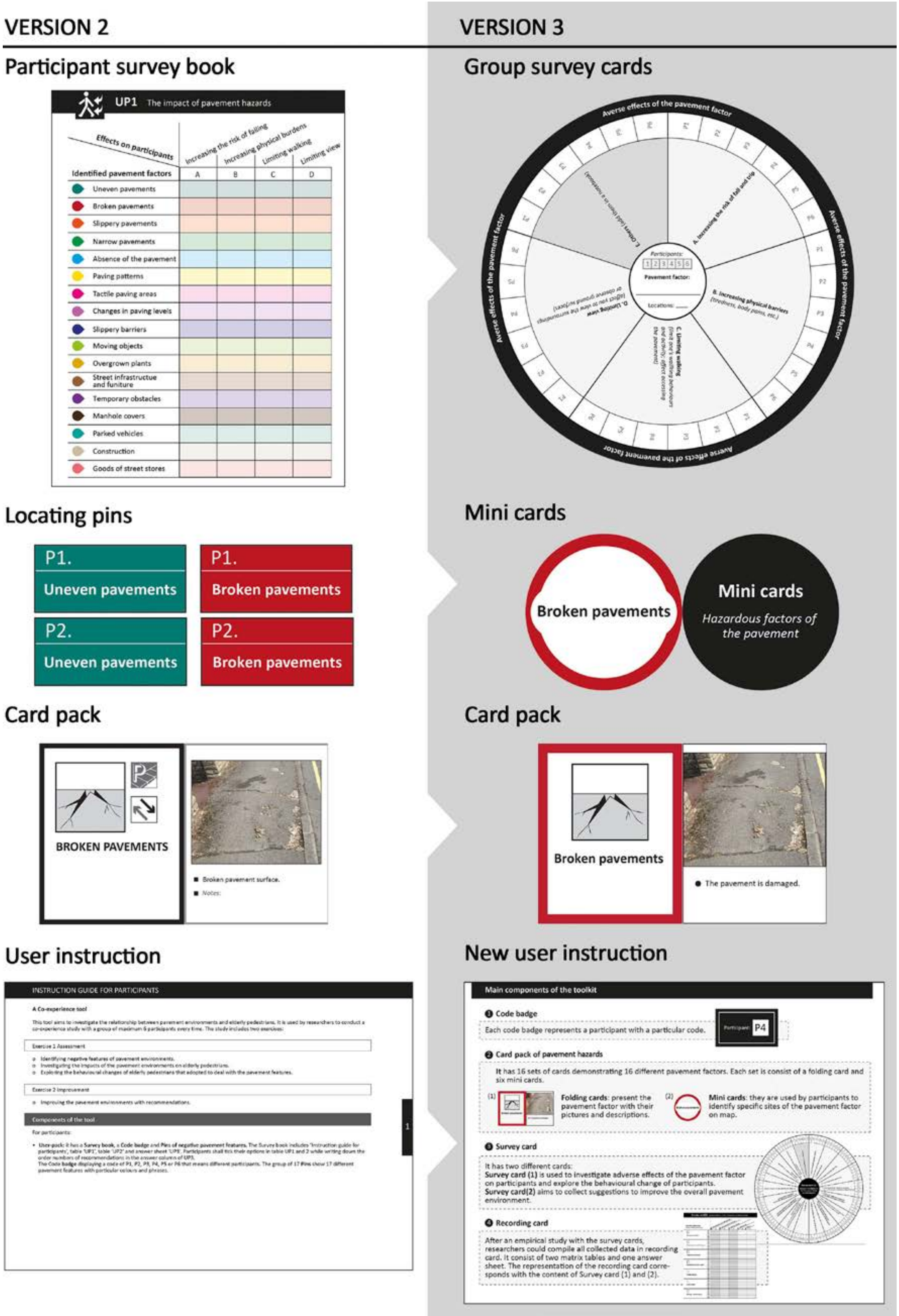


Figure 7-1. Changes between version 2 and version 3.

The recording card did not have any major revisions as it received less negative comments from the users. It was improved slightly to guarantee data to be recorded correctly and efficiently. The new recording card enables researchers to mark pavement hazards first in the column header, and then, to assemble relevant responses in the category.

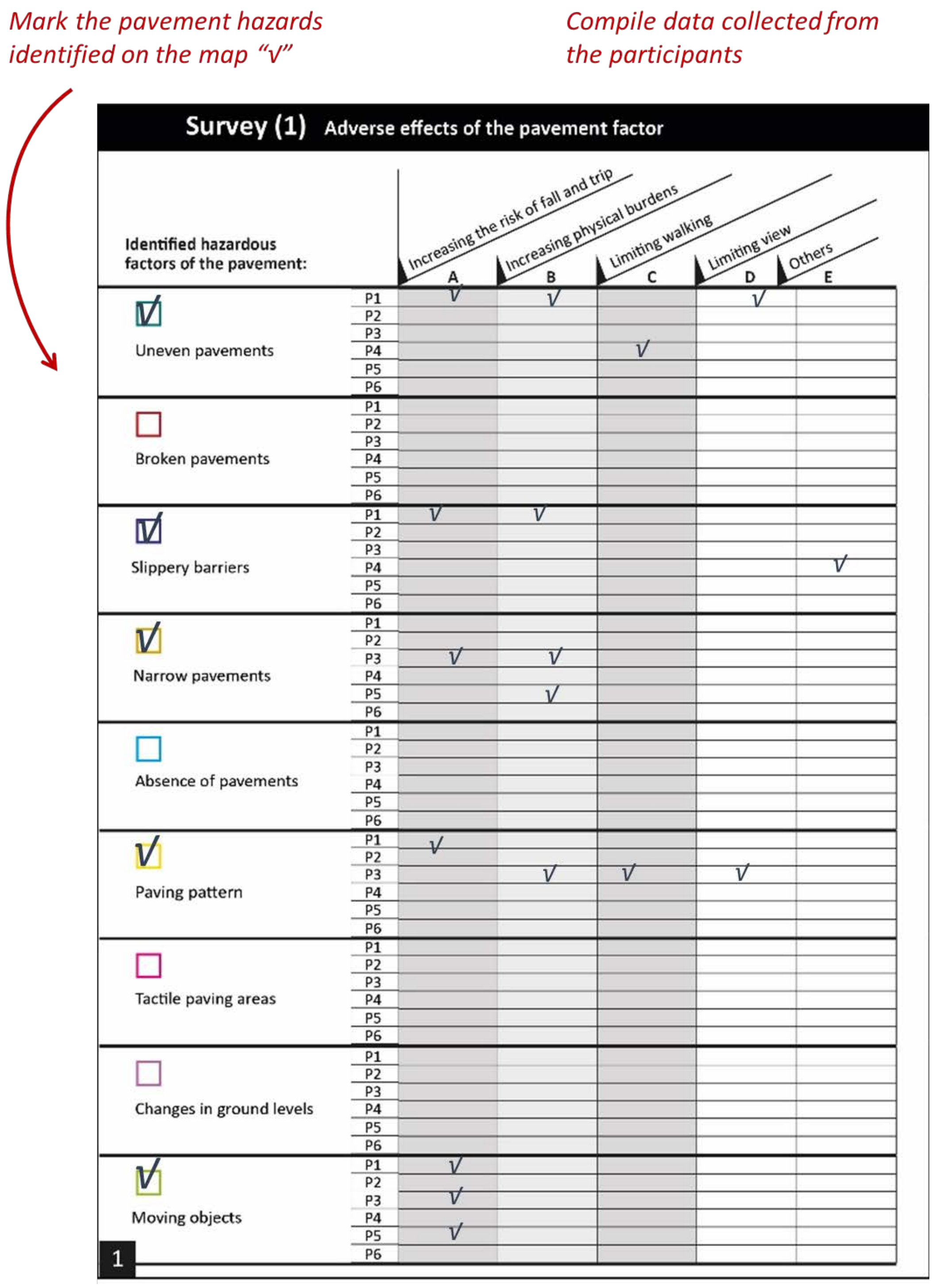


Figure 7-2. Use of the revised recording card.

7.2 Version 3 of the participatory study toolkit

Version 3 has five components consisting of (1) code badges, (2) user instruction, (3) a card pack, (4) survey cards, and (5) a recording card (see Figure 7-3). There are six code badges in total, and each of them uses a unique number, such as 1, 2, or 3 to represent an elderly participant. The code badges allow participants' identity to be codified and help to avoid participants giving answers repeatedly in group exercises. The user instruction introduces the aim, objectives, target groups, exercises, and components of the toolkit (see Figure 7-4). It also provides a step-by-step guide for using the toolkit and demonstrates tasks of both user groups (elderly participants and researchers). The card pack incorporates 16 card boxes and 96 mini cards. Each card box contains a pavement card and six mini cards representing a pavement hazard using a particular colour (refer to Appendix IX). The pavement card boxes are not only used to expand users' ideas but also are employed by participants to preliminarily identify hazards of a pavement environment. The survey cards constitute 16 copies of survey card 1 and a copy of survey card 2 that are used to explore the relationship between each pavement hazard and older pedestrians (elderly participants). As discussed early, the earlier matrices were turned into three pie charts. Survey card 1 was made up of the first two pie charts to explore and specify the adverse impact and behavioural effect of pavement hazards on participants. As the two charts look into the same topic, they were combined together into a single component and were printed separately on each side of survey card 1. Survey card 2 requests participants to nominate improvements in the pavement environment considering pavement issues and walking risks and behavioural varies in walking triggered by the hazards. Each segment of survey card 1 displays an adverse effect of pavement hazards or a behavioural factor, and each segment of survey card 2 offers a recommendation to the pavement. The outer ring of each division split into six individually showing one of the participant codes to allow participants to give an answer by simply ticking their code. Also, the survey card 1 and survey card 2 provide an option of 'Others' allowing participants to add extra findings in addition to the provided content.

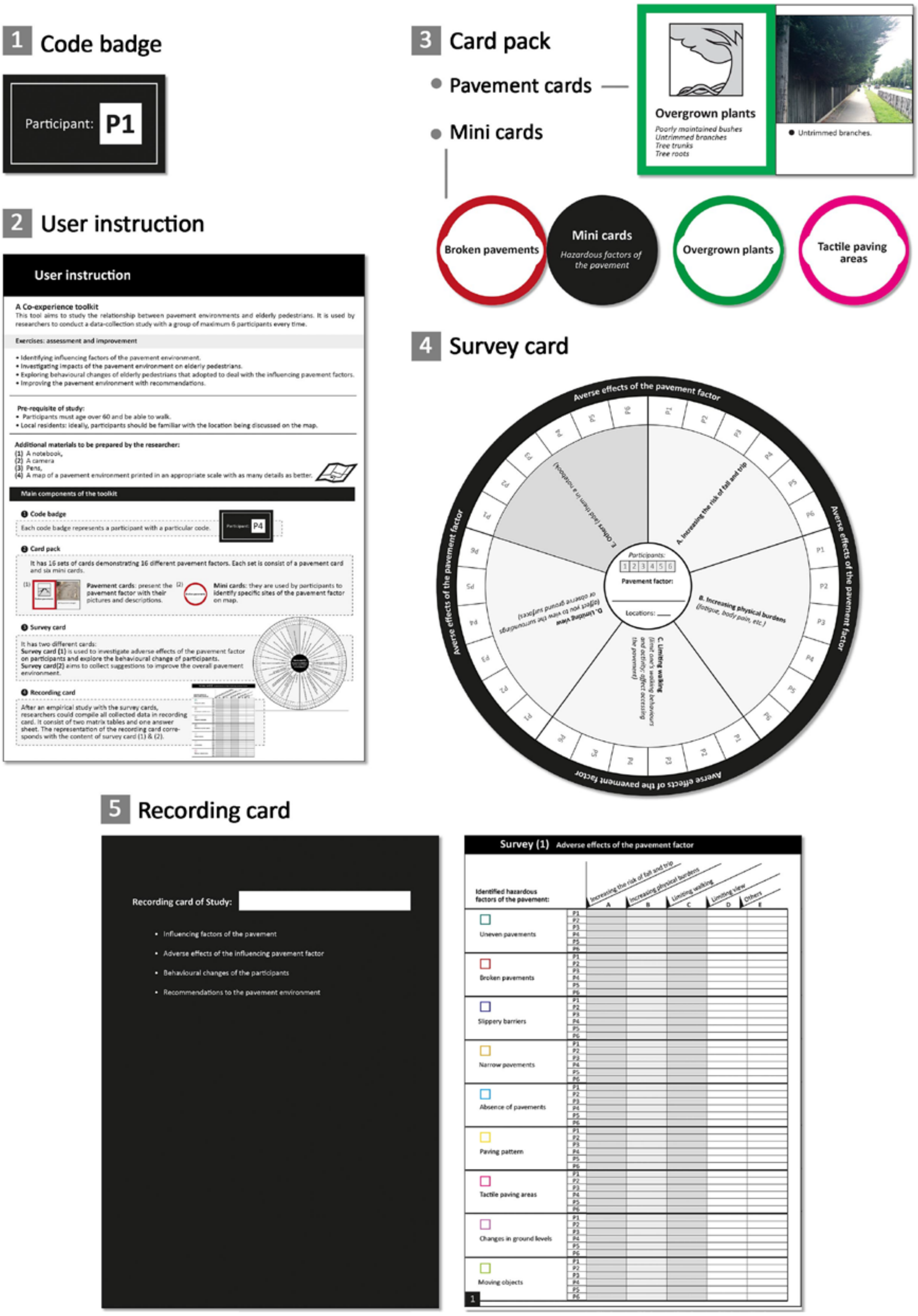


Figure 7-3. Components of version 3.

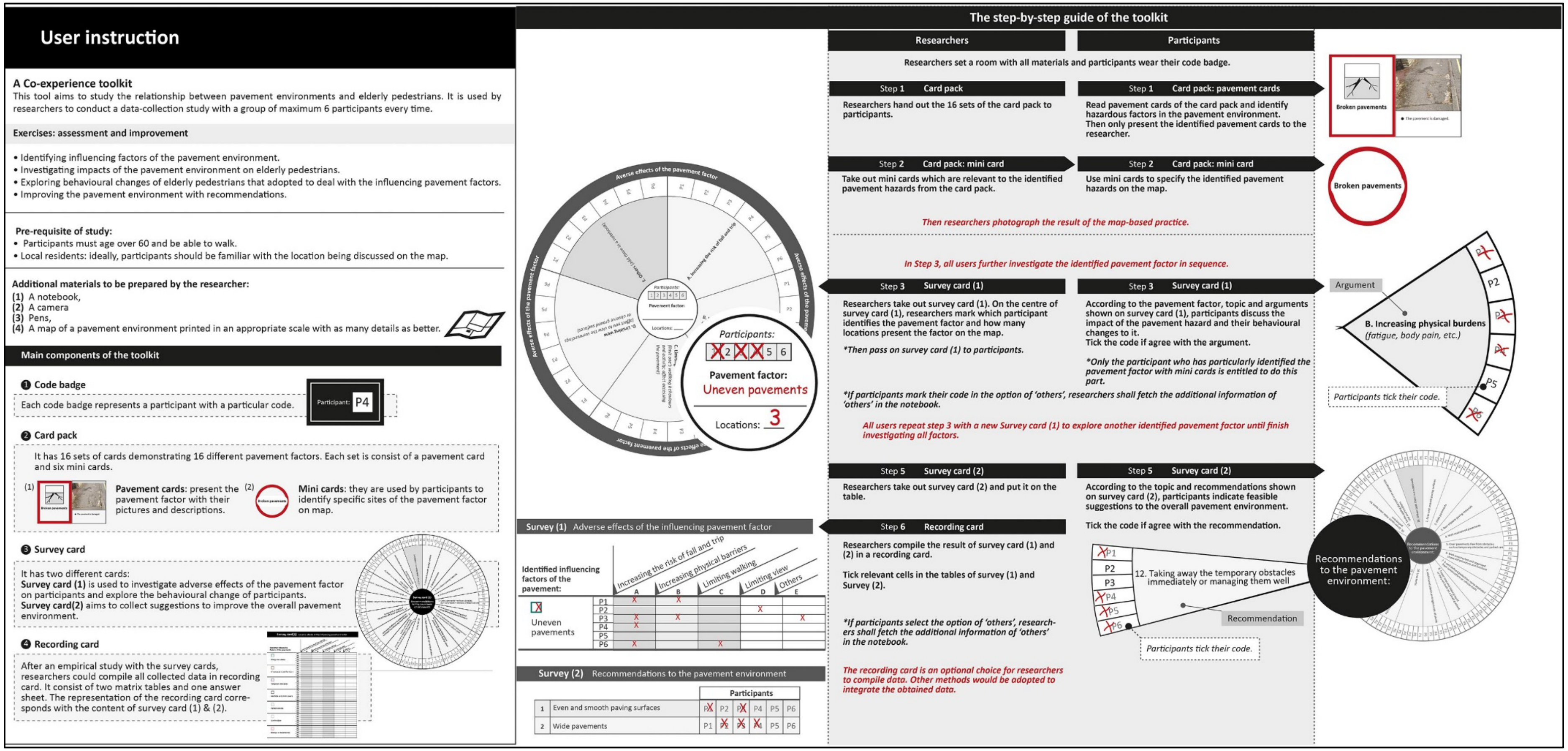


Figure 7-4. The user instruction of the revised tool.

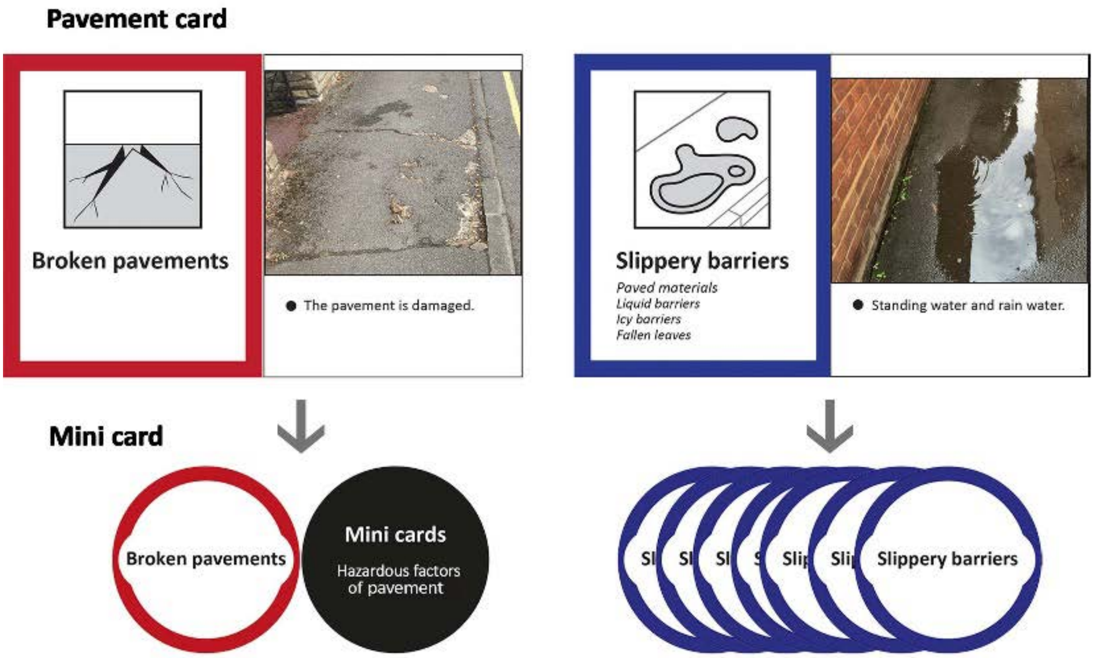


Figure 7-5. The card pack: pavement cards and mini cards.

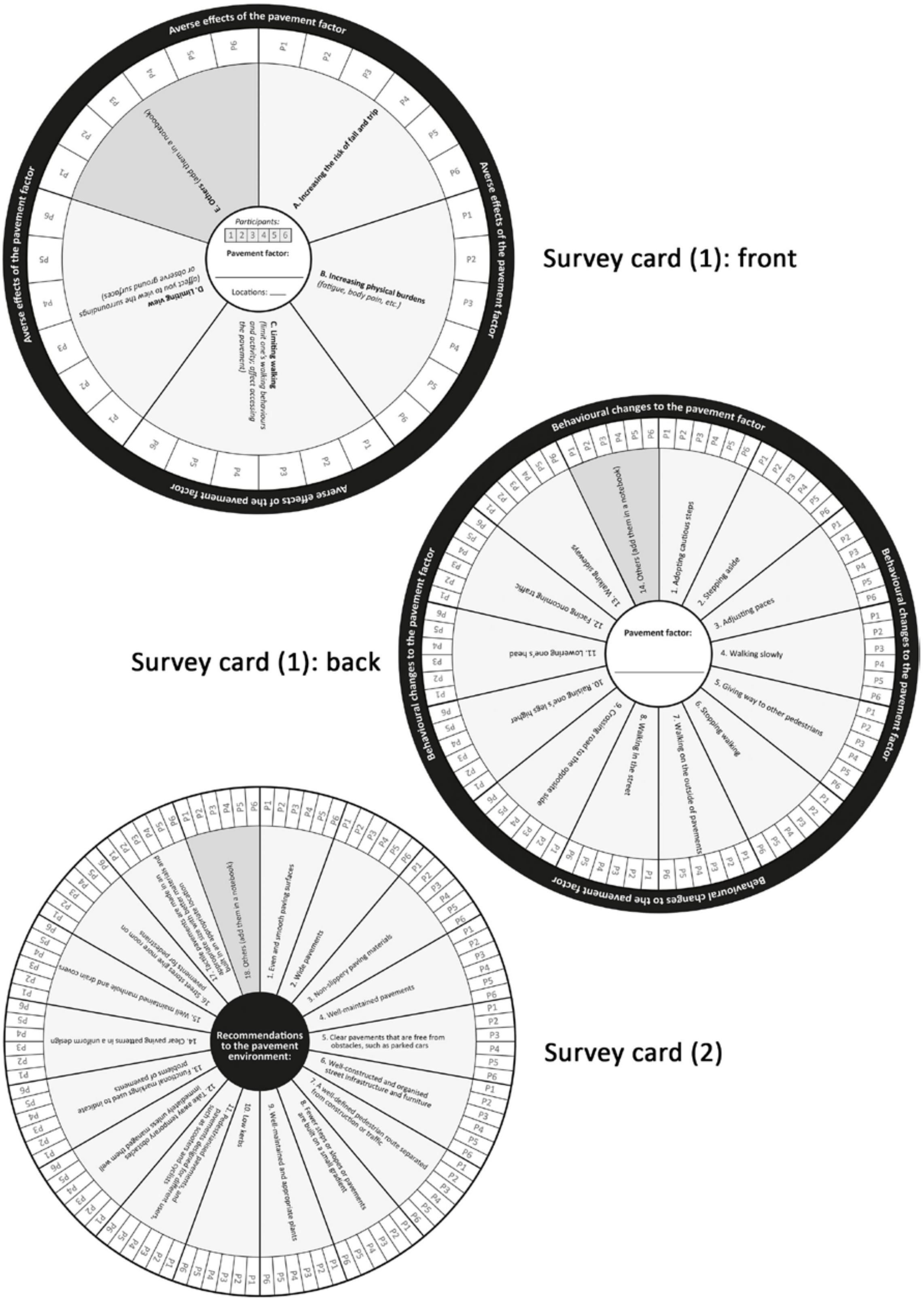


Figure 7-6. The survey cards of version 3.

7.2.1 Use of version 3

According to Figure 7-7 and 7-8, researchers must first prepare a map and bring camera to photograph results of the map-based assessment in order to use the toolkit to undertake a participatory study. Camera was requested because visual information could enable researchers to quickly record the exact locations of the pavement hazards and continue to review the results after the study. At the beginning of the study, researchers need to introduce all components of the toolkit to participants and teach them to use the tool and assign a code badge to each participant. Next, participants use the card pack to conduct a brainstorming session on problems with the pavement. Following this, researchers can start to assess the pavement environment by asking participants to demonstrate hazards that exist in the context using relevant pavement card boxes. Then, researchers collect these identified card boxes and take out mini cards from them, and participants use the mini cards to locate the hazards on the map (see Figure 7-9). Afterwards, researchers photograph the result of the map-based exercise. In the following step, researchers use a copy of survey card 1 to further explore one of the identified pavement hazards only with the participants who have referred this issue on the map. Before the data collection, researchers need to indicate the identified pavement issue on the centre of survey card 1 so that participants know what factor they need to focus upon. Also, researchers need to write down the code of the participants who pinpoint the problem on the map and the locating number of the hazard on survey card 1 (see Figure 7-10). As to participants' tasks of survey card 1, they need to tick their codes on card segments if they agree with the statement presented by the portion. Each survey card 1 is used to study a pavement hazard identified on the map already. The more pavement issues are analysed, the more copies of survey card 1 will be used. Based on the results of the map-based assessment and survey card 1, participants carry on recommending improvements in the pavement environment on survey card 2. Finally, researchers cluster all data collected by those survey cards in their recording card.

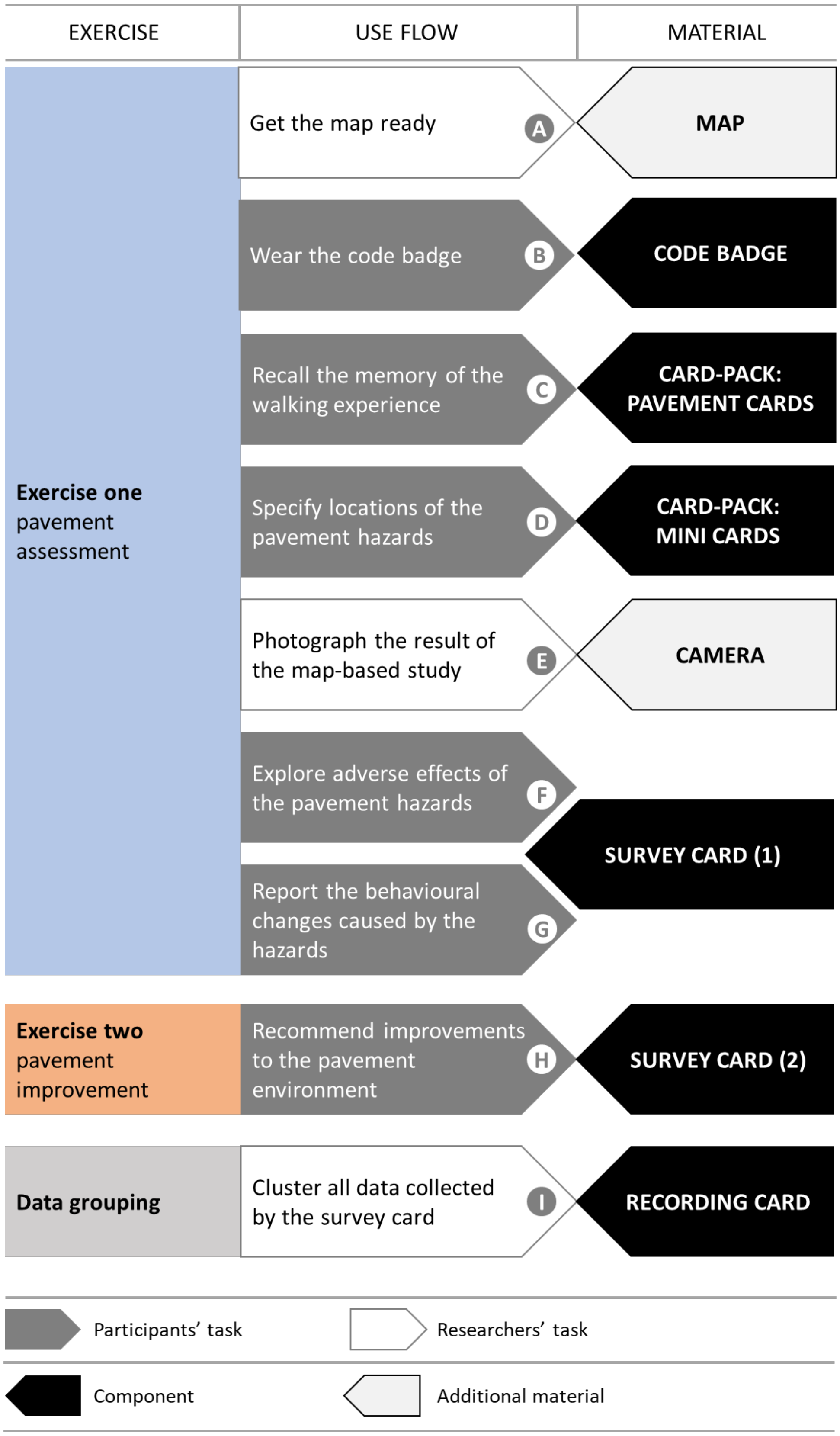


Figure 7-7. Use of version 3.

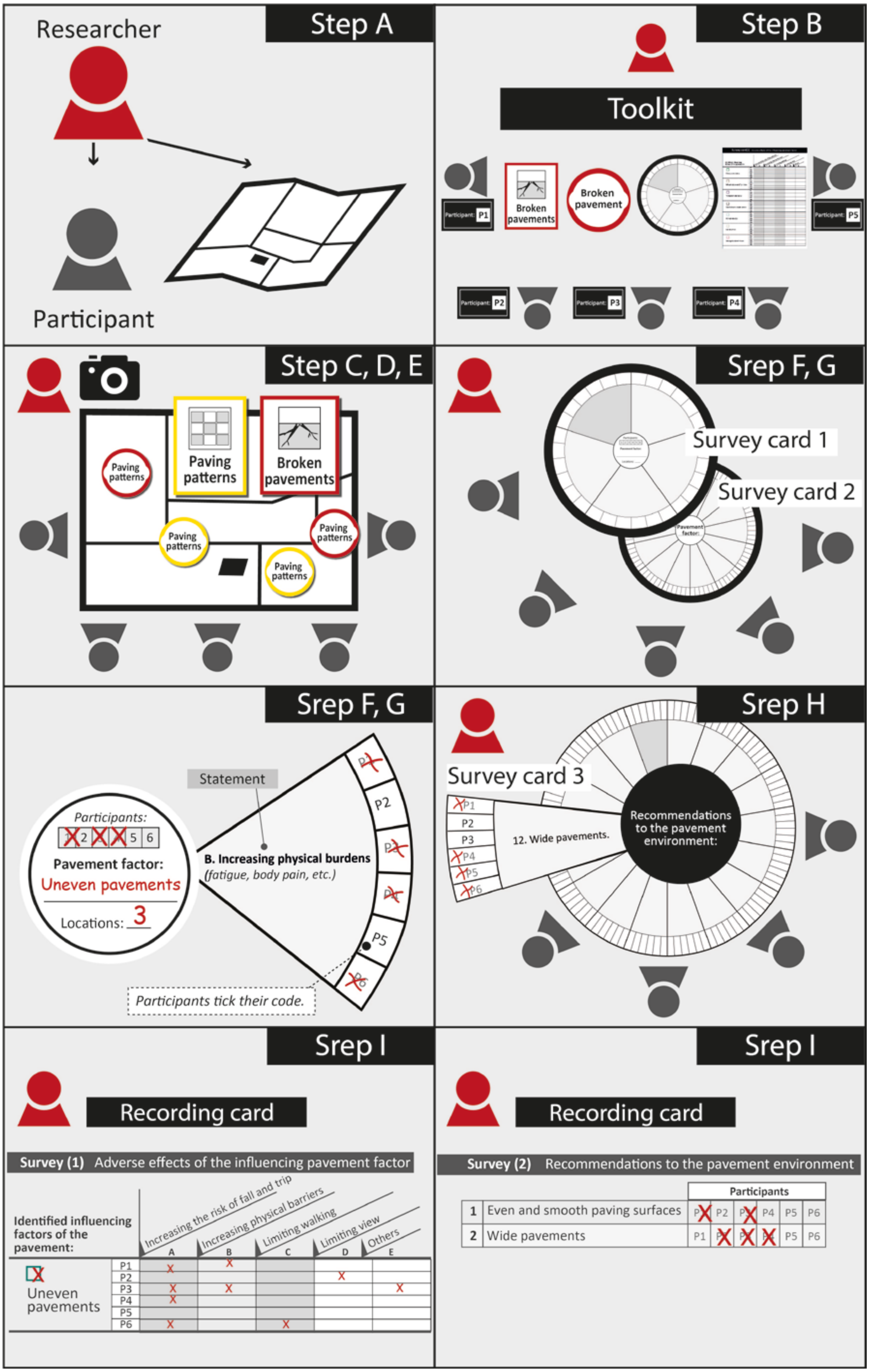


Figure 7-8. Storyboard of version 3 shows steps that are consistent with those in Figure 7-7.

Figure 7-9. The map-based assessment with the card-pack on a 1:5000 map (e.g. Google Maps).

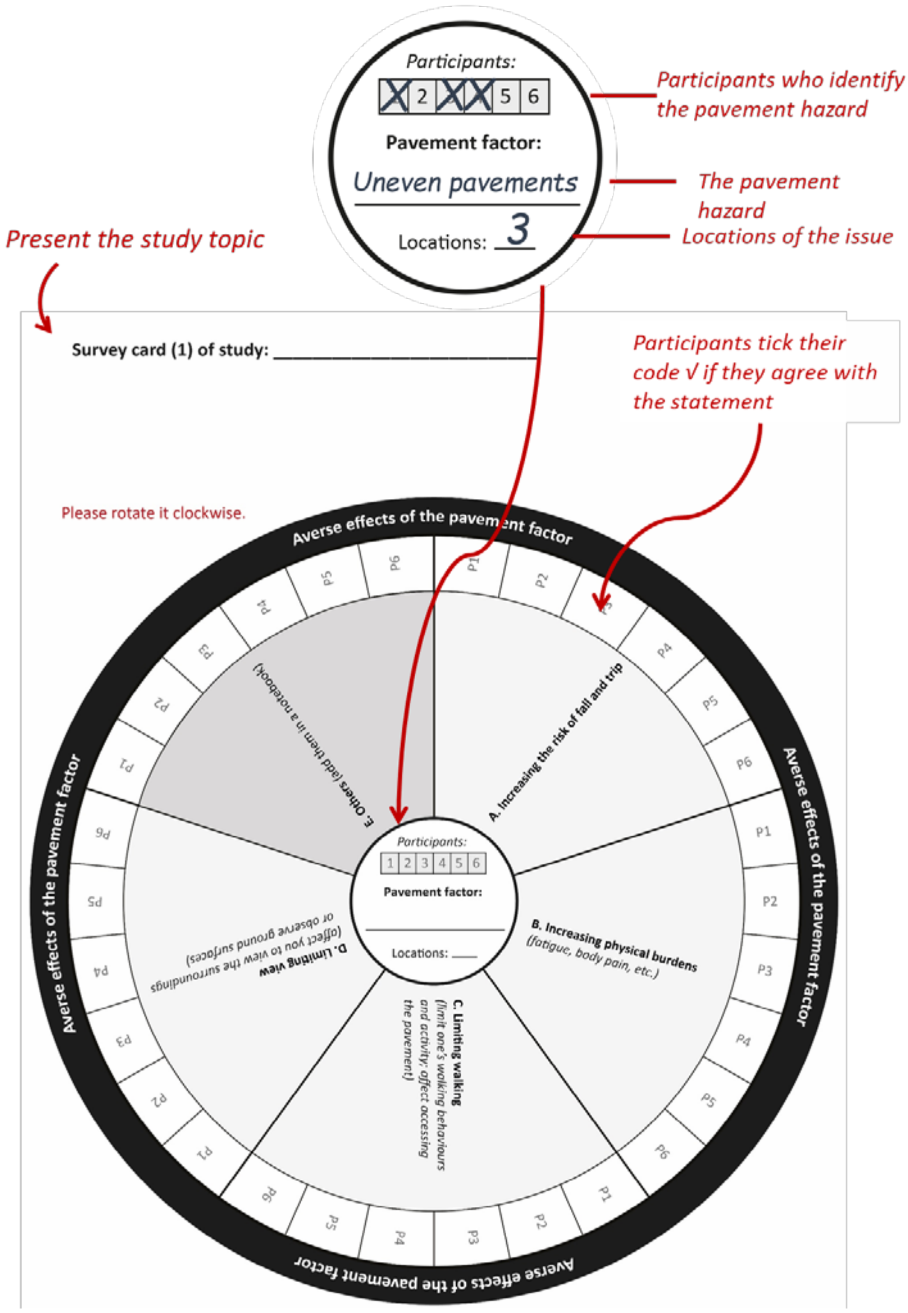


Figure 7-10. Use of the survey card (e.g. survey card 1).

7.3 Testing of version 3

Version 3 has undergone several revisions since the last version, thereby it needs to be tested again to evaluate if the tool works better for users. As the toolkit would be used to implement a group study with two kinds of user groups, the feedback from researchers and study participants (older people) could be different according to their standpoints. The last testing did not fully understand the concerns of the two user groups as most time of the study was spent in coordinating the workshop group.

Therefore, version 3 was evaluated in two sections conducted separately with elderly participants in workshops and with researchers in an interview-based study to seek their in-depth and diverse views.

7.3.1 Workshops with elderly users

There were two workshops conducted to examine if elderly participants could use version 3 to carry out exercises properly in a group activity. Eight senior residents in London were recruited to the workshops through an invitation email along with a participant information sheet. The participants were divided into groups of four which had been found to be a valid sample of a group study (Owen and Noonan, 2013). As requested by the study, they were older than 60 and walking regularly in the pavement environment which would be investigated by the toolkit.

7.3.1.1 Methods

The map used for the map-based exercise was created based on Google Maps and it displayed a part of the pavement environment in Uxbridge town centre in West London. As the group size was bigger than the previous mini workshop, the map was made in a larger size and scale (A1 size with a ratio scale of 1:2000) to enable all group members to read it correctly. The workshops were filmed to ensure small details, findings, and significant user behaviour to be found and analysed (Jewitt, 2012). In addition, the feedback of the participants was collected by a questionnaire which consisted of eight closed-ended questions developed based on the one used in the last evaluation. Therefore, each question also had three options ‘yes’, ‘no’, and ‘neutral’ and a blank space for the participants to give more explanations and comments. ‘Yes’ stands for the ‘agreement’, ‘No’ means the ‘disagreement’, and ‘neutral’ presents that the participants would neither agree nor disagree. The questions were:

1) Is the tool well designed?
2) Is the tool easy to use?
3) Does the tool include enough information related to the study topic?
4) Does the tool present the relationship between the pavement environment and older pedestrians?

5) Does the tool enable you to accurately identify problems with the pavement environment?
6) Does the tool enable you to present the adverse impact of pavement hazards?
7) Does the tool enable you to indicate behavioural changes caused by pavement hazards?
8) Does the tool allow you to suggest recommendations to improve the pavement environment?

7.3.1.2 Analysis and results

Table 7-1. Results of the questionnaires used in the workshop (n=response)

Question	**Yes (n=60)**	**No (n=0)**	**Neutral (n=4)**
Is the tool well designed?	8	-	-
Is the tool easy to use?	8	-	-
Does the tool include enough information related to the study topic?	6	-	2
Does the tool present the relationship between the pavement environment and older pedestrians?	8	-	-
Does the tool enable you to accurately identify problems with the pavement environment?	8	-	-
Does the tool enable you to present the adverse impact of pavement hazards?	7	-	1
Does the tool enable you to indicate behavioural changes caused by pavement hazards?	7	-	1
Does the tool allow you to suggest recommendations to improve the pavement environment?	8	-	-

Responses collected by the closed-ended questions were counted and qualitative data, such as additional explanations, insights, and narratives of the participants, were transcribed and categorised according to different topics. Table 7-1 shows that the questionnaire received 60 'yes', zero 'no', and four 'neutral' from the workshop participants. All workshop members (n=8) found that version 3 was well designed and easy to use and it was a 'quite acceptable routine'. The content of the toolkit was complex, and hence some members were observed to consume more time than others in reading and understanding the instruction. However, the information was well explained and easy to understand, so it worked well when the participants understood the methodology. Six older adults were satisfied with the content of the tool as they found that:

> "Many items were well defined and every aspect of the pavement was covered…all the factors were included…lots of thoughts have gone into identifying all the different factors…my attention was drawn towards problems that elderly people don't always consider…it is a visual study and I could see what would be needed."

However, two participants gave a 'neutral' answer to the design and usability of version 3 and they explained that the 'procedure document (the instruction) requires more time for consideration' because too much information was provided. Regarding inputs of the toolkit, all participants (n=8) agreed that version 3 clarified the relationship between the pavement and their concerns and provided them with an 'open opportunity to discuss issues'. Version 3 enabled them to identify problems with the pavement environment, to present the impact of the pavement factors and to indicate their behavioural changes. Also, based on the group discussion, they were allowed to suggest recommendations to improve the pavement environment concerning the respects of both design and personal behaviour. Version 3 even inspired some users to get some ideas that were not related to the study topic, such as the mental effect of the pavement and provisions for other road users.

Data from the video revealed that the map presented an appropriate size and ratio scale regarding engaging all the members in the group study. Also, it allowed the mini cards to be placed in exact hazardous locations on the map. It also found that the pavement cards and mini cards promoted more group discussion and interaction by making the groups more active in generating eliminated information (see Figure 7-11). However, the size of the survey cards limited the participants in giving answers properly. As the survey cards were too small, one of the participants in each group had to act as a group leader to speak out the card information and write down responses for other group members (see Figure 7-12). In this situation, there was a decrease in the diversity of the data collected by the survey card as the 'leaders' often influenced the whole groups' choices with their personal preferences (see Figure 7-13). The study also found that it was time-consuming to indicate the information about the participant who pinpointed hazards on the map and the number of hazardous locations repeatedly on every single copy of survey card 1. Additionally, the observer of the workshop found that it was complicated to compile the data from the survey cards to the recording card as the formats of the two materials were different (the survey cards were made using pie charts and the recording card was developed on matrices).

Figure 7-11. The group discussion in the study (photographs have been permitted by participants).

Figure 7-12. Use of survey cards in the group study (photographs have been permitted by participants).

