

Wayfinding Behaviour in Unfamiliar Environment during Evacuation

An exploratory study based on driving simulator



Xiao Yang
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By

Xiao Yang

Student number: 4255453

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Graduation committee

Thesis Supervisor	Prof. Dr. Ir. S. P. Hoogendoorn	CiTG, TU Delft
Daily Supervisor	Dr. R. G. Hoogendoorn	CiTG, TU Delft
Daily Supervisor	Dr. E. J. E. Molin	TBM, TU Delft
External supervisor	Drs. E. Kinkel	CiTG, TU Delft



Preface

This master thesis is the last piece of work I finished at the Delft University of Technology, to obtain my Master of Science degree in Transport, Infrastructure and Logistics. I would like to express my gratitude to all the people who have contributed to my thesis research. Due to them, I could hold on at the last stage and completed the work in time.

First and foremost, I would like to thank all the members in my graduation committee. My daily supervisor Raymond Hoogendoorn inspired me the research direction and guided me to set up the evacuation experiment. The feedback given by Serge Hoogendoorn led to great improvements in this final thesis. And thanks to Erica Kinkel, I could work out questionnaires for the experiment. I also appreciate the advices from Eric Molin, which were valuable to the quality of my thesis.

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Finally, I thank my family for their constant support to my study. I have experienced frustration and disappointment during my thesis research. But after the bitterness, the joy in the end comes much sweeter.

I would like to dedicate this thesis to the memory of my grandmother. I am really sorry and regretful for not being there with you. Your support and encouragement always motivated me to pursue my goal in life.

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Summary

This research intends to explore city visitors' evacuation wayfinding behaviour. This research field has been consistently overlooked. And there is no doubt the city visitors have difficulties in finding ways during evacuation, due to lack of knowledge and unfamiliarity of the environment.

To start with, an explicit literature study is performed. It introduces Dynamic Disaster Model as a fundamental theory of psychological reactions in disaster and illustrates the evacuation responses of city visitors in respect of travel choices. Further, it identifies different categories of wayfinding factors according to empirical findings. Six types of factors are investigated in this research, including personal profile, spatial abilities, wayfinding strategy, psychological condition, spatial layout and navigational aids.

Based on the literature study, a theoretical framework of evacuation wayfinding process is proposed, consisting of three sub-processes, namely decision making, decision execution and information processing. Additionally, hypotheses of city visitors' evacuation wayfinding behaviour are assumed, with respect to six types of wayfinding factors.

To examine the hypotheses, an evacuation experiment based on driving simulator is conducted. Based on the descriptive and statistical analysis of experiment results, the effects of wayfinding factors in evacuation are investigated. The gender, spatial abilities, wayfinding strategies and psychological condition have significant impact in this experiment. Other wayfinding factors did not show significant impact or their effect cannot be effectively proved in this experiment. The gender and spatial abilities are major determinants of evacuation wayfinding performance.

Male participants outperformed females in large extent. Since gender and spatial abilities are interrelated, one possible explanation is the differences between their spatial abilities. Males have better map reading skill and spatial orientation ability, which can lead to higher success rate and shorter evacuation time. Regarding to wayfinding strategies, most participants applied survey strategies, which has higher chance to succeed and harder to get lost, compared to route strategy. The time pressure and anxiety experienced in evacuation can lead to negative or positive effect on evacuation wayfinding behaviour, depending on the level of stress. In addition, despite of the importance mentioned in literature, the effect of city landmarks on evacuation wayfinding behaviour is insignificant in the experiment. But considering the bias caused by experiment design, its effect in real life remains unclear.

Finally, on the basis of literature study and experiment result, a conceptual evacuation wayfinding model is constructed, which explains how city visitors find ways in a vehicular-based urban evacuation. The theoretical framework is used to build the conceptual model, which also has three sub-processes.

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1. Introduction

In the recent decades, severe natural and man-made disasters, such as floods, hurricanes, tsunamis, earthquakes and terrorist attacks occurred more frequently. All these kinds of disasters can cause massive economic damage and large number of casualties. Some types of disasters are unpredictable, like earthquakes, tsunamis and terrorist attacks. But disasters such as floods, storms and hurricanes, which happen almost every year, are predictable. Predicted disasters gave preparation time to local government and population in risk area to take action. Evacuation is often the only possible way to protect citizens from disasters has gained more and more focus. The number of studies on evacuation has increased substantially and the research subjects within this domain are expanding as well.