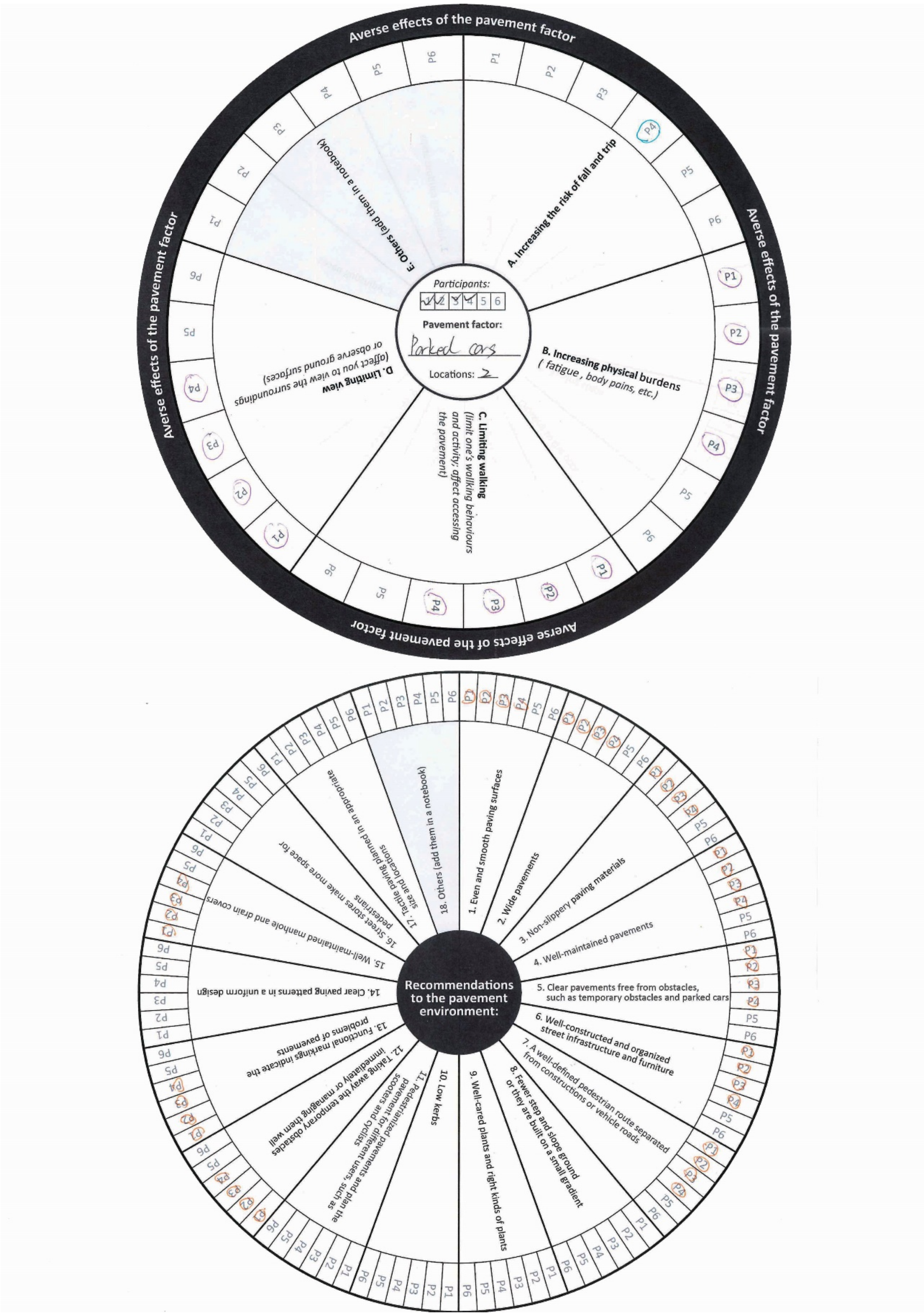


Figure 7-13. Unanimous answers shown on the survey cards (survey card 1 in the top and survey card 2 in the bottom).

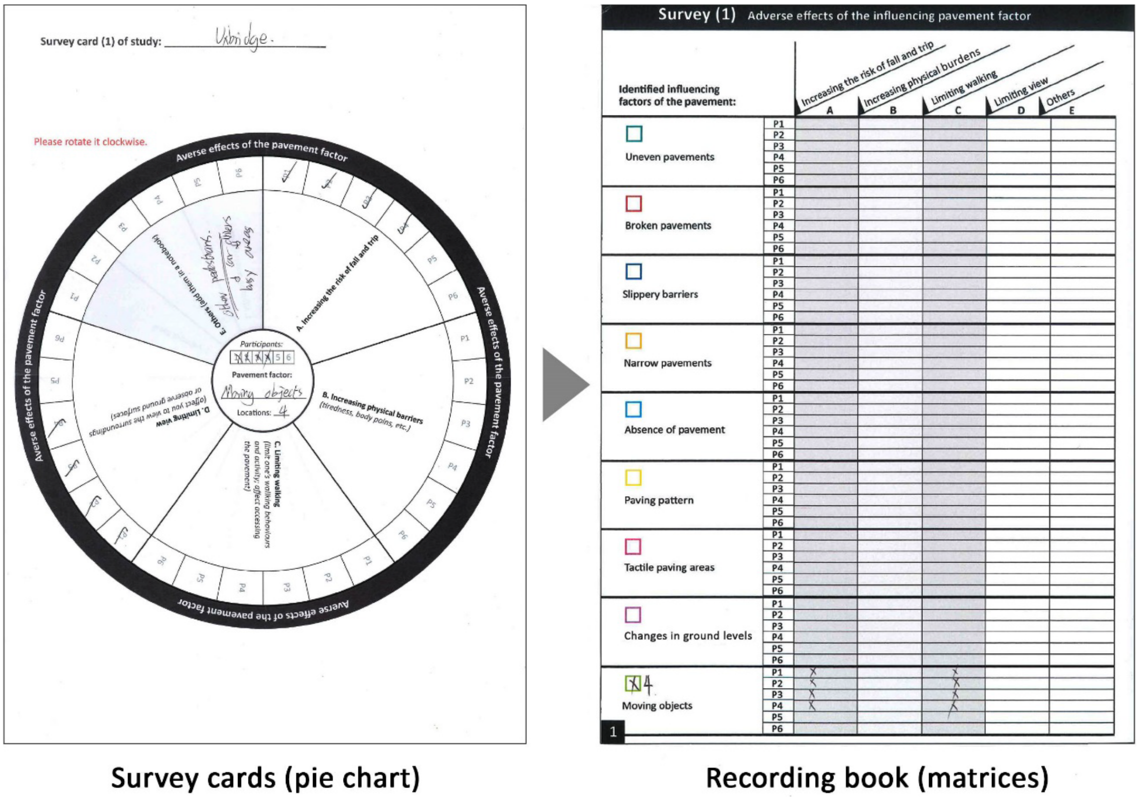


Figure 7-14. Use of the recording cards in the interview-based study.

7.3.2 The interview-based test with researchers

The interview-based study was used to test if researchers could self-learn the tool and use it to plan a study themselves so that they could give proper and objective comments on version 3. The interview-based test was conducted with eight researchers recruited from academic and industrial fields and the local authority of Uxbridge. The interviewees were sampled for the purpose of diversity (Martínez-Mesa *et al.*, 2016), thereby they comprised four experienced researchers, two early-stage researchers, a designer, and a councillor who were professionally engaged in the field of transport environments, travel behaviour, inclusive design, tool design, highway and pavements, neighbourhood maintenance, residential services, or architectural design. In line with the sample criteria introduced in Chapter 3.6, the participants were chosen because they could be targeting users of the tool and they could provide various expertise regarding assessing and developing the toolkit.

Table 7-2. Interviewees of the interview-based testing

Participant	Field of work
Experienced researcher (n=4)	• Transport environments and travel behaviour • Inclusive design • Tool design
Early-stage researcher (n=2)	• Highway and pavements
Designer (n=1)	• Architectural design
Local councillor (n=1)	• Neighbourhood maintenance and residential services

7.3.2.1 Methods

Interviews are the most common method to get users involved in the development process of design solutions (Stenmark, Tinnsten and Wiklund, 2011). They allow interviewees' experience and feelings to be expressed and enables their perspectives to be in-depth explored (Kvale, 2003 and Berg, 2007, cited in Alshenqeeti, 2014). Therefore, an interview was carried out in the study to better understand researchers' experience and opinions on version 3. The study was divided into two sections including a simulation and a formal assessment that requested the interviewees to learn how to use the toolkit on their own and examine it from a researcher perspective. In the first section of the study, they were asked to simulate a study using the tool based on a 1:5000 printed map of a pavement environment where they had been familiar with. A demonstration video was used helping the researchers to learn about the tool and to understand its rationale efficiently (Vrbik and Vrbik, 2017). As Figure 7-15 shows, the video explains what components that the toolkit provides and how they can be used for different exercises.

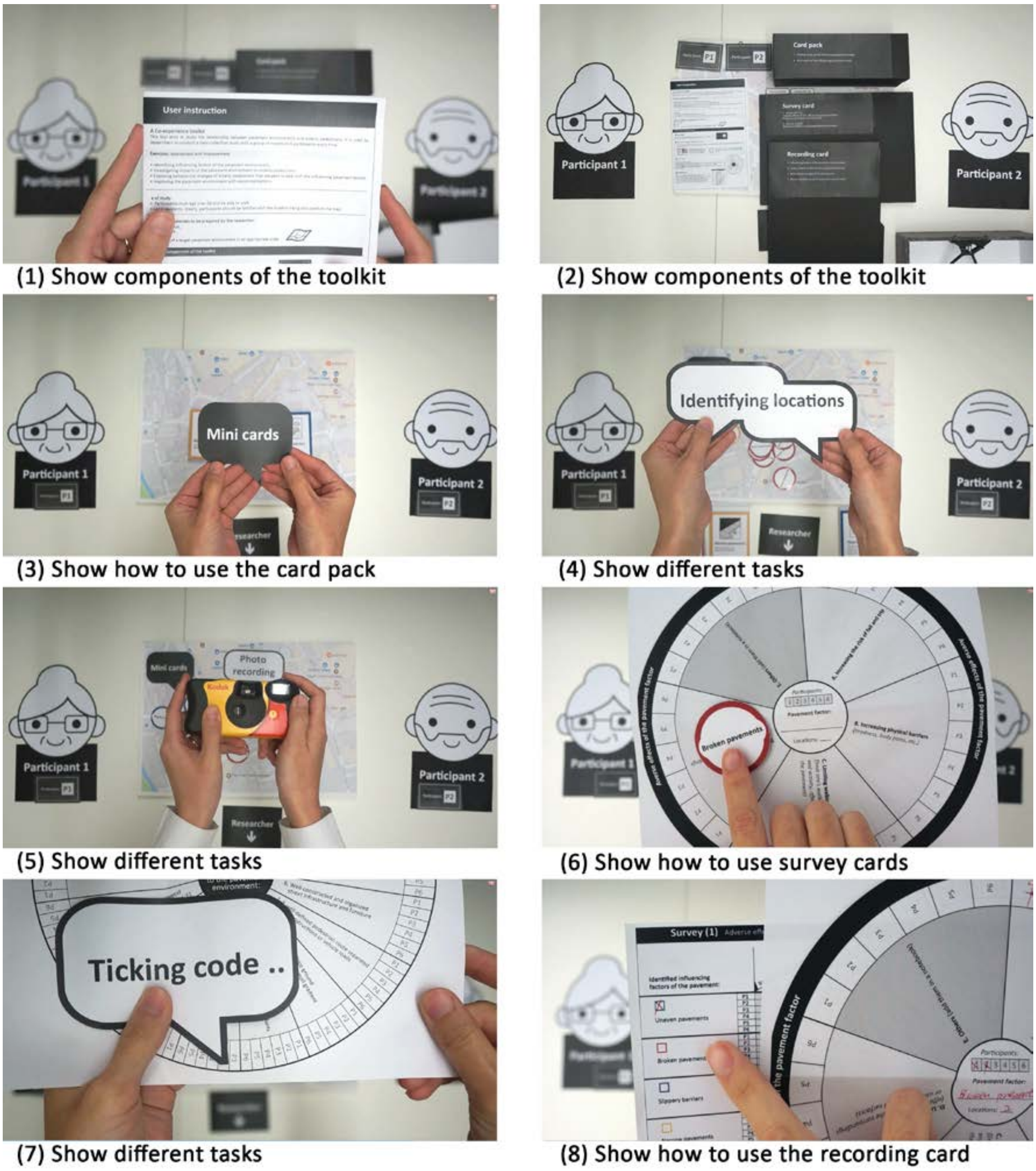


Figure 7-15. The demonstration video of the toolkit.

In section two of the study, the researchers were asked to share their user experience and perspective of the toolkit. A questionnaire including eight closed-ended questions and three open-ended questions was employed to record their feedback concerning the design, information, utility, and outputs of the tool. Questions of the survey were formed on the questionnaire used previously (see in Chapter 6.7.2):

1) Is the toolkit well designed regarding the aspect of the layout, colours, fonts, images, size, and portability?
2) Is the toolkit easy to learn?

3) Is the toolkit easy to use?
4) Does the toolkit cover the information related to the study topic?
5) Does the toolkit present the relationship between the pavement and older pedestrians?
6) Does the toolkit enable you to do the exercises properly?
7) Does the toolkit allow you to efficiently compile or interpret the data?
8) Does the toolkit explicitly present the output?
9) What will you do with the toolkit or the data?
10) Do you have any suggestions for the toolkit?
11) Do you have other comments on the toolkit?'

7.3.2.2 Results and feedback

The distribution of the answers to each question was calculated and the answers to the open-end questions were transcribed and coded and finally grouped into four topics, namely applications of the toolkit, outputs of the toolkit, suggestions to the toolkit, and other comments.

Table 7-3. Results of the interview-based questionnaires (n=response)

Question 1 to 8	**Yes (n=88)**	**No (n=2)**	**Neutral (n=22)**
1. Is the toolkit well designed?	38	-	10
Layout	4	-	4
Colours	5	-	3
Fonts (size and style)	6	-	2
Images	8	-	0
Size (overall and each component)	8	-	0
Portable use	7	-	1
2. Is the toolkit easy to learn?	2	-	6
3. Is the toolkit easy to use?	4	-	4

4.	Does the toolkit cover all information related to the study topic?	8	-	-
5.	Does the toolkit assist you to identify the relationship between the pavement and older pedestrians?	6	2	-
6.	Does the toolkit enable you to do the exercises properly?	8	-	-
7.	Does the toolkit allow you to efficiently compile or interpret the data?	8	-	-
8.	Does the toolkit explicitly present the output?	7	-	1

Table 7-3 shows that the study obtained 88 ‘yes’, two ‘no’, and 22 ‘neutral’ from the questionnaires. Regarding the design of the toolkit, more than half of the interviewees found that the layout (n=4 yes) of version 3 was good, and colours (n=5 yes) and fonts (n=6 yes) were appropriately used. Images used by the tool and the size of the prototype were user-friendly (n=8 yes), and the toolkit was portable enough to be carried or used in different contexts (n=7 yes). However, the other researchers argued that the layout (n=4), colours (n=3), and font size (n=2) of version 3 were deficient and might restrict the usability of the toolkit. For example, they explained that the background colours (black and white) might be too formal and hardly to distinguish different sections of the toolkit. In addition, the font size might be too small for older adults, and the presentation of the survey cards showed some information upside down to users. According to the answers to question 3, many researchers (n=6 neutral) found it was complicated and challenging to figure out how to use the tool for the first time. The instruction was not easy to follow up as too many items had to be known in the study. Also, it was confusing to learn how different pieces worked together, so more explanations of the components would be necessary. However, the responses (n=4 yes & n=4 neutral) to question 4 indicated that the tool was not difficult to use once the researchers figured out the rationale of the tool based on the video and instruction.

The researchers (n=8 yes to question 4) were satisfied with the information provided by version 3 as it enabled them to do different tasks properly. They (n=6 yes to question 5 & n=8 yes to question 6) found that the relationship between the pavement and older pedestrians was explicitly revealed by the tool, and findings on the impact of the pavement and walking behaviour of elderly people could be developed by being further investigated. However, the number of hazardous locations was not as important as other information on survey card 1, because this result had been uncovered by the map. The recording card allowed the researchers to organise data efficiently (n=8 yes to question 7) and come into outcomes in a straightforward manner (n=7 yes to question 8). Nevertheless, a researcher believed that a digital matrix would be better for quick data recording.

Table 7-4. Results of the open-ended questions to the interview-based questionnaires

<table>
<tr><th>Question 9 to 11</th><th>Categories (n=reference)</th></tr>
<tr><td rowspan="2">9. What will you do with the toolkit or the data?
(applications and outputs of the toolkit)</td><td>• Introduce the tool to local authorities (n=4)
• Train road engineers and designers (n=1)
• Carry out an investigation with different samples (1)</td></tr>
<tr><td>• Conduct further analysis or probes (n=5)
• Create a better environment (n=3)
• Create a report (n=2)
• Inclusive design (n=2)
• Create design solutions (n=2)
• Improve travel experience (n=1)</td></tr>
<tr><td>10. Do you have any suggestions for the toolkit?
(suggestions to the toolkit)</td><td rowspan="2">• Colour coding (n=7)
• More explanations and specifications (n=4)
• Redesign the survey card (n=2)
• Simplify the toolkit (n=1)
• The format of the toolkit (n=1)
• Data-collection (n=1)</td></tr>
<tr><td>11. Do you have other comments on the toolkit?
(other comments on the toolkit)</td></tr>
</table>

As to the application of the toolkit (question 9), four researchers would introduce the tool to local governments to make them more acknowledge the impact of the pavement on older pedestrians and improve the pavement concerning older people's needs. A person commented that 'this toolkit is very useful to investigate problems and recommendations from senior people's perspectives; therefore, the government can develop pavements to fit into older adults' needs. Likewise, the local councillor in this study would use the tool to train road engineers and designers in the local authority so that they would know about and understand the perspective and walking experience of older adults and eventually, reduce environmental risks. In addition, a researcher would use the tool to do more investigations with senior residents in different locations and compare the results. In terms of developing the output, most researchers (n=5) would conduct a further study on the significant factors emerged by the tool, such as the risk of fall. The researcher who worked on highway and pavement projects would have a quantitative analysis using professional software like Excel or MATLAB. Some interviewees (n=3) would use the study results to create a better and more age-friendly environment for older pedestrians. A researcher commented that 'my research is about attracting people to go tourist attractions, especially older people and disabled people…I will use this toolkit to develop pavements around the tourist attractions'. Two researchers (n=2) chose to compose a report for local authorities and translate the data and the content of the tool into design solutions to make improvements in pedestrian safety. The researcher who was an expert in transport research would improve the travel experience of older people based on the behavioural adaptions induced by pavement hazards.

For future development of the tool (question 10 and question 11), almost all researchers (n=7) suggested that different parts of the toolkit and segments of the survey cards to be distinguished and coded by more colours. Also, the survey cards could be redesigned to find a better way to display information (n=2). The tool could give more precise explanations and specifications of the components (n=4). A researcher suggested that the toolkit should be simplified with all its components better organised, and a digital format could be considered to further refine the tool (n=1). Additionally, more original opinions besides the content provided by the tool could be sought by the participatory study (n=1).

7.3.3 Discussion

Version 3 received more positive feedback from the users compared to the previous version. In general, version 3 was simple and well designed, and it enabled the users to efficiently investigate pavement hazards and their impact on walking among older pedestrians and assisted the researchers to improve the pavement environment and to understand older pedestrians' walking needs from a new angle (Yin and Pei, 2019). The elderly users indicated that version 3 covered almost every factor of their walking behaviour and every aspect of the pavement. These views were well defined and emerged all the problems that they had encountered in the real world. The tool also included some facets that the older adults had not thought of or considered before that made them think they had the same responsibility as local councils. Version 3 provided the researchers with a new way to conduct an easy group study with older adults (Yin and Pei, 2019). It helped them to quickly and efficiently get information about hazardous factors of the pavement and barriers to walking. Some of the researchers would introduce the tool to local governments and use the tool to train construction engineers and road designers so that they could be more aware of older pedestrians, and hence to improve the age-friendliness of the pavement environment. The researchers also found that the data collected by the tool was analysable that could be easily transcribed into an assessment report or design guidance or solutions. They would interpret the outcomes with more evidence in their work field, analyse the data using a technical approach, seek insights into the results, and explore pavements in different areas with diverse populations. An expert would improve the travel experience of older people in outdoors based on the behavioural varies identified by the tool.

Although version 3 had been revised a lot, some users still had to take a longer time to learn the toolkit, especially at the beginning of the study, as they were confused about the instruction and the link between each section of the tool. However, the tool worked well for them as soon as they understood the principle. The demonstration video was found to greatly help the researchers to self-learn about the toolkit. Therefore, the idea of the demonstration film would be kept for future dissemination of the tool. Some operations of survey card 1, such as the recording of the results of the map-based study, was less useful to the researchers. The size and layout of the survey cards restricted the elderly participants' action although they indeed promoted the group discussion. In this situation, two participants had to play a leadership role to write down other people's answers to the survey cards. In line with O.Nyumba *et al.* (2018), they were found to influence the study results especially when the other participants did not stand firm on their opinions or were not active. To avoid the issue, the survey cards needed to be redesigned into a more user-friendly layout with a larger size to enable all participants to be more engaged in the group interaction. Also, more colours could be used to distinguish different segments of the survey cards to enable a clear presentation. Apart from that, grouping data from the survey cards to the recording card was not an effective action as the layout of the two materials were different. In this case, some researchers preferred to use a different approach, such as Excel, to compile data. An interviewee recommended a digital format for the recording card.

7.4 The final version of the toolkit: W-KIT

Based on the testing, the tool was further amended with its final version named W-KIT. W-KIT is a combination of two phrases, 'walk it' and 'work it', meaning that researchers and older adults work together on walking environments. Figure 7-16 displays that W-KIT consists of four sections which are (1) instruction, (2) card sets, (3) study cards, and (4) participant stickers. Those parts were numbered to show a definite connection and order to assist users to use the materials in sequence (see Figure 7-17). W-KIT takes off the recording card because the recording card of the last version was found to be less useful for the researchers in last study. W-KIT requests researchers to use camera to document the study results instead of using a recording card. In addition, a notebook must be prepared by them to collected additional findings and ideas besides the information listed by the tool.

W-KIT clarifies the previous exercises and divides them into four activities which can be carried out together or separately for various purposes with the tool components being used individually or cooperatively. The four activities are:

1. Exercise one (a map-based exercise): identifying hazardous factors of the pavement in specific locations on a map
2. Exercise two: investigating the adverse impact of pavement hazards
3. Exercise three: exploring behavioural changes in walking when encountering pavement hazards
4. Exercise four: proposing recommendations to improve the pavement environment

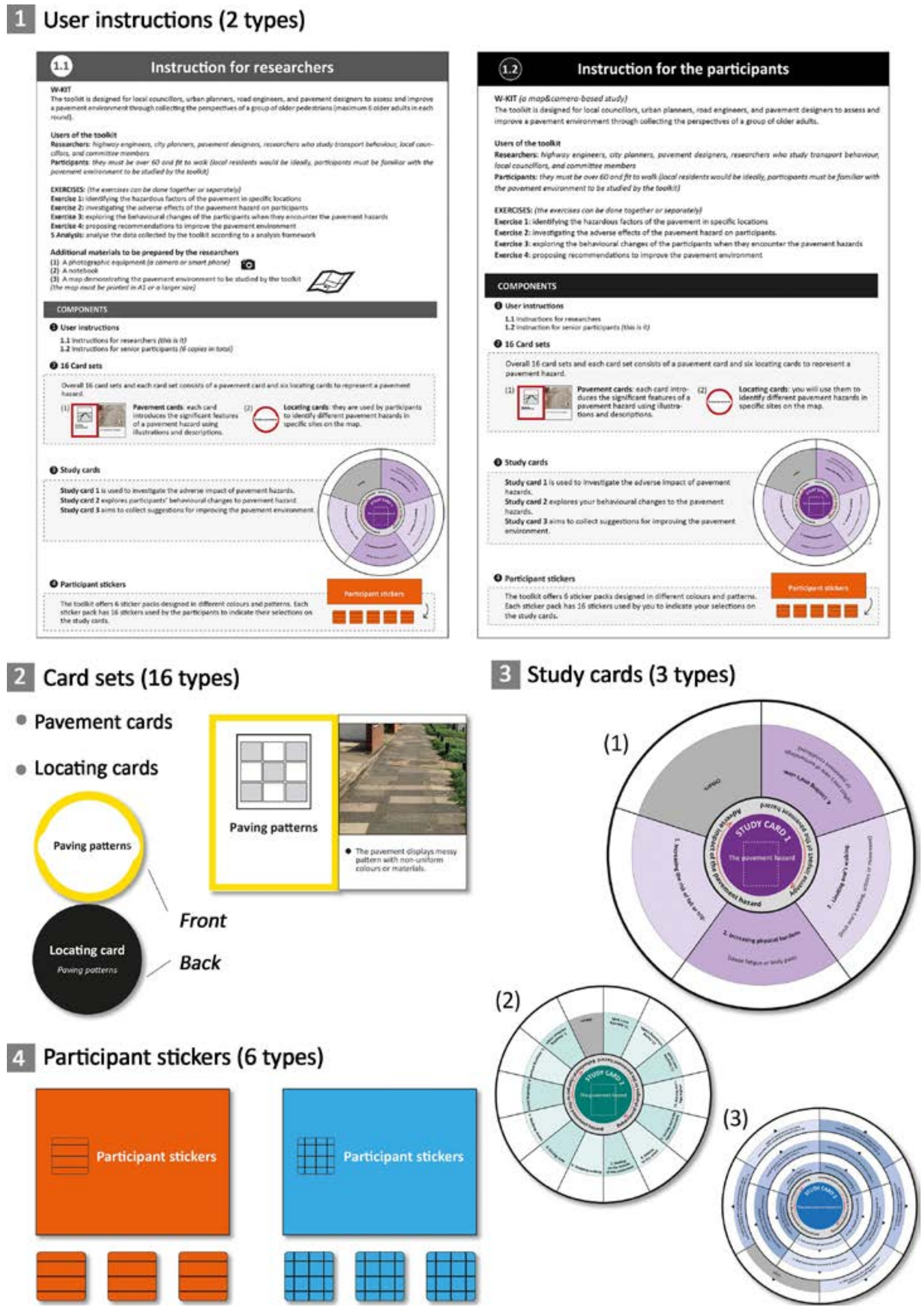


Figure 7-16. The components of W-KIT.

Figure 7-17. The prototype of W-KIT.

7.4.1 Instruction

The instruction for W-KIT is designed into two types using different background colours respectively serves researchers and study participants (see Figure 7-18). It displays a more specific and ordered presentation introducing the aim, objectives, target users, and components of W-KIT as well as the additional materials to be supplied by researchers. The instruction also introduces a more specific use flow with precise steps ordered and grouped into four item numbers and theme colours corresponding with the exercises (see Figure 7-19). By this means, the new instruction can help users to understand the process of conducting a participatory study using the W-KIT. In addition, it indicates the materials used for different tasks and highlights important rules in colours. The researcher instruction additionally provides an analysis framework adapted from the research conclusions of DS-I (see Figure 7-20). The framework categories pavement hazards into poor pavement conditions and pavement obstructions and demonstrates relationships between the pavement environment and older pedestrians regarding the impact of pavement hazards and walking behaviour and requirements of older adults. Researchers can use the framework to analyse the data collected by W-KIT in a simple way and discuss the results in a systemic structure.

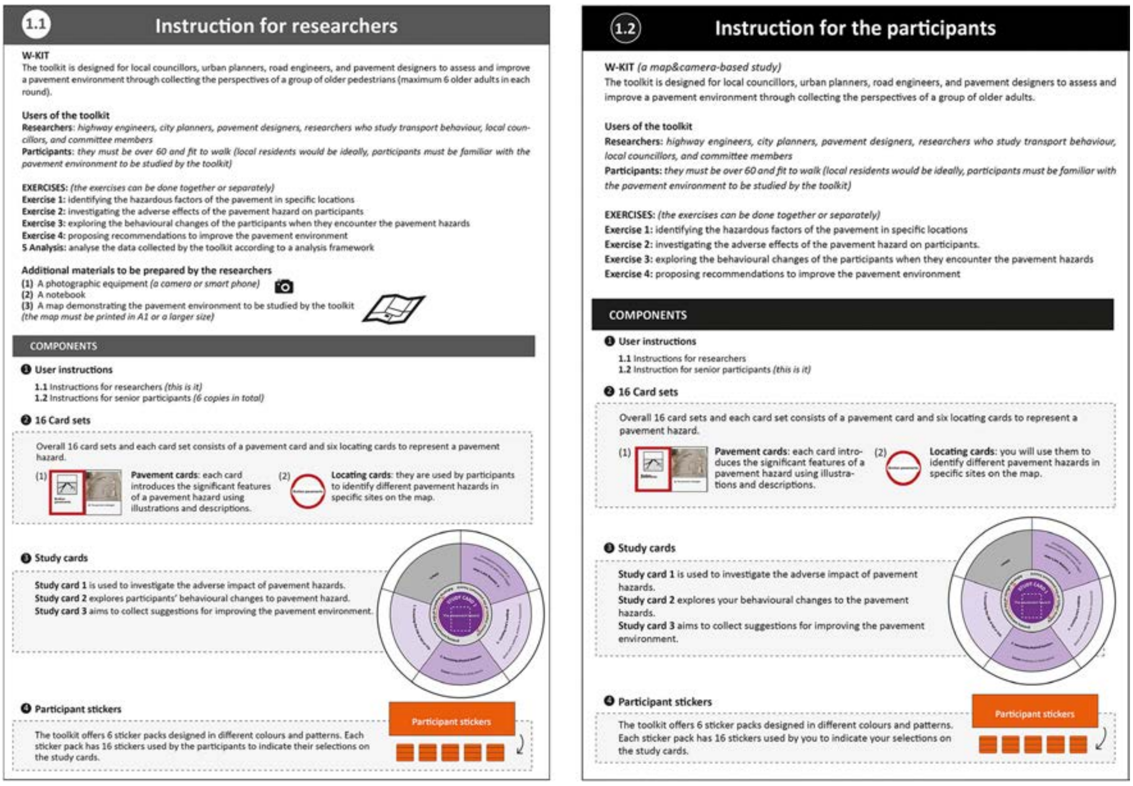


Figure 7-18. The instruction for researchers and elderly participants.

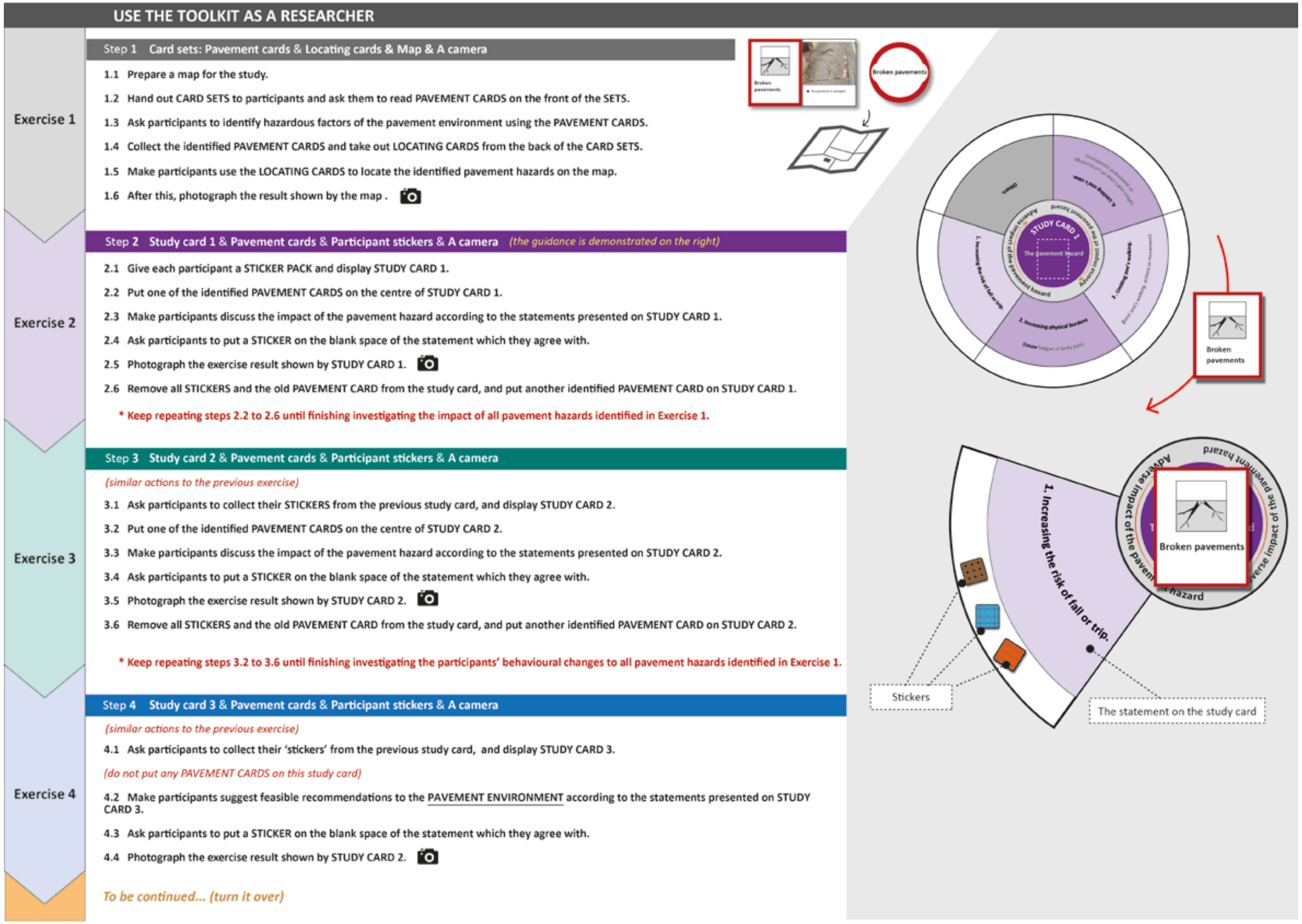


Figure 7-19. Exercises of W-KIT and the step-by-step guide of the tool (an example of the researcher instruction).

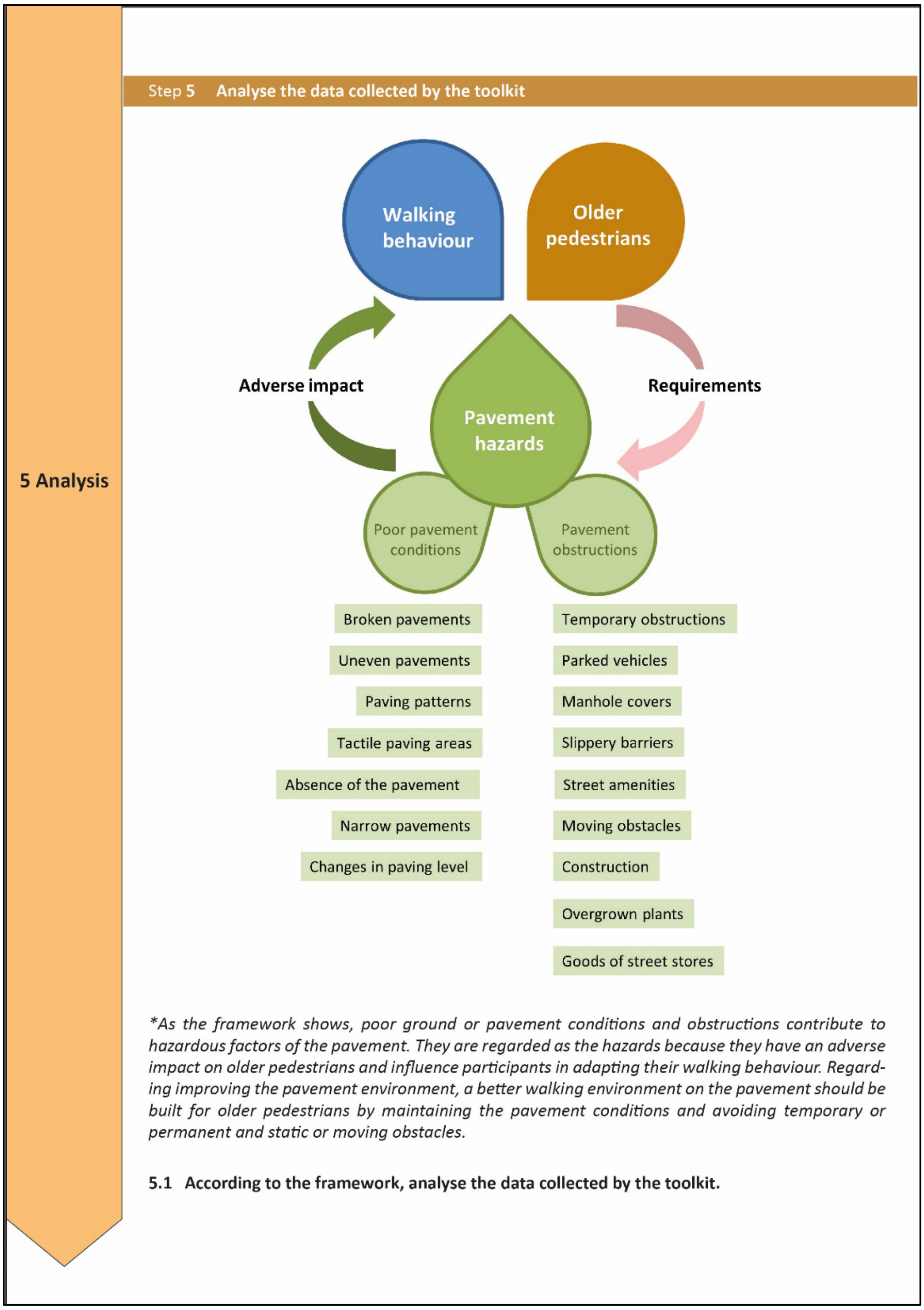


Figure 7-20. The analysis framework offered by W-KIT.

7.4.2 Card sets

W-KIT renames the previous card-pack to card sets and renames the mini cards to locating cards to clarify the character and function of the materials. The card set independently combines a pavement card and six locating cards. To enhance the efficiency and usability of the toolkit, the locating cards are displayed in a transparent holder attached to the card sets, and each locating card shows one of the hazardous factors on its both sides (see Figure 7-21 &22).

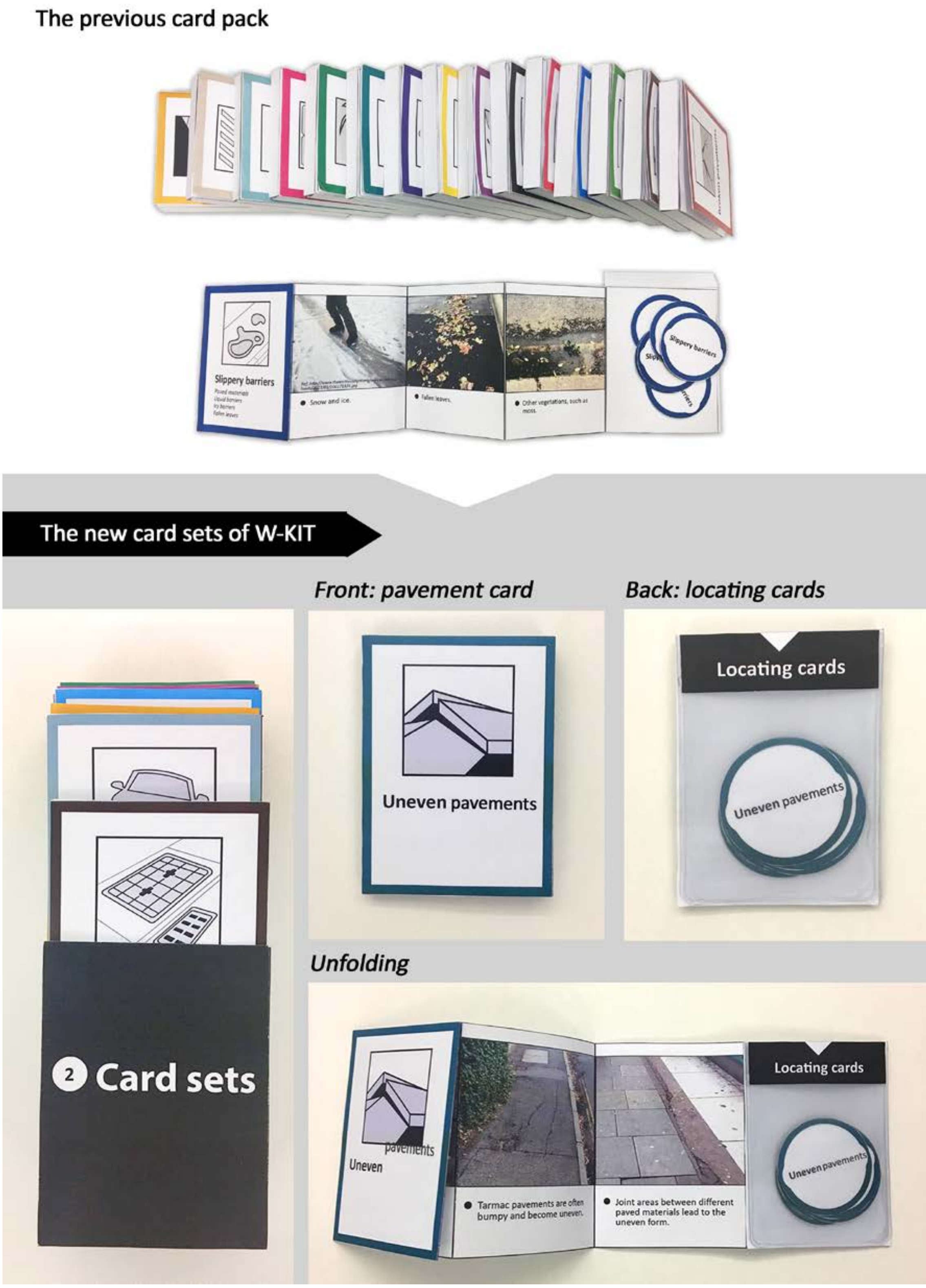


Figure 7-21. The card sets of W-KIT: pavement cards and locating cards.

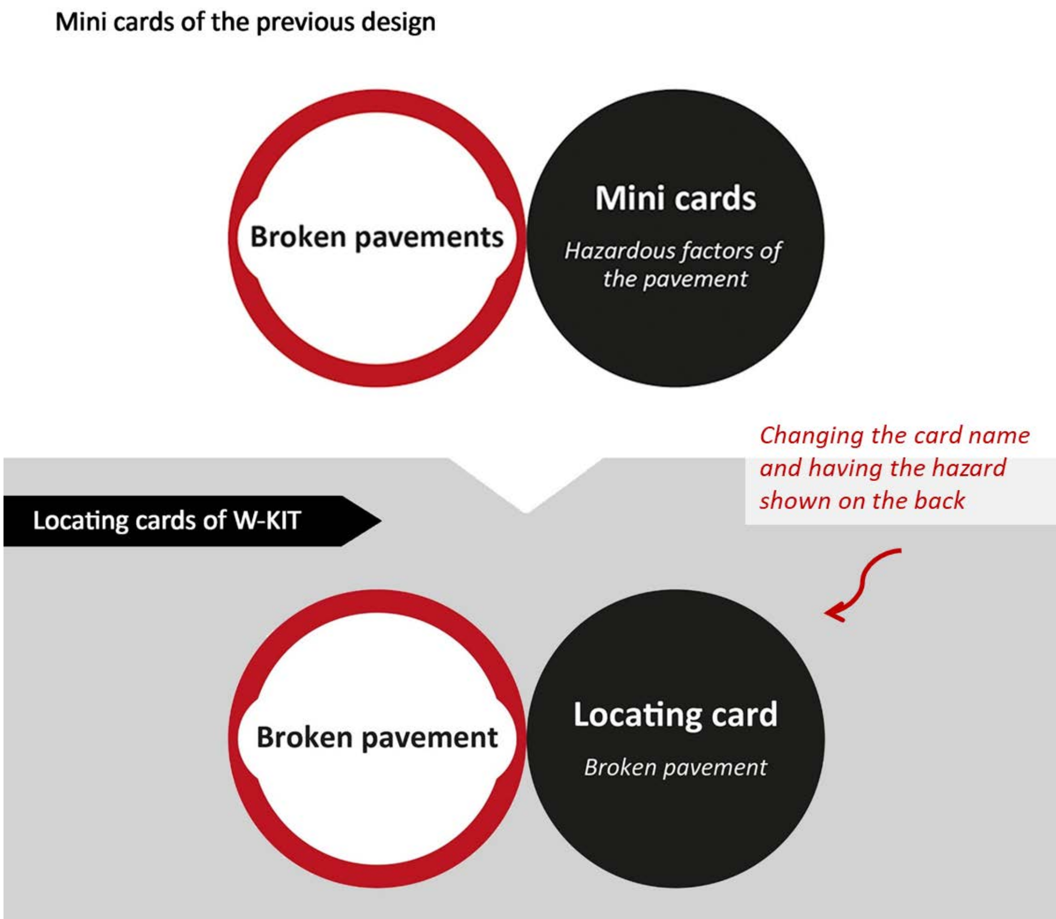


Figure 7-22. Differences between the previous mini cards and the locating cards.

7.4.3 Study cards

As the exercises of the W-KIT were divided into four exercises, survey card 1 was changed and separated into study card 1 and study card 2 used for different tasks, and survey card 2 was developed to study card 3. The study cards are four times as big as the survey cards to enable all users to actively engage in the group study. They are coded by different theme colours with their adjacent parts distinguished by different shades of the colour. However, the option 'Others' is presented in grey particularly to notice users that it is a unique option comparing with others. Also, the direction of the statement in each card segment was adjusted to ensure the text to be seen horizontally from all angles.

Study card 1 is used to investigate the adverse impact of the pavement hazards in exercise two. Study card 2 explores the behavioural changes of older adults in exercise three. Study card 3 aims to collect recommendations for the pavement in exercise four.

The content of the study cards is further explained with more details so that users can better understand the study topic and give proper answers. Each study card only has one copy offered for users to use it repeatedly. While using study card 1 and study card 2, researchers shall place a card set on the centre of the study card. Then, they can replace the card set with a new one to investigate the impact of another pavement hazard. However, no pavement card needs to be put on the study card as study card 3 is employed to improve the pavement environment rather than a single pavement problem. Different from using survey card 1, researchers do not need to write down the result of exercise one (a map-based exercise) on the study card because such information can be figured out by the map.

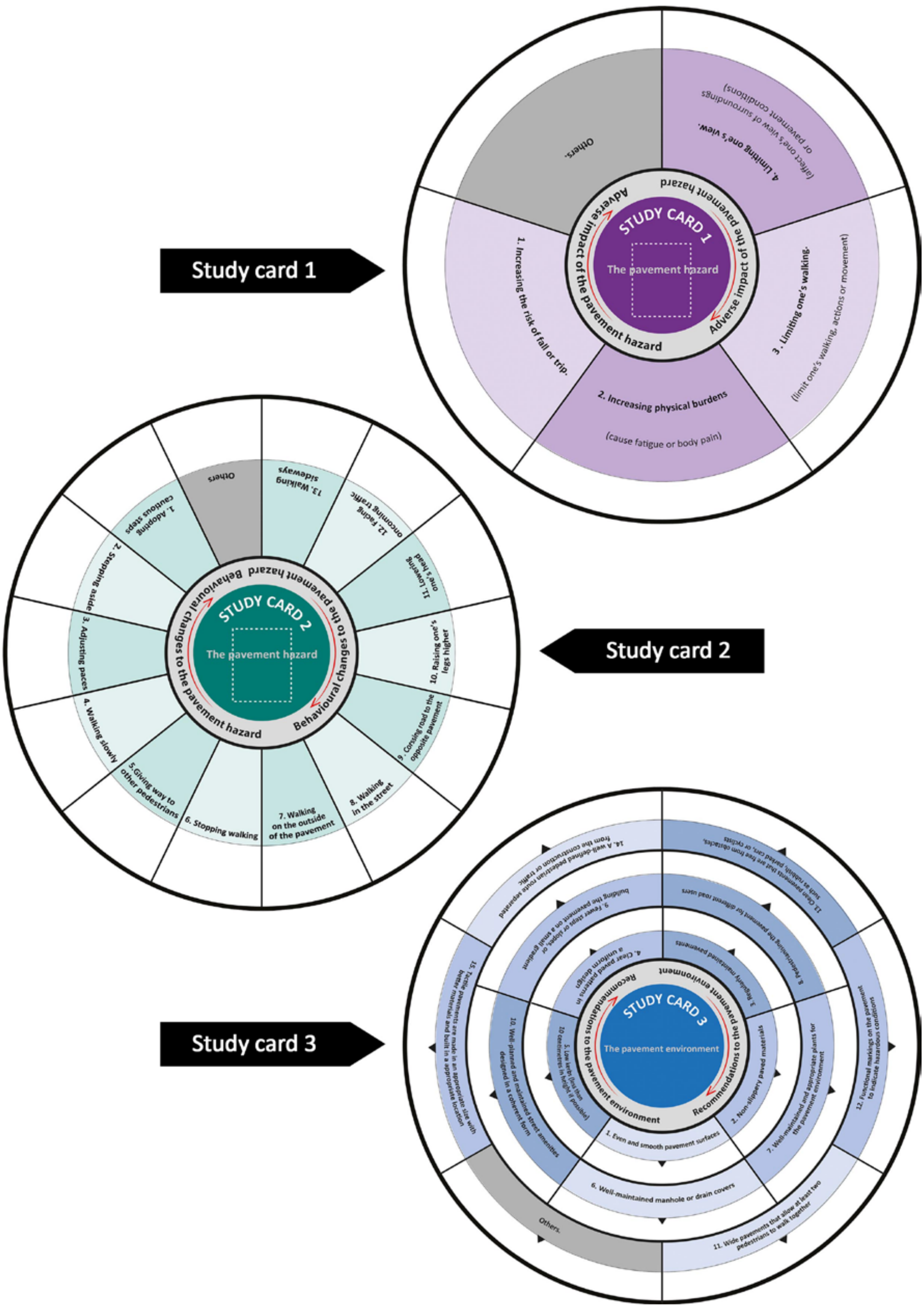


Figure 7-23. The study cards of W-KIT.

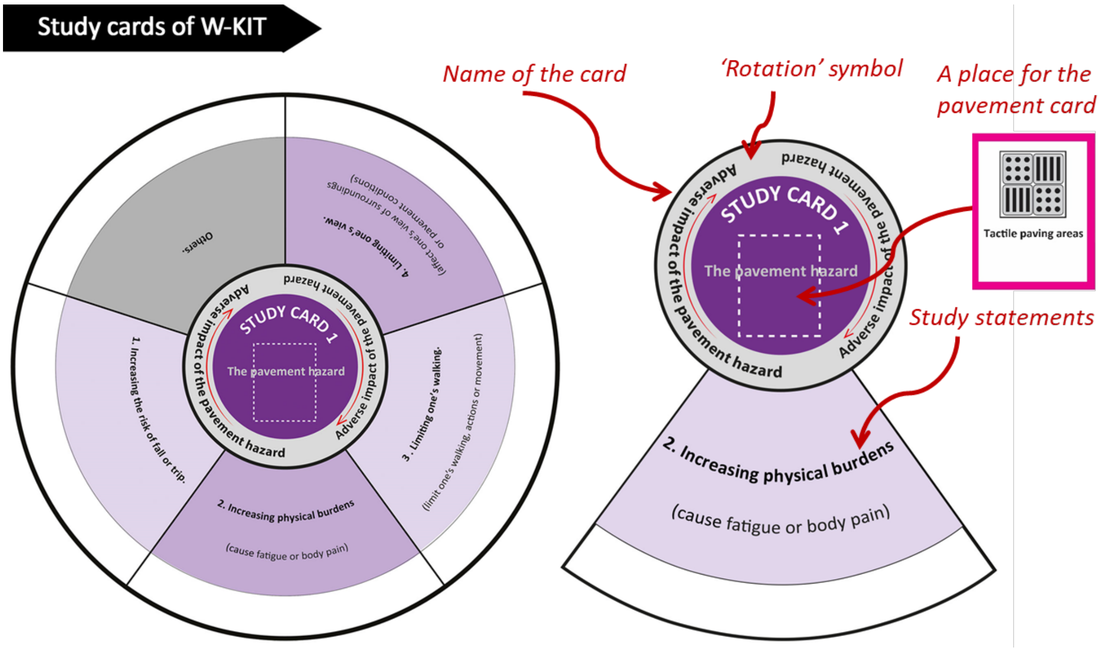


Figure 7-24. Use of the study cards of W-KIT.

7.4.4 Participant stickers

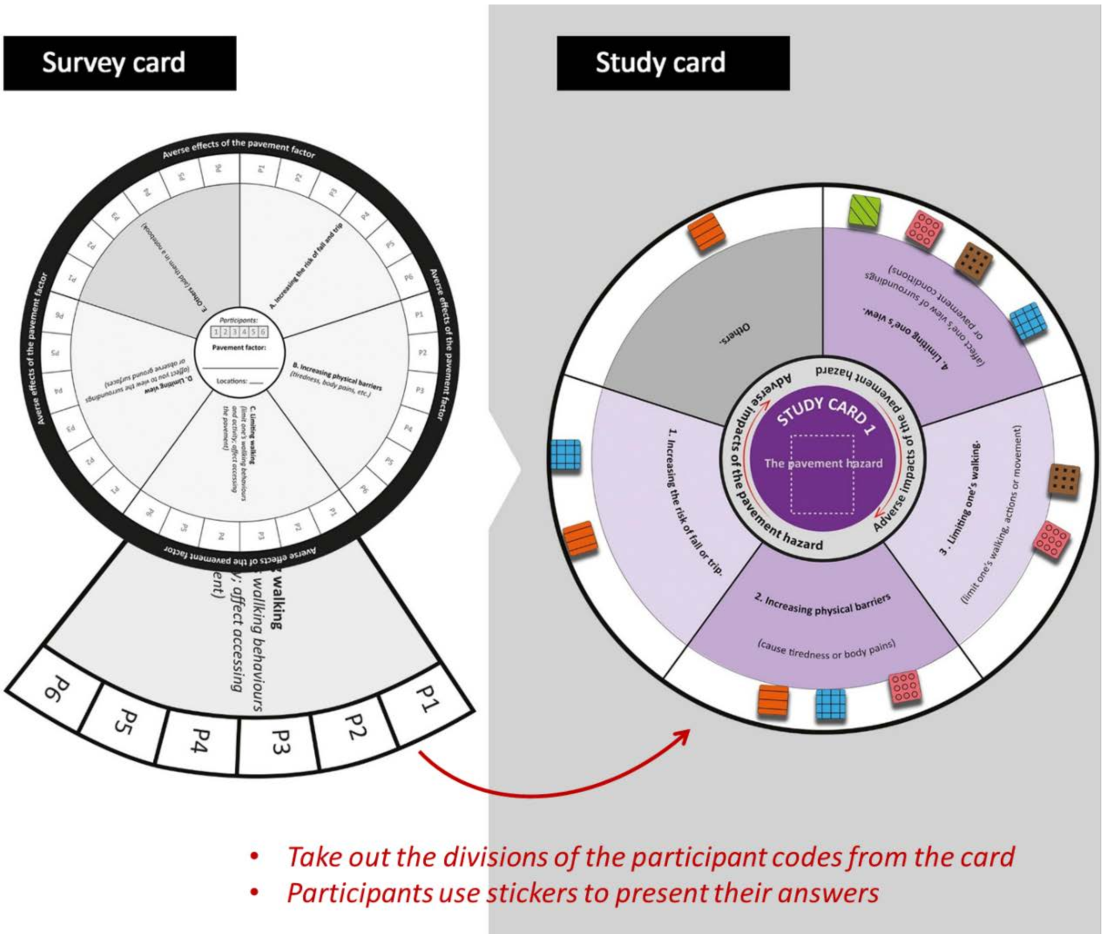


Figure 7-25. Differences between the previous survey card and the study card.

The participants' answers were observed to be influenced by the code divisions on the survey cards in the last evaluation as sometimes the participants ticked their code according to other group members' choices without thinking about whether they agreed with the card statements or not. To increase the rigour of the data collection, the code divisions were not provided by the new study card. Instead of this, participant stickers were made for participants to indicate their answers on the study card (see Figure 7-25). The participant stickers aim to empower participant's ability of decision making by allowing them to have the initiative in their hands, so that they would indicate their ideas while not be affected by the others.

There are six groups made for six participants and they classified by a distinct colour and pattern. Each sticker group has 16 copies enabling participants to mark their selections in all segments of the study cards. The stickers offer an easier way for researchers to see the results of the study cards as colours and patterns can effectively communicate information more than text (Ware, 2013). The patterns, as an alternative indicator of the stickers, can also assist users who have colour blindness to read messages (Ellfattah, 2006).

Figure 7-26. The participant stickers of W-KIT.

7.5 Use of W-KIT

According to Figure 7-27 & 28, W-KIT requests researchers to pre-prepare a map to show a pavement environment and a camera for data-recording. In exercise one, researchers distribute the card sets to participants and ask them to read the pavement cards on them to deliberate the study topic. Next, researchers encourage participants to discuss about hazards that influence their walking in the pavement environment. Then, participants refer the card sets that correspond with the hazards. Researchers need to collect the identified card set and take out the associated locating cards and make participants to locate the named hazards on the map using the locating cards. At the end of exercise one, researchers photograph the results of the map-based study.

Exercise two, exercise three and exercise four will be carried out based on the study cards. In exercise two & three, researchers put one of the card sets referred already in exercise one on the centre of study card 1 and study card 2. Then, participants conduct a group discussion about the physical and behavioural impact of the pavement issue under the inspiration of the statements presented by the study cards. They can put a sticker on the blank space of the card segments if their idea are in line with the statements. After that, researchers photograph the results of the study cards (see Figure 7-29), and the participants recycle their stickers from the study cards. As exercise two and exercise three have to further investigate all pavement issues identified in exercise one, researchers need to use study card 1 and study card 2 repeatedly until they finish the exploration.

In exercise four, study card 3 is used by participants to propose feasible and appropriate recommendations for the pavement environment rather than working out a single problem. Therefore, researchers do not need to present the card sets on study card 3. The participants still need to place their stickers on study card 3 if they agree with the suggestions shown on the card. In the end, researchers also need to record the results of study card 3 using camera. After the participatory study, researchers can interpret the data collected by W-KIT according to the analysis framework provided by the instruction or to analyse the evidence using other methods.

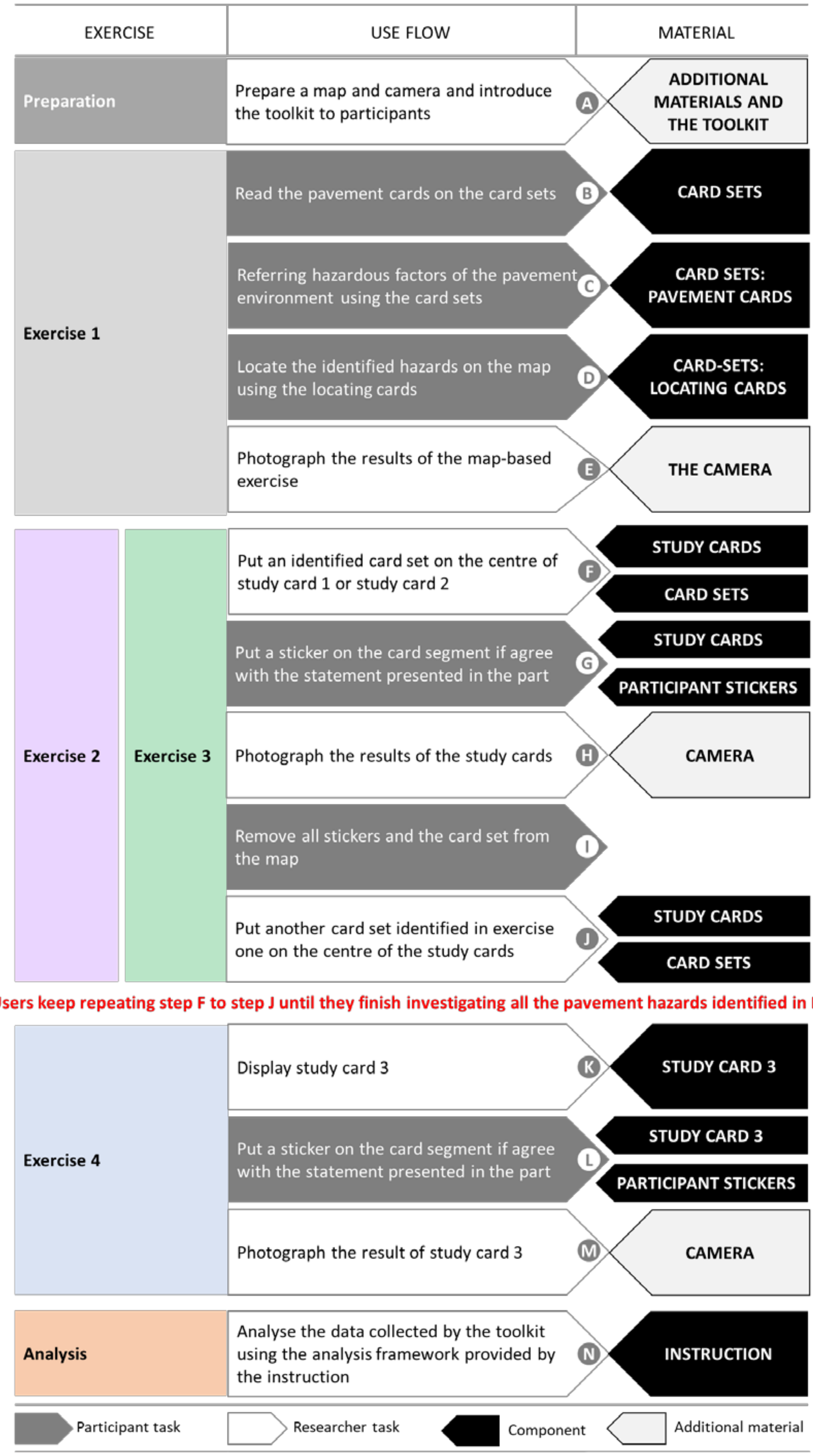


Figure 7-27. Use of W-KIT.

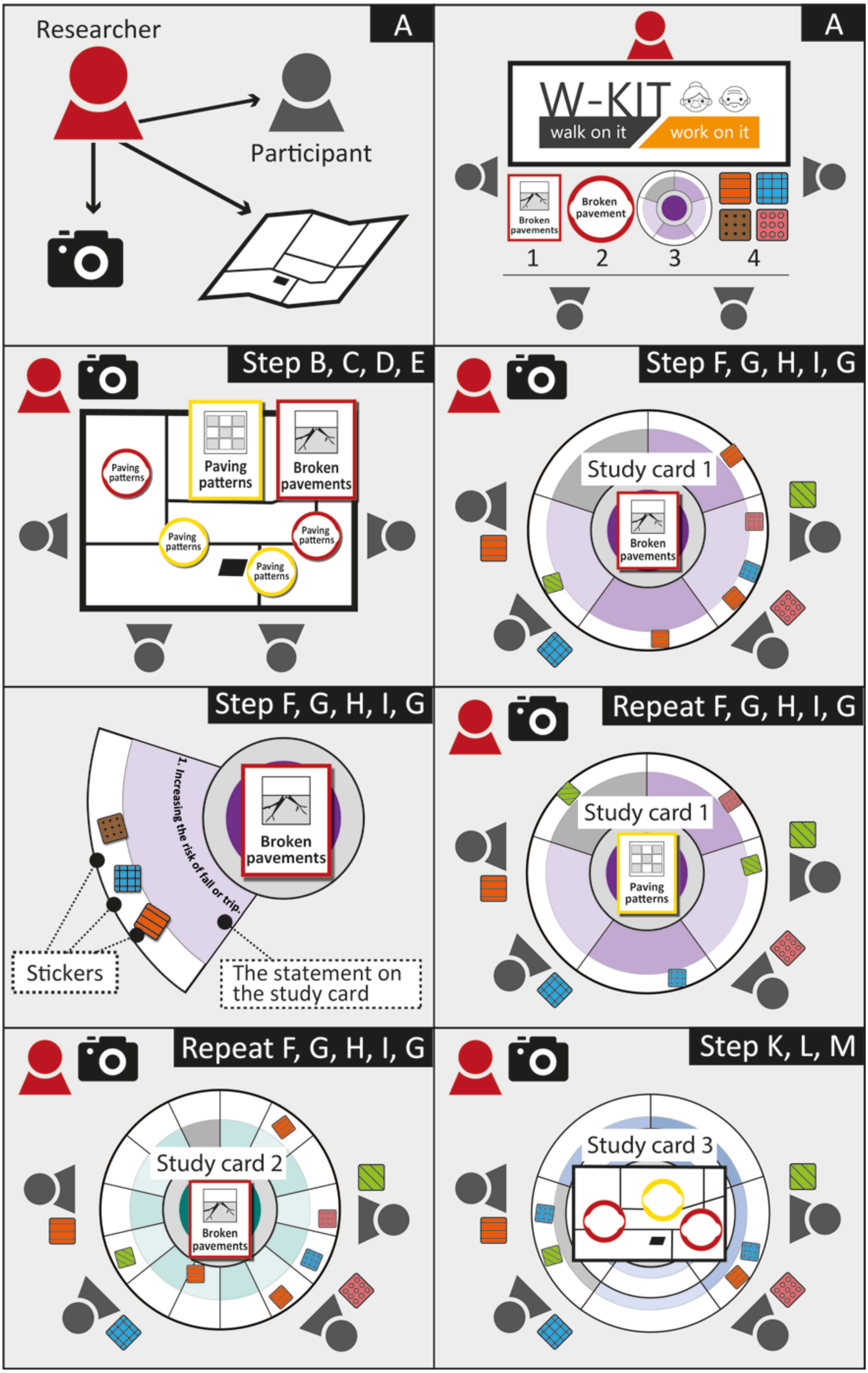


Figure 7-28. Storyboard of W-KIT shows steps that are consistent with those in Figure 7-27.

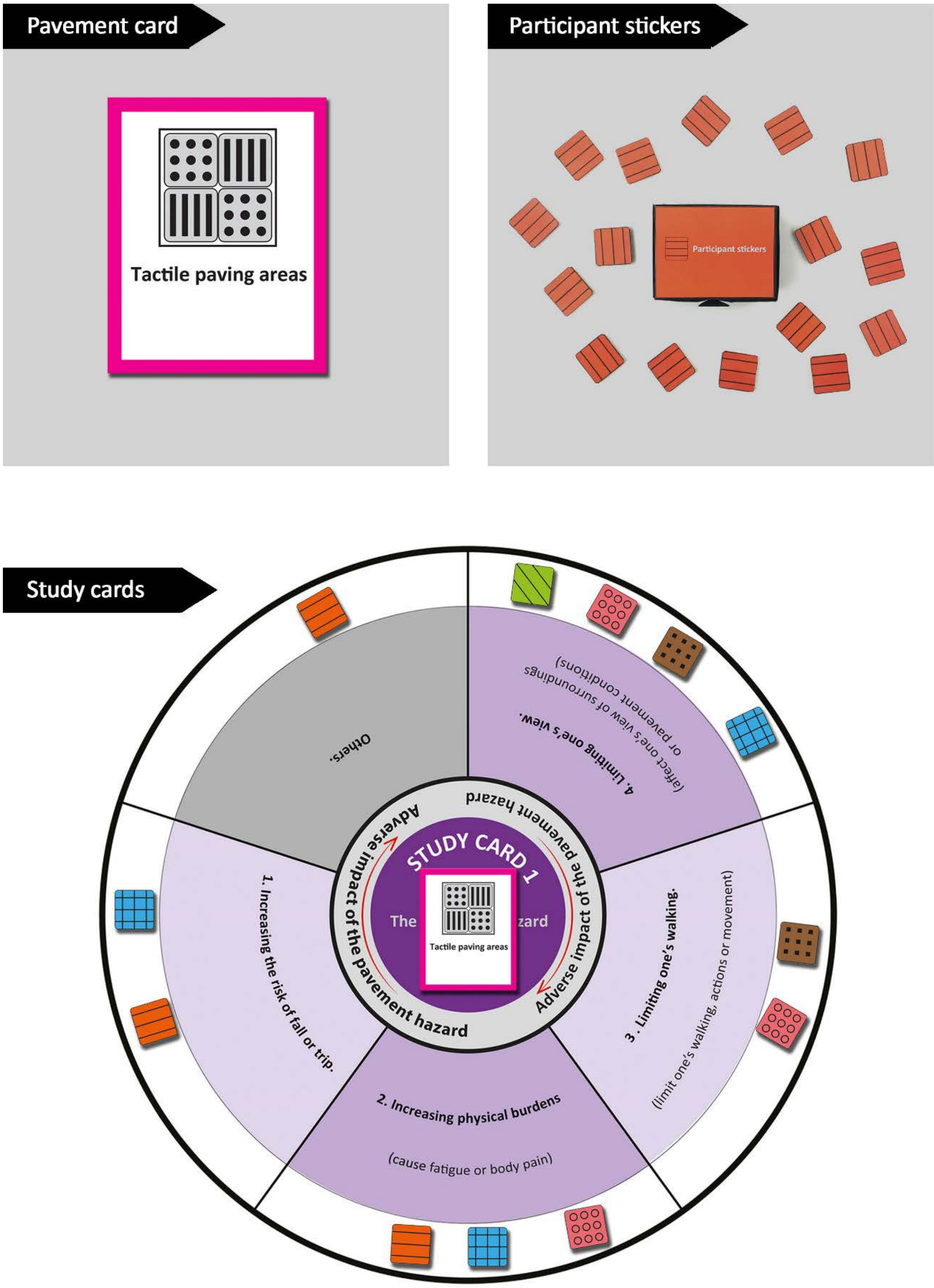


Figure 7-29. The results of study card 1.

7.6 Dissemination of W-KIT

A website (https://yinlulu07.wixsite.com/wkit) has been developed to disseminate the lastest version W-KIT. It introduces the study background, components, and exercises of

W-KIT (See Figure 7-30). A demonstration video is also available on the website to assist users to learn about W-KIT by themselves in an easier way (See Figure 7-31).

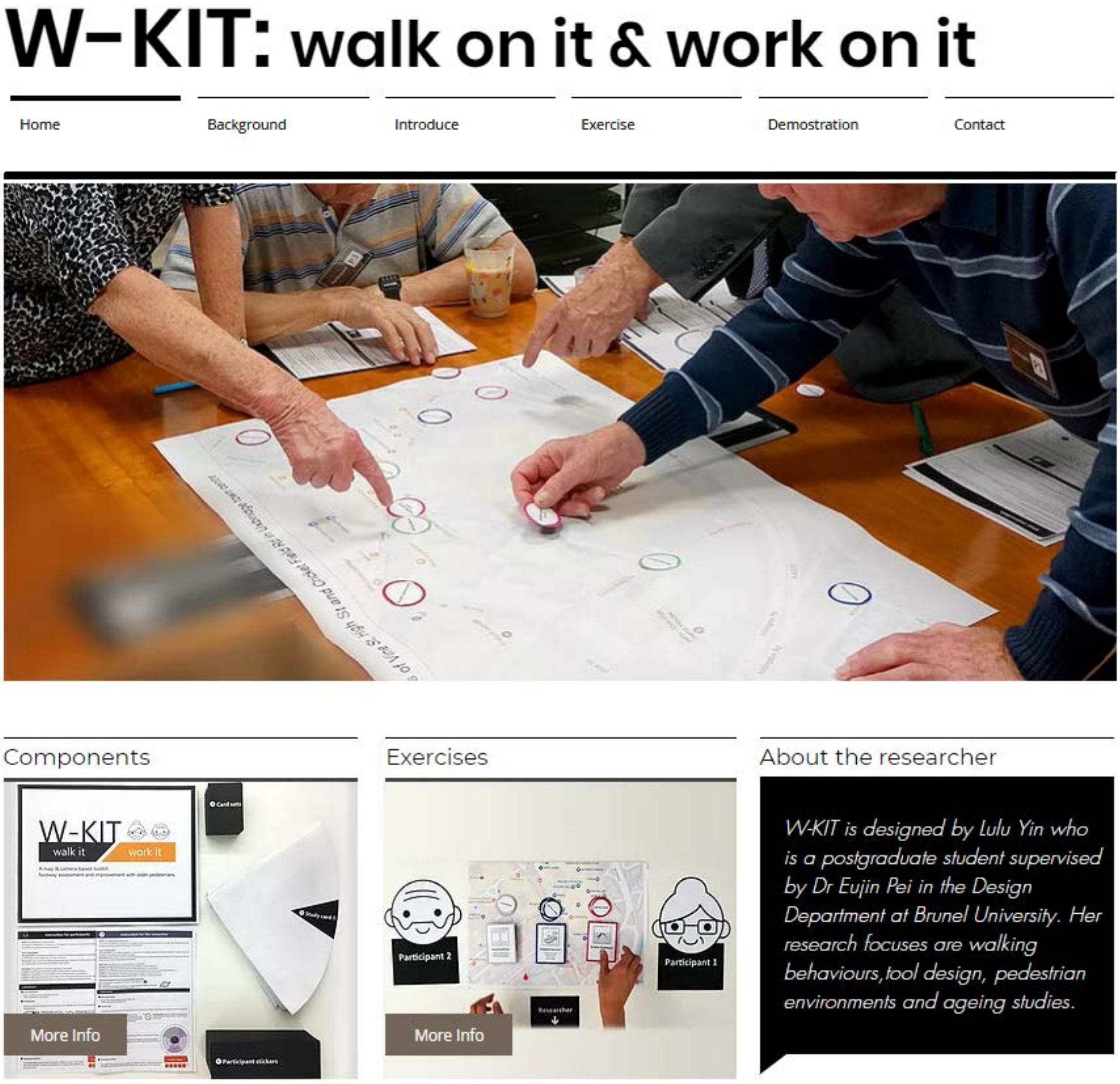


Figure 7-30. The website of W-KIT.

Figure 7-31. The demonstration video of W-KIT.

7.7 Summary

This chapter has described an additional change in the toolkit and the revised version, version 3. Version 3 consisted of participant code badges, instruction sheets, survey cards, a card pack, and a recording card which were modified based on the old design in Chapter 6. It also enabled researchers to assess and improve pavements based on a map in a participatory study with six older adults maximum. Version 3 aimed to boost group interaction and discussion. Then, it was evaluated by eight elderly users in workshops to explore if version 3 could allow them to undertake a group study appropriately. In addition, eight experts were recruited to an interview-based study to test the tool as a researcher. They were asked to self-learn the toolkit and use it to simulate a data collection. According to the evaluation study, the elderly users reported that version 3 was easy to understand and to use. The content of version 3 was useful for the group study as they provided a comprehensive view of real-world matters with many details. However, the instruction was complicated with too much information to receive. The design of the survey cards hindered them from reading the card or sharing personal ideas in the group. In the interview-based study, the researchers found that the components were well designed and organised. The tool was useful for them to proceed with an efficient study and to develop their work. However, they needed more time to learn the rational of the toolkit and to figure out the connection between the components of the toolkit. Based on the outcomes of the testing, the study delivered a final version and named it to W-KIT. W-KIT encompasses instruction, 16 card sets, three study cards, and six packs of participant stickers which are developed on the last version. W-KIT sets four exercises separated from the previous exercises make users easily to understand and focus on their tasks in each stage. The exercises enable users to investigate hazardous factors of the pavement, explore behavioural changes in walking among elderly participants and seek improvements in the pavement environment. W-KIT also newly offers an analysis framework facilitating researchers to analyse the collected data and to identify the relationship between the pavement environment and older pedestrians. To disseminate W-KIT, a website has been build offering a detailed introduction and demonstration of the toolkit to the public.

8 Conclusions

This chapter reviews the PhD study and research outcomes and discusses contributions and limitations of the study and its future plan.

8.1 Overview of this research

This research explored relationships between the pavement environment and older pedestrians by seeking answers to four research questions: (1) What pavement factors are hazardous to older pedestrians?, (2) What is the impact of pavement hazards on older pedestrians?, (3) What are the requirements of older pedestrians for the pavement environment?, and (4) How to involve older adults in the process of developing pavements in their neighbourhood?. To find out appropriate answers to the research questions, the study was divided into six stages including research clarification, descriptive study I (DS-I), prescriptive study I (PS-I), descriptive study II (DS-II), prescriptive study II (PS-II), and descriptive study III (DS-III). The research clarification was known as literature review, and it helped to refine the research questions, to make research aim and objectives, and to identify research gaps. Descriptive study I (DS-I) was the main data collection, and it was carried out using ground theory with a combination of inductive studies and deduction studies. The prescriptive studies (PS-I and PS-II) describes the development process of the toolkit; and descriptive study II & III (DS-II and DS-III) describes the evaluation studies, including an expert review and two user tests for feedback. Both qualitative methods and quantitative methods incorporating interviews, observations, questionnaires, cultural probes, and workshops were employed to collect data and to identify user feedback. A qualitative data analysis consisting of transcription, coding, and grouping (categorising) was used to analyse qualitative information, and a statistical data analysis was adopted to interpret quantitative evidence. CAQDAS (computer assisted qualitative data analysis) tools NVivo and Excel were run to improve the accuracy and effectiveness of the analysis.

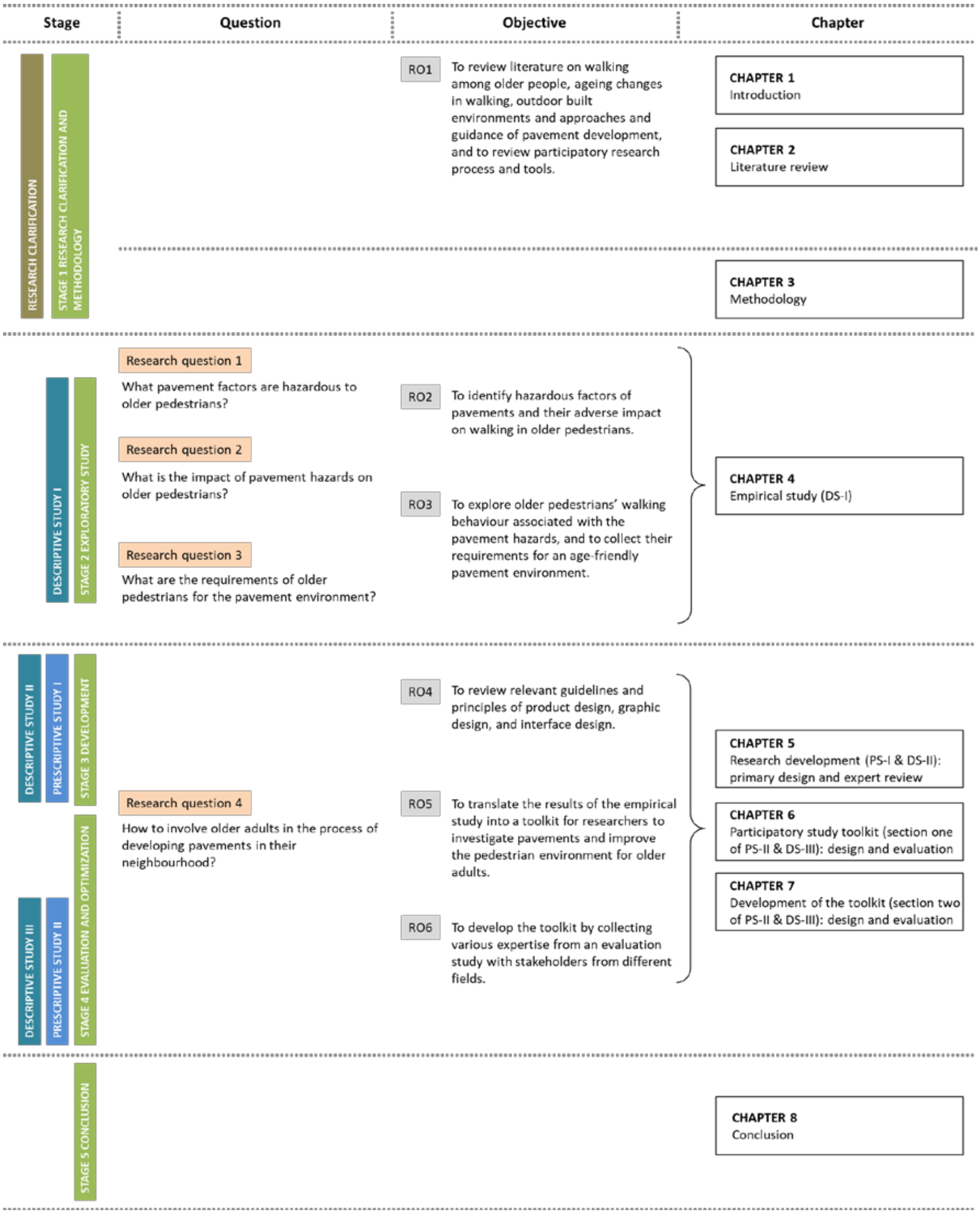


Figure 8-1. An overview of the research.

8.1.1 Pavement hazards and their adverse impact (RQ1 and RQ2)

Hazardous factors of the pavement were identified as poor pavement conditions and pavement obstructions. They were classified into uneven pavements, overgrown plants, slippery barriers, broken pavements, moving obstacles (e.g. cyclists and skateboarders), temporary obstructions (e.g. rubbish), poorly maintained or designed street amenities, manhole covers, parked vehicles, construction, narrow pavements, the absence of the pavement, goods of street stores, paving patterns, tactile paving areas, and changes in paving level (e.g. kerbs, steps and slopes). These hazards could bring about the risk of falling or tripping, limit walking and view of older pedestrians, or cause physical burdens (fatigue or pain) on an older adult's body. For example, the uneven and broken pavements, slippery barriers, and confusing paved patterns, steps, and slopes were found to be the most common issues that caused falls to older pedestrians (CDC, 2007; WHO, 2007b; Curl, 2016). Also, fall-related accidents could be increased by overgrown tree roots, pavement facilities, tactile footpaths, and raised manhole covers (Devon County Council, 2016). Apart from that, sloped and bumpy surfaces could alternatively result in the fatigue or pain in older people's back, legs, or ankles. The overgrown trees and bushes, parked cars, construction, poorly maintained or designed street amenities, such as bus stops, benches, bins, and goods of street stores, such as advertising boards, and stalls, could occupy the walking space or block the pavement, and hence adversely limit older adults' walking or view (TfL, 2016b; O'Sullivan *et al.*, 2017).

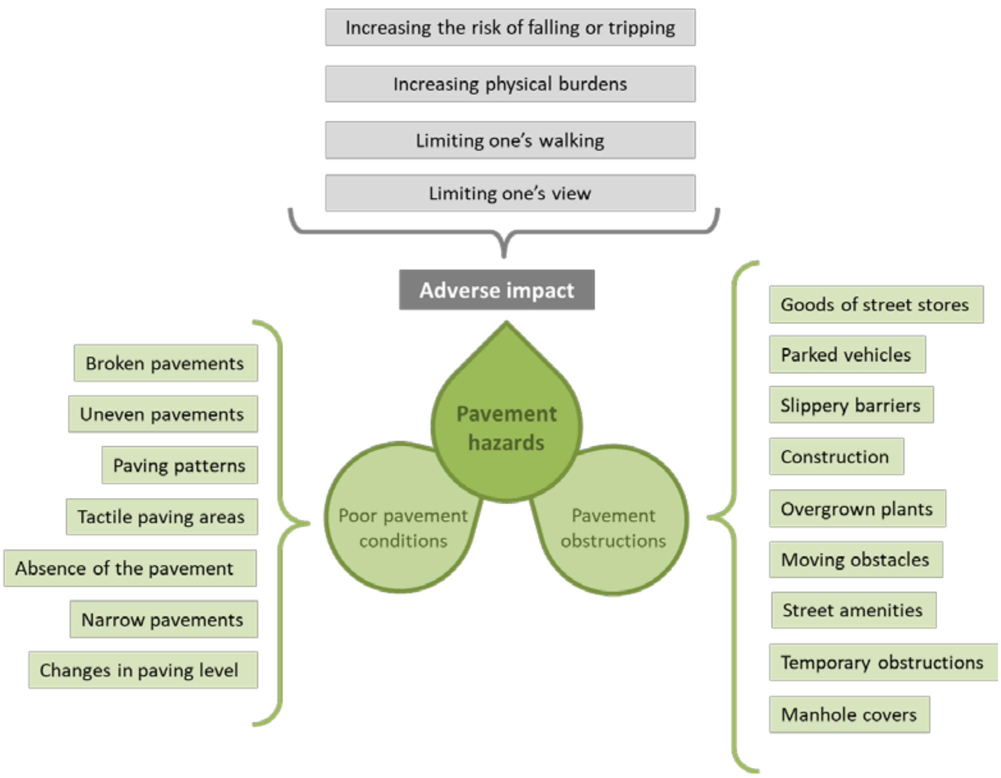


Figure 8-2. Pavement hazards and their adverse impact.

8.1.2 Behavioural changes of older pedestrians caused by the pavement hazards (RQ2)

Older pedestrians were found to adapt their walking behaviour or gait patterns to avoid the risky situations caused by pavement hazards. For instance, in line with Shkuratova, Morris and Huxham (2004) and Kang and Dingwell (2008), cautious and slow steps and stepping aside were found to be the most significant behavioural change of older people appeared when they wanted to keep stable or balance on poor pavement conditions or when they confronted by obstructions on the pavement. When encountering the slipperiness and unevenness on the paved surfaces, older adults preferred to raise their steps higher than usual or to adjust their paces more often. Some barriers, such as overgrown plants and buildings under construction, always took up the inside area of the pavement and elderly pedestrians had to lower their neck or to walk on the outside of the pavement to avoid the barriers. Apart from that, moving obstacles including scooters, cyclists, and skateboarders, were found to be notable elements that compelled older adults to stop walking to keep safe. A narrow walking space could also make older people stop walking to give way to other pedestrians. Further still, older pedestrians have to cross to the opposite pavement or walk on the road if the pavement condition was extremely hazardous or if there was no pavement available. During walking in the street, they usually faced oncoming traffic to observe surroundings so that they could detect potential dangers early and avoid them quickly (Luoma and Peltola, 2013).

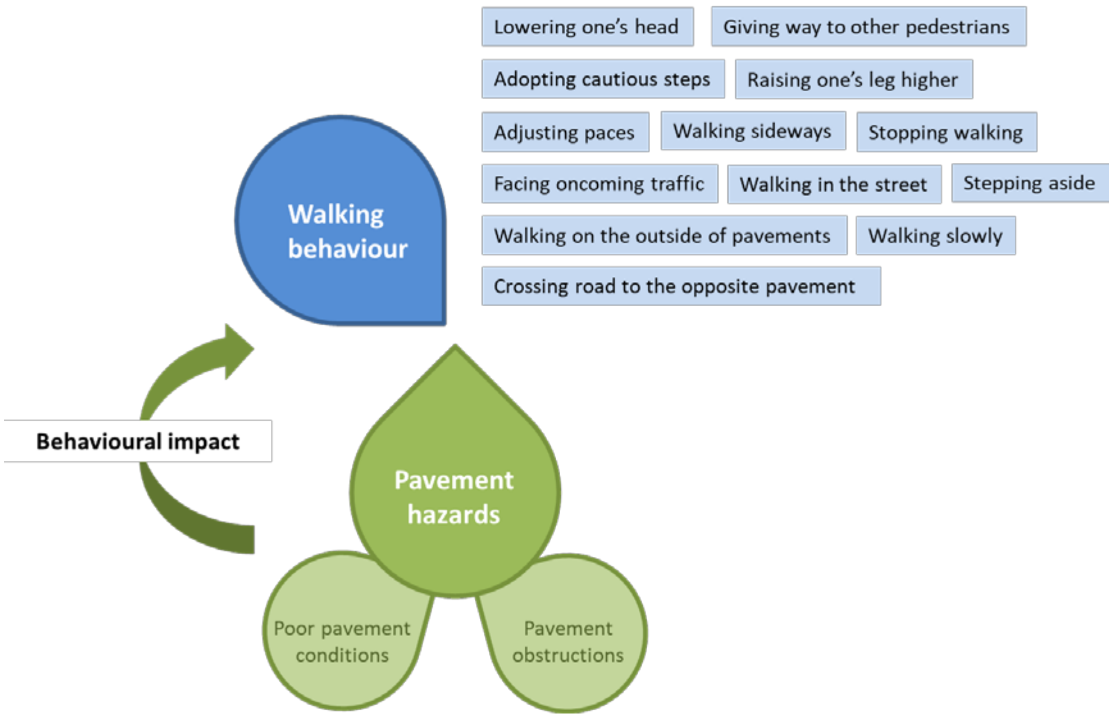


Figure 8-3. Older pedestrians' behavioural changes in walking.