Evacuation wayfinding problem of pedestrians and evacuation transportation research are two most intensively studied topics. Essentially, this indicates different research focuses on two major types of evacuees: pedestrians and drivers respectively. In the behavioural study field, evacuation participation choice (the decision to evacuate) and departure time choice have gained most attentions. Since these two choices can largely determine the success of evacuation and clearance time. Most vehicular based evacuation researches are served for evacuation planning purpose. As a result, they considered the problem at aggregate level. Most importantly, evacuation researches related to drivers normally only concerns local residents.

However, few researchers noticed a specific group - city visitors, who are unfamiliar with the environment. This group includes tourists and business travellers. Because of the unfamiliarity, they will also encounter wayfinding problems in evacuation, especially in a complex environment, like a city.

1.1 Evacuation of city visitors

In urban area, the primary victims in disasters are local residents. Considering this fact, most researchers concentrate on the evacuation of local households. But the city visitors (shortened as visitors later in the report) haven't gained enough attention yet. They only temporarily stay in the city, having little or none knowledge of environment. Visitors mainly consist of tourists and business travellers.

Phillips and Morrow (2007) pointed out that tourists are high-risk populations in disasters. The first reason is that the tourism businesses are significantly attached to natural disasters due to their special locations. For instance, tropical beaches attracting tourists are often on the potential paths of hurricanes. As an example, the Hawaiian island of Kauai was attacked by hurricane in 1982 (Murphy & Bayley, 1989). Another important reason is that tourists are unfamiliar of the environment. In addition, cultural differences (e.g. due to language barriers) between visitors and residents may lead to difficulties in evacuation. Since visitors cannot understand warning messages and evacuation instructions announced by local language, they can only rely on limited assistant tools, such as tourist map, city landmarks or even

only sense of orientation to find ways. Due to both environmental and cultural unfamiliarity, visitors can be easily to get lost in the city during evacuation. In sum, the city visitors are more vulnerable than local residents in disasters.

Despite the vulnerability of city visitors, there are few evacuation studies in this field. The fairly small number of visitors, compared to residents, is the main cause for this. Normally, city visitors are considered less important, because the proportion of them is too small to make an influence to the overall evacuation result (Lindell, 2008). However, perhaps this is not the case for tourism cities. The 2004 Indian Ocean tsunami killed around 5,000 persons in Thailand, among which foreign tourists accounted for 50% of victims (Mäntyniemi, 2012). The Florida state in USA has over 80 million tourists every year, which is one of the most affected states by tropical cyclones (Villegas et al., 2013). During holidays, the population of visitors can even larger than local residents, in some famous tourist resorts. Due to series disasters, the rapid development of tourism industry has experienced a decline in past decades. The decrease of tourists caused huge economic loss in tourism industry (Cahyanto et al., 2014). Therefore, to ensure tourists safety and stabilise the development of tourism industry, the evacuation research on city visitors is crucial.

Within the limited studies in this particular field, most researches are associated with precaution measures. Drabek (1995, 2000) published some articles discussing disaster planning and policies in tourism industry, and focusing on the response of tourism businesses. Recent years, some researchers have taken visitors' evacuation behaviour into consideration. The major study topics of visitors are risk perception and evacuation participation choice (Cahyanto et al., 2014; Matyas et al., 2011; Villegas et al., 2013). The unfamiliarity of city visitors is also mentioned in several studies. Despite that, there has no empirical research on their evacuation wayfinding behaviour available yet.

1.2 Wayfinding in evacuation

Evacuation wayfinding problem has been intensively studied in the last decade. However, the research focus is pedestrian wayfinding in the built-in environment, e.g. buildings, ships, airplanes and stations, etc. The behavioural patterns of pedestrians and drivers are quite distinctive. Thus, the large amount of pedestrian wayfinding studies has limited contribution to drivers' evacuation wayfinding problem.

As far as the researcher's knowledge, there is no study focused on drivers' evacuation wayfinding problem. One possible explanation is that evacuees who drive to evacuate are generally assumed to be locals who know the environment well. Another reason is that it is presumed city visitors will not have wayfinding problem in evacuation. In fact, Drabek's (1999) study suggests visitors may have difficulties in finding ways during evacuation.