8.1.3 The effect of ageing declines

This study has identified that physical weaknesses of older adults could increase the impact of pavement hazards and limit older pedestrians' behavioural changes in walking. The declined strength in elderly people's quadriceps and ankle dorsiflexion (Mänty *et al.*, 2012; Sheehan and Gottschall, 2012) could additionally slow down the limited walking speed caused by poor pavement conditions. The risk of falling caused by pavement hazards to older adults could be further increased by age-related declines in older people's walking ability, stability, or vision (WHO, 2007b; Schrager *et al.*, 2008; Pirker and Katzenschlager, 2017). Older people could more easily feel the body pain or fatigue triggered by sloping or stepped pavements when they aged (Mänty *et al.*, 2012). Some strategic behaviour, such as raising one's legs higher or lowering one's head, adopted by older adults to mitigate pavement hazards could be limited by the declined flexion and strength and age-related pain in older adults' neck, joints, or muscles (Oxley *et al.*, 2016).

8.1.4 Recommendations for the pavement environment (RQ3)

This study also identified the walking need of older pedestrians and translated and developed them into recommendations on the pavement environment. This research found that wide, rigid and even surfaces were mostly required by older people as they were least satisfied with the paved surface and pavement width. The pavement should be at least 3 metres and wide enough for at least two pedestrians to walk side by side (Clifton, Livi Smith and Rodriguez, 2007; Kim, Choi and Kim, 2011). Tarmac and big slabs could be used more often to construct pavements instead of small stones to improve the unevenness of pavements. A smaller gradient could additionally contribute to the flatness and smoothness of the pavement (Day, 2008; Burton, Mitchell and Stride, 2011). In addition, the quality of the pavement surface could be enhanced by using well-maintained manhole covers, lower kerbs, and fewer steps. To increase the walking safety on pavements, paved materials should present clear colours and patterns to clearly indicate hazardous pavement condition, such as uneven or broken pavements, for older pedestrians (TfL, 2016b). Also, special ground markings could be used to inform pedestrians of the risk factors on the pavement (TfL, 2011).

A clean and bright environment that is free from any obstructions could further contribute an age-friendly walking environment (Mackett, 2014). To meet the standard, temporary barriers, such as rubbish, overgrown trees, and parked cars should not occupy the pavement (Rackliff, 2013; Handler, 2014). Street amenities could be in a uniform design or grouped if they clutter the pavement environment (Camden Council, n.d.; TfL, 2016b). In addition, tactile footpaths should be constructed in an appropriate location and size to mitigate their chance of becoming pavement obstructions. To deal with hazardous factors caused by cyclists, construction, or the absence of the pavement, a pedestrianised pavement for different road users with a separated walking path from the traffic could be provided (Soni and Soni, 2016).

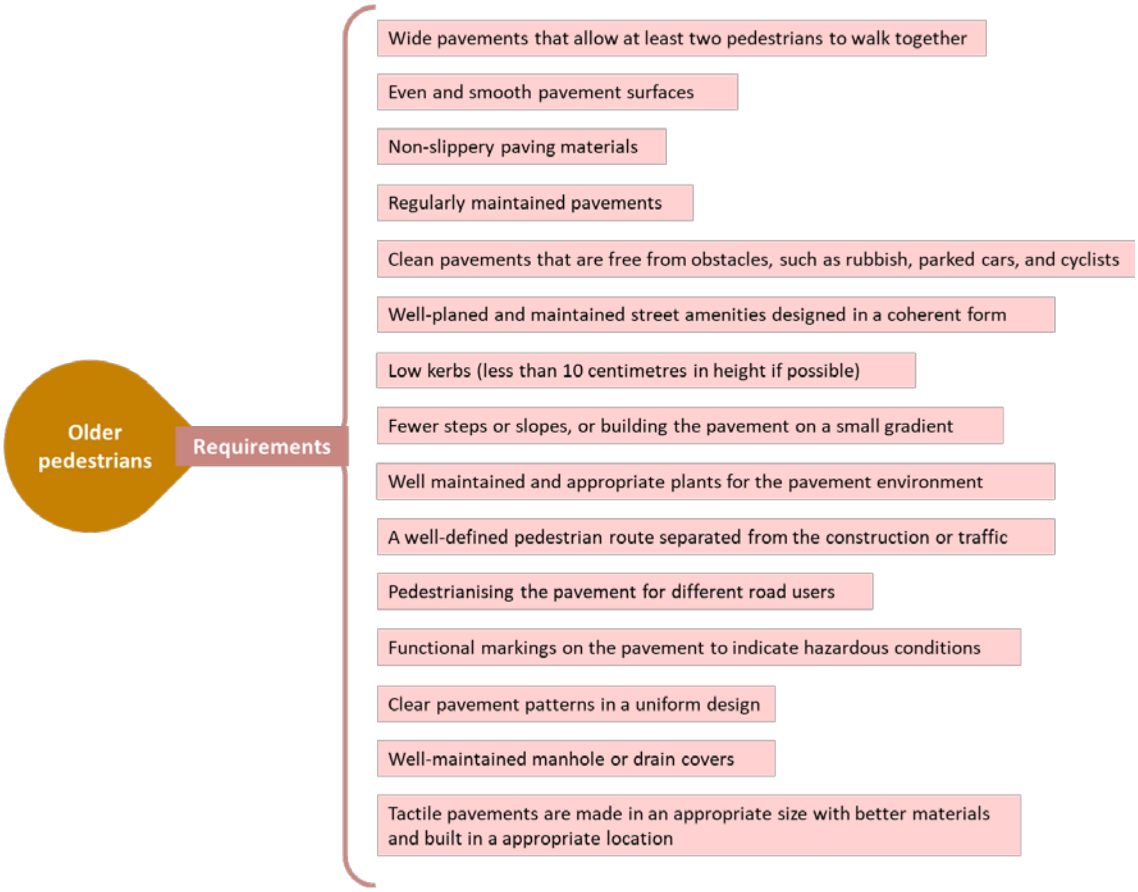


Figure 8-4. Older people's requirements for the pavement.

8.1.5 A participatory study toolkit (RQ4)

The data collected from the empirical study (DS-I) resulted in a toolkit to enable older pedestrians' ideas and needs to be involved in pavement development. Also, it intends to provide an efficient way for researchers to study the relationship between pavements and older pedestrians and to further explore the study topic. The toolkit then was defined as a participatory study toolkit used by researchers, namely urban planners, pavement designers, and road engineers, to assess and improve the pavement environment through a group study with the maximum of six older adults being involved as study participants. It allows participants to share their walking experience and to indicate their ideas. At the same time, the tool assists researchers to identify pavement hazards and their impact on walking among older people, to make improvements in the pavement environment, and to seek new knowledge and findings by collecting data from the participants. As a result, researchers can receive plenty analysable information which has been systemically categorised by the tool. Based on the data, they are able to prioritise pavement issues and identify behavioural factors that older pedestrians adopted to deal with the hazards and to create design guidance on pavements.

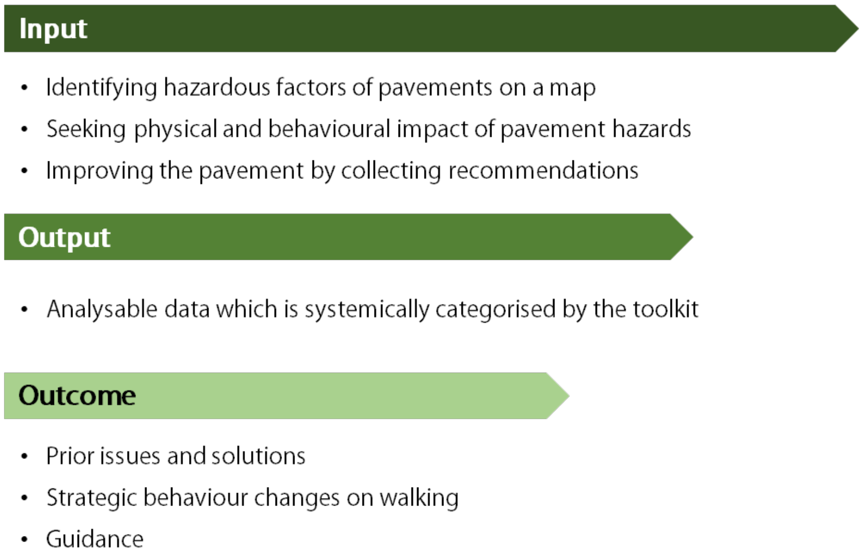


Figure 8-5. The inputs, outputs, and outcomes of the toolkit.

8.2 Contributions and implications

This enquiry contributes to different shareholders' interests concerning the theoretical knowledge about pavement environments and walking as well as the development of the toolkit.

8.2.1 Contributions to new knowledge

Many studies have been carried out to explore built environments and their influence on road users (Michael, Green and Farquhar, 2011; Kerr, Rosenberg and Frank, 2012). However, there are insufficient evidence for the relationship between the pavement environment and older pedestrians regarding the behavioural change and walking need of the older adults. The research provides insights into the area that hardly explored in other studies. The contributions of this study are listed as follows:

- The empirical study (DS-I) has expanded and complemented the knowledge of the pedestrian environment, walking behaviour, and age-friendly environments based on an in-depth exploration on walking experience, walking behaviour, and opinions of older people. Additionally, it clarified correlations among the physical declines of older adults, pavement hazards, and walking behaviour. It offers explanations of four key areas:

- How and why certain pavement conditions could be seen as hazards by older people
- How and why certain obstructions of pavements could be seen as hazards by older people
- How the perceived hazards affect walking behaviours of older people
- What are considered to be good pavement environments by older people

- This knowledge could help people who are responsible for designing and maintaining pavements to deliver better pavement environments for older people. The outcomes could benefit policy and decision making, and some changes in older people's walking could be suggested by local councils as the strategic behaviour adopted to minimise the risk of falling in hazardous locations. For example, the behavioural factor 'facing oncoming traffic' identity by the study has been recommended by many governments as a protective action to people who are forced to walk in the street (Luoma and Peltola, 2013).
- Furthermore, the research knowledge was used to create following outcomes:
    - A new theoretical framework (see Figure 8-6) that explains interrelationships of 3 core elements: 1) pavement hazards (including poor pavement conditions and pavement obstructions), 2) effects on walking in older people, and 3) requirements for good pavement environments of older people
    - A toolkit that enables older people to be involved in the participatory study process that could help to identify potential pavement hazards and improvements
    - Both the framework and toolkit could be used by those who are responsible for designing and maintaining pavements
    - The framework and toolkit also provide a systematic approach for researchers/design practitioners to explore specific relationships between a certain group of users and the design of their pavement environments.

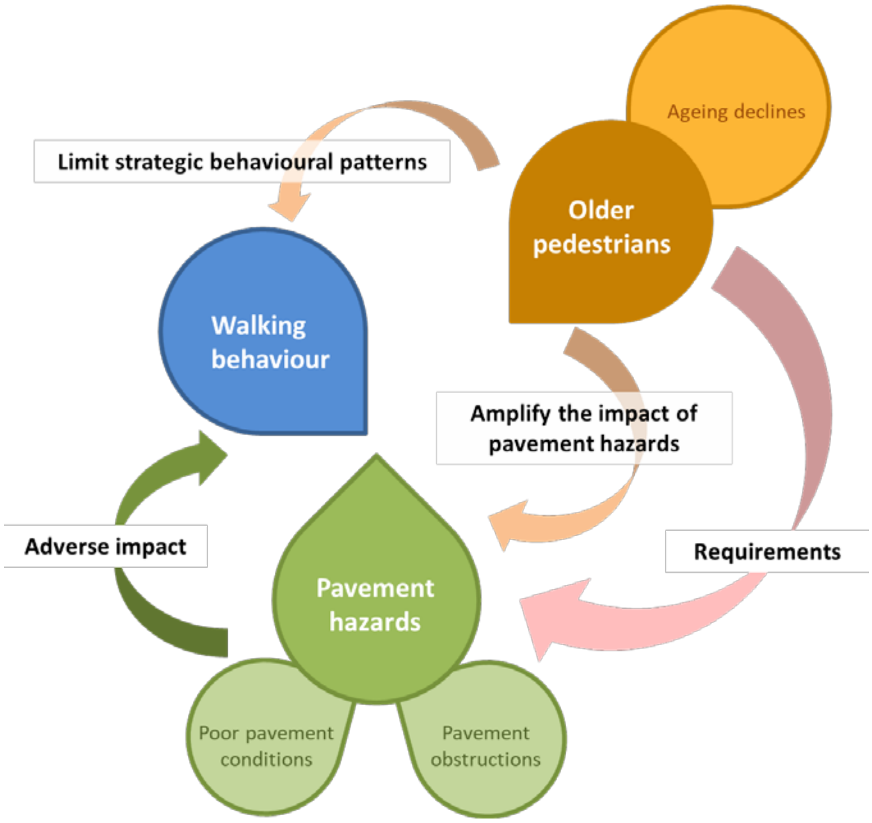


Figure 8-6. The theoretical contribution of the study.

8.2.2 Contribution to the participatory study

Involving older adults in the urban development can save the cost, make appropriate design strategies and develop age-friendly cities and sustainable neighbourhood (Kujala, 2003; Buffel, Phillipson and scharf, 2012). As discussed early, a participatory study toolkit had been created to in this study to contribute on user-centred design and user-centred approach regarding the development of pavement:

- The toolkit includes 1) the process, 2) the physical materials to probe users and record results and 3) the instructions for users to assess, improve, and develop pedestrian environments.
- It offers a participatory process for older people to work on the pavement programme with researchers, such as local councillors, road engineers, and urban designers.
- It also provides a new way for researchers to know about the hazardous impact of poor pavement conditions and to better understand the walking need, walking experience and waling behaviour of older pedestrians.

- The developing process of the toolkit provides a way in which similar tools can be created.
- Different components of the toolkit can assist researchers to conduct different tasks for various purposes.
- The inclusion of older adults enables researchers to seek extensive and in-depth interpretations of the data collected by the tool.
- According to the expertise and user feedback, the outcomes of the participatory study conducted using the toolkit, in the long run, can contribute to sustainable pavement development and age-friendly cities and influence the policy making of built environments and travel experience of older adults.
- A website, which shows the design background, components, exercises and a demonstration video of the final version of the toolkit, has been built to increase the dissemination of the toolkit.

8.3 Limitations and challenges

During the research, there were some limitations to the study topic, samplings, and research methods.

8.3.1 Constraints of the topic

The inquiry topic required data to be collected in terms of the pavement environment and walking behaviour of older pedestrians. However, few existing studies were found to be strictly relevant to the study topic. This might have limited the description of the research context, blurred the scope of the study, and restricted the comparison between new findings and the previous evidence. To deal with those issues, relevant literature from a wide range of fields covering the built environment, transport, human factors, and policy making had to be reviewed. Second, the outcomes of this research, especially the definition and categories of pavement hazards and the walking behaviour, might be slightly general and broad. The study was an initial exploration of these areas and it might not fully explain the knowledge from diverse aspects. More researches have to be conducted to carry on investigating and developing the study topic and definitions.

The practical toolkit created by this PhD study can be used as an alternative for future researchers to conduct relevant explorations.

8.3.2 Limitations of the sample size

According to Robson (2015), there is no specific standard for deciding on a sample size for a data collection, and various dimensions of sampling shall be considered depending on different studies. Even so, this research may be regarded as using a small group of participants recruited from a localised area. To overcome the limitation, both inductive and deductive processes along with qualitative and quantitate methods were applied to collect data from participants to increase the rigour and comprehensiveness of data. In addition, a purposive sampling strategy was used to enable elderly participants to be recruited from different age ranges and neighbourhoods and allow experts to be assembled from diverse professions and backgrounds. In this way, the study topic has been fully understood and the tool could be thoroughly evaluated and enhanced with various expertise.

8.3.3 Limitations of the descriptive studies

Although a mixed research method assisted this study to gather a large amount of data from participants, it was highly time-consuming to prepare the research pack and to carry out the combined study. The study spent plenty of time in designing and making the interview booklet, observation pack, and cultural probe kit. The questionnaire used by DS-I also took a long time to be made to ensure the precision. Additionally, to ensure a higher response rate (Robson and McCartan, 2015), the questionnaires was used in interviews and that consumed more time to be implemented.

The qualitative data obtained by the descriptive studies resulted in a complicated data analysis consisting of transcribing, coding, and categorising and the use of NVivo, and the questionnaire brought out a large amount of quantitative data that requested the assist of Excel to facilitate a statistical analysis. Even though the study has adopted the two software in the analysis, some key information might be ignored or filtered out from the original data by the subjective measure of this research (Matthews and Ross, 2010).

8.3.4 Challenges of developing the toolkit

The design process of the tool did not have relevant user feedback included in its every step, therefore, some changes to the tool might not be efficient or meet diverse user needs. Although the toolkit was tested three times with experts and target users, it was only revised based on the review of a limited sample. The researchers in the evaluation study expressed distinct needs and suggestions for the tool. However, so of their concerns could not be fully satisfied or fulfilled in the current stage regarding the definition and capacity of the toolkit. For example, some users would like to discuss the influence of other pedestrians and the mental impact of pavements in the participatory study conducted by the tool. Nevertheless, they could not expand these ideas as the information was not relevant to the main content of the toolkit or the objectives of the study.

8.4 Recommendations for future work

Some recommendations are considered for future work concerning the limitations of the study and the user comments on the toolkit. For future research, the definition of the pavement environment and walking behaviour could be clarified by knowledge from different fields, such as urban environments and ageing studies. Also, the topic could be developed with more ideas and information from studying the travel experience of diverse pedestrians in various pavement environments. Some experts in this research mentioned that they would like to see more technical knowledge provided by the tool. Therefore, behavioural factors and gait patterns of the pedestrians can be captured and analysed using more professional equipment in future studies. Also, future researchers can expand the guidance of the age-friendly pavement composed by this study with more technical details of paved materials and specifications of street amenities and construction policies. The design and content of the toolkit will be updated regularly with future findings and forthcoming user feedback. Several versions of the tool may be published to meet the desire of different user groups, and a digital format of the tool may be created as an alternative in the next stage for users to carry out studies and get results in real time.

8.5 Summary

This chapter concludes significant outcomes of the study and presents the contributions and limitations of this research regarding the data collection, data analysis, sampling, and the design process. The doctoral study extends the knowledge of the pedestrian environment and walking based on the empirical findings identified by a mix of qualitative approaches and quantitative methods. A theoretical framework has been created to demonstrate the study results, and a toolkit has been designed for researchers to investigate and improve pavements with senior pedestrians being involved in the process. It is a heuristic tool that allows users to do a group study and to seek new findings based on a localised area using a customised map for reference. It can be argued that the research uses small sample groups; nevertheless, the study findings have been found to be comprehensive and representative by being compared with other studies. In future, this project can be iterated by adopting more technical research techniques gaining data from a larger sample, and the toolkit will be developed to a widespread application.

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Appendix I: Paper for DRS 2018

DRS 2018 Design Research Society 2018 Catalyst

University of Limerick
25th - 28th June 2018

A co-experience toolkit: investigating the issues of the pavement environment and the relationship with elderly pedestrians

YIN Lulu[a]; PEI Eujin[b] and YIN Lulu[a*]

[a] Department of Design, College of Engineering, Design and Physical Science, Brunel University London
[b] Department of Design, College of Engineering, Design and Physical Science, Brunel University London
* Corresponding author e-mail: lulu.yin@brunel.ac.uk
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Pedestrian pavements play an important role in assisting or restricting the quality of walking. Poorly designed and maintained pavements may pose a challenge to the walking experience of older adults. This research aims to investigate pavement problems and their effects on elderly pedestrians. An empirical study was conducted in London with 41 older people aged over 60 who were fit to walk. In this study, we classified 16 influencing factors of the pavements and four adverse effects of them and identified 13 behaviours that elderly pedestrians displayed when they encountered the pavement factors. In addition, 17 recommendations were proposed in order to improve the pavement environment based on the requirement of the elderly pedestrians. Taking a step further, we developed a co-experience toolkit that could be used by researchers and professionals involved in the study of pavement design and urban planning to assess and improve the pavement environment with older adults. This toolkit is designed to encourage the users to understand the relationship between pavements and elderly pedestrians better.

pedestrian pavement, older people, behaviour change, built environment, design tool

1. Introduction

According to Shrestha (2016), older adults have a higher frequency of walking compared to driving or taking public transport. This form of transport has drawn the attention of many researchers examining how the built environment can influence the walking experience of elderly people (Frank et al., 2010; Ewing & Cervero, 2010). For instance, pavements have been recognised as an important factor to encourage walking and to increase the amount of walking activity (Choi, 2012; Lo, 2009). Publications, such as the 'Manual for Streets' by Department for Transport (2007) and 'Pedestrian Comfort Guidance for London' by Transport for London (2010), have highlighted key issues of the pavement and created design guidelines for the pavements. For example, pavement conditions and barriers of both static and moving obstructions can influence the level of access, which in turn have implications for pedestrians' safety and their quality of walking (Rackliff, 2013).

Some research approaches and tools have been designed to evaluate and monitor the quality of the pavement and to collect the feedback of pavement users. For example, local authorities in London have set up a web page for residents to report the problems of roads and pavements ("London Borough of Hillingdon - Report potholes or damage", n.d.). Volunteers have been recruited as "Street Champions" to record and detect the conditions of pavements ("London Borough of Hillingdon- Street Champions", n.d.). Tools, such as an 'Audit checklist' (Curl, 2016), help to evaluate the risks of older adults when walking along pavements, such as falls.

Although the existing studies and approaches cover general information about outdoor walking, they do not investigate how the pavement conditions influence the walking behaviour of elderly pedestrians. In summary, the relationship between pavements and older adults' walking experience is decidedly less discussed regarding the impacts of pavements on elderly pedestrians especially their physically behavioural aspects. The perspective of older people to the pavement is also less understood. To investigate this further, we set out three main research questions: (1) what are the factors of the pavement environment influencing the elderly pedestrians; (2) what are the behavioural changes of the elderly pedestrian walking on the pavement; and (3) what is the relationship between the pavement environment and elderly pedestrians.

2. The empirical study

An empirical study was organised to investigate the factors of the pavement that could influence the walking behaviour of elderly pedestrians and collected the requirements for improving the pavement. 41 older people (9 for stage-one and 32 for stage-two) from London were recruited to participate in the study. There were similar ratios of male and female participants (22 females and 19 males) who were either retired or semi-retired. The participants were needed to be above 60 years old and fit to walk. The pavement environment in Hillingdon, Ealing and Camden of London were chosen for the research because a large number of senior residents whose walking significantly engaged in the pavement lived in the vicinity.

Table 1 Methods of the study.

Stage-one (n=9)			
Aim	Research techniques	Duration	Collected data
Investigating the influencing factors of the pavement	Interviews	45 minutes	Personal opinions of the participants
Exploring the behavioural changes of the elderly pedestrians	Observations	Two rounds: 30 to 60 minutes per round	Findings beyond the perspectives of the participants
Collecting the recommendations for improving the pavement	Cultural probes	3 to 7 days	Covered information reported by the participants
Stage-two (n=32)			
Aim	Research techniques	Duration	Collected data
Quantifying the collected data	A mix of interview and questionnaire	60 minutes	The priority of the collected data

In stage-one, the data collection was carried out with 9 participants using a set of interviews, observations and cultural probes to gain insights into their walking experience and their perspectives about the quality of the pavement. Additionally, the participants' behavioural changes and the pavement problems in the surroundings of their residence are observed and recorded using photographs. The interview was used to fully understand and record the in-depth views of the participants (Silverman, 2010). A question book was offered to the participants investigating the pavement issues and their particular experience on the pavement. In the observation, the hazards to the participants on the pavement were identified, and their actions beyond their perspectives were captured (Gray, 2014). The cultural probe known as a self-reporting tool was used by the participants to record the phenomenon that was exposed when they were walking alone (Arthur, 2012). It consisted of a diary booklet, a disposable camera, a local map and two pens which enabled the participants to photograph, mark and report the information. At the end of stage-one, plenty of data was received, while the significant findings needed to be further verified with a more substantial number of samples. Therefore in stage-two, a mixed method of interview and questionnaire was employed to specify the priority of the findings by quantifying the data efficiently (Ravitch & Carl, 2016). This combination assisted the participants to understand the study enquires better, therefore, generating valid data (Hussein, 2009). Finally, 32 participants filled out the questionnaires, and all the questions were completed with valid responses.

To analyse the substantial data, descriptive coding was used to categorise and generalise the scripts into words and short phrases (Miles, Huberman & Saldana, 2014). The collected results were then grouped into 16 influencing factors of pavements, 13 associated behavioural changes, 4 categories of adverse effects and 17 recommendations to improve the quality of the for pavement environments.

2.1. Findings and discussion

Table 2 Influencing factors of the pavement and their adverse impacts.

<table>
<tr><th colspan="2">Factors of the pavement environment that influence the walking of elderly pedestrians</th><th>Adverse effects of the pavement factors</th></tr>
<tr><td>1</td><td>Uneven pavements</td><td rowspan="16">• Increasing the risk of falling and being tripping

• Increasing negative physical impacts
(tiredness and pains)

• Limiting one's walking
(limiting one's walking activity or behaviours)

• Limiting one's view
(affect one's view of the pavement surrounding or condition)</td></tr>
<tr><td>2</td><td>Overgrown plants
(overgrown bushes and trunks, overhanging branches and ruderal)</td></tr>
<tr><td>3</td><td>Slippery obstacles
(slippery paving surfaces, liquid, ice, snow, fallen leaves, and moss)</td></tr>
<tr><td>4</td><td>Broken pavements</td></tr>
<tr><td>5</td><td>Moving objects
(bicycles, mobile scooters and skateboarders)</td></tr>
<tr><td>6</td><td>Temporary obstacles
(rubbish and temporarily placed objects on pavements)</td></tr>
<tr><td>7</td><td>Street infrastructure and furniture
(poorly planned or maintained street lights, cable boxes, street signs, bins, benches and bus stops)</td></tr>
<tr><td>8</td><td>Manhole and drain covers
(contributing to uneven and slippery surfaces)</td></tr>
<tr><td>9</td><td>Parked vehicles</td></tr>
<tr><td>10</td><td>Constructions
(safety barriers; build and repair works of road, pavements and street buildings)</td></tr>
<tr><td>11</td><td>Narrow pavements
(the paving width of pavement is narrow, or pavements are occupied by obstacles)</td></tr>
<tr><td>12</td><td>Absence of pavement
(no paved path for pedestrians)</td></tr>
<tr><td>13</td><td>Street stores
(commercial objects; tables and chair; and booths)</td></tr>
<tr><td>14</td><td>Confusing paving patterns
(messy paving slabs)</td></tr>
<tr><td>15</td><td>Tactile paving areas</td></tr>
<tr><td>16</td><td>Stepped and sloping ground</td></tr>
</table>

Table 2 shows 16 key factors that influence the participants' walking and records the negative impact such as the risk of falling. In consonance with Oxley and Hern (2016) and Wang et al. (2016), this study also found that slippery, uneven and poorly maintained pavements, and pavements with missing slabs, and kerbs, and inadequate street lighting were common hazards which would increase the fall risk. Our participants additionally reported that protruding tree roots, street infrastructure and drain covers would contribute to the risk of slips and falls. Besides, they indicated that narrow pavements made them have difficulty in navigating along the path. Furthermore, the pavements would be narrowed by permanent obstacles and further affected older people walking on the road (I'DGO, n.d.). Contrasting colours of ground patterns were sometimes mistaken for changes in the ground level (Pollock, 2012). Some participants also claimed that they experience physical discomfort when walking on poor ground surfaces. For example, the unevenness of pavements resulted in pain in their ankles and the overgrown tree branches compelled them to bend down and led to neck pain. Moreover, they experienced tiredness when they had to spend extra energy to walk up and down on the slopes. Although tactile paving is designed to support the walking of people with visual impairments, it can be a hazard as it can create slippery and uneven surfaces (I'DGO, 2010); therefore, it made older adults fall and unstable and further initiated pain in their hip and ankles.

Table 3 Behavioural changes of the elderly pedestrians.

Behavioural changes of the elderly pedestrian	
1	Adopting cautious steps
2	Walking around
3	Adjusting paces
4	Walking slowly
5	Giving way to other pedestrians
6	Stopping walking
7	Walking on the outside of pavement
8	Walking on the road
9	Crossing to the opposite side
10	Lowering one's head
11	Raising steps
12	Facing oncoming traffic
13	Swerving one's body

Table 3 presents 13 main behavioural changes that the elderly pedestrians adopted when encountering the influencing factors of the pavement. For example, they usually walked with careful steps to cope with the pavement issues. Sometimes they intentionally walked away from the obstacles; adjusted their pacing more often; walked slowly; raised their steps higher; and gave way for other pedestrians to mitigate the risk. This is in line with previous studies that show that they slowed down the pace of their steps when facing potential hazards (Spirduso, Francis & MacRae, 2005); and those who encountered irregular surfaces often adopted a more conservative gait pattern to negotiate the uneven ground (Mitra, Siva, & Kehler, 2015). Walking on the outside of the pavement was also a main tactic of the participants when the width of pavements was comprised of environmental obstacles, such as overgrown plants and inappropriate street furniture. Furthermore, the participants were compelled to walk on the road or to cross to the other side when the pavement was in severely slippery and broken condition; when a pavement was not available and when there was no designated footpath. At the same time of walking on the road, they usually faced oncoming vehicles so that they could observe the traffic flow. In fact, facing oncoming vehicles could reduce the number of injuries caused by traffic (Luoma & Peltola, 2013). At times, the participants would stop to observe before deciding how to deal with a situation to avoid the risk involved. For example, they stopped walking before stepping onto a slippery surface or when a cyclist was approaching. Besides, it was observed that the participants had to lower their head while avoiding the overhanging branches; or to look down on the pavement and observe the ground condition.

In this study, recommendations were also collected to improve the quality of the pavements. We also took on board the resources from the government publications and standards to pavement design, such as HD 39/16 (DMRB, 2016), Manual for Street (DfT, 2007) and Pedestrian Comfort Guidance for London (TFL, 2010), and references from other notable studies, such as Bayliss (2015) and Rackliff (2013). In summary, the recommendations include having:

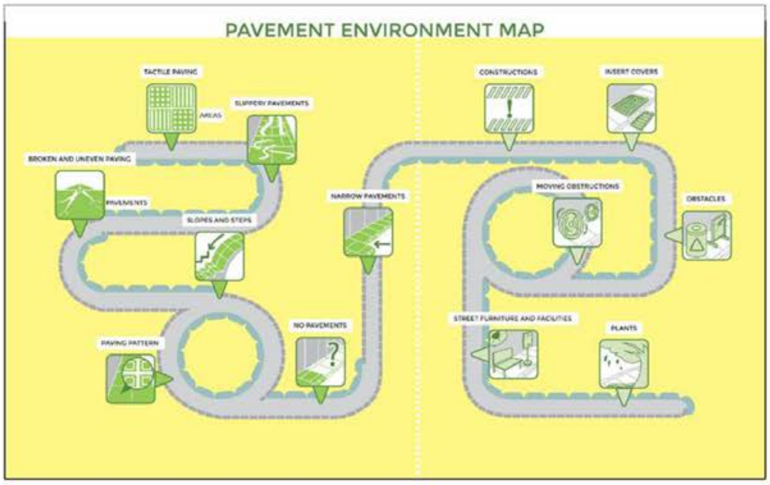
- even and smooth paving surfaces
- wide pavements
- non-slippery paving materials
- well-maintained pavements
- clear pavements free from obstacles, such as temporary obstacles and parked cars

- well-constructed and organised street infrastructure and furniture
- a well-defined pedestrian route separated from constructions or vehicle roads
- fewer step and slope ground or they are built on a small gradient
- well-cared plants and right kinds of plants
- low kerbs
- pedestrianized pavements and plan the pavement for different users, such as scooters and cyclists
- taking away the temporary obstacles immediately or managing them well
- functional markings indicate the problems of pavements
- clear paving patterns in a uniform design
- well-maintained manhole and drain covers
- street stores make more space for pedestrians
- tactile paving planned for appropriate size and in appropriate locations

3. Concept development

The result of the data collection was concluded and embodied into a database with infographic displays. In addition to the database, a decision was made to develop a tool that could be utilised to assess and improve the pavement environment. This toolkit is designed to encourage users to gain a better understanding of the relationship between pavements and elderly pedestrians. For the first phase, we analysed existing approaches and tools which were designed to do reports and monitor the issues of the pavement. For example, FixMyStreet application ("FixMyStreet", n.d.) allows users to report the local problems like graffiti, fly tipping, broken paving slabs, or street lighting with photographs and descriptions. It then sends the organised reports to the local council and presents the problems on a digital map. Based on the ideas, we developed the concept including an analysis map and a demonstration card-pack which were used to probe the pavement environment. The analysis map was in a neutral design layout, and it was simulated as a pavement environment in which problems could be identified with the 'locating icons' reprinting different pavement issues. Users could assume the map as a local pavement environment and marked significant building and street names on the map. Then they could use the locating icons to demonstrate pavement hazards like the uneven pavements, narrow pavement and plants. Further discussions would be generated based on the map and elicit more relevant findings. In addition to the map, the card-pack includes 16 foldable cards which reported the significant findings of the empirical study: (1) the description and photos of different pavement factors, (2) the impact of poor pavements on elderly pedestrians, (3) changes to their walking behaviour; and (4) recommendations for built pavements. Users could use the analysis map to investigate issues of the pavement, and then turn to the card-pack learning the relationship between the pavement and elderly pedestrians.

Analysis map with locating icons



Card-pack

Figure 1 Design concept of the tool

3.1. Expert interview

In the concept stage, we invited seven academics to an interview to seek their feedback based on their different expertise such as accessibility, design methodology, inclusive design, behavioural science and civil engineering. During the interview, we discuss the information and design of the concept; application of the design concept and potential users; and recommendations for the tool.

3.2. Comments on the design concept

The academics declared that the tool was important and original and it provided new information in the certain research area and demonstrated a clear relationship between pavements and elderly pedestrians. It was useful in providing a better understanding of elderly people's perception of the pavement. Specifically, the analysis map highlighted the issues in a specific location. It was useful to do the investigation, and the sign planning contributed to decision making. Moreover, the card-pack was useful to provide a lot of specific content and universal solutions, and it was easy to use. The information shown on the cards urged people to look into details and to make them think about more. For example, they would consider the solutions to the pavement issue concerning its impacts on elderly pedestrians. Different information on the card showed the relationships between the pavement and older pedestrians for different users. However, personal preference to use the card would induce the miss of the information. Overall the whole view was easy to follow even though the connection between the map and card-pack could be made more explicit.

The tool would contribute to the users who are interested in the identification of the pavement issues while unfamiliar with the pavement environment. They may apply the finding in their work or use it as a checklist. They would be designers, researchers, local councillors and general public groups who worked on pavement design, environment design, urban design, place making, and community development. Moreover, the result and concepts may have a potential to be applied in academic projects. School students may use the map and card-pack to explore neighbourhoods. Lecturers can use them as a teaching tool, using it to generate guideline for an observation study and co-design.

In terms of the further development of the tool, firstly, the academics indicated that it could be used as a document or investigation tool. But if it is an idea generated tool, less information and data should be given. Secondly, the interactive process of the tool should be well designed. A tool in the physical format would be good to use practically for older adults in the real world. Thirdly, colour coding was recommended in the tool design. For example, the pavement factor could be distinguished by different colours. Fourthly, the user flow should be simplified in clarifying the information of the task that users need to complete. Finally, the tool should explain what it is, why and how it is used, and display the information that users need. It needs to deliver efficient results for people to report, produce and write something.

4. Co-experience toolkit

Based on the previous findings and discussion, a co-experience toolkit has been developed. It provides an opportunity for older adults to indicate their perspectives of walking on local pavements. Meanwhile, it assists people who work on designing, maintaining and monitoring the urban walking environment to assess and improve the pavements. Apparently, the users are made up of two groups of people who are 'researchers' (pavement designers, city planners and road engineers) and 'participants' (older adults who are fit to walk). This toolkit allows one researcher to conduct a co-study with up to six 'participants' every time. They could identify the problems and impacts of the pavement, and explore older pedestrians' behavioural changes to the pavement issues. In addition, they could propose recommendations in order to improve the quality of the pavement environment. In the co-experience study, participants would discuss and share their ideas in an interactive way, and consequentially the researcher could collate and model the results into the desired direction (Battarbee, 2003, cited in Fan & Lu, 2017, p. 4).

4.1. Components and usage of the co-experience toolkit

The toolkit is designed in a physical format in consideration of facilitating the interactive activity and efficiently seeking for the opinion of the elder users. Matrix is the main design element of the tool, and it was used to assemble the data. Because the data in matrix could be interpreted and described straightforwardly; and the relationship in the data could be uncovered by identifying and comparing the similarities and differences in the cross-sections (Corbin & Strauss, 2015).

This physical tool consists of four components including (1) 6 groups of 16 'Pins' and 16 'Landmarks' that each of them shows the type of a negative factor in the pavement, and being coded with a particular colour and a distinct participant code (e.g. P1, P2, or P3); (2) 6 'Participant survey books' which are used by the older adults to indicate the pavement factors that affect their walking, to specify their behaviours and to also suggest recommendations to improve the pavement; (3) A 'Card-pack' that includes 16 cards that providing descriptions of different factors of pavements using photographs and description; (4) A 'Researcher recording card' that is used by researchers to compile all data from the co-experience exercise. The recording card is in the form of a booklet that offers user instruction and tables for the researchers to record information being discussed. The user instruction introduces the background, objectives, pre-requisite materials, exercises and components of the toolkit. An additional material which is a local map that would be prepared by the researchers and printed in an appropriate scale (size A2 and A1 are recommended) so that it can be easily read with clearly labelled street names and landmarks.

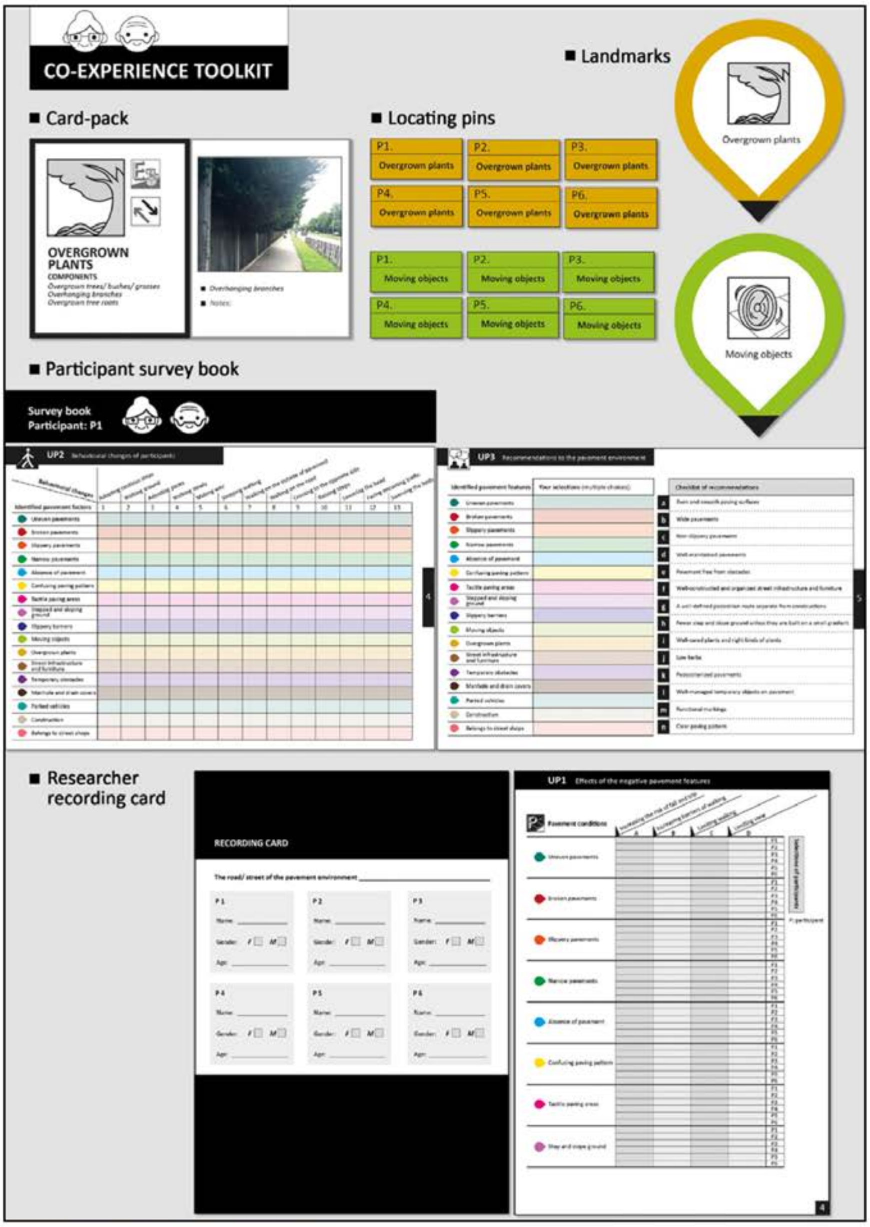


Figure 2 Components of the Co-experience toolkit

4.2. Test of the co-experience toolkit

To test the tool, we intended to find out if the tool shows information in a proper way; enables the users to know what they could do and how to do; provides an efficient way to collect data; ensures users do appropriate exercises; assists users to identify problems and get solutions; and enables the collected data easy to be used; or supports the researchers in their work field and expands their knowledge (Grinyer, 2016; the design guideline of "IBM Design Research | Resources | Toolkit", 2017).

4.3. Methods

The toolkit was evaluated by nine senior citizens aged over 60 in Hillingdon, as well as five doctoral students from civil engineering, design and ageing study to act as researchers. Each researcher was allocated to a group with two of the older adults as the participants, and overall there were five groups. The groups were asked to use the toolkit to assess and improve the pavement environment of Uxbridge town centre (London). Each group sat together with the map in the centre of the table, and the components of the toolkit were distributed among the group according to their role. Every participant got a group of 16 'Pins' and 1 'Survey book', and the researcher got the 16 'Landmarks' and a 'Recording card'. At first, the researcher collected the personal information of the participants in the 'Recording card'. Next, the researcher asked them to identify the factors of the pavement environment that would affect their walking by placing the relevant 'Pins' on the map. At the same time, the participants further discussed why they had chosen those pavement factors, and the researcher selected the significant ones based on the group discussion. Then the researcher highlighted the significant pavement factors with their corresponding 'Landmarks' on the map, and signed them in the recording card. Following that, the participants indicated the impacts of the highlighted pavement factors on them and, the behaviours that they would have shown when encountering with those pavement factors. According to the row heading of the matrix tables in the 'Survey book', the participants ticked off their responses. Finally, they made suggestions on how the pavement conditions could be improved according to a list of supplied recommendations in the 'Survey book'. At the end of the activity, the researcher compiled all of the responses from the 'Survey books' in the 'Recording card'.