Drivers' wayfinding process under normal situation has been heavily studied for decades. Influential factors of wayfinding can be divided into two major categories: internal factors (personal factors) and external factors (mainly refers to

environmental factors) (Boumenir, Georges, Rebillard, Valentin, & Dresch-Langley, 2010; Farr, Kleinschmidt, Yarlagadda, & Mengersen, 2012). The personal factors include personal profile, spatial abilities, physical and psychological condition and preferred wayfinding strategies, etc. The environmental factors involve characteristics of the environment, such as signage, spatial layout and other elements. It is reported that the signage in building can help pedestrians find the exit under emergency. Landmark, as a city element, is often mentioned in literature. Similarly, it is important in wayfinding process, performing as environmental cues.

To fill the blank, this research intends to explore evacuation wayfinding behaviour of drivers in an unfamiliar environment. To be more specific, this research investigates the impact of potential wayfinding factors through an evacuation experiment. Further, it generalises evacuation wayfinding process to conceptual model. It is expected that the results of this research can provide some insights of city visitors' wayfinding behaviour during evacuation.

2. Problem analysis

In this chapter, the missing link in evacuation study is identified, following with a description of research objective and research questions. Then boundaries of this research are stated. Finally, research approaches and structure of the report are presented.

2.1 Problem description

As mentioned in the introduction, evacuation wayfinding of unfamiliar travellers has been consistently overlooked. Although lacking empirical support, there is no doubt that city visitors will have difficulties in wayfinding during evacuation, due to unfamiliarity of environment, lack of information and language barriers, etc. In addition, due to lack of knowledge, they may not be able to find ways or select route based on their spatial knowledge of city network. This indicates that visitors don't have the understanding of distance, travel time and traffic condition, etc. However, most of current vehicular evacuation studies related to route selection assumed full knowledge of evacuees. The process of wayfinding has been neglected from these studies. Because the focus of evacuation research normally is local residents.

Evacuation wayfinding in unfamiliar environment is important, considering large share of city visitors using cars as transport means for their trip (Van Middelkoop, Borgers, & Timmermans, 2003). In addition, their wayfinding performance has an impact on road safety and evacuation success. Even under normal condition, navigating in an unfamiliar environment can be very demanding to a driver's attentional resources. And collisions are likely to happen when drivers are searching for anticipated but unknown locations, due to distractions (Burns, 1998). Therefore, wayfinding under emergency can lead to higher stress and more aggressive and careless behaviour, potentially causing traffic accidents.

To be concluded, despite the importance of city visitors' evacuation wayfinding problem, there is a scarcity of research in this field. Hence, this report intends to make some contributions from both theoretical and empirical aspects.

2.2 Research objective

In order to ensure city visitors' safety in disasters and improve their wayfinding performance in evacuation, more insights are required in the wayfinding behaviour of city visitors. As an exploratory study, the purpose of this research is to investigate city visitors' evacuation wayfinding behaviour in unfamiliar environment. Meanwhile, the effect of relevant wayfinding factors in evacuation is examined. To this end, a theoretical framework of evacuation wayfinding process is demonstrated and a conceptual evacuation wayfinding model is constructed.

The theoretical framework builds on theories and empirical findings in wayfinding studies. As a result, several hypotheses regarding to city visitors' behaviour in evacuation wayfinding are proposed. In order to examine those hypotheses and collect empirical evidence within this domain, an evacuation experiment based on driving simulator is designed and executed. In the end, the conceptual evacuation

wayfinding model is built on the basis of theoretical framework and collected behavioural data.

In summary, the result of this research is expected to provide some evidence on how unfamiliar drivers find ways under emergency and the impact of different wayfinding factors in this process.

2.3 Research questions

According to problem description and research objective discussed above, the main research question can be formulated:

How do city visitors find ways in a vehicular-based urban evacuation?

To answer the main research question, a set of sub-questions should be answered first:

1. *What is the city visitors' evacuation process in terms of travel behaviour?*
2. *Which factors have an impact on evacuation wayfinding behaviour in unfamiliar environment?*
3. *What is the effect of city landmarks on evacuation wayfinding behaviour in unfamiliar environment?*

2.4 Research scope

The topic of this research can be expanded in wide range, thus a clear scope should be defined. Considering the complexity of research subject and the time limitation, boundary is defined from four aspects.