After the exercise, further user comments were collected in a survey questionnaire that consisted of nine questions: (1) Is the tool easy to use?; (2) Is the toolkit efficiently designed?; (3) Does the tool include the information that you expect?; (4) Does the tool enable you to indicate your ideas?; (5) Do the objectives of the co-study were achieved using this tool?; (6) Did you obtain new knowledge from using the tool?; plus 'Does the tool enable you to collect and compile the data quickly and easily?'; 'What will you do with the results that have been collected using the tool?'; and 'How does the tool contribute to your work?' which were designed for researchers only.

Figure 3 Test of the co-experience toolkit

4.4. Result and discussion

Each of the workshops took around 45 minutes, and we observed the significant phenomenon in the workshops. Additionally, we analysed the user feedback in questionnaires and discussed advantages and disadvantages of the toolkit and its components in aspects of usage, design and information delivery. In terms of the creation, most users agreed that the toolkit was user-friendly, highly straightforward, simple and well explained with a good layout and physical components, and the colours were well coded. However, a few users commented that the guidance and terms presented by the tool were slightly confusing and the matrix tables of the 'Survey book' were slightly complicated to use in the beginning. Moreover, the 'Pins' assisted the researchers to find out the priority of the pavement factors by exploring how many participants identified a particular pavement hazard in a specific location. However, they did not enable the participants to identify a pavement issue in various locations; thereby it limited the operation of the participants. On the other hand, the tool allowed the users to identify the problems of the pavement environment, the impact of the pavement and the behaviour changes of the older adults as it provided detailed and well-explained information. The tool also allowed users to arrive at the recommendations to the pavements by giving a comprehensive list. Even though one research student found that the relationship between the behaviours and pavement factors was slightly ambiguous, many users indicated that the tool could clearly demonstrate the relationship. In terms of the data recording, many researchers found it was efficient, easy and quick to compile the data on the recording card. However, one researcher also preferred a digital format rather than a physical layout as he believed it would be easier to compare the result.

As for the output of the tool, the researchers felted that it served its purpose and it had helped them to expand their knowledge regarding the relationship between older pedestrians and pavement. It gave them a better understanding towards the needs of elderly people and to suggest improvements to the pavement. Furthermore, the researchers would develop their work with the relevant response of the participants. For example, they would make a checklist or a guideline for designing inclusive environments for older adults, and relate the results to the body strength, health and other personal conditions of different participants.

In addition to their comments, we observed that even though the toolkit aimed to serve as a co-experience study, some participants did not cooperate with each other well in generating ideas and discussing ideas as expected. According to our analysis, this happened because of the design of the 'Survey book'. It efficiently facilitated the participants to have answers to the study questions. However, some participants were less likely to think about, or expand their responses, or talked to others in the group when they selected their preferences from the provided tables.

5. Development of the co-experience toolkit

According to the analysis result and user suggestions, we redesigned the toolkit by developing its design, form, usage and communication. In addition to the previous version, the new toolkit offers 6 participant code badges to be used to represent the participants with a number, such as "P1" (participant one). Moreover, it provides 7 user instructions (6 for the participants and 1 for the researcher) that introduce the components and a use flow of the tool. Furthermore, a new 'Card-pack' was created by integrating the function of the 'card-pack' and 'pins' in the previous toolkit. Each card set in the new 'Card-pack' was made up of a 'Folding card' and six 'Mini cards'. The folding cards are used to explain the pavement factor and to identify the hazards that influence elderly pedestrians' walking in a pavement environment. The mini cards are applied to further confirm the issues in particular locations of the pavement environment. Lastly, the improved version provides 17 group survey cards for replacing the individual survey books. The survey cards are categorised into: sixteen 'Survey Card (1)' are used to investigate the adverse effect of the pavement factor and explore behavioural changes of participants, and one 'Survey Card (2)' is used to collect the suggestions to improve the pavement environment. Besides the revised materials, the researcher would also be given a recording card that is kept in the same design as its former vision. What else remains is that the researchers must pre-prepare a local map of a pavement environment along with the new toolkit.

5.1. Improvements to the co-experience toolkit

Figure 4 displays the new version of the toolkit and shows the differences between the developed toolkit and the former one. First of all, we abolished the 'Landmarks' as the researchers declare that the 'Landmarks' had the same function as the 'Pins' while excluded some pavement factors that identified by the 'Pins'. However, all identified pavement issues should be further studied. Secondly, more pictures are used in the instruction enabling users to easily and quickly recognise the information and keep it in a longer-term memory (Dewan, 2015). Additionally, we modified the personal 'Survey books' to group 'Survey cards' in order to encourage discussions and idea generation among the participants. The function of the group 'Survey card' remains the same, although it has now been redesigned with a circle layout to ensure that all users could read it from different angles and to be fully involved in the group discussion and exercise. It encourages researchers to be more active to explore extra findings in the survey. To guarantee the data is collected properly in the group interaction, we additionally created 'Code badges' for the participants to distinguish their role when giving their responses. Moreover, the toolkit has also been revised to allow users to position the pavement issues in various certain sites with the commonly-used 'Mini cards' rather than using the personally-used 'Pins'. Comparing to the former version, the researchers can record the amount of the locations where presenting the pavement factor and the number of the participants who identified the factor on the 'Survey cards' rather than in the 'Recording book'. Therefore, the correlation between each pavement factor and the participants (elderly pedestrians) would be more clear and specific.

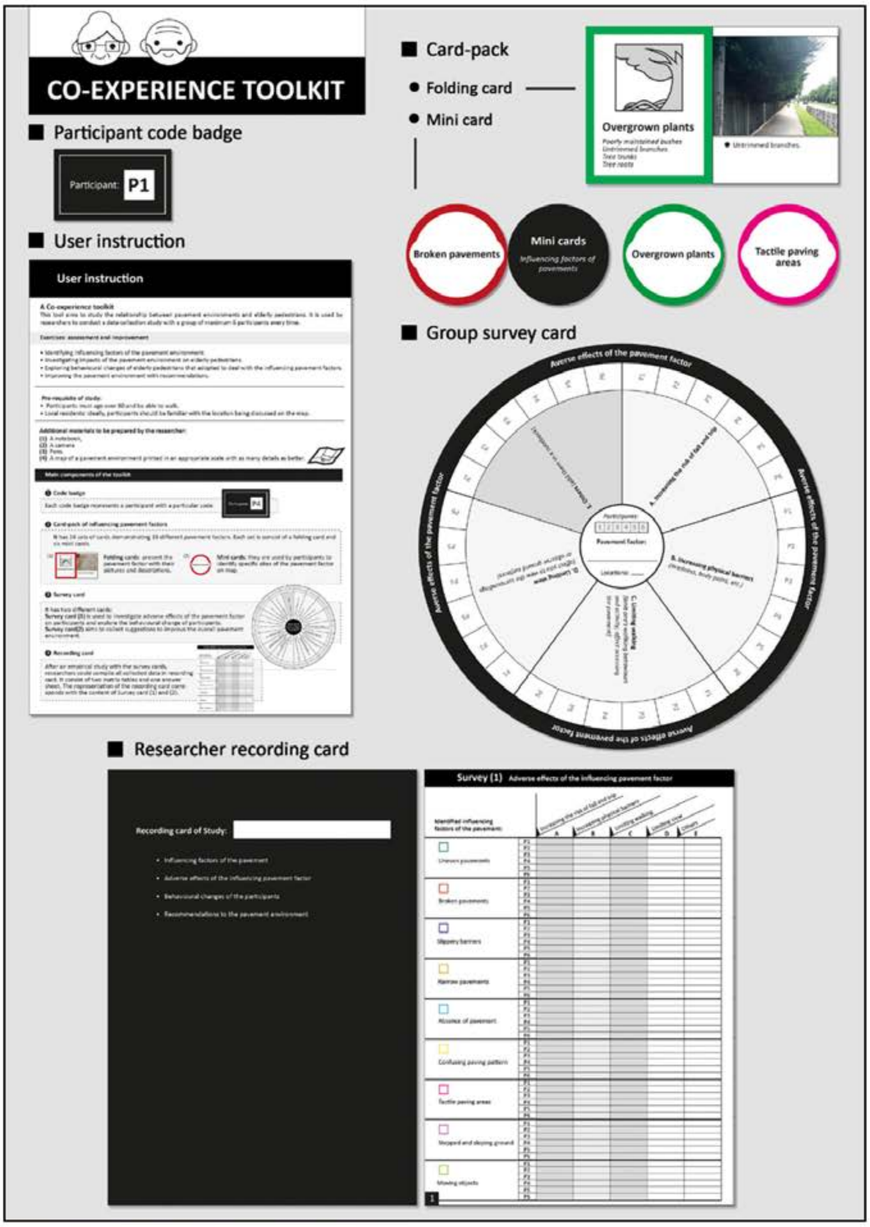


Figure 4 Developed version of the co-experience toolkit

6. Conclusion

From this study, we extend the findings of pavements and walking behaviour and develop a co-experience tool that not only identifies problems also provides practical recommendations to improve the pavement. The toolkit offers a new opportunity for researchers to listen to the needs of the elderly pedestrian. It is a heuristic tool allows users to participate in a co-experience study based on a localised area using a printed map for reference. Initial test shows that the toolkit has received a lot of positive feedback; even so, it has been further optimized. Although the studies used a small sample of participants, we have provided a representative result from each user group. In future works, we will involve broader user groups in the usability testing of the latest developed toolkit.

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About the Authors:

Lulu Yin is pursuing her doctoral studies at Brunel University London. Her research focuses on designing a co-study toolkit to investigate the walking environment of pavements and the walking behaviour of elderly pedestrians.

Eujin Pei is the Programme Director for the BSc Product Design and BSc Product Design Engineering courses at Brunel University London. He is a Chartered Engineer and a Chartered Technological Product Designer possessing considerable expertise in leading industrial collaborative projects.

Appendix II: Paper for LENS conference

A Toolkit: Fostering a Participatory Study of Sustainable Pavement Development

Lulu Yin
Michael Sterling Building MCST258,
College of Engineering, Design and Physical Sciences
Department of Design
Kingston Lane, Uxbridge, UB8 3PH
United Kingdom
Email: lulu.yin@brunel.ac.uk
Eujin Pei
Michael Sterling Building MCST156,
College of Engineering, Design and Physical Sciences
Institute of Materials and Manufacturing
Department of Design
Kingston Lane, Uxbridge, UB8 3PH
United Kingdom
Email: eujin.pei@brunel.ac.uk

ABSTRACT

Walking is a popular transport means for seniors doing daily errands, and pedestrian pavements play a key role in influencing the quality of older people's walking. Walking experience of older pedestrians and their perspectives to the outdoor environment are crucial in planning and designing pavements.

However, their walking experience and perspective on the pavement are less involved in the process of urban development. A participatory toolkit is created providing a chance for older people to share their walking experience and to indicate their opinions of the pavement in a group study conducted by researchers who develop the pedestrian environment. The tool allows users to identify hazardous factors of the pavement, seek the impact of pavement hazards, and improve the pavement using recommendations. Based on the outputs of the toolkit, the researchers can have a better understanding of the relationship between pavements and elderly people and create an age-friendly pedestrian environment.
Key Words: sustainable development, pavement, older adult, toolkit

1. INTRODUCTION

Walking is the most satisfying, environmental and age-friendly transport means for sustainable advancement (Kim, Choi, & Kim, 2011; Mateo-Babiano, 2016). It is also regarded as the most effective mode of travelling for older people who live in cities and want to be less reliant on driving (Fisk et al., 2009). However, the condition of built environments and environmental barriers can affect the safety and quality of older people's walking (Achuthan, Titheridge, & Mackett, 2010; Rackliff, 2013). Furthermore, behavioural changes on the walking pattern of older pedestrians are associated with the hazardous appearance on walking paths (Caetano et al., 2016; Kovacs, 2005). Many guidelines, such as Manual for Streets (DfT, 2007) and Pedestrian Comfort Guidance for London (Iversen, 2010), have come out recommendations and guidance on building and designing the pavement to deal with the risk of falling and to promote walking in pedestrians. Even so, the walking experience of older pedestrians and their comments on pavements are not fully regarded by road engineers or design teams. Older adults consume much more time in local neighbourhoods, thus, it is vital to understand their concerns when building walkable environments for them (Grant, Edwards, Sveistrup, Andrew, & Egan, 2010). Therefore, we designed a map-based toolkit providing a participative process for older pedestrians to share their perceptions and walking patterns and generate ideas with researchers, namely urban planners, environment designer, and construction consultants, in the process of developing the pavement. Meanwhile, the tool enables the researchers to explore issues of the pavement and their impact on older people's walking.

2. A PARTICIPATORY STUDY TOOLKIT

The tool enables researchers (e.g. urban designers) to conduct a study to identify hazardous factors of the pavement in specific locations, investigate the adverse effect of the pavement factors, exploring behavioural changes of older adults (study participants) caused by the pavement hazards, and propose recommendations to improve the pavement environment. Shih et al. (2009) found that more ideas could be generated between people when they share their individual opinions in a group. Therefore, the study will be done with a group of older adults. People older than 60 are usually defined as elders (Un.org, n.d.), and a mini group is easier to organise and to make participants feel more comfortable in a concentrate discussion (Krueger & Casey, 2015). So, there has to be a maximum of six participants in the study and they have to be aged over 60 and fit to walking.

The content of the toolkit was created based on the findings of our empirical study (Yin & Pei, 2018). As to the outcomes, it categorised 16 pavement hazards, namely uneven pavements, overgrown plants, slippery barriers, broken pavements, moving objects, temporary obstacles, poorly maintained or designed street amenities, manhole and drain covers, parked vehicles, construction, narrow pavements, absence of the pavement, shopkeeper's goods, confusing paving patterns, tactile paving areas, and changes in ground levels, such as steps and slopes. These pavement hazards could increase the risk of falling and physical burdens to older pedestrians and limit their walking and view. Additionally, they could trigger particular changes in the walking behaviour of older adults. There were 13 behavioural varies have been classified based on the study results and they were adopting cautious steps, stepping around, adjusting paces, walking slowly, giving way, stopping walking, walking on the outside of the pavement, walking in the street, crossing road to the opposite pavement, lowering one's head, raising one's legs higher, facing oncoming traffic, and swerving one's body. To deal with the hazards and build an age-friendly environment, pavements could be developed by improving the pavement quality, providing pedestrianized pavements, well-maintaining street amenities, and avoiding pavement obstructions.

2.1. Components of the toolkit

Figure 1 shows that the toolkit has five components: (1) code badges, (2) user instruction, (3) a card pack, (4) survey cards, and (5) a recording card.

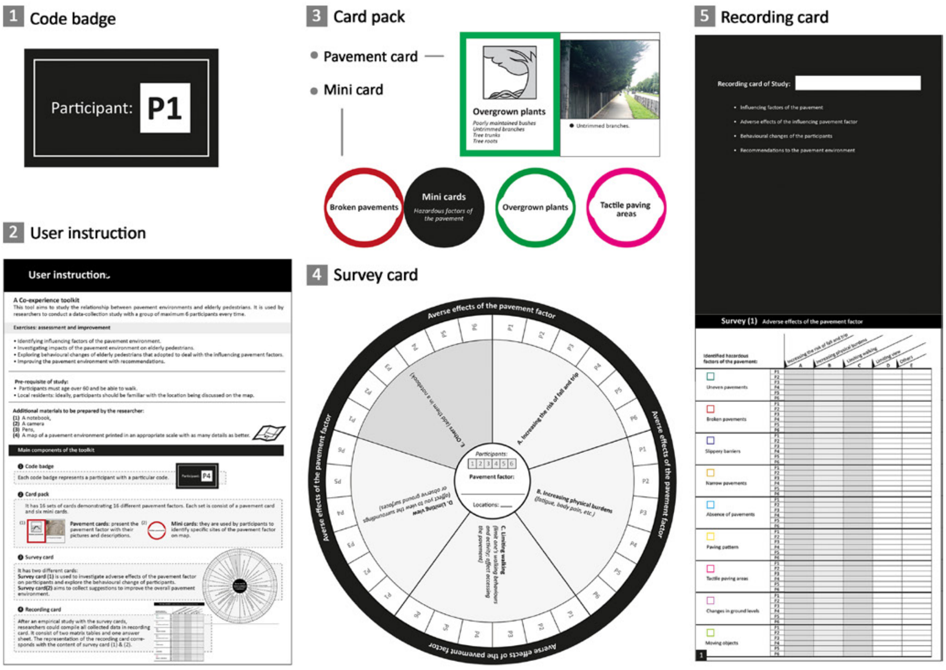
Code badges: there are six code badges, and each of them uses a unique number, such as 1, 2, or 3 to represent a study participant. The code badges allow participants' identity to be confidential and help to avoid participants giving answers repeatedly in group exercises.

User instruction: the user instruction introduces the aim, objectives, target users, practices, and components of the toolkit, and provides a step-by-step guide for using the toolkit.

Card pack: the card pack incorporates 16 pavement cards and 96 mini cards. Each pavement card corresponds with six mini cards representing one of the pavement hazards found in our empirical study. The pavement card box are not only used to expand users' ideas, but also employed by participants to preliminarily identify hazards of a pavement environment.

Survey cards: the survey cards constitute 16 copies of survey card 1 and a copy of survey card 2 that are used to explore the relationship between each pavement hazard and older pedestrians (study participants). Survey card 1 was made to explore the physical and behavioural impact of each pavement problem on study participants, and survey card 2 allows the participants to suggest improvements to the pavement environment using the recommendations constructed in the empirical study. The survey cards were made into a pie chart to ensure that all users to read them from different angles. Each segment of survey card 1 displays an adverse effect of the pavement hazard or a behavioural factor triggered by it, and each segment of survey card 2 offers a recommendation to the pavement. The outer ring of each division split into six individually showing one of the participant codes that allows participants to give an answer by ticking their code. Also, both of the survey cards provide an option of 'Others' allowing participants to add extra findings in addition to the provided content.

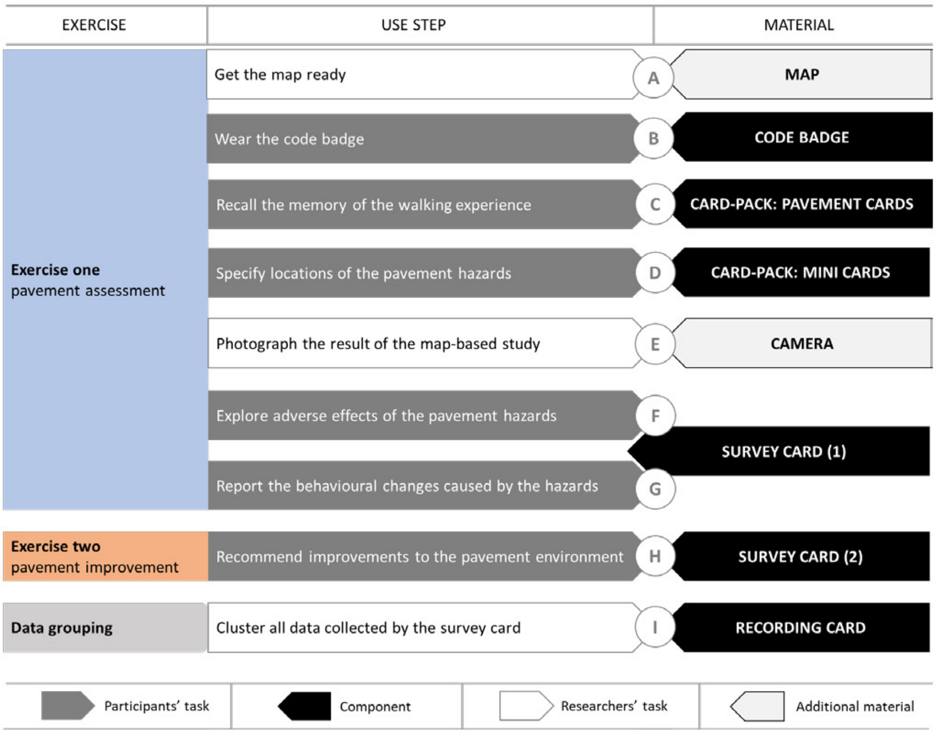
Recording card: the recording card has three matrices, and all their column headers is a list of the 16 pavement hazards while their row headers respectively are the impact of the pavement hazards, behavioural changes of participants, and improvements to the pavement. Each row of the matrices was divided into six divisions for researchers to group data while to distinguish different participants' answer to the same category.



[Figure 1] ***The participatory study toolkit***

2.2. Use of the toolkit

To use the tool, researchers must first prepare a map and bring a camera to photograph results of the map-based assessment. At the beginning of the study, researchers need to introduce all components of the toolkit to participants and teach them to use the tool and assign a code badge to each participant. Next, participants use the card pack to conduct a brainstorming session on problems with the pavement. Following this, researchers can start to assess the pavement environment by asking participants to demonstrate hazards that exist in the context using relevant pavement card boxes. Then, researchers collect these identified card boxes and take out mini cards from them, and participants use the mini cards to locate the hazards on the map. Afterwards, researchers photograph the result of the map-based exercise so that they can quickly record the exact locations of the pavement hazards and continue to review the results after the study. In the following step, researchers use a copy of survey card 1 to further explore one of the identified pavement hazards only with the participants who have referred this issue on the map. Before the data collection, researchers need to indicate the identified pavement issue on the centre of survey card 1 so that participants know what factor they need to focus upon. Also, researchers need to write down the code of the participants who pinpoint the problem on the map and the locating number of the hazard on survey card 1. As to participants' tasks of survey card 1, they need to tick their codes on card segments if they agree with the statement presented by the portion. Each survey card 1 is used to study a pavement hazard identified on the map already. The more pavement issues are analysed, the more copies of survey card 1 will be used. Based on the results of the map-based assessment and survey card 1, participants carry on recommending improvements to the pavement environment on survey card 2. Finally, researchers cluster all data collected by those survey cards in their recording card.



[Figure 2] *Use of the toolkit*

3. TESTING OF THE TOOLKIT

As the toolkit would be used to implement a group study within two kinds of users, the feedback from researchers and study participants (older people) could be different according to their standpoints. Therefore, the toolkit was evaluated in two sections conducted separately with elderly participants in workshops and with researchers in an interview-based study to seek their in-depth and diverse views. Workshop is a common method to develop a design tool and to identify users' interests and the impact of a design solution (Rail Safety and Standards and Board, 2008). The workshop aimed to examine if elderly participants could use the toolkit to carry out practices properly in a group activity. Eight senior residents (older than 60 and fit enough to walking) in London were recruited to the workshops and they were divided into groups of four. A map was used for the map-based assessment and it was created based on Google Maps. It displayed a part of the pavement environment in London and it was made in A1 size with the ratio scale of 1:2000 to enable all group members to read it correctly. Interviews allow interviewees' experience and feelings to be expressed and enables their perspectives to be in-depth explored (Kvale, 2003 and Berg, 2007, cited in Alshenqeeti, 2014). The interview-based study was adopted to test if researchers could self-learn the tool and use it to plan a study themselves. Eight researchers were invited from academic and industrial fields and the local authority of Uxbridge to the study. They were sampled for a purpose of diversity (Patton, 2009) and a reason that they acquired relevant knowledge or research interest regarding the content of the toolkit (Creswell & Plano Clark, 2017). The participants comprised four experienced researchers, two younger researchers, a designer, and a councillor. They were professionally engaged in the field of transport environments, travel behaviour, inclusive design, tool design, highway and pavements, neighbourhood maintenance, residential services, or architectural design. In the study, the researchers were asked to simulate a data collection using the tool and to share their user experience and perspective of the toolkit. In addition to the testing, a questionnaire was used in both workshop and the interview to collect the user feedback concerning the design, information, utility, and outputs of the tool.

3.1. Results and discussion

Data collected by the questionnaires were analysed using statistical analysis (Lavrakas, 2008) to work out response rate to each question. Some qualitative information, such as additional explanations, insights, and narratives of the users, were transcribed and coded and finally grouped into content, design, usability, inputs, outputs, and other comments. In general, the tool was simple and well designed, and it enabled the users to efficiently investigate pavement hazards and their impact in walking among older pedestrians. It assisted the researchers to improve the pavement environment and to understand older pedestrians' walking needs from a new angle. The elderly users indicated that the tool covered almost every factor of their walking behaviour and every aspect of the pavement. These views were well defined and emerged all problems that they had encountered in the real world. The tool also included some facets that the older adults had not thought of or considered before that made them think they had the same responsibility as local councils. The researchers said that the tool provided them a new way to conduct an easy group study with older adults. It helped them to quickly and efficiently get information about hazardous factors of the pavement and barriers to walking. Some of the researchers would introduce the tool to local governments and use the tool to train construction engineers and road designers so that they could be more aware of older pedestrians and, hence to improve the age-friendliness of the pavement environment. The researchers also said that the data collected by the tool was analysable that could be easily transcribed into an assessment report or design guidance or solutions. They would interpret the outcomes with more evidence in their work field, analyse the data using a technical approach, seek insights into the results, and explore pavements in different areas with diverse populations. An expert would improve the travel experience of older people in outdoors based on the behavioural varies identified by the tool.

On the other hand, some users had to take a longer time to learn the toolkit, especially at the beginning of the study, as they were confused about the instruction and the link between each section of the tool. However, the tool worked well for them as soon as they understood the principle. Some operations of survey card 1, such as the recording of the results of the map-based exercise, was less useful to the researchers. Also, the size and layout of the survey cards restricted the elderly participants' action although they indeed promoted the group discussion. In this situation, two participants had to play a leadership role to write down other people's answers to the survey cards. In line with O.Nyumba et al. (2018), they were found to influence the study results especially when the other participants did not stand firm on their opinions or were not active. To avoid the issue, the survey cards needed to be redesigned into a more user-friendly layout with a larger size to enable all participants to be more engaged in the group interaction. Apart from that, grouping data from the survey cards to the recording card was not an effective action as the layout of the two materials were different. In this case, some researchers preferred to use a different approach, such as Excel, to compile data. An interviewee also recommended a digital format for the recording card.

4. CONCLUSION

Wennberg, Phillips, & Ståhl (2017) state that it is crucial to understand older people′s knowledge and perspectives to outdoor environments and to include them in the process of shaping their environments. The toolkit gives a chance for older people to participate in urban development and provides a new way for urban planners, environment designers, and local councillors to know about the hazardous impact of poor pavement conditions and better understand the need and experience of walking among older pedestrians. User-involvement studies have been commonly conducted in the environment-development as they could help to mitigate the unnecessary cost and unaccepted design (Kujala, 2003). Collaborating with older people in urban development has a great impact on building a sustainable community and making policies for age-friendly cities (Buffel, Phillipson, & Scharf, 2012). In addition, outdoor infrastructure can be improved based on a better understanding of elderly people′s mobility requirements and walking experience and an in-depth investigation of walking hazards in older

adults (Ormerod et al., 2015). In future, the toolkit will be modified based on the user feedback so that it better assists target users with the participatory study.

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Appendix III: Photographs of pavement hazards

Poor pavement conditions:









Floral issues:



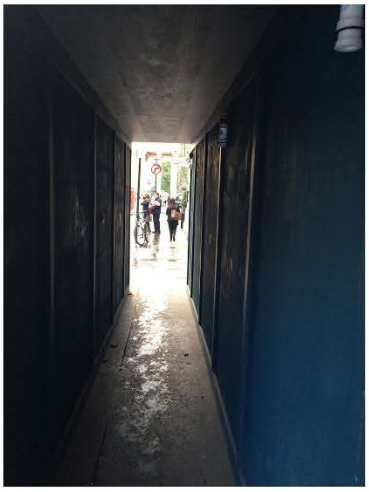






Poorly maintained or designed street amenities:

Construction:



Temporary obstacles, street stores and moving obstructions:

Temporary obstacles

Street stores

Cyclists

Manhole covers, slippery barriers and parked cars:

Manhole or drain covers

Slippery barriers

Parked vehicles

Appendix IV: The interview-based questionnaire used in the empirical study

Investigating the pavement environment and walking behaviour of older adults

Questionnaire & Interview

Participant No.:

Age:

Gender:

State of occupation:

Resident postcode:

Dear participants,

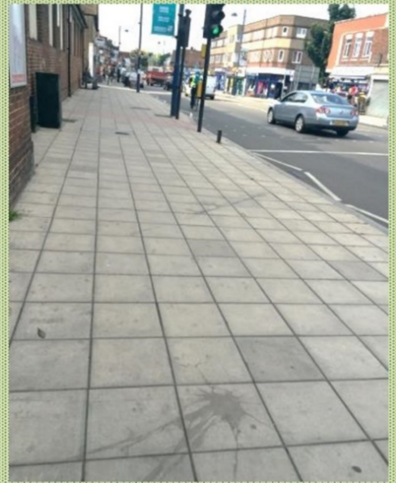
My name is Lulu Yin. I am a PhD student in Design Department at Brunel University London. My research project is investigating pavement environment and its effects on the walking behaviour of older adults. Both positive and negative aspects of the pavement environment are studied in this project. This research aims to find out relationships between the pavement environment and the walking behaviour of older people. Ultimately, the project will deliver an assessment toolkit to help designers, policy makers and urban planners to build a good pavement environment for older residents in local neighbourhoods.

In order to collect data of pavement environment and walking behaviour. I will process an interview with you. This interview will be conducted with a provided questionnaire which includes 12 questions. During the interview, I will record your verbal narratives with a notebook, a sound recorder and a camera. If you feel uncomfortable to be recorded by any devices, you can ask me to not use them or you can quit this interview. You can also ask any other questions before, during and after the interview.

A consent form and a participant inform sheet will be provided to you before the interview. After you sign the consent form and know everything about this investigation, we can start to carry out it.

After the investigation, please give a feedback to this survey as well as my research project.

PAVEMENT ENVIRONMENT



WALKING BEHAVIOUR

- Walking experience
- Time of walking
- Purpose of walking
- Behavioural factors

PERSONAL INFORMATION OF WALKING

Q1. What is the average time of your walking? (every time) [✓]

- ◯ < 30 minutes
- ◯ 30–59 minutes
- ◯ 1–2 hours
- ◯ > 2 hours

Q2. How **often** do you **go out for a walk** within a week? [✓]

- ◯ Almost everyday
- ◯ Sometimes (less than once a week)
- ◯ 1 to 3 times a week
- ◯ 4 to 6 times a week

Q3. What is your **common purpose** for a walking? (*Please select* [✓] ***options*** *and tell me the* ***most common one in them***)

- ◯ For recreation (museum, library, galleries)
- ◯ For accessing to buses/ trains/ tubes
- ◯ Going to a hospital or dental clinic
- ◯ For shopping
- ◯ For visiting friends and family
- ◯ For exercises
- ◯ For social events (lunch clubs, coffee, tea)
- ◯ For formal events (post office, bank, national insurance)
- ◯ For religious events
- ◯ For work/ volunteer jobs
- ◯ Others

1

PERSONAL INFORMATION OF WALKING

Q4. What **physical changes** have appeared in your **walking patterns** over the last few years? *(Multiple choice* [ⓥ])

- ◯ Walking speed is getting slower
- ◯ Having an increased body pain
- ◯ Easily to lose balance during walking
- ◯ Having a decreases in vision
- ◯ Easily to feel fatigued
- ◯ Easily trip or fall
- ◯ Having a reduction in flexibility
- ◯ Others

Q5. Have you ever **fallen down** or **tripped** on pavements?

- ◯ Yes (to Q6)
- ◯ No (to Q7)

Q6. What **objects** make you **fall or trip** on the pavement? *(Multiple choice* [ⓥ])

- ◯ Slippery obstacles
- ◯ Paving materials
- ◯ Poor pavement conditions
- ◯ Manhole covers
- ◯ Street facilities
- ◯ Plants
- ◯ Steps or slopes
- ◯ Others: __________

2

Q7. What **pavement conditions** or **environmental factors** in your neighbourhood commonly affecting your walking?

Q8. What is the impact of **the hazard** (you select) on your **walking**?

Please select "√"

Please select walking behaviour to each aspect:

	Please select "√"	Walking behaviour
A. Narrow pavements		
B. Uneven pavements		
C. Slippery barriers		
D. Broken pavements		
E. No pavement		
F. Confusing pavement patterns		
G. Tactile paving areas		
H. Moving obstacles		
I. Overgrown plants		
J. Bus stops		
K. Rubbish		
L. Parked cars		
M. Tables/ chairs/ A-board of street shops		
N. Street furniture (street lights, signposts, benches)		
O. Construction		
P. Manhole covers		
Q. Kerbs or slopes		
R. Others_______________		

1) Walk slowly
2) Walk carefully
3) Adjust pace of walking (shorten or lengthen steps)
4) Lower my head
5) Step aside obstacles
6) Lift my steps higher
7) Give way to other pedestrians
8) Walk in the street
9) Face oncoming traffic
10) Walk on the outside of the pavement
11) Stop walking
12) Walk sideways
13) Cross road to the opposite pavement
14) Limit my walking (occupy pavements)
15) Increase a risk of falling/ tripping
16) Increase physical burdens (pain/ fatigue)
17) Limit my view during walking

3

Q7. What **pavement conditions** or **environmental factors** in your neighbourhood commonly affecting your walking?

Q8. What is the impact of **the hazard** (you select) on your **walking**?

Please select "√"

Please select walking behaviour to each aspect:

A. Narrow pavements	√	4, 5, 6, 7, 8, 9
B. Uneven pavements		
C. Slippery barriers		
D. Broken pavements	√	12,15, 16
E. No pavement		
F. Confusing pavement patterns	√	7, 8, 9, 11, 13
G. Tactile paving area	√	7, 8,
H. Moving obstacles		
I. Overgrown plants		
J. Bus stops		
K. Rubbish		
L. Parked cars		
M. Tables/ chairs/ A-board of street shops		
N. Street furniture (street lights, signposts, benches)		
O. Construction		
P. Manhole covers		
Q. Kerbs or slopes		
R. Others________________		

1) Walk slowly
2) Walk carefully
3) Adjust pace of walking (shorten or lengthen steps)
4) Lower my head
5) Step aside obstacles
6) Lift my steps higher
7) Give way to other pedestrians
8) Walk in the street
9) Face oncoming traffic
10) Walk on the outside of the pavement
11) Stop walking
12) Walk sideways
13) Cross road to the opposite pavement
14) Limit my walking (occupy pavements)
15) Increase a risk of falling/ tripping
16) Increase physical burdens (pain/ fatigue)
17) Limit my view during walking

3

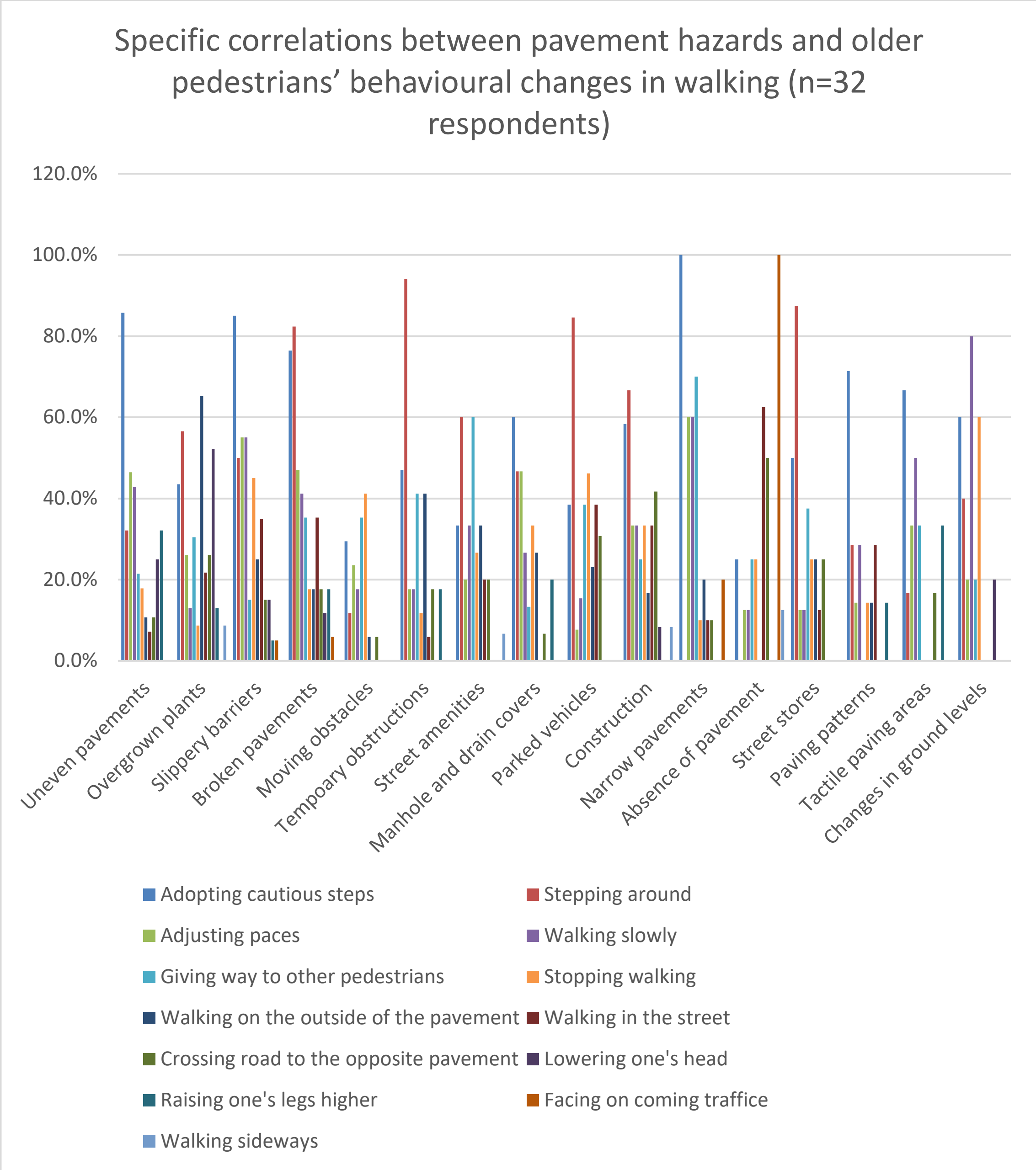
POSITIVE ASPECTS OF pavement ENVIRONMENT

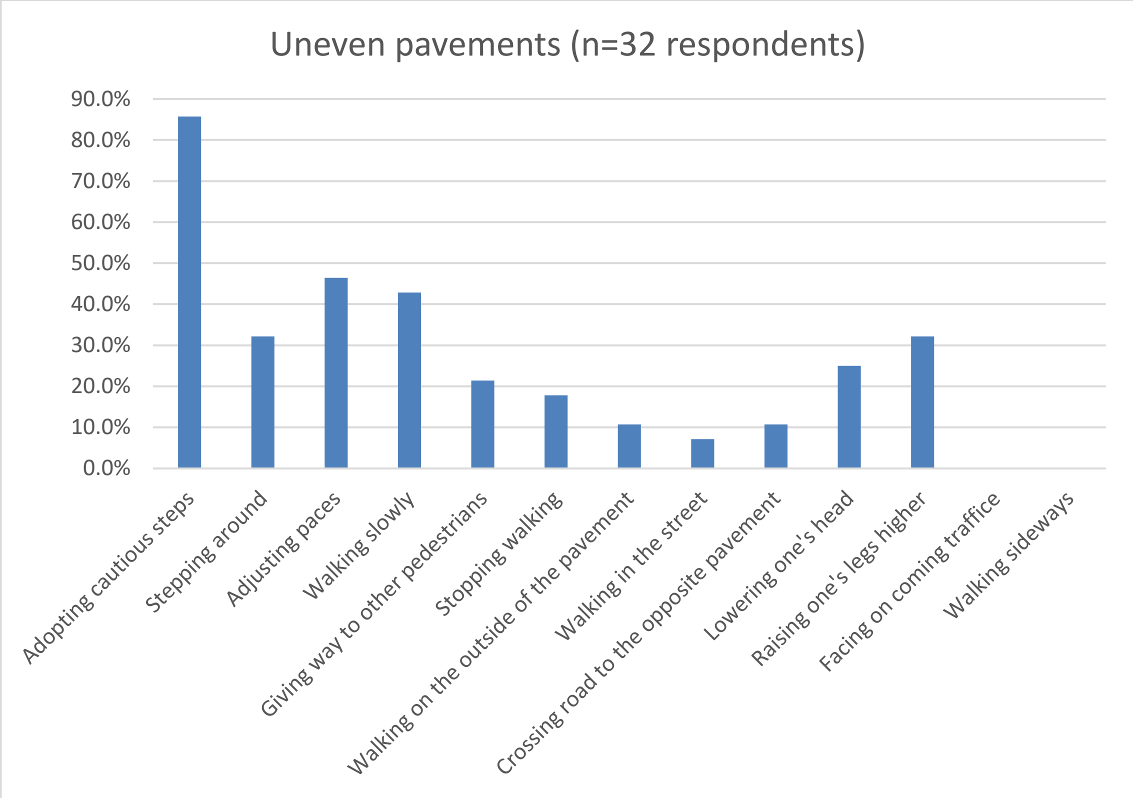
Q9. What are your requirements for the pavements environment? *[Please select [✓] **options** and tell me the **most outstanding one in them**]*

- ◯ Wide pavements
- ◯ Smooth and flat pavements
- ◯ Less changes in paving level
- ◯ Non-slippery pavements
- ◯ Well-cared plants
- ◯ Free from obstacles
- ◯ Clear pavement patterns
- ◯ Pedestrianised pavements
- ◯ Functional marks
- ◯ Well managing the temporary objects (rubbish, tables, chairs, advertising boards, etc.)
- ◯ Appropriate street furniture and infrastructure
- ◯ No cycling or skateboarding on pavements
- ◯ Lower kerbs
- ◯ Others: __________

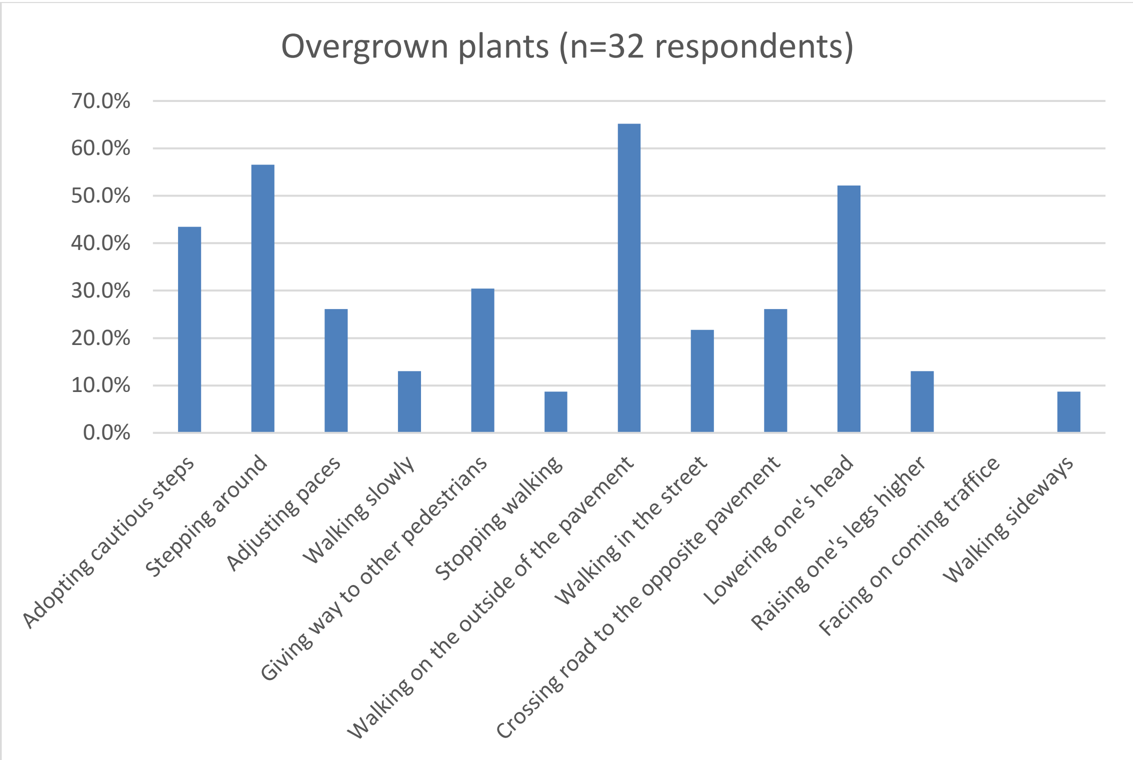
4

Appendix V: Specific correlations between pavement hazards and older pedestrians' behavioural changes in walking

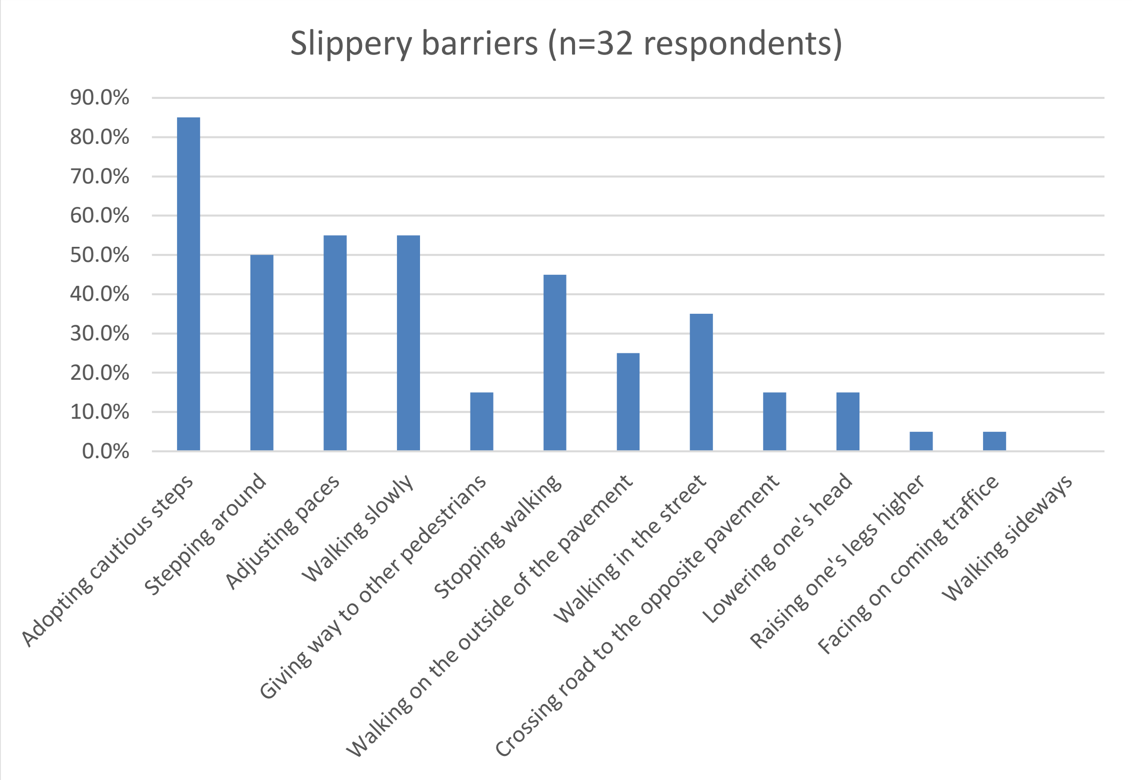




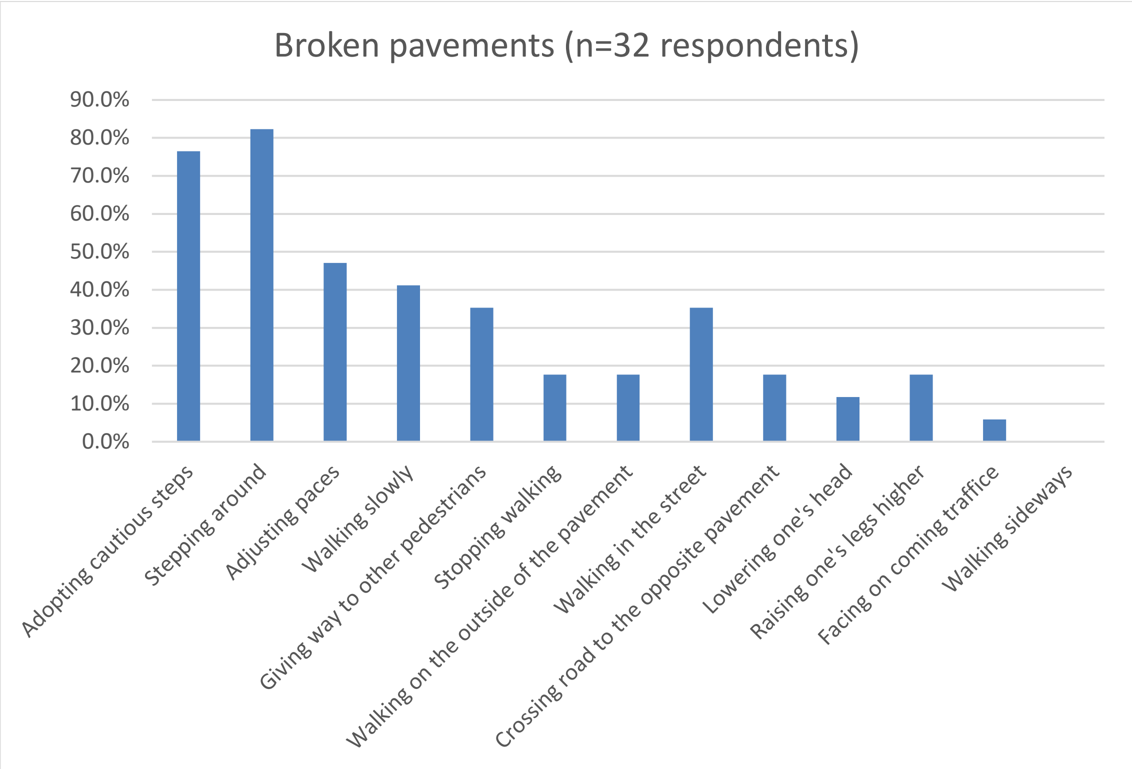
Uneven pavements (n=32 respondents)
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways



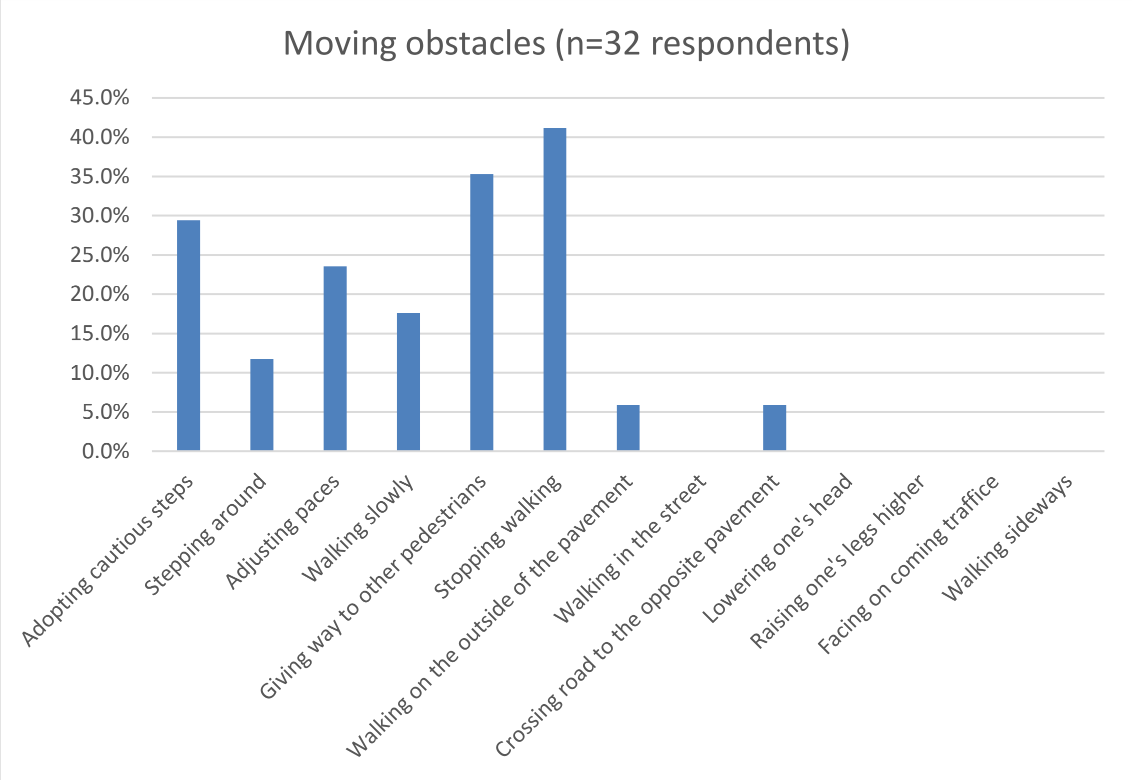
Overgrown plants (n=32 respondents)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

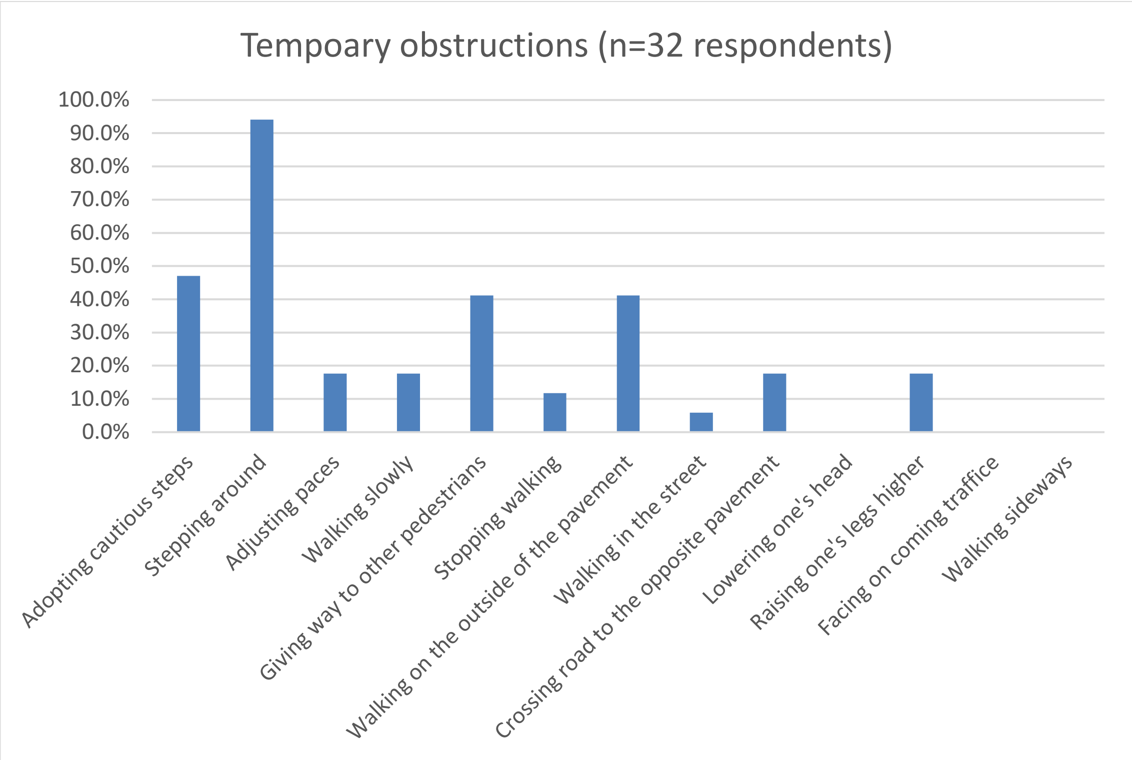


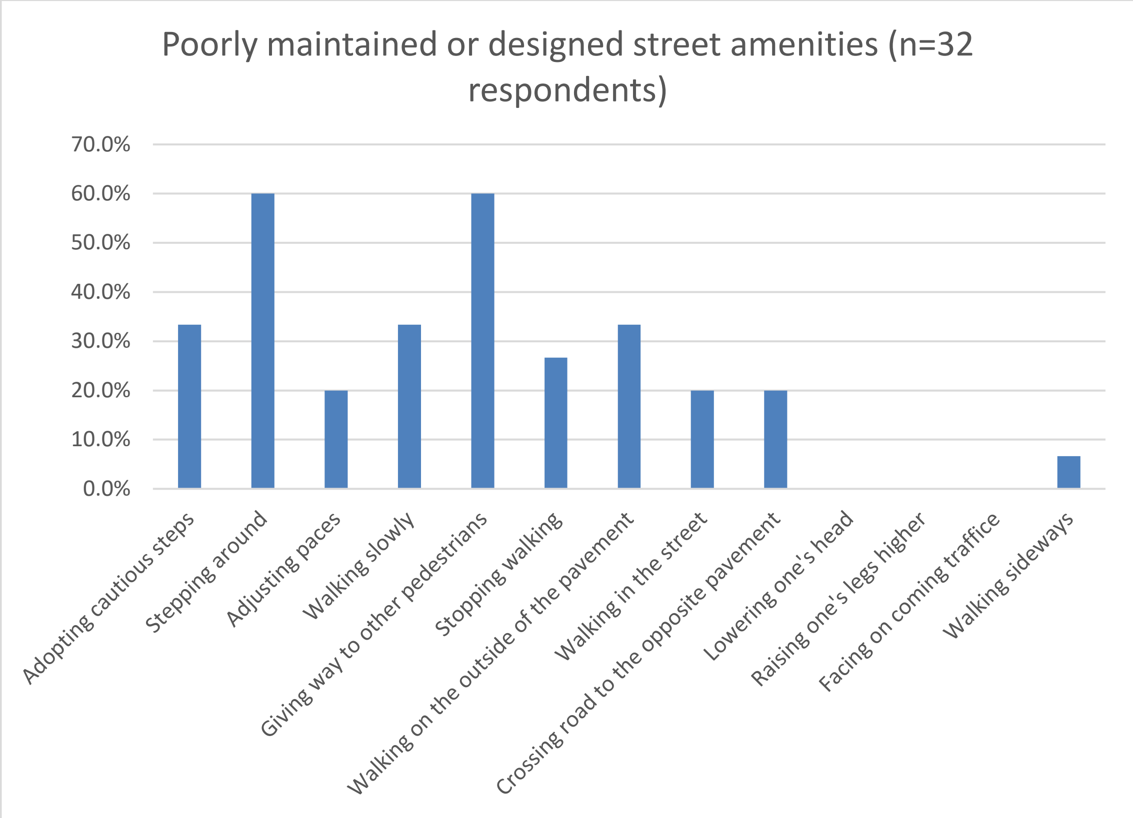
Slippery barriers (n=32 respondents)
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

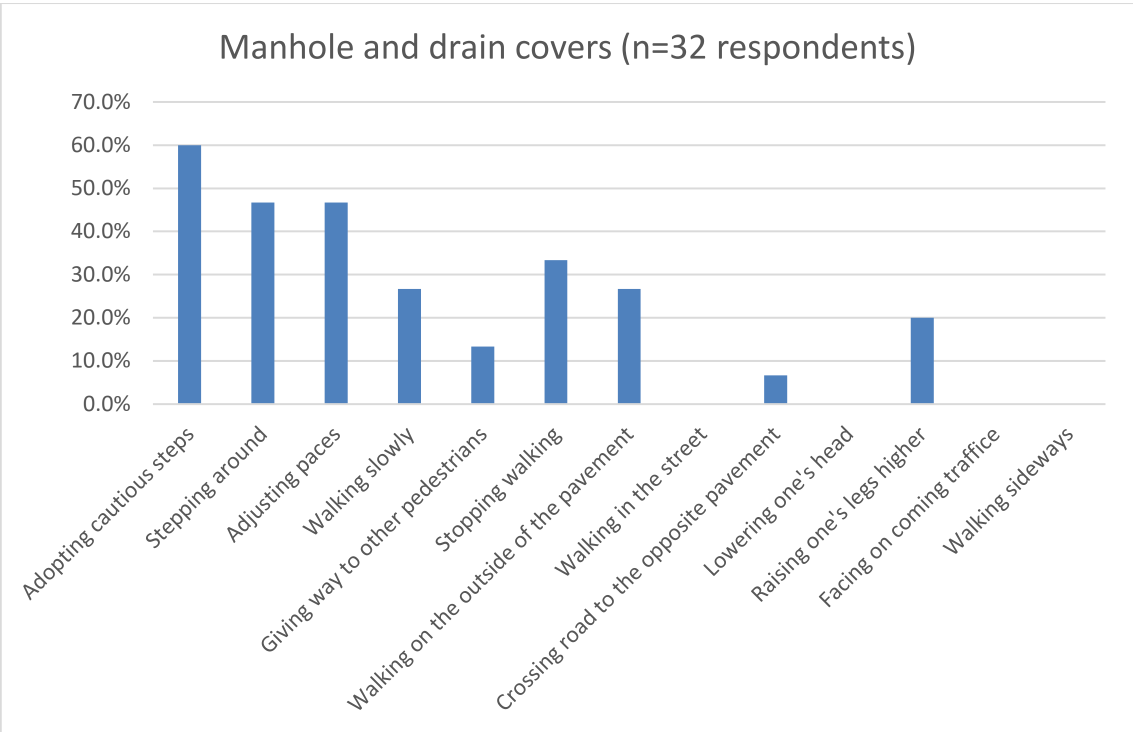


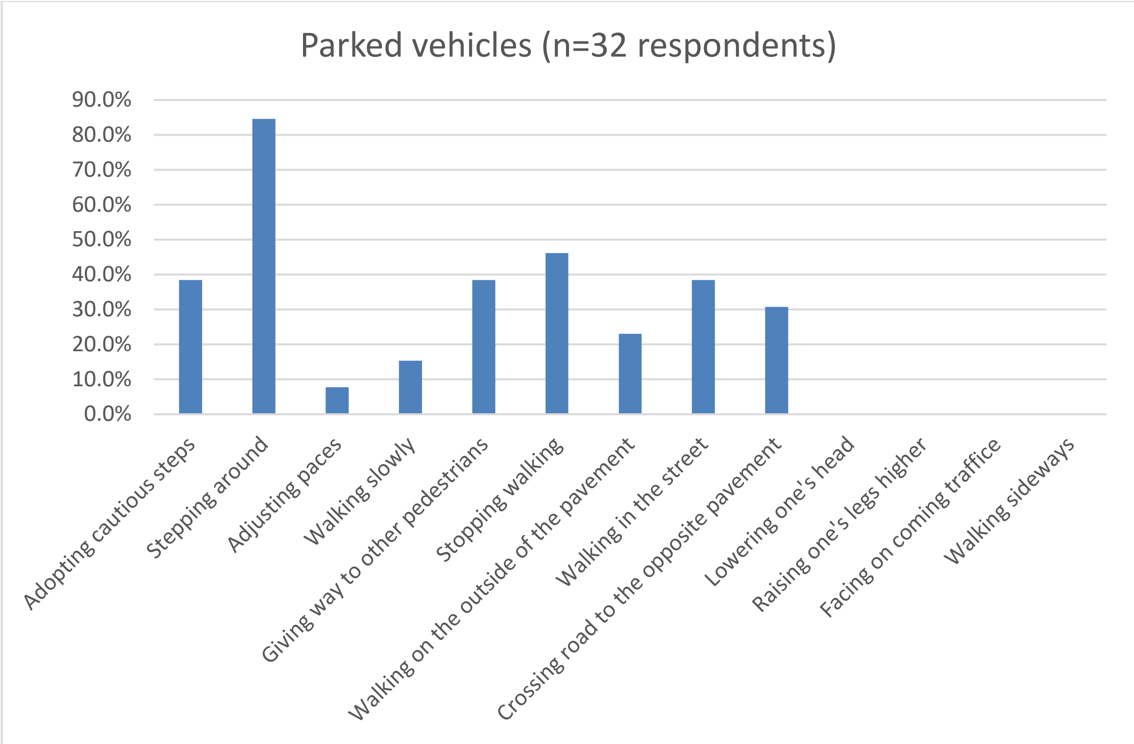
Broken pavements (n=32 respondents)
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

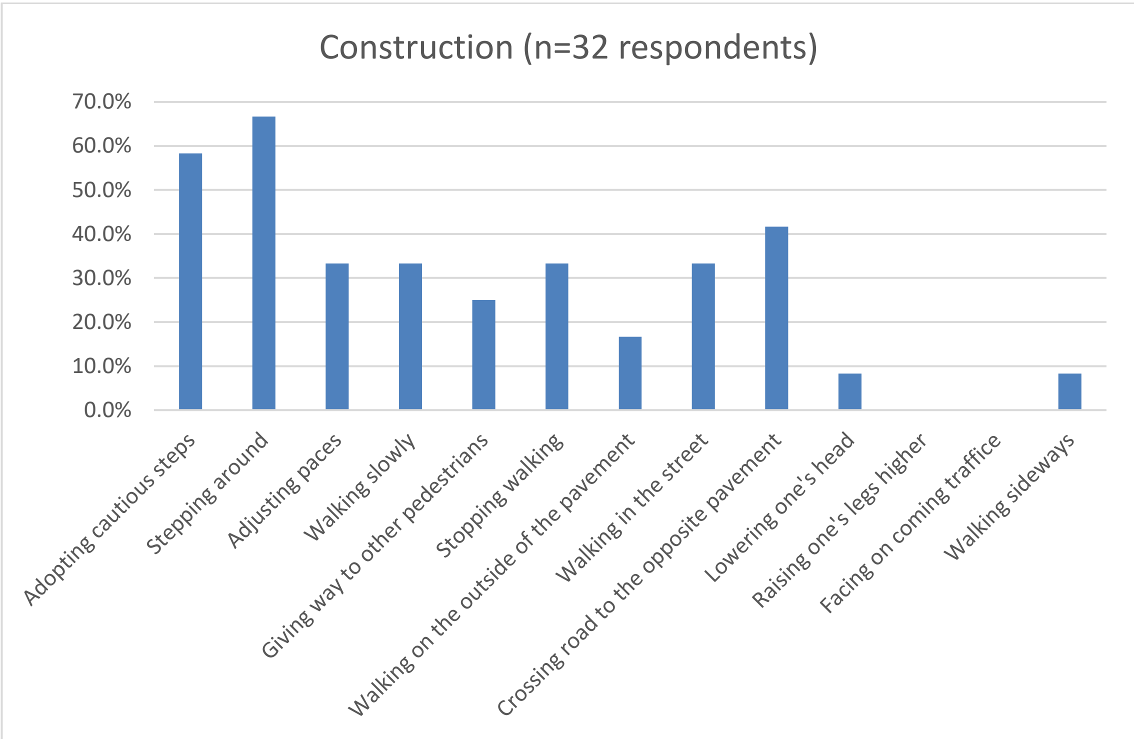

Moving obstacles (n=32 respondents)
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

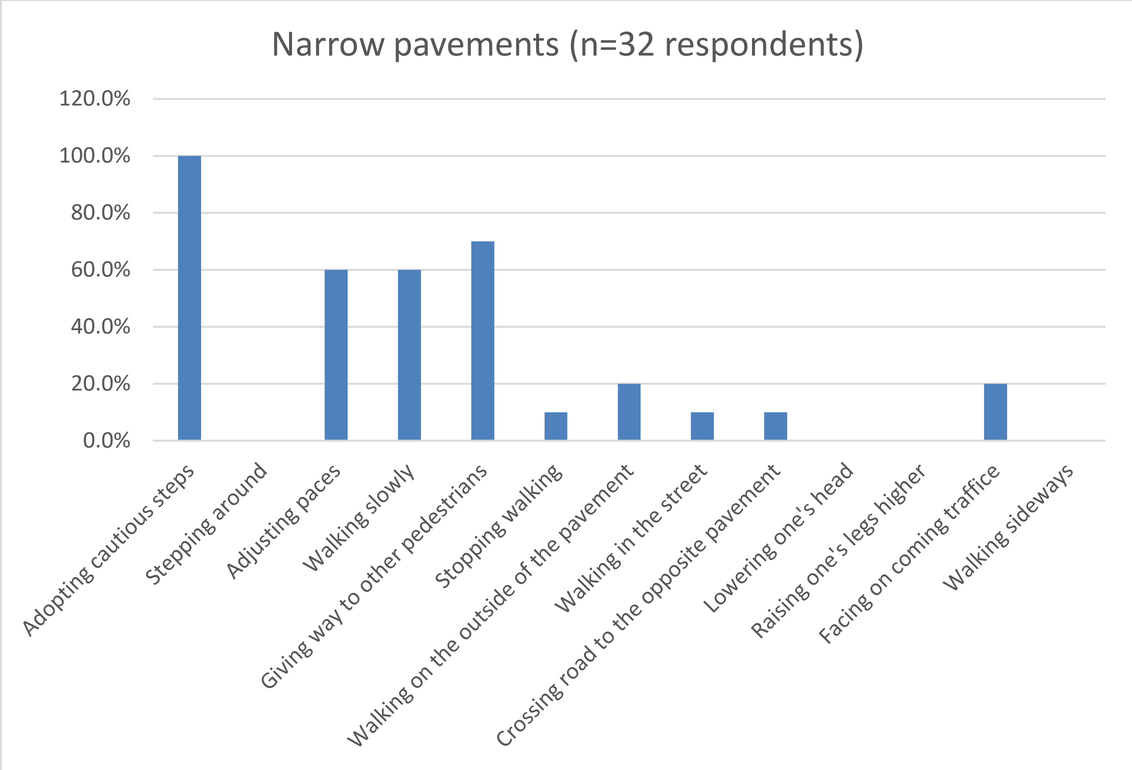

Tempoary obstructions (n=32 respondents)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

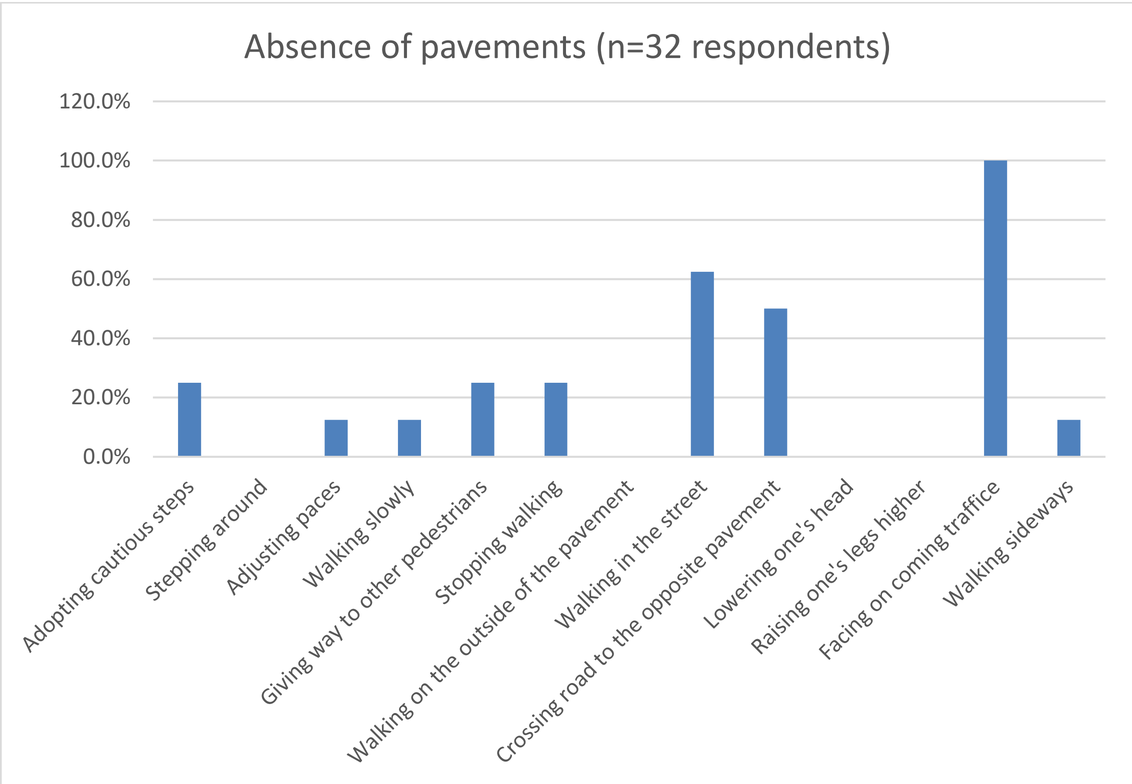

Poorly maintained or designed street amenities (n=32 respondents)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

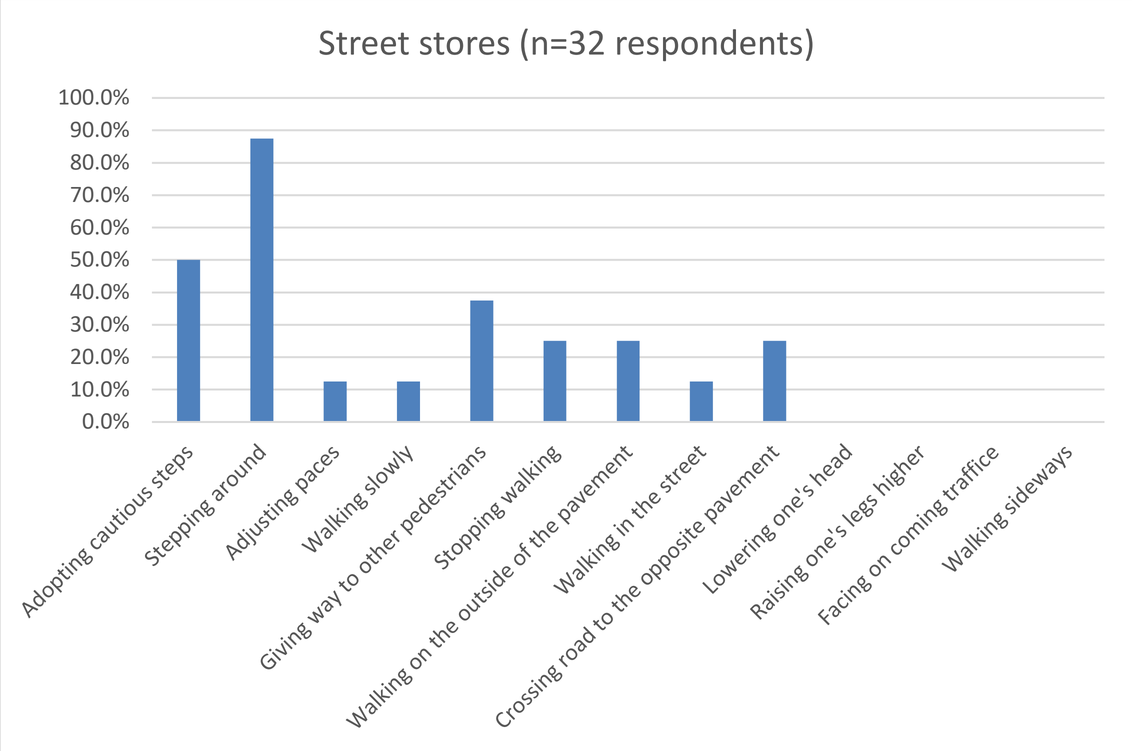

Manhole and drain covers (n=32 respondents)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

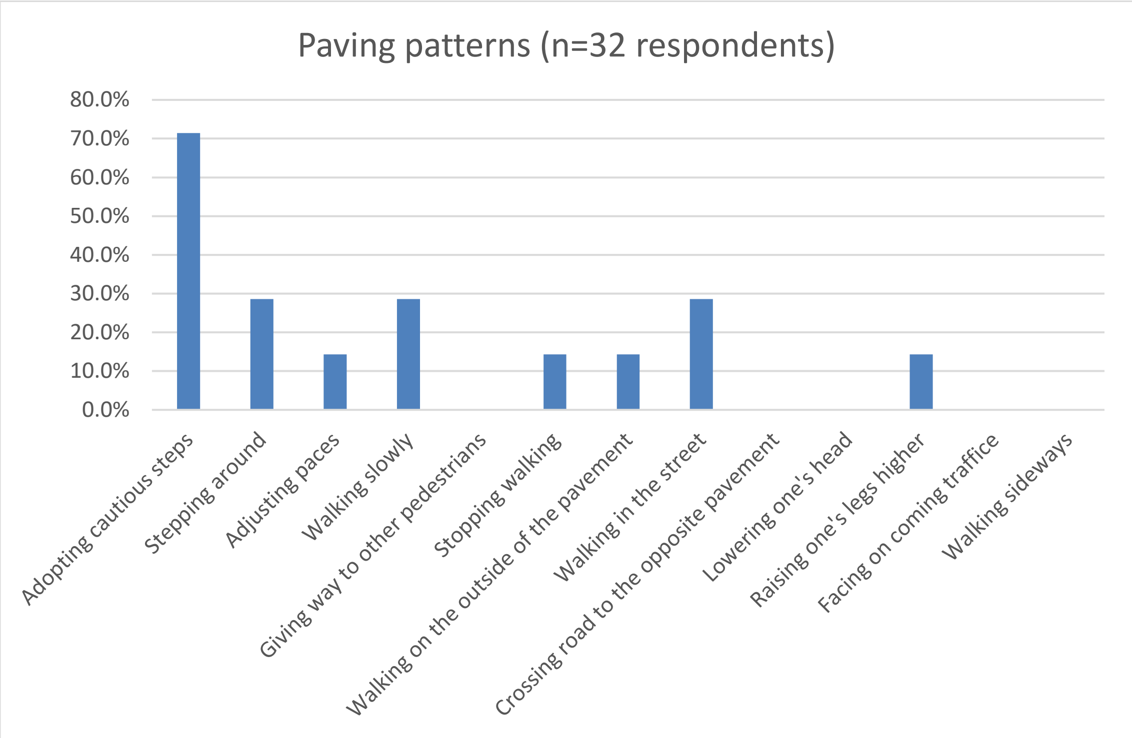

Parked vehicles (n=32 respondents)
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

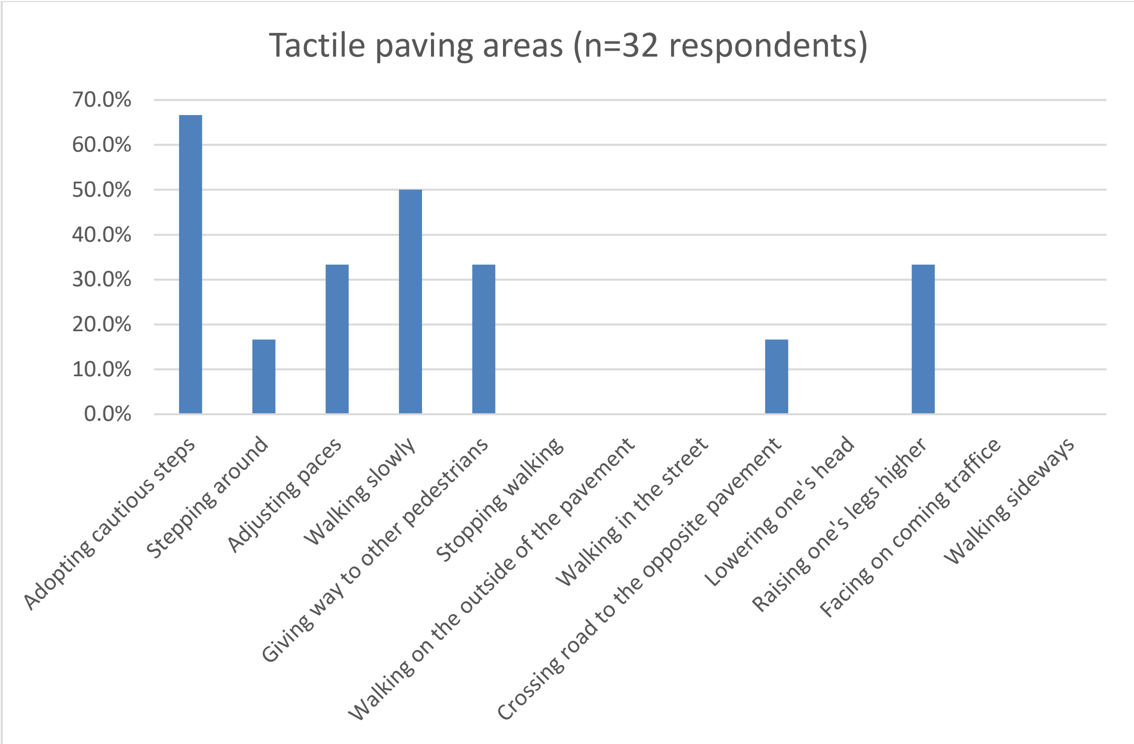

Construction (n=32 respondents)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

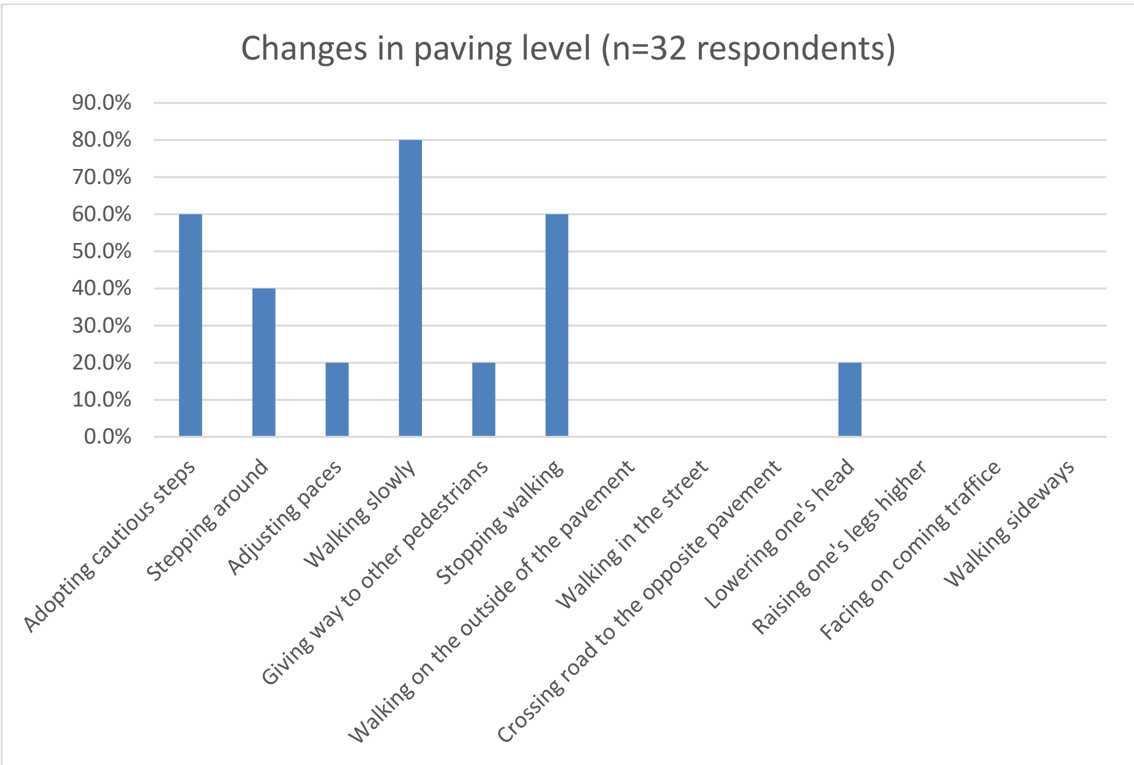

Narrow pavements (n=32 respondents)
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways


Absence of pavements (n=32 respondents)
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways


Street stores (n=32 respondents)
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways


Paving patterns (n=32 respondents)
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways


Tactile paving areas (n=32 respondents)
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways


Changes in paving level (n=32 respondents)
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Adopting cautious steps
Stepping around
Adjusting paces
Walking slowly
Giving way to other pedestrians
Stopping walking
Walking on the outside of the pavement
Walking in the street
Crossing road to the opposite pavement
Lowering one's head
Raising one's legs higher
Facing on coming traffice
Walking sideways

Appendix VI: Database of the initial toolkit

The brochure:

1

Study the relationship between pavement environment and older pedestrians

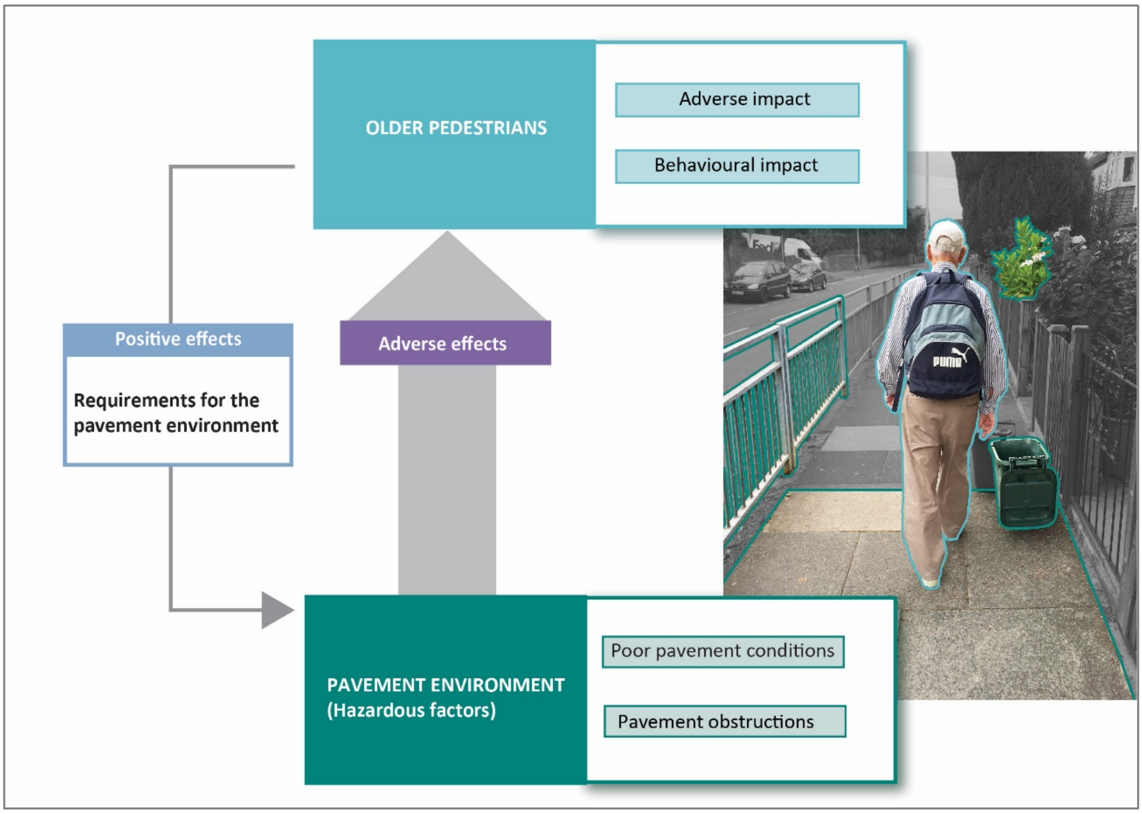
Walking is the most regular activity for older people to keep health and a popular transport form for doing daily errands. Pedestrian pavements play an important role in assisting or restricting the quality of walking. Poorly designed or maintained pavements may pose a challenge to older people's walking. An empirical study was conducted in London with 41 senior residents aged over 60 while fit to walking to identify the hazards of pavements. It also explored the behavioural changes of older pedestrians associated with the pavement hazards and gathered of the older adults' recommendations on the pavement. A mix of qualitative and quantitative methods including interviews, observations, cultural probes and questionnaires was used to collected data from the participants. Coding and statistical analysis assisted with computer aid were applied in analysing the obtained data. The study found that the hazardous pavement factors were made up of poor pavement conditions and environmental obstructions including broken, uneven and narrow pavements, and slippery obstacles, parked vehicles, plants and so on. The factors could increase the risk of falling or cause physical barriers on the participants or limit their walking and view. Accordingly, the participants adapted their walking behaviour and gait patterns due to the pavement hazards. For example, they often adopted cautious steps, walked slowly, walked around, gave way for others, adjusted paces or stopped walking on the pavement in poor conditions. On the other hand, the participants came up with suggestions to the pavement regarding minimising the problematic conditions and creating a safe and comfortable walking environment for them.