1. Vehicular urban evacuation

Since finding ways in a city is more difficult compared to rural areas, the large-scale evacuation studied in this research is assumed to happen in a city. According to previous research, vehicle is the dominant transport mode in evacuation and large amount of city visitors travelling by car nowadays, therefore it is assumed that all city visitors using vehicle as transport means for evacuation. Except for above reasons, other transport modes like tram, metro, bus and train are difficult to conduct empirical research.

2. Predictable disaster

For unpredictable disasters, like earthquake and tsunami, the disaster normally strike before evacuation, potentially causing road degradation and casualties. In this research, the effects of disaster impact are not taken into consideration. Additionally, the traffic density on road in evacuation experiment was low, which suggests the evacuation was performed at fairly early stage. Therefore, the result derived from this research is not applicable to post-impact evacuation. Due to above reasons, a predictable disaster is a basic premise of this study, which gives enough

evacuation time to city visitors. It is assumed that city visitors will be informed before the disaster strike and they have enough (but limited) time to find their ways to a shelter.

3. No interference to visitors' decision making

Visitors will make their own decisions without any information from interactive sources, like route suggestion from locals, authorities' guidance and instructed evacuation signs on road, etc. This research concentrates on investigating the impact of personal factors, such as personal profile, spatial abilities, and environmental factors, mainly referring to landmarks. In order to simplify the research problem, influence of other information sources will not be discussed here.

4. Individual perspective

The process of wayfinding is quite personal, and hence it needs to be addressed from individual perspective. Except that, the wayfinding behaviour varied for each individual, which is largely determined by personal characteristics. Thus, it is difficult to generalise collective behaviour from individuals' behavioural data. And after all, the empirical data collected in this research is only from 51 samples. To conclude, this research is conducted based on individual's characteristics and decision making process.

2.5 Report outline

This report consists of five major parts, as blocks shown in Figure 2.1. Each part corresponds to one thesis chapter. In this schematic overview, the introduction and problem analysis are omitted. This section briefly illustrates the contents in each chapter.

Literature study

This chapter builds a general understanding of disaster phases, city visitors' evacuation responses and wayfinding process. The first section introduces Leach's Dynamic Disaster Model as a fundamental theory of evacuation psychological conditions. Then a review of visitors' evacuation responses is presented, based on travel choices they make in disaster. In the end, theoretical theories and empirical findings in wayfinding studies are elaborated, and factors influencing wayfinding process are identified.

Wayfinding framework

On the basis of literature study, a theoretical framework of wayfinding process in evacuation is proposed first in this chapter. The next section classifies and lists potential factors influencing evacuation wayfinding performance. Meanwhile, hypotheses of visitors' wayfinding behaviour during evacuation are proposed, in terms of different types of influential factors.

Methodology (evacuation experiment)

The first section explicitly explains the design, assumptions and procedures of the evacuation experiment based on driving simulator. The experiment consists of two phases, a visiting trip as a trial and an evacuation scenario. After that, the way data collected from the experiment is described in section 5.2. Then section 5.3 discusses methods applied to data analysis.