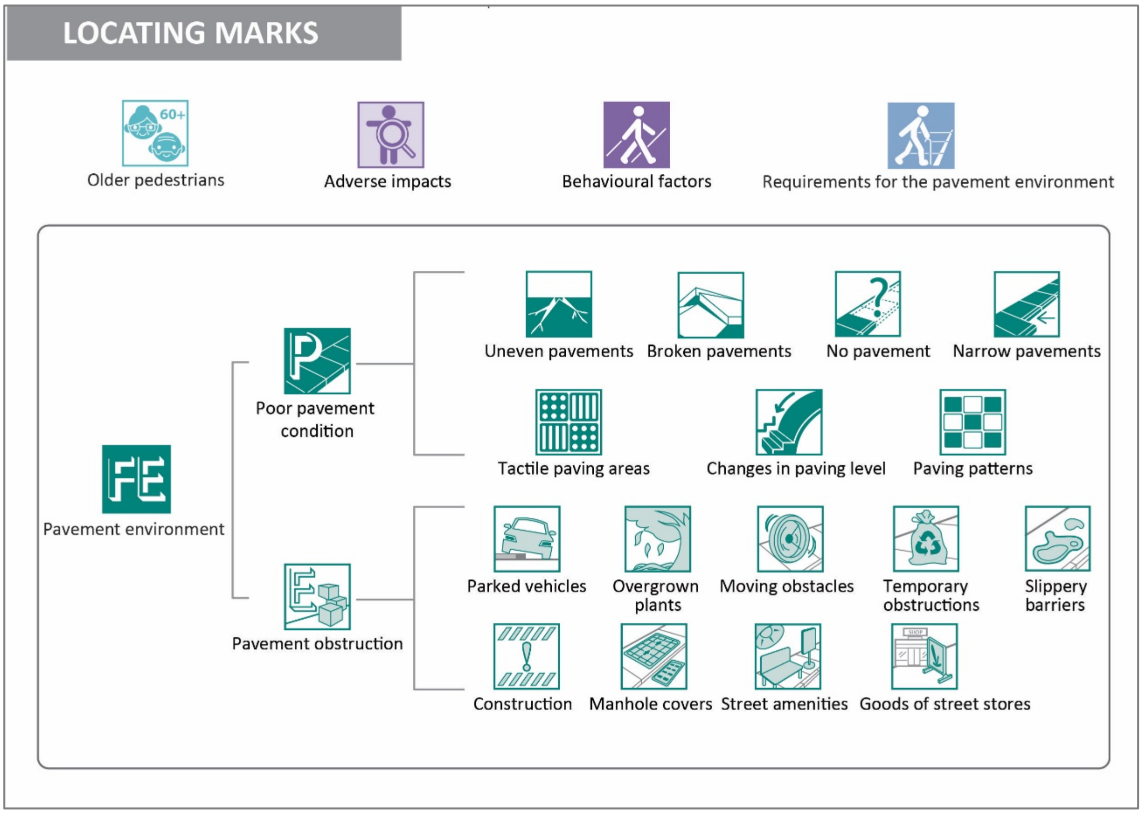
TOOLKIT:

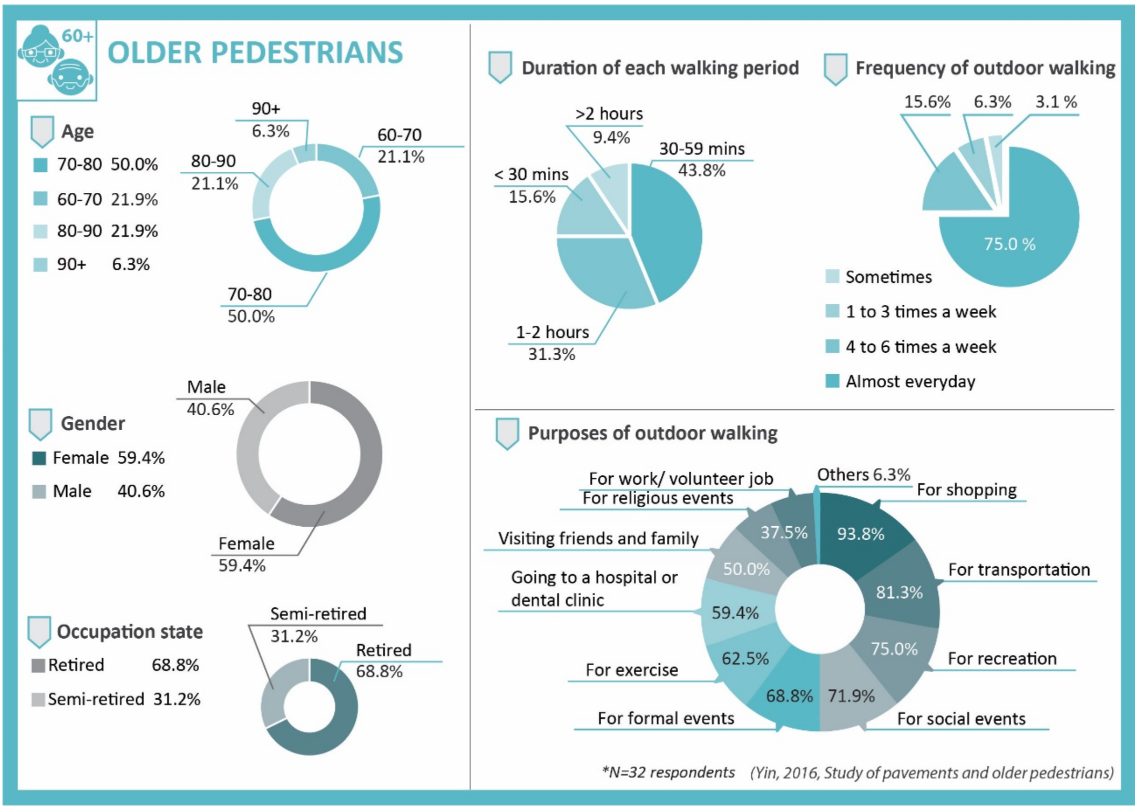
Pedestrian-friendly design was found to make pavement environment positively affect older pedestrians and ensure them a safe and comfortable walking. In order to contribute to pedestrian-friendly design concepts, a toolkit was created offering an effective and interactive way to demonstrate the relationships between the pavement environment and older pedestrians to the users who are environment designers, urban planners and other specialists and researchers to apply it into their own work and create pedestrian-friendly environments for elderly people.

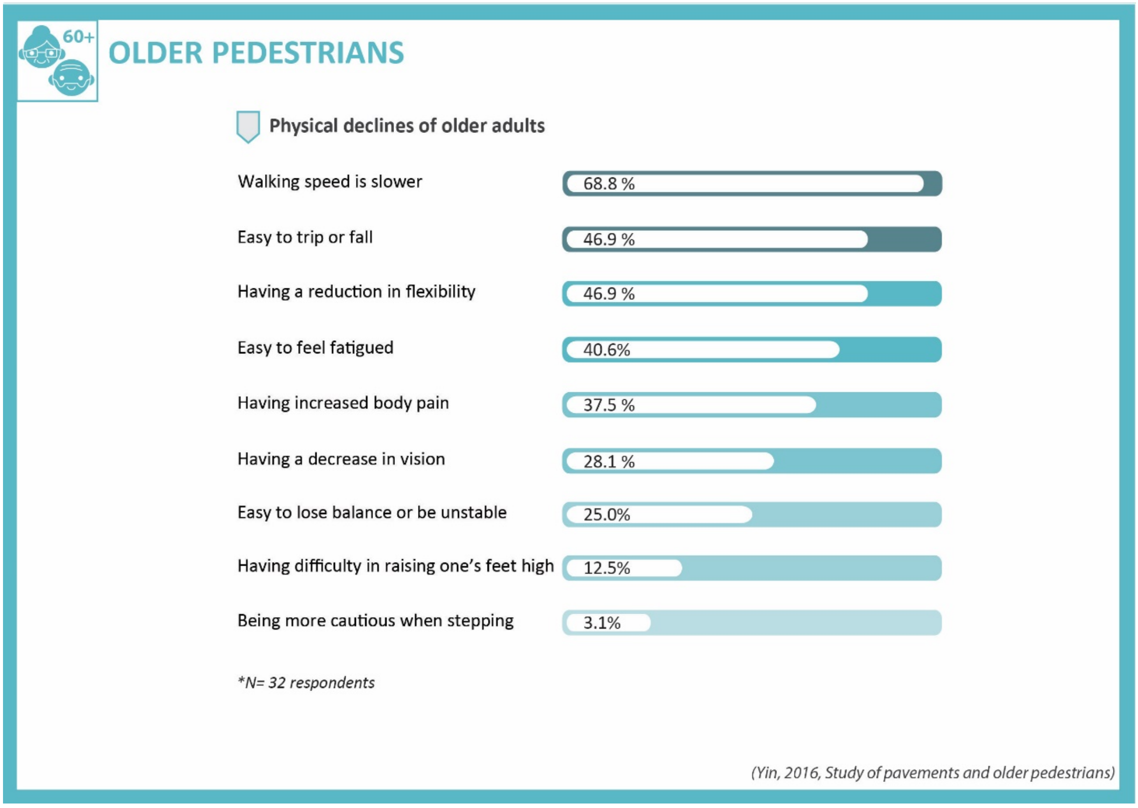
DEFINITIONS:

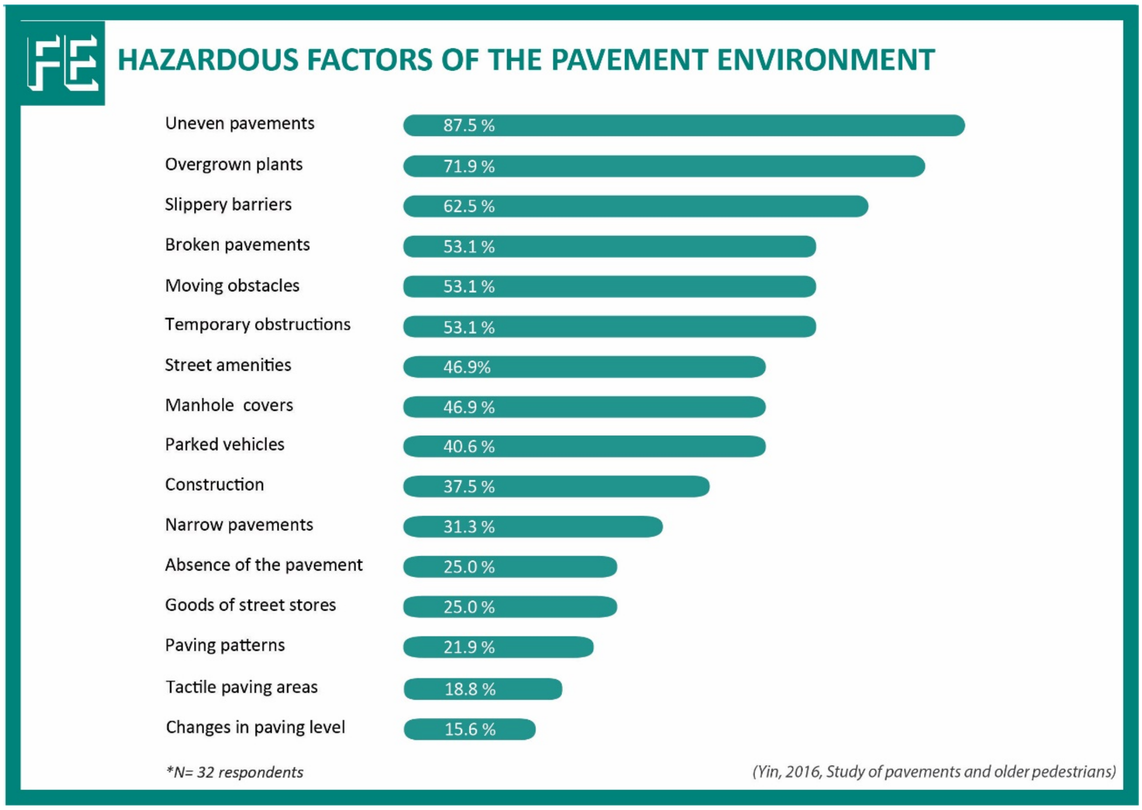
Pavement environment	Pavement environment is the walking environment on the pavement.
Poor pavement conditions	Quality of pavements and ground conditions.
Pavement obstructions	Moving or static and temporary or permanent barriers.
The impact of pavement hazards on older pedestrians	Physical or behavioural impacts on walking.
Behavioural changes in older people's walking	Walking behaviours of older pedestrians.

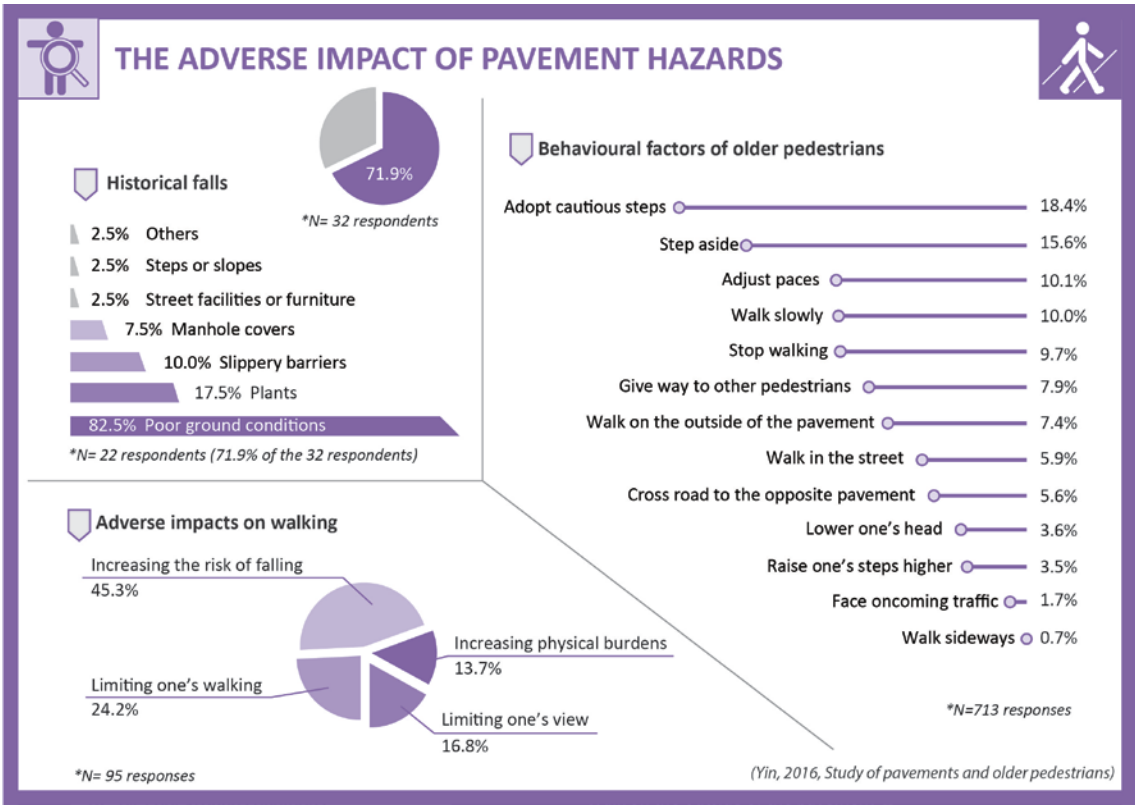

OLDER PEDESTRIANS
Adverse impact
Behavioural impact
Positive effects
Requirements for the pavement environment
Adverse effects
PAVEMENT ENVIRONMENT (Hazardous factors)
Poor pavement conditions
Pavement obstructions


LOCATING MARKS
Older pedestrians
Adverse impacts
Behavioural factors
Requirements for the pavement environment
Pavement environment
Poor pavement condition
Uneven pavements
Broken pavements
No pavement
Narrow pavements
Tactile paving areas
Changes in paving level
Paving patterns
Pavement obstruction
Parked vehicles
Overgrown plants
Moving obstacles
Temporary obstructions
Slippery barriers
Construction
Manhole covers
Street amenities
Goods of street stores

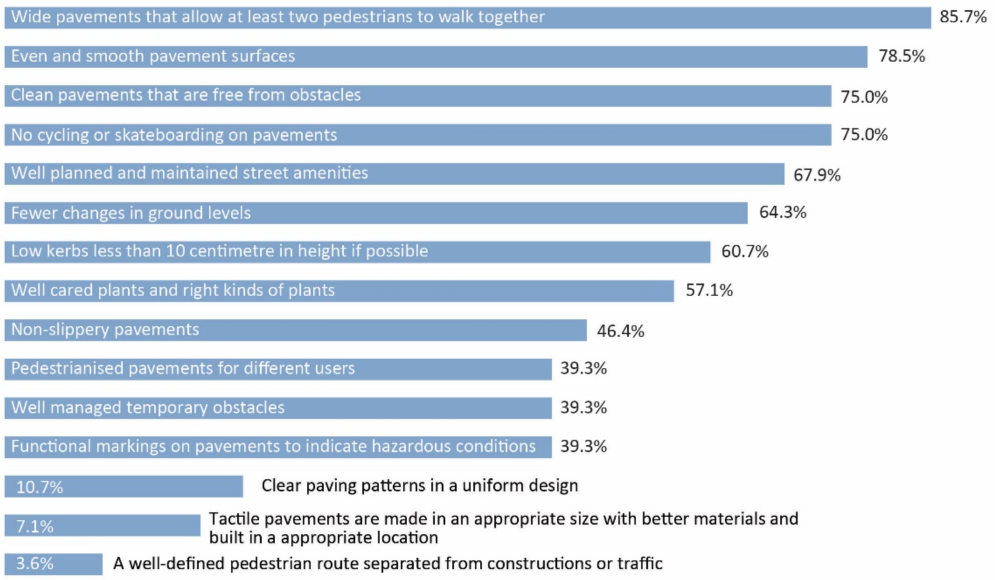

60+
OLDER PEDESTRIANS
Age
70-80 50.0%
60-70 21.9%
80-90 21.9%
90+ 6.3%
90+ 6.3%
60-70 21.1%
80-90 21.1%
70-80 50.0%
Gender
Female 59.4%
Male 40.6%
Male 40.6%
Female 59.4%
Occupation state
Retired 68.8%
Semi-retired 31.2%
Semi-retired 31.2%
Retired 68.8%
Duration of each walking period
>2 hours 9.4%
30-59 mins 43.8%
< 30 mins 15.6%
1-2 hours 31.3%
Frequency of outdoor walking
15.6%
6.3%
3.1 %
75.0 %
Sometimes
1 to 3 times a week
4 to 6 times a week
Almost everyday
Purposes of outdoor walking
For work/ volunteer job
For religious events
Others 6.3%
For shopping
Visiting friends and family
37.5%
93.8%
50.0%
Going to a hospital or dental clinic
For transportation
81.3%
59.4%
75.0%
62.5%
For exercise
For recreation
68.8%
71.9%
For formal events
For social events
*N=32 respondents
(Yin, 2016, Study of pavements and older pedestrians)


60+
OLDER PEDESTRIANS
Physical declines of older adults
Walking speed is slower 68.8 %
Easy to trip or fall 46.9 %
Having a reduction in flexibility 46.9 %
Easy to feel fatigued 40.6%
Having increased body pain 37.5 %
Having a decrease in vision 28.1 %
Easy to lose balance or be unstable 25.0%
Having difficulty in raising one's feet high 12.5%
Being more cautious when stepping 3.1%
*N= 32 respondents
(Yin, 2016, Study of pavements and older pedestrians)


HAZARDOUS FACTORS OF THE PAVEMENT ENVIRONMENT
Uneven pavements 87.5 %
Overgrown plants 71.9 %
Slippery barriers 62.5 %
Broken pavements 53.1 %
Moving obstacles 53.1 %
Temporary obstructions 53.1 %
Street amenities 46.9%
Manhole covers 46.9 %
Parked vehicles 40.6 %
Construction 37.5 %
Narrow pavements 31.3 %
Absence of the pavement 25.0 %
Goods of street stores 25.0 %
Paving patterns 21.9 %
Tactile paving areas 18.8 %
Changes in paving level 15.6 %
*N= 32 respondents
(Yin, 2016, Study of pavements and older pedestrians)

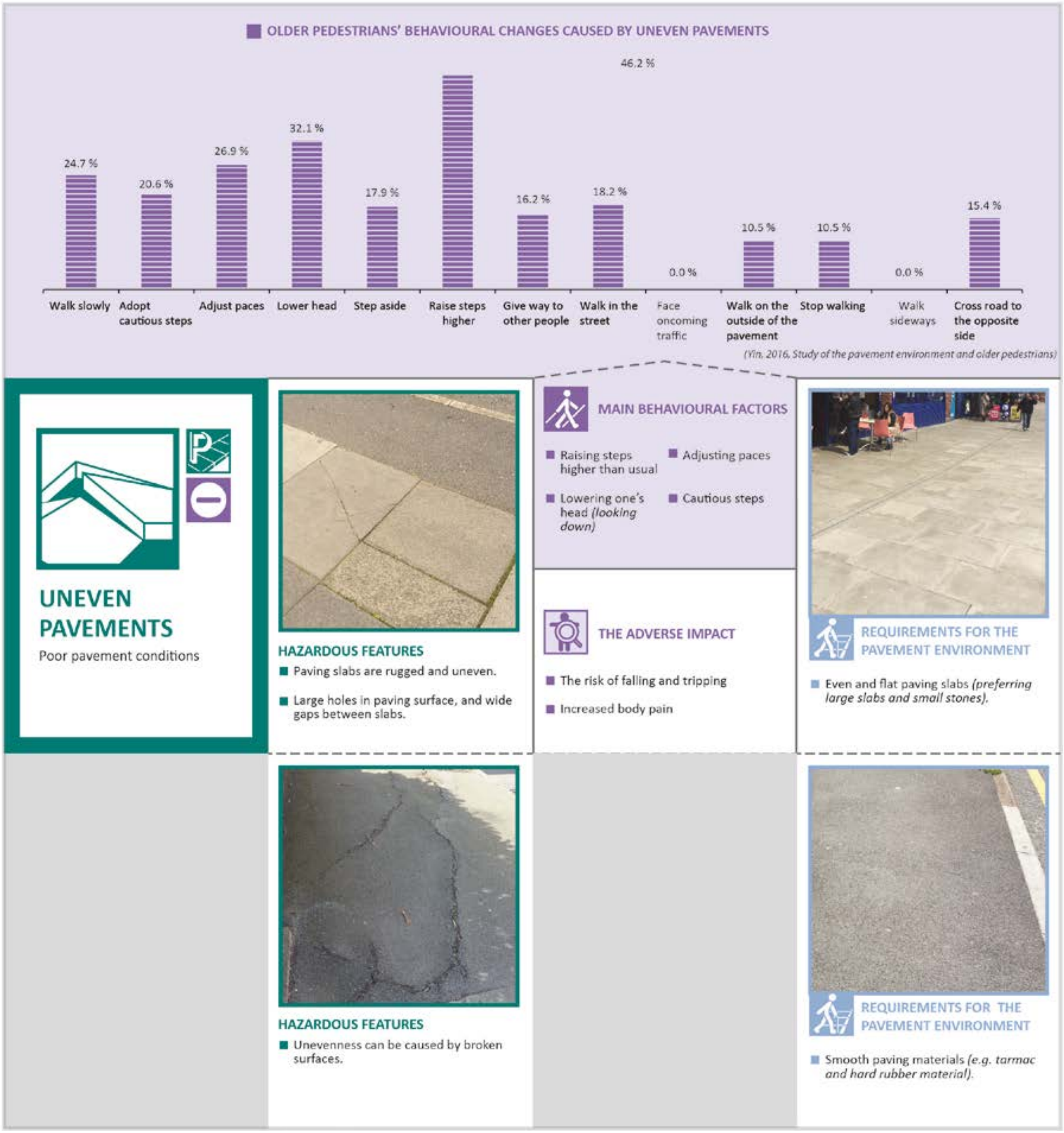

THE ADVERSE IMPACT OF PAVEMENT HAZARDS
Historical falls
71.9%
*N= 32 respondents
2.5% Others
2.5% Steps or slopes
2.5% Street facilities or furniture
7.5% Manhole covers
10.0% Slippery barriers
17.5% Plants
82.5% Poor ground conditions
*N= 22 respondents (71.9% of the 32 respondents)
Behavioural factors of older pedestrians
Adopt cautious steps 18.4%
Step aside 15.6%
Adjust paces 10.1%
Walk slowly 10.0%
Stop walking 9.7%
Give way to other pedestrians 7.9%
Walk on the outside of the pavement 7.4%
Walk in the street 5.9%
Cross road to the opposite pavement 5.6%
Lower one's head 3.6%
Raise one's steps higher 3.5%
Face oncoming traffic 1.7%
Walk sideways 0.7%
*N=713 responses
Adverse impacts on walking
Increasing the risk of falling 45.3%
Increasing physical burdens 13.7%
Limiting one's walking 24.2%
Limiting one's view 16.8%
*N= 95 responses
(Yin, 2016, Study of pavements and older pedestrians)

OLDER PEDESTRIANS'S REQUIREMENTS FOR THE PAVEMENT ENVIRONMENT

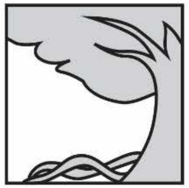


(Yin, 2016, Study of pavements and older pedestrians)

The card pack:



Appendix VII: The card pack of the participatory study toolkit



OVERGROWN PLANTS

COMPONENTS

Overgrown trees/ bushes/ grasses
Overhanging branches
Overgrown tree roots

- Overhangn tree branches.
- *Notes:*

- Overgrown bushes.
- *Notes:*

- Overgrown tree trunks and tree roots.
- *Notes:*

TEMPORARY OBSTACLES

COMPONENTS

Rubbish
Rubbish for collection
Temporary objects

- Rubbish.
- *Notes:*

- Rubbish for collection.
- *Notes:*

- Temporary objects.
- *Notes:*

UNEVEN PAVEMENTS

COMPONENTS
Uneven surfaces

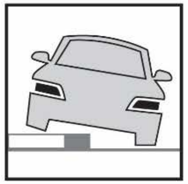
- Wide gaps exist between paved slabs.
- *Notes:*

- Paved surfaces are rugged and uneven.
- *Notes:*

- The junction between different paving materials are uneven.
- *Notes:*

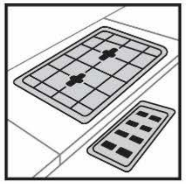
- Areas paved around drain covers are uneven for purpose to enable water to flow into the drain.
- *Notes:*

- Missing slabs contribute to the unevenness.
- *Notes:*



PARKED VEHICLES

- Vehicles are parking on pavements.
- *Notes:*



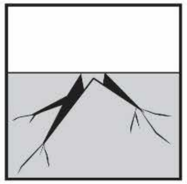
MANHOLE COVERS

COMPONENTS

Concrete covers
Metal covers
Manhole covers
Drian covers

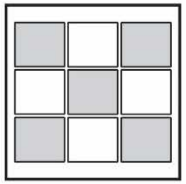
- Concrete insert covers.
- *Notes:*

- Metal manhole covers.
- *Notes:*



BROKEN PAVEMENTS

- Broken pavement surface.
- *Notes:*



CONFUSING PAVING PATTERNS

- Massive paved pattern or it is not in uniformed design.
- *Notes:*

GOODS OFSTREET STORES

COMPONENTS
Commercial objects
Furniture
Booths

- Commercial boards.
- *Notes:*

- Tables and chairs of street stores.
- *Notes:*

Ref: http://l450v.alamy.com/450v/ey3wpm/diners-sitting-at-al-fresco-tables-on-frith-street-in-london-soho-uk-ey3wpm.jpg

- Booths of street shops.
- *Notes:*

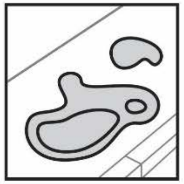
CHANGES IN PAVING LEVEL

COMPONENTS
Steps
Slopes
kerbs

- Stepped ground.
- *Notes:*

- Sloping ground.
- *Notes:*

- kerbs.
- *Notes:*



SLIPPERY BARRIERS

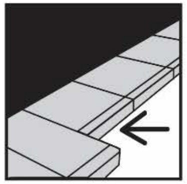
COMPONENTS
Water/ ice/ snow
Fallen leaves
Moss
Slippery pavement surfaces

- Standing water and rain water.
- *Notes:*

- Snow and ice.
- *Notes:*

- Fallen leaves.
- *Notes:*

- Moss.
- *Notes:*

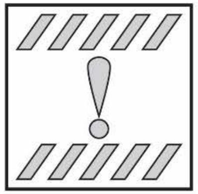


NARROW PAVEMENTS

COMPONENTS
Narrow width
Limited walking space

- The width of pavements is narrow.
- *Notes:*

- Walking space is limited by environmental characteristics on pavements.
- *Notes:*



CONSTRUCTION

COMPONENTS

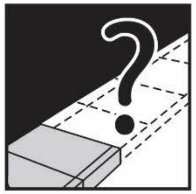
Street construction
Buildings under construction
Construction barriers

- Street construction.
- *Notes:*

- Street buildings under construction.
- *Notes:*

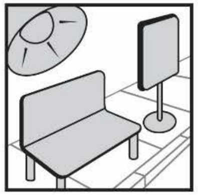
- Construction of street infrastructure.
- *Notes:*

- Barriers of construction.
- *Notes:*



ABSENCE OF THE PAVEMENT

- Roads are built without pavement.
- *Notes:*



STREET INFRASTRUCTURE AND FURNITURE

COMPONENTS

Street lights
Street signs
Benches
Bus stops
Cable boxes
Bins
Road barriers

- Dim street lights.
- *Notes:*

Ref: http://luxreview.com/upload/system/2015/07/10133020.jpg

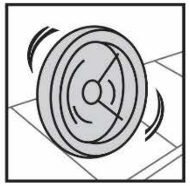
- Street signs are made in an inappropriate size.
- *Notes:*

- Public benches are planned in an inappropriate location.
- *Notes:*

- Cable boxes are designed in an inappropriate size and built in an inappropriate location.
- *Notes:*

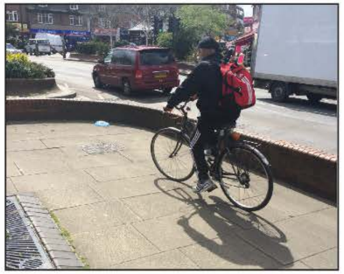
- Bus stops are designed in an inappropriate size and built in an inappropriate location.
- *Notes:*

- Public bins are designed in an inappropriate size.
- *Notes:*



MOVING OBJECTS

COMPONENTS
Bicycles
Mobile scooters
Skateboards



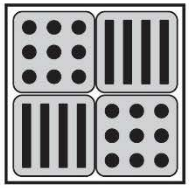
- Adult cyclists ilegally cycling on pavements.
- *Notes:*

- Mobility scooters on pavements.
- *Notes:*

Ref: http://www.swindonadvertiser.co.uk/resources/images/3674575/

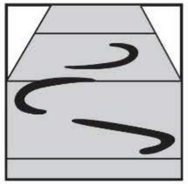
- Skateboarders skating on pavements.
- *Notes:*

Ref: https://static.pexels.com/photos/2011/man-person-street-sidewalk.jpg



TACTILE PAVING AREAS

- Tactile paving areas are built into uneven surfaces on reasonable purposes while they would be hazards to elderly pedestrians.
- *Notes:*



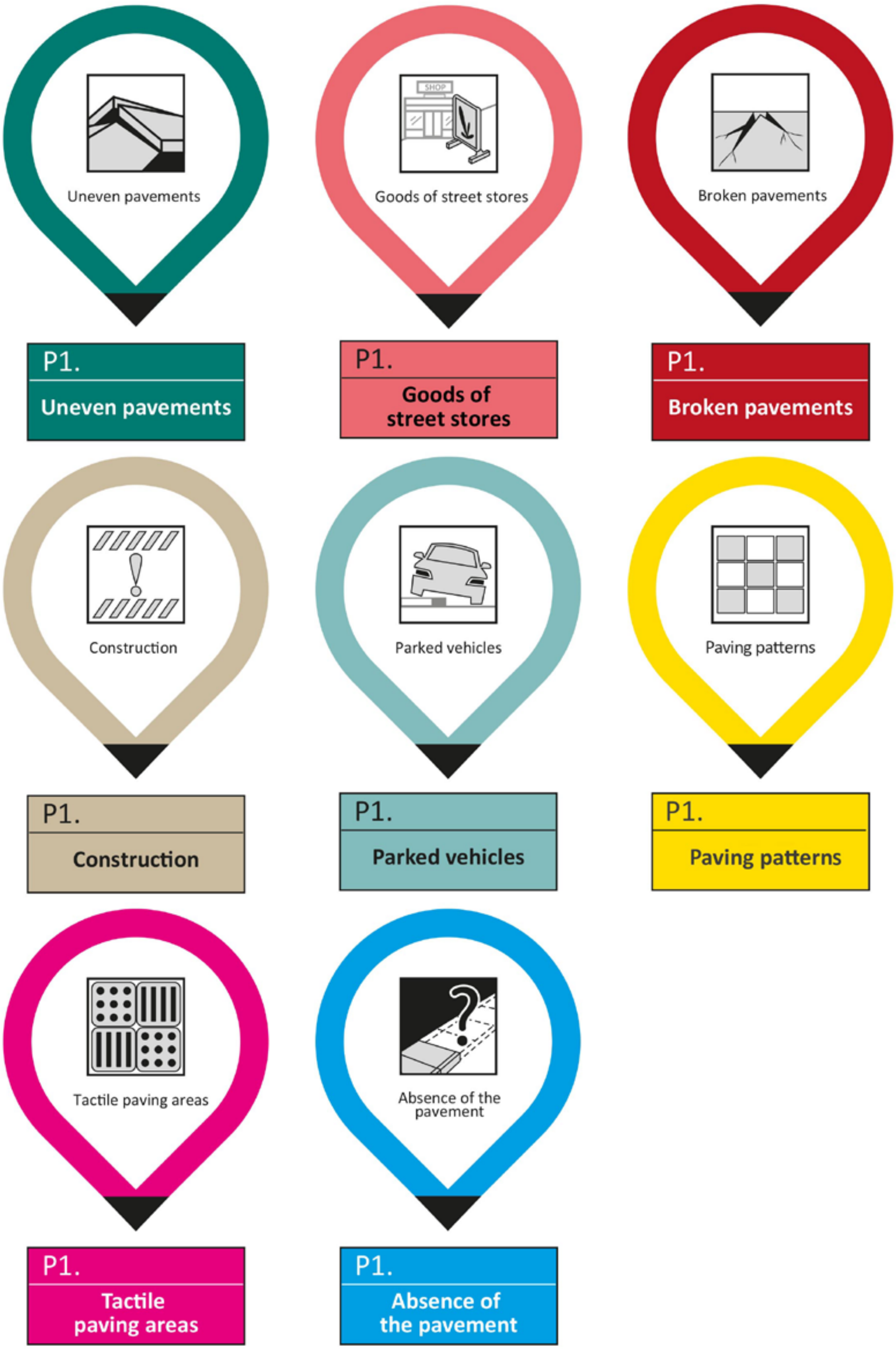
SLIPPERY PAVEMENTS

COMPONENTS
Paving materials

- Built paving materials, such as York Stone, would become slippery when they get old and less maintained.
- *Notes:*

Appendix VIII: The developed version of the participatory study toolkit

Landmarks and locating pins:



P1.
Narrow pavements

P1.
Slippery barriers

P1.
Street infrastructure and furniture

P1.
Overgrown plants

P1.
Manhole covers

P1.
Moving objects

P1.
Changes in paving levels

P1.
Temporary obstacles

The survey book:

Survey book
Participant: P1

INSTRUCTION GUIDE FOR PARTICIPANTS

A Co-experience tool

This tool aims to investigate the relationship between pavement environments and elderly pedestrians. It is used by researchers to conduct a co-experience study with a group of maximum 6 participants every time. The study includes two exercises:

Exercise 1 Assessment

- o Identifying negative features of pavement environments.
- o Investigating the impacts of the pavement environments on elderly pedestrians.
- o Exploring the behavioural changes of elderly pedestrians that adopted to deal with the pavement features.

Exercise 2 Improvement

- o Improving the pavement environments with recommendations.

Components of the tool

For participants:

- **User-pack**: it has a **Survey book,** a **Code badge** and **Pins of negative pavement features.** The Survey book includes 'Instruction guide for participants', table 'UP1', table 'UP2' and answer sheet 'UP3'. Participants shall tick their options in table UP1 and 2 while writing down the order numbers of recommendations in the answer column of UP3.
  The Code **badge** displaying a code of P1, P2, P3, P4, P5 or P6 that means different participants. The group of 17 **Pins** show 17 different pavement features with particular colours and phrases.

1

Instruction

1. The researcher gives a brief introduction to the study and tool.

2. Conduct a co-experience study:

- **Exercise 1:**

a. Identify the negative features those exist in a target pavement environment by placing the relevant **Pins** on the **Map**.

b. Discuss the reasons of your identifications. On the basis, the researcher will highlight the significant pavement features by placing their corresponding **Landmarks** on the Map.

c. Turn to **page 3**. According to the **row heading** of table **UP1**, discuss the negative impacts that are caused by the identified pavement features on you when walking.

d. Complete table **UP1** by ticking the effects that caused by those pavement features.

e. Turn to **page 4**. According to the **row heading** of table **UP2**, discuss your behavioural adaptations to the identified pavement features.

f. Complete **table UP2** by ticking the behavioural adoptions that related to the identified pavement features.

- **Exercise 2:**

a. Turn to **page 5**. According to the **Checklist of recommendations**, discuss how to solve the identified pavement issues with the recom-mendations.

b. Transcribe the **order number** of your suggested recommendations from the checklist to the **answer column** of **UP3**.

2

UP1 The impact of pavement hazards

Effects on participants / Identified pavement factors	Increasing the risk of falling A	Increasing physical burdens B	Limiting walking C	Limiting view D
Uneven pavements				
Broken pavements				
Slippery pavements				
Narrow pavements				
Absence of the pavement				
Paving patterns				
Tactile paving areas				
Changes in paving levels				
Slippery barriers				
Moving objects				
Overgrown plants				
Street infrastructue and funiture				
Temporary obstacles				
Manhole covers				
Parked vehicles				
Construction				
Goods of street stores				

3

UP2 Behavioural changes in walking

Identified pavement factors \ Behavioural changes	1 Adopting cautious steps	2 Stepping aside	3 Adjusting paces	4 Walking slowly	5 Giving way to other pedestrians	6 Stopping walking	7 Walking on the outside of pavements	8 Walking in the street	9 Crossing road to the opposite side	10 Raising one's steps higher	11 Lowering one's head	12 Facing oncoming traffic	13 Walking sideways
Uneven pavements													
Broken pavements													
Slippery pavements													
Narrow pavements													
Absence of the pavement													
Paving patterns													
Tactile paving areas													
Changes in paving level													
Slippery barriers													
Moving objects													
Overgrown plants													
Street infrastructure and furniture													
Temporary obstacles													
Manhole covers													
Parked vehicles													
Construction													
Goods of street stores													

4

UP3 Recommendations for the pavement environment

Identified pavement features	Your selections (multiple choices):
Uneven pavements	
Broken pavements	
Slippery pavements	
Narrow pavements	
Absence of the pavement	
Paving patterns	
Tactile paving areas	
Changes in paving level	
Slippery barriers	
Moving objects	
Overgrown plants	
Street infrastructure and furniture	
Temporary obstacles	
Manhole covers	
Parked vehicles	
Construction	
Goods of street stores	

	Checklist of recommendations
a	Even and smooth pavement surfaces
b	Wide pavements
c	Non-slippery pavements
d	Well-maintained pavements
e	Pavements that are free from obstacles
f	Well constructed and organised street infrastructure and furniture
g	A well-defined pedestrian route separate from construction
h	Fewer steps and slopes or pavement are built on a small gradient
i	Well maintained appropriate plants and right kinds of plants
j	Low kerbs
k	Pedestrianised pavements
l	Well managed temporary objects on pavements
m	Functional markings
n	Clear paving patterns

5

The recording card:

RECORDING CARD

The road/ street of the pavement environment ____________________

P 1	**P 2**	**P 3**
Name: ____________	Name: ____________	Name: ____________
Gender: ***F*** ☐ ***M*** ☐	Gender: ***F*** ☐ ***M*** ☐	Gender: ***F*** ☐ ***M*** ☐
Age: ____________	Age: ____________	Age: ____________
P 4	**P 5**	**P 6**
Name: ____________	Name: ____________	Name: ____________
Gender: ***F*** ☐ ***M*** ☐	Gender: ***F*** ☐ ***M*** ☐	Gender: ***F*** ☐ ***M*** ☐
Age: ____________	Age: ____________	Age: ____________

INSTRUCTION GUIDE FOR RESEARCHERS

A Co-experience tool

This tool aims to investigate the relationship between pavement environments and elderly pedestrians. It is used by researchers to conduct a co-experience study with a group of maximum 6 participants every time. The study includes two exercises:

Exercise 1 Assessment

- Identifying negative features of pavement environments.
- Investigating the impacts of the pavement environments on elderly pedestrians.
- Exploring the behavioural changes of elderly pedestrians that adopted to deal with the pavement features.

Exercise 2 Improvement

- Improving the pavement environments with recommendations.

Pre-requisite of study:

- Participants must age over 60 and be able to walk.
- Local residents: ideally, participants should be familiar with the location being discussed on the map.

Materials to be prepared by the researcher

- A street map of a target location in an appropriate scale.
- Optional materials such as slides, videos and pictures to show pavement environments in this location; and a notebook and additional recording facilities (Dictaphone, video camera, etc.).

Components of the tool

For participants:

- **User-pack**: it has a **Survey book,** a **Code badge** and **Pins of negative pavement features.** The Survey book includes 'Instruction guide for participants', table 'UP1', table 'UP2' and answer sheet 'UP3'. Participants shall tick their options in table UP1 and 2 while writing down the order numbers of recommendations in the answer column of UP3.
  The Code **badge** displaying a code of P1, P2, P3, P4, P5 or P6 that means different participants. The group of 17 **Pins** show 17 different pavement features with particular colours and phrases.

For the researcher:

- **Recording card**: it is used to record the collected data during and after the co-experience study. It includes **Instruction Guide for Researchers**, table **UP0**, **UP1** and **UP2** and an answer sheet **UP3**. The researchers need to tick the options in table UP0, UP1 and UP2 while write down the order numbers of recommendations in the answer column of UP3.