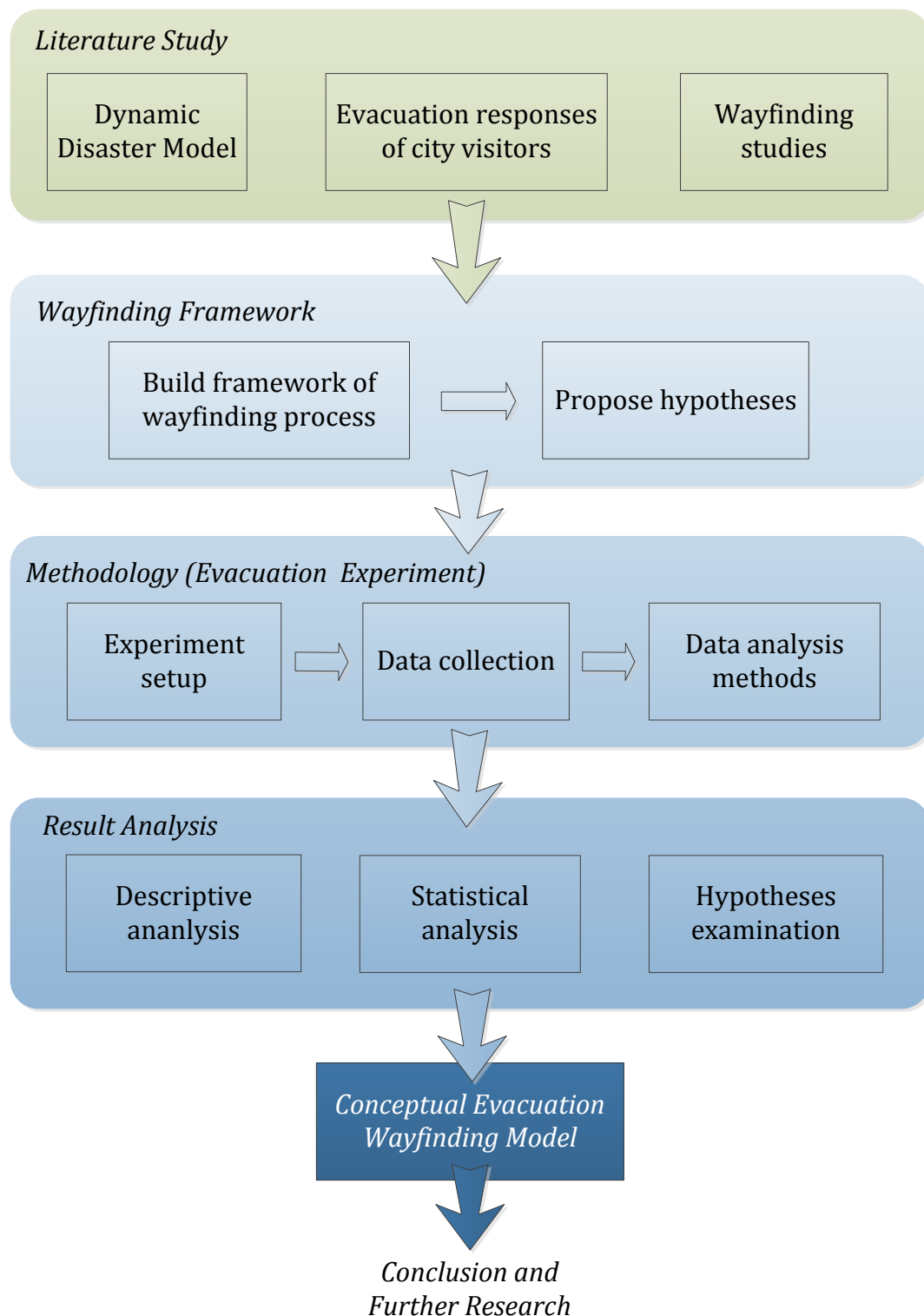


Figure 2.1 Report outline

Result analysis

The collected data are analysed in two ways, descriptive and statistical, based on the nature of data and the sample size. The descriptive analysis involves means, standard deviation, percentages and various types of charts. In terms of statistical analysis, according to the distribution of samples, ANOVA (Analysis of Variance) and non-parametric tests are used respectively. Based on the result of analysis, each hypothesis proposed in chapter 4 is examined.

Conceptual evacuation wayfinding model

On the basis of result analysis, the effect of influential factors in evacuation wayfinding process is clarified. As a result, a detailed conceptual evacuation wayfinding model of city visitors is constructed in this chapter. The general evacuation wayfinding processes are described in accordance with the processes in theoretical framework.

Conclusion and further research

The report ends with conclusions derived from the evacuation experiment and answers to the research questions. Then a discussion of the whole research is presented, including limitations in experiment and disadvantages of data analysis. Finally, recommendations are given for further research related to city visitors' wayfinding in evacuation.

3. Literature study on evacuation wayfinding

This chapter gives insight of research subjects related to visitor's wayfinding behaviour in evacuation. In the first section, we build a general understanding of disaster and evacuation by introducing Leach's Dynamic Disaster Model as a fundamental theory. After that, a review of city visitors' evacuation responses is presented, with respect to travel choices in evacuation. Next, important wayfinding factors and their effects are discussed in detail. The last section describes main conclusions of literature study.

3.1 Dynamic Disaster Model

Human behaviour is important in life-threatening situations, and has attracted psychologists study for years. The research found that the disaster type is not that matter, since victims' psychological responses follow a pattern and this pattern is transferable. From psychological perspective, human behave distinctively under different intensities of threat. Based on observations, victims' behaviour can be generalised at each specific stage (Vorst, 2010).

Leach (1994) built up a Dynamic Disaster Model, which defines disaster phases in terms of its evolutionary effects on human behaviour. As presented in Figure 3.1, the model divides a disaster into five phases, and pre-impact phase has two sub-stages, threat and warning phases. In the figure, behaviours demonstrated at the arrows' right side are possible responses at each phase, resulted from potential psychological reactions listed at the left side.

For predictable natural disasters, the evacuation warnings can be announced days before the impact. Therefore, a successful evacuation in urban area should be organized and operated before the disaster strike. However, in real-life, because people often deny the fact of coming threat, they may refuse to evacuate as warnings. Hence, the evacuation can also happen at the impact stage. Under this consideration, threat, warning and impact phases are discussed in detail in the report.

Threat Phase

At this stage, the sign of coming disaster has been noticed, the authorities have already identified the threat, and the messages have been disseminated via social media and other sources. People are aware of the threat, but they try to ignore and refuse to accept the fact. This denial causes people's inactivity at this stage. A condition called cognitive dissonance may happen. It makes people try to reduce uncomfortable feelings by rejecting or ignoring warnings. The cause of cognitive dissonance is the inconsistency of perceptions (Pel, Bliemer, & Hoogendoorn, 2012). However, people are more likely to actively seek for confirming information, such as messages from other sources or observation from other people's behaviours (Leach, 1994). Psychologists stated that "being in control" is a strong motivation for human behaviour and the coming disaster threatens the feeling of control. Therefore, people

tend to search for information first, instead of leave immediately. This has been observed in many evacuation cases (Hofinger, Zinke, & Künzer, 2014).

Warning Phase

This is the phase evacuation mostly likely to happen. The threat is imminent and the consequences are clear. Because the danger is so real, people have an overwhelming drive to do something, which leads to over-activity. Behaviours under this state can be ineffective and even inappropriate, due to their impaired information processing abilities and decision making capabilities (Leach, 1994). People are anxious and stressful, because of inability and perceived time pressure (Pel et al., 2012). But the dominant emotion in this phase is still denial. Only people possessed higher risk perception would decide to evacuate immediately.

Impact Phase

Normally, a successful precautionary evacuation should end before the impact. However, depending on the disaster type and the scale of evacuation, it can last after the strike. The major psychological reactions at this stage are bewilderment and stun. Additionally, the impact may cause perceptual narrowing and impaired reasoning ability. All these negative conditions result in more difficulties to escape. Thus, people behave reflexively and even mechanically under the impact (Leach, 1994).