- **Landmarks - Negative features of pavement environments**: they display the same 17 different negative pavement feature as those shown on the Pins.

Instruction of use

In each round, the researcher is only allowed to use 1 **Map** of a pavement environment and 1 **Recording card** with up to 6 group members plus an equal number of **User-packs**. Exercise 1 and 2 can either be conducted together or separately.

1	Place all materials in the study room.

2	Hand out a **User-pack** to each participant and make them read the **Instruction Guide** carefully. Collect the personal information (*name, gender and age*) of participants on the cover page of the **Recording card**.

4	Give a brief introduction to the study and tool:

- **Aim and objectives of using the tool.**
- **Main components of the tool.**

5	Conduct a co-experience study with the participants:

- **Exercise 1**:

a. Make participants identify the negative pavement features those exist in a target pavement environment by placing the relevant **Pins** on **Map**.

b. Then turn to **page 3** of your **Recording card** and tick the identified negative pavement features in table **UP0**. Make participants discuss the reasons of their choices. According to their further discussion, use **Landmarks** to highlight the significant pavement features. Then demonstrate the significant pavement features in table **UP0**.

c. Turn to **page 4** and **5** of your **Recording card** and let participants turn to **page 3** of the **Survey book**. According to the **row heading** of table **UP1**, make participants discuss the negative impacts of the identified negative pavement features on them.

d. Make participants complete the table **UP1** by ticking the effects that caused by the identified negative pavement features.

e. Turn to **page 6, 7,8** and **9** of your **Recording card** and let participants turn to **page 4** of the **Survey book.** According to the **row heading** of table **UP2**, make them discuss their behavioural adaptations to the identified negative pavement features.

f. Make participants complete the table **UP2** of the **Survey book** by ticking their behavioural adoptions that related to the identified pavement features.

- **Exercise 2**:

a. Turn to **page 10** and **11** of your **Recording card** and let participants turn to **page 5** of the **Survey book**. According to the **Checklist of recommendations**, lead them to discuss how to solve the identified pavement features with the recommendations.

b. Make participants transcribe the **order number** of their suggested recommendations from the **checklist** to the **answer column** of **UP3**.

6	After the study, compile the data of all Survey books in your Recording card.

a. In the **Recording card**, tick the options in table **UP1** and **2** and write down the order numbers of selected recommendations in the answer column of **UP3**.

UP0 Hazardous factors of the pavement environment

Pavement conditions	P1	P2	P3	P4	P5	P6	Highlight significant pavement features
Uneven pavements							
Broken pavements							
Slippery pavements							
Narrow pavements							
Absence of the pavement							
Paving patterns							
Tactile paving areas							
Changes in paving level							

Environmental factors	P1	P2	P3	P4	P5	P6	Highlight significant pavement features
Slippery barriers							
Moving objects							
Overgrown plants							
Street infrastructue and funiture							
Temporary obstacles							
Manhole covers							
Parked vehicles							
Construction							
Goods of treet stores							

P: participant

3

UP1 The impact of pavement hazard

Pavement conditions	Increasing the risk of falling A	Increasing physical burdens B	Limiting walking C	Limiting view D	Selections of participants
Uneven pavements					P1
					P2
					P3
					P4
					P5
					P6
Broken pavements					P1
					P2
					P3
					P4
					P5
					P6
Slippery pavements					P1
					P2
					P3
					P4
					P5
					P6
Narrow pavements					P1
					P2
					P3
					P4
					P5
					P6
Absence of the pavement					P1
					P2
					P3
					P4
					P5
					P6
Paving patterns					P1
					P2
					P3
					P4
					P5
					P6
Tactile paving areas					P1
					P2
					P3
					P4
					P5
					P6
Changes in paving level					P1
					P2
					P3
					P4
					P5
					P6

P: participant

4

UP1 The impact ofpavement hazards

Environmental factors	Selections of participants	Increasing the risk of falling A	Increasing physical burdens B	Limiting walking C	Limiting view D
Slippery barriers	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Moving objects	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Overgrown plants	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Street infrastructure and furniture	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Temporary obstacles	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Manhole covers	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Parked vehicles	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Construction	P1				
	P2				
	P3				
	P4				
	P5				
	P6				
Goods of street stores	P1				
	P2				
	P3				
	P4				
	P5				
	P6				

P: participant

5

UP2 Behavioural changes of participants

Pavement conditions	1 Adopting cautious steps	2 Stepping aside	3 Adjusting paces	4 Walking slowly	5 Giving way to other pedestrians	6 Stopping walking	7 Walking on the outside of pavements	8 Walking in the street	9 Crossing road to the opposite side	10 Raising one's steps higher	11 Lowering one's head	12 Facing oncoming traffic	13 Walking sideways	
Uneven pavements														P1
														P2
														P3
														P4
														P5
														P6
Broken pavements														P1
														P2
														P3
														P4
														P5
														P6
Slippery pavements														P1
														P2
														P3
														P4
														P5
														P6
Narrow pavements														P1
														P2
														P3
														P4
														P5
														P6
Absence of the pavement														P1
														P2
														P3
														P4
														P5
														P6
Paving patterns														P1
														P2
														P3
														P4
														P5
														P6
Tactile paving areas														P1
														P2
														P3
														P4
														P5
														P6
Changes in paving level														P1
														P2
														P3
														P4
														P5
														P6

Selections of participants

P: participant

6 7

UP2 Behavioural changes of participants

Environmental factors	Adopting cautious steps 1	Stepping aside 2	Adjusting paces 3	Walking slowly 4	Giving way to other pedestrians 5	Stopping walking 6	Walking on the outside of pavements 7	Walking on the road 8	Crossing road to the opposite side 9	Raising one's steps higher 10	Lowering one's head 11	Facing oncoming traffic 12	Walking sideways 13	Selections of participants
Slippery barriers														P1
														P2
														P3
														P4
														P5
														P6
Moving objects														P1
														P2
														P3
														P4
														P5
														P6
Overgrown plants														P1
														P2
														P3
														P4
														P5
														P6
Street infrastructue and funiture														P1
														P2
														P3
														P4
														P5
														P6
Temporary obstacles														P1
														P2
														P3
														P4
														P5
														P6
Manhole covers														P1
														P2
														P3
														P4
														P5
														P6
Parked vehicles														P1
														P2
														P3
														P4
														P5
														P6
Construction														P1
														P2
														P3
														P4
														P5
														P6
Goods of street stores														P1
														P2
														P3
														P4
														P5
														P6

P: participant

8

9

Pavement conditions	P 1	P 2	P 3	P 4	P 5	P 6
Uneven pavements						
Broken pavements						
Slippery pavements						
Narrow pavements						
Absence of the pavement						
Paving patterns						
Tactile paving areas						
Changes in paving level						

Environmental factors	P 1	P 2	P 3	P 4	P 5	P 6
Slippery barriers						
Moving objects						
Overgrown plants						
Street infrastructure and furniture						
Temporary obstacles						
Manhole covers						
Parked vehicles						
Construction						
Goods of street stores						

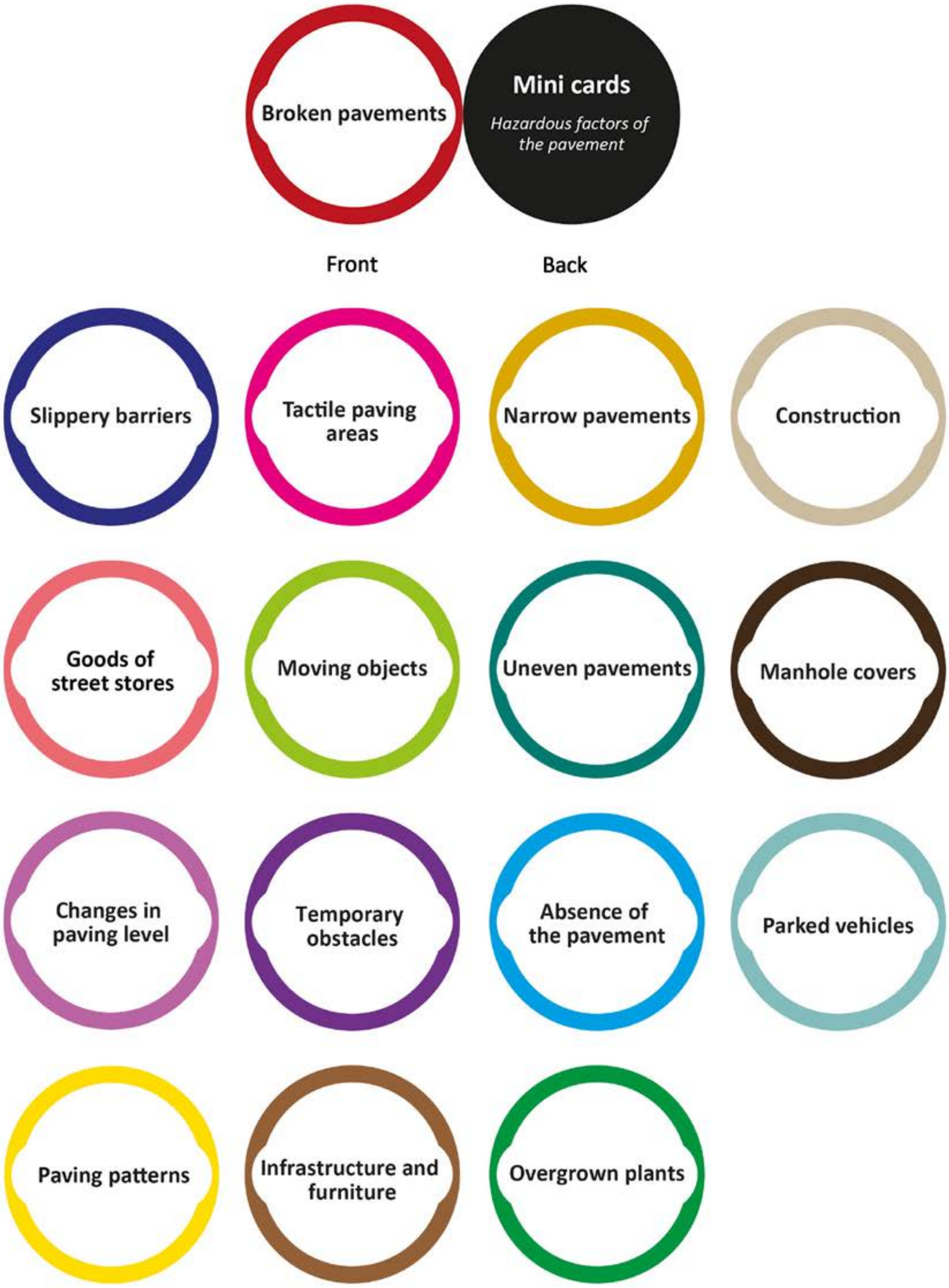
P: participant

Checklist of recommendations

a	Even and smooth pavement surfaces
b	Wide pavements
c	Non-slippery pavements
d	Well-maintained pavements
e	Pavements that are free from obstacles
f	Well constructed and organised street infrastructure and furniture
g	A well-defined pedestrian route separate from construction
h	Fewer steps and slopes or pavement are built on a small gradient
i	Well maintained appropriate plants and right kinds of plants
j	Low kerbs
k	Pedestrianised pavements
l	Well managed temporary objects on pavements
m	Functional markings
n	Clear paving patterns

Appendix IX: The revised participatory study toolkit

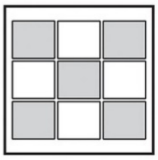
Card-pack_ mini cards:



Card-pack_ pavement cards:

Broken pavements

- Pavements are damaged.



Paving patterns

- Confusing pavement patterns caused by poor maintenance.

Moving objects

Bicycles
Mobile scooters
Skateboards

- Adult cyclists.

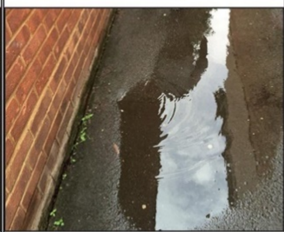
- Mobility scooters.

- Skateboarders.

Slippery barriers

Paved materials
Liquid barriers
Icy barriers
Fallen leaves

- Built materials, such as York stones, become gradually slippery when they are worn down and less maintained.



- Standing water and rain water.

- Snow and ice.

- Other vegetation, such as moss.

- Fallen leaves.

Changes in paving level

Steps
Slopes
Kerbs

- Pavements are built in a stepped form.

- Sloping pavements.

- Kerbs are also a hazard of the pavement environment.

Uneven pavements

- Wide gap exists between slabs and makes pavements uneven.

- Paved surfaces are often bumpy and become uneven.

- Joint areas between different paving materials lead to the unevenness.

- Areas around drain covers are regarded as uneven surfaces as they are built on a different level to the pavement.

- Missing slabs also contribute to the unevenness.

Narrow pavements

Narrow building size

Pavements are narrowed down by obstructions

- Pavements are narrow because of the building size.

- The pavements are narrow due to some environmental obstacles such as bus stops and street stores.

Street amenities

Street lights
Street signs
Benches
Cable boxes
Bins
Bus stops

- Dim street lighting.

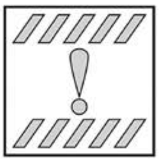
- Street signs designed in an inappropriate size.

- Public benches are built in an inappropriate location.

- Poorly planned bus stops.

- Poorly designed or planned public bins.

- Poorly designed or planned street infrastructure such as a super small cable on the cross area of pavements.



Construction

Street constructions
Building constructions
Construction barriers

- Street construction blocks the pavement.

- Street buildings under construction hinder a clear walking path on pavements.

- Construction of street infrastructure occupies pavements.

- Construction barriers are left on pavements.

Parked vehicles

- Vehicles park on pavements.

Goods of street stores

Commercial objects
Furniture
Booths

- Commercial objects of street stores.

- Tables and chairs of cafés.

- Booths of street shops.

Overgrown plants

Poorly maintained bushes
Untrimmed branches
Tree trunks
Tree roots

- Untrimmed branches.

- Poorly maintained bushes.

- Protruding tree trunks and roots.

Tactile paving areas

- Tactile paving areas make up unevenness
- Tactile pavements are slippery when they get wet.

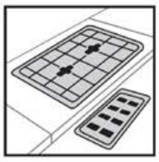
Temporary obstacles

Rubbish
Rubbish for collection
Temporary objects

- Rubbish.

- Garbage for collection.

- Personal belongings.



Manhole covers

Manhole covers *Concrete covers*
Drain covers *Metal covers*

- Concrete insert covers are uneven as their edge tilt up.

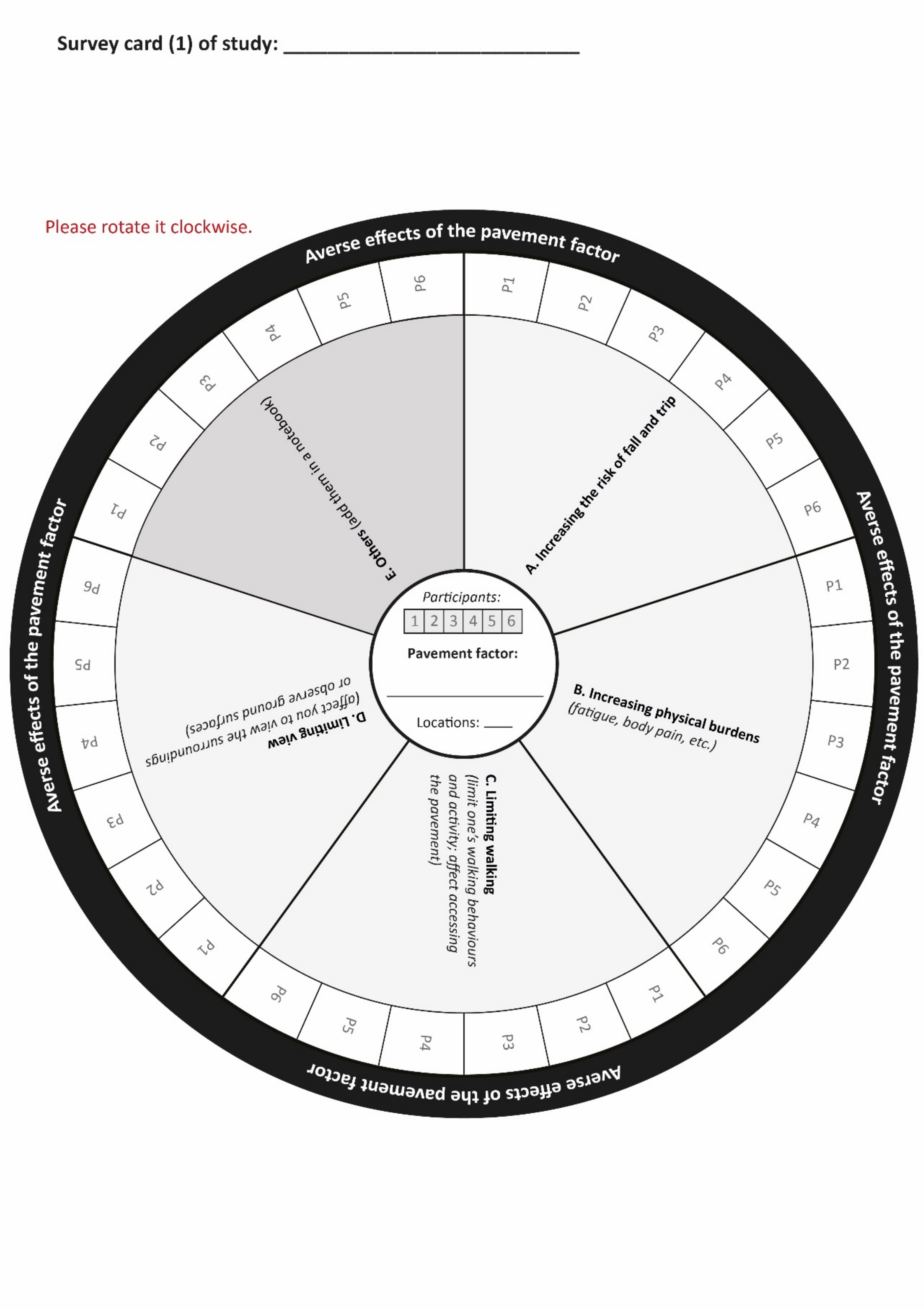
- Drain covers become a slippery barrier when water flowing over them.

- Metal manhole covers contribute to slipperiness when they get wet.

Absence of the pavement

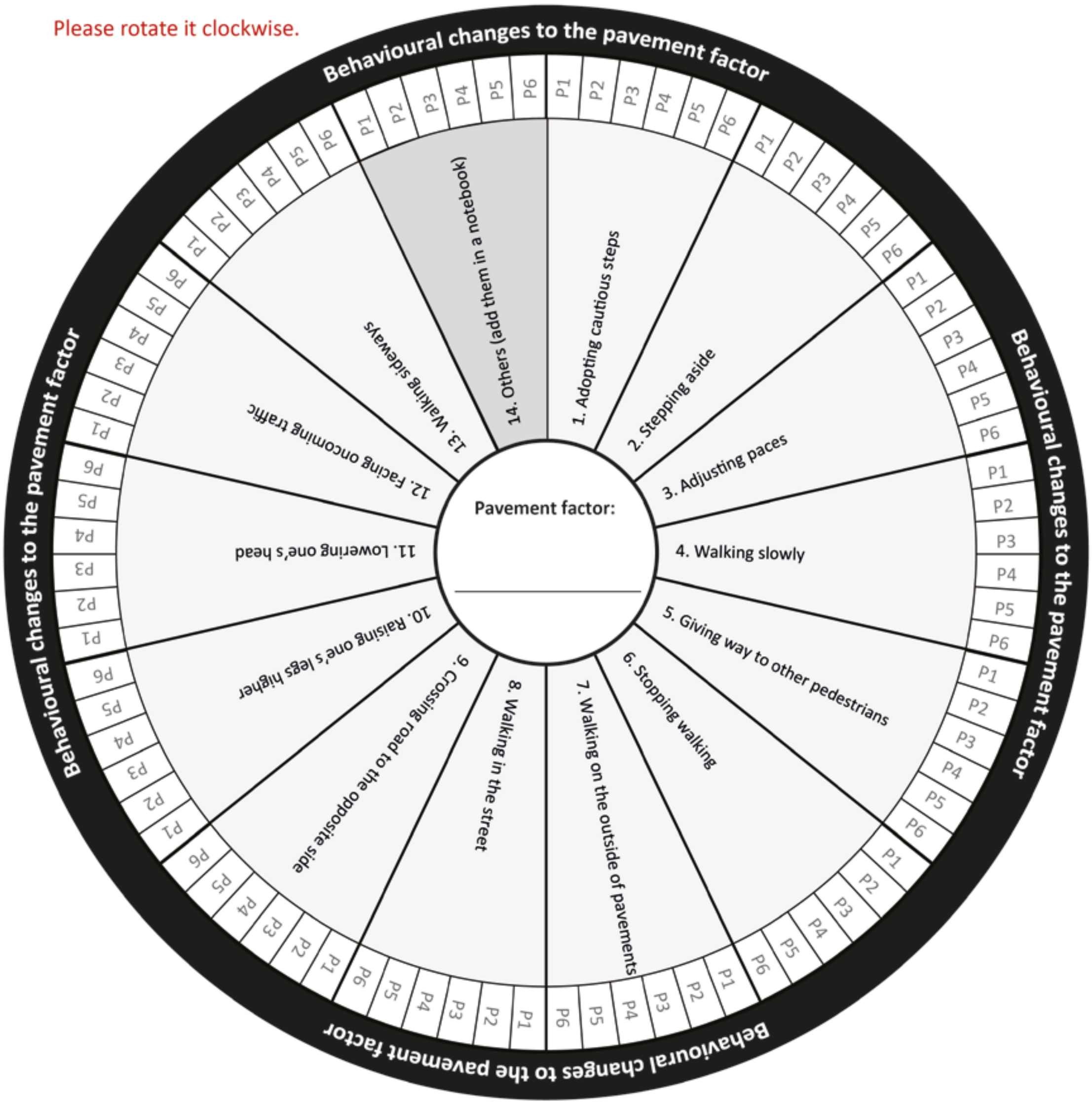
- There is no pavement on the road.

Survey card (1) front:



Survey card (1) back:

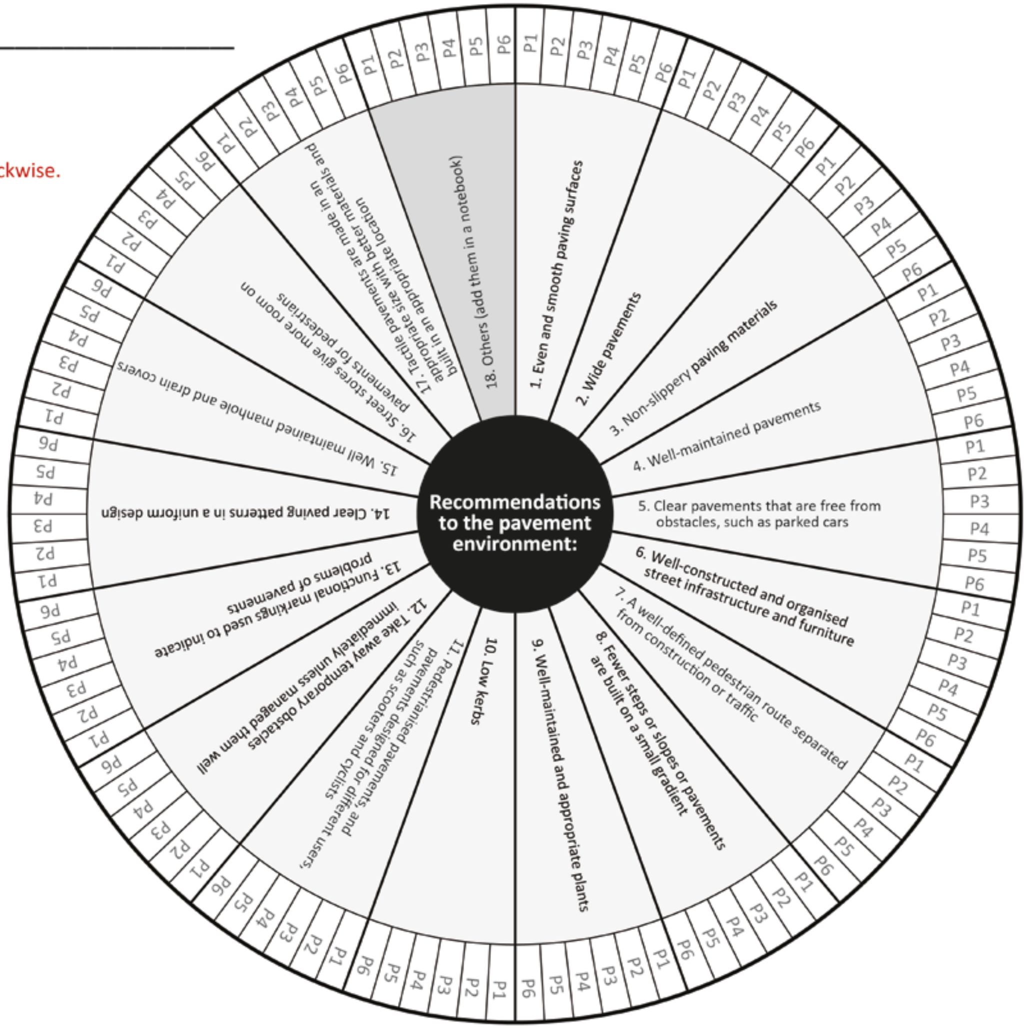
Survey card (1) of study: ___________________________



Survey card (2):

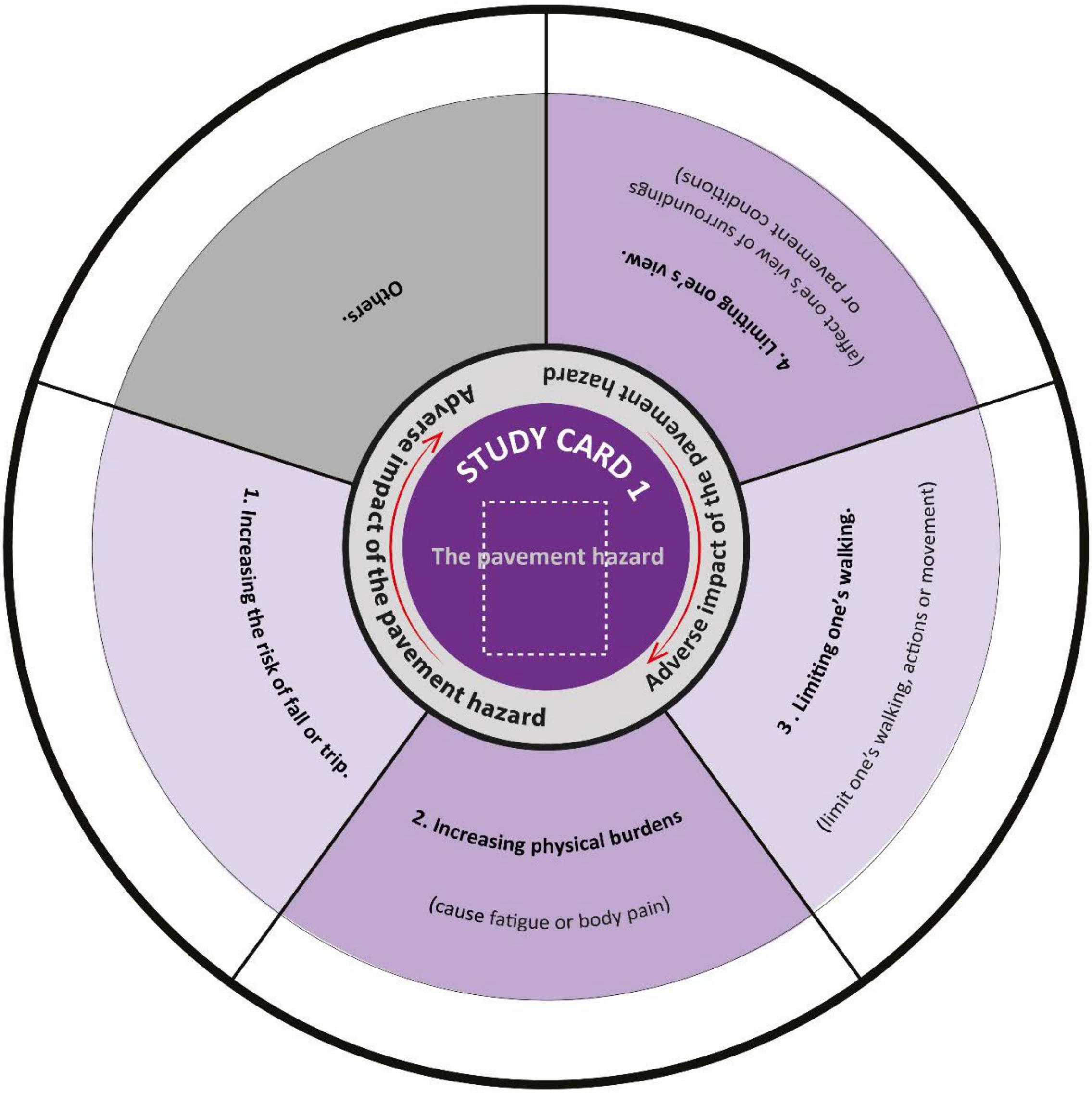
Survey card (2) of study: ___________________________

Please rotate it clockwise.

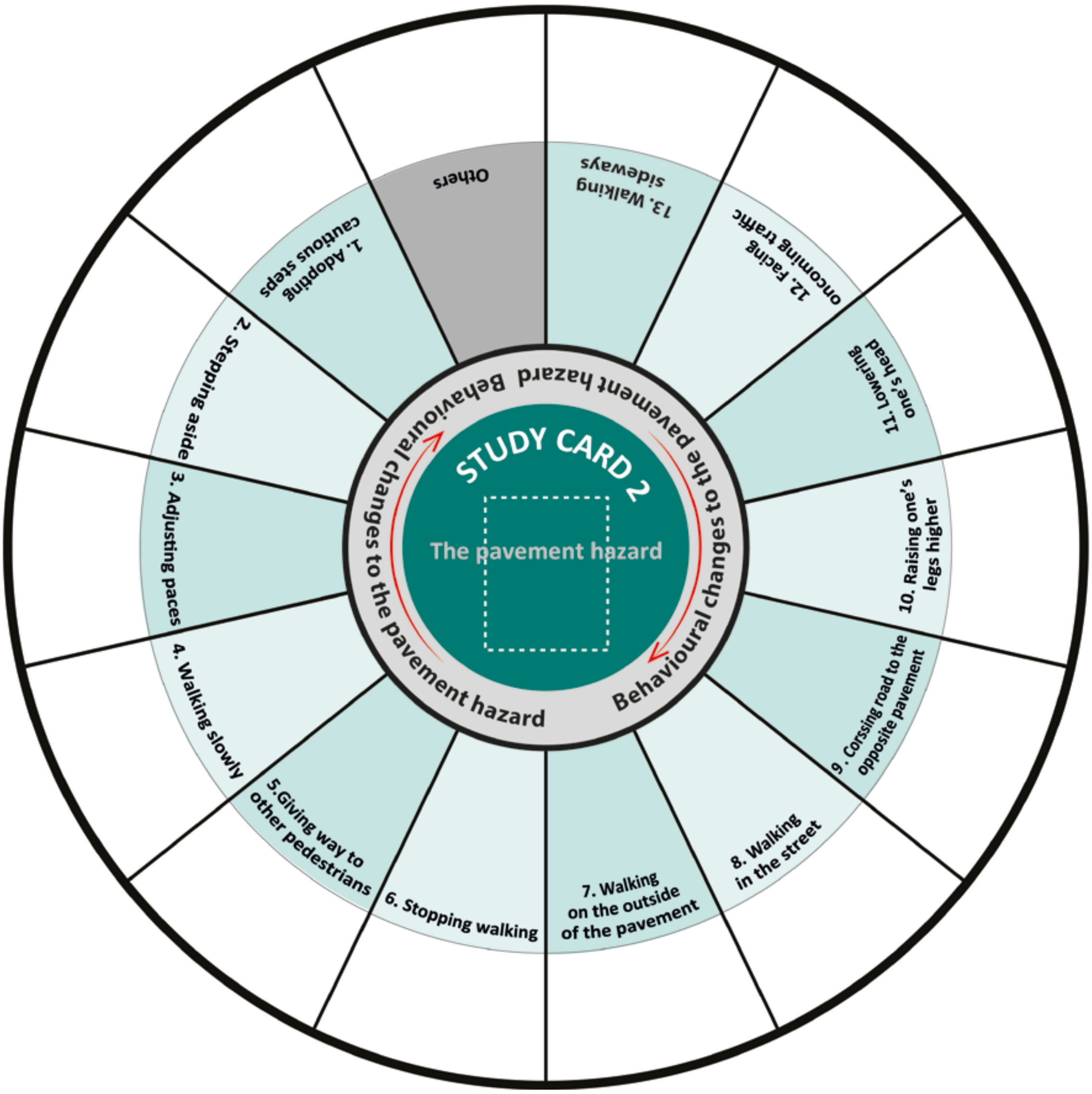


Appendix X: Study cards and participant stickers of W-KIT

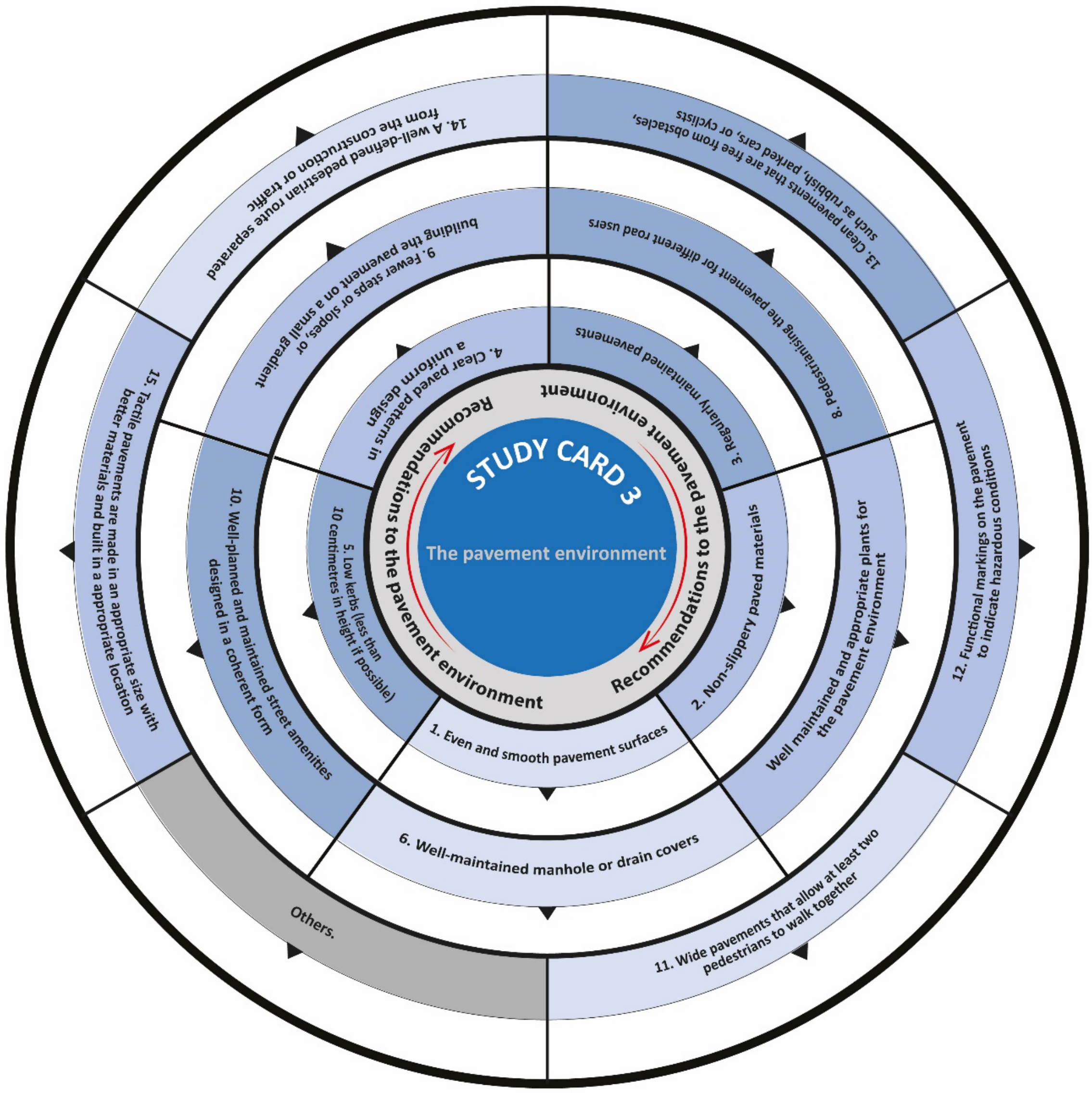
Study card 1:



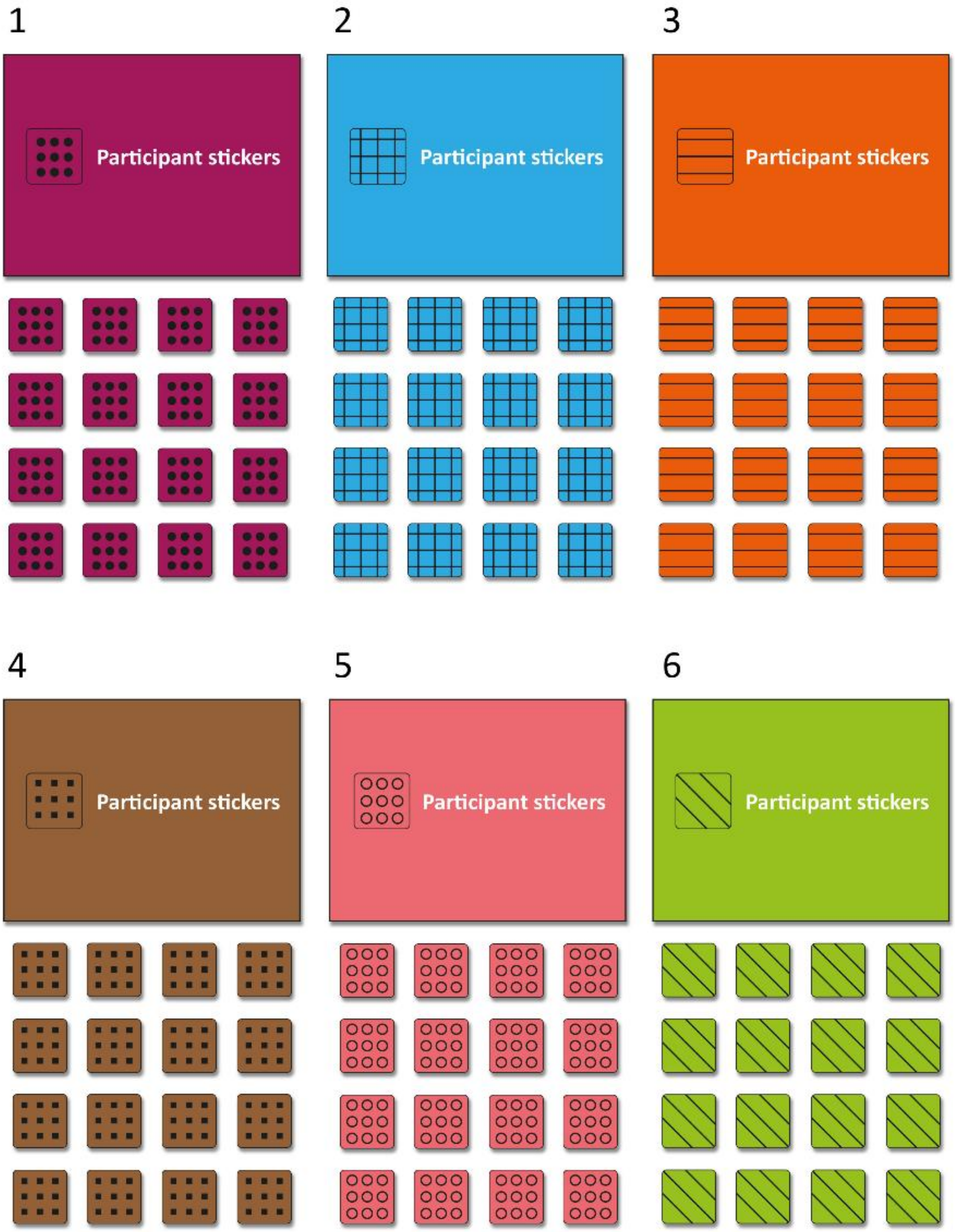
Study card 2:


STUDY CARD 2
The pavement hazard
Behavioural changes to the pavement hazard
Behavioural changes to the pavement hazard
Others
1. Adopting cautious steps
2. Stepping aside
3. Adjusting paces
4. Walking slowly
5.Giving way to other pedestrians
6. Stopping walking
7. Walking on the outside of the pavement
8. Walking in the street
9. Corssing road to the opposite pavement
10. Raising one's legs higher
11. Lowering one's head
12. Facing oncoming traffic
13. Walking sideways

Study card 3:


STUDY CARD 3
The pavement environment
Recommendations to the pavement environment
Recommendations to the pavement environment
1. Even and smooth pavement surfaces
2. Non-slippery paved materials
3. Regularly maintained pavements
4. Clear paved patterns in a uniform design
5. Low kerbs (less than 10 centimetres in height if possible)
6. Well-maintained manhole or drain covers
Well maintained and appropriate plants for the pavement environment
8. Pedestrianising the pavement for different road users
9. Fewer steps or slopes, or building the pavement on a small gradient
10. Well-planned and maintained street amenities designed in a coherent form
11. Wide pavements that allow at least two pedestrians to walk together
12. Functional markings on the pavement to indicate hazardous conditions
13. Clean pavements that are free from obstacles, such as rubbish, parked cars, or cyclists
14. A well-defined pedestrian route separated from the construction or traffic
15. Tactile pavements are made in an appropriate size with better materials and built in a appropriate location
Others.

Participant stickers:



Appendix XI: Ethical approval letters

Brunel University London

Brunel University London
Uxbridge UB8 3PH
United Kingdom

www.brunel.ac.uk

28 July 2015

STATEMENT OF ETHICS APPROVAL

Proposer: Lulu Yin Student ID No: 1320475/3

Dear Lulu,

Project Title: Investigating the factors and the sidewalk conditions that can influence the walking behaviour of the elderly.

Under delegated authority from the College Research Ethics Committee, I have considered the application recently submitted by you. I am satisfied that there is no objection on ethical grounds to the proposed study.

Approval is given on the understanding that you will adhere to the terms agreed with participants and to inform me of any change of plans in relation to the information provided in the application form.

In addition, please provide notification to the College Research Office when the study is complete, if it fails to start or is abandoned.

Yours sincerely,

John Park
College Research Mananger
T +44(0)1895 266057| **E** john.park@brunel.ac.uk
Brunel University London
College of Engineering, Design and Physical Sciences

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

11 February 2016

LETTER OF APPROVAL

Applicant: Miss Lulu Yin

Project Title: A PhD research project

Reference: 2278-LR-Feb/2016-1697

Dear Miss Lulu Yin

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Zhao Hua

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Page 1 of 1

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

13 September 2017

LETTER OF APPROVAL

Applicant: Mrs Lulu Yin

Project Title: Evaluation of a co-experience toolkit

Reference: 7424-LR-Sep/2017- 8329-1

Dear Mrs Lulu Yin

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London