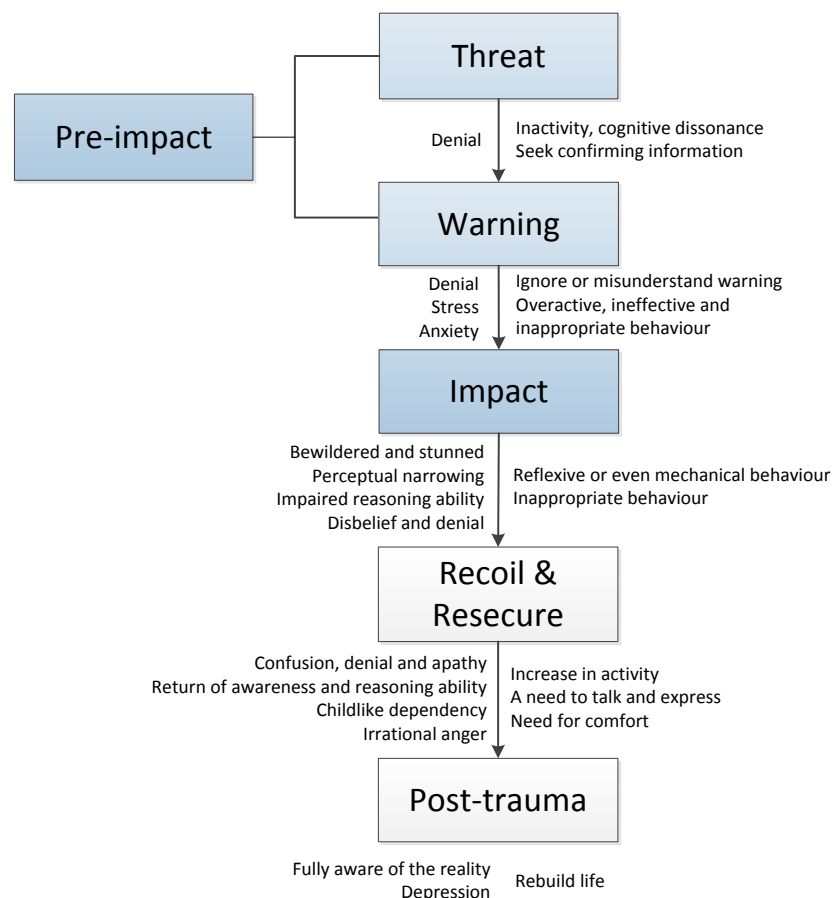


Figure 3.1 Dynamic Disaster Model (Leach, 1994)

3.2 Evacuation responses of city visitors

After a general introduction of disaster phases, the evacuation behaviour of city visitors should be discussed. This section illustrates visitors' responses to disasters, based on empirical studies. The description of evacuation responses is built on travel choice model. After all, the evacuation is a travel activity.

The general evacuation process of visitors is similar to residents. However, they make different choices at decision points. In addition, the psychological reactions of visitors slightly differ from the residents.

First response to threat (Threat phase)

City visitors are considered to be less-informed about evacuation information in disaster. They lack the information sources, such as media, which is the main channel for residents to receive warnings. In some cases, visitors may have shorter forewarning time compared to residents. The hotel staff and their "temporary neighbours" in hotel disseminate threat information immediately after receiving (Drabek, 1999). On the contrary, residents need to turn on TV/radio or interact with someone to know the situation, especially for people who lives alone (Stern & Sinuany-Stern, 1989). After receiving warnings, visitors will seek information to confirm the threat as well. If the initial information source is trustworthy, such as emergency office and other authorities, visitors are more likely to prepare to leave immediately (Drabek, 1999).

Evacuation participation choice

The evacuation participation choice (evacuation likelihood) is the most studied topic for tourists. This choice is largely determined by risk perceptions. People with higher risk perceptions are more likely to evacuate (Cahyanto et al., 2014). Tourists' risk perception is influenced by several factors. These factors can be categorized into two aspects: disaster characteristics and personal attributes. Disaster characteristics are objective factors related to disaster itself, like the scale, intensity, lasting time and impact area. Personal attributes include transport mode, information source, prior experience, demographic profile, knowledge of disaster, and familiarity of surroundings, etc. (Matyas et al., 2011; Villegas et al., 2013).

First time visitors usually have higher risk perception and likelihood to evacuate, due to anxiety caused by unfamiliarity (Reisinger & Mavondo, 2005). Cahyanto et al. (2014) found people who have prior experience and knowledge of the disaster perceived less risky, compared to people who without. These two evidences suggest city visitors have higher risk perception in general. Since visitors, foreign visitors in particular, are unfamiliar with the environment and without prior experience and knowledge. As a result, they are more likely to evacuate. This conclusion is supported by Drabek's (1996) interviews of hotel managers.

Evacuation departure time choice

Unlike residents, visitors tend to evacuate at fairly early stage. As mentioned above, they can be informed earlier than residents, in terms of initial warnings. Additionally, considering visitors only carry limited size of baggage for trip, they need less time for preparation before evacuation. Actually, because of stress and fear, large proportion of tourists just left without their property at threatened area (Drabek, 1999).

Destination choice

Contrary to residential households, few visitors would seek refuge at their friends or relatives house, since they may have no friends or families nearby. The primary criterion of destination selection for them is distance. To be more precise, travel time to destination from their origin locations is most important. Hence, most visitors went to public shelter in community or another hotel safe and nearby. And the travel time to those locations usually less than one hour (Drabek, 1999).

Route choice/wayfinding

For now, there is no empirical study related to visitor evacuation route choice or wayfinding problem. In Drabek's (1999) research, most tourists did receive some assistance from hotel staff before the evacuation. Nevertheless, over one third (36%) asked for improvement on route information provision. This result indicates the fact that city visitors have difficulties in finding ways.

Extensive studies of household evacuation route selection strategies are available. But visitors are distinctive from households on this travel choice. They cannot make route choices based on experiences and even have a hard time to understand provided information along road. It is a rather a wayfinding process for visitors, than a route selection. More detailed discussion about wayfinding process is presented at next section.

The integrated flow chart of visitors' evacuation process is shown in Figure 3.2. Their psychological reactions and steps of travel choice are elaborated in this flow chart. It is based on the Dynamic Disaster Model and the description of evacuation process.

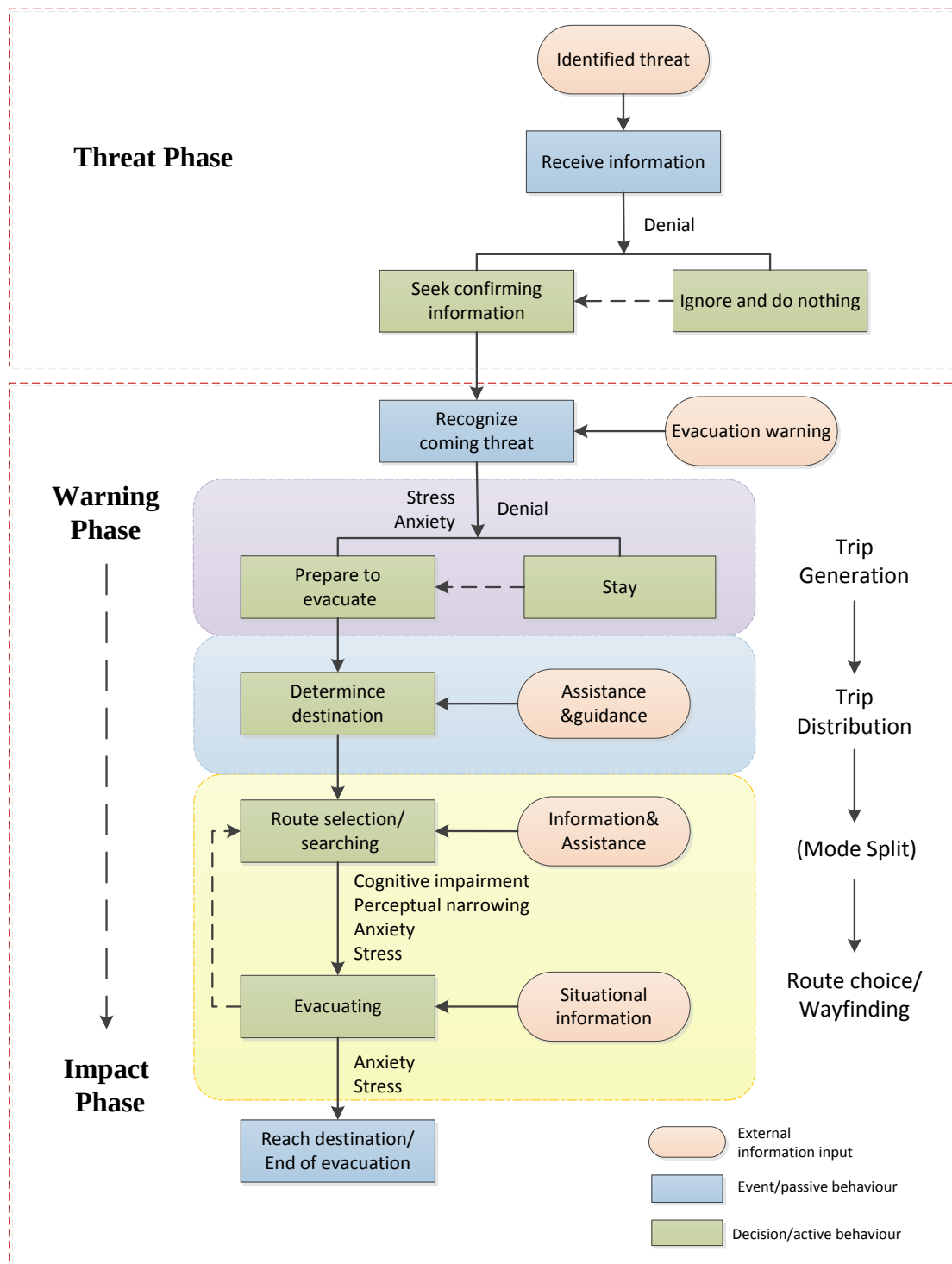


Figure 3.2 Integrated evacuation process of city visitors

3.3 Wayfinding studies

Researchers have studied wayfinding for decades, providing large amount of theories and empirical evidence. This section discusses the effects of important factors. Theories of environmental learning and spatial knowledge are presented as well, since all spatial behaviour is based on individuals' cognitive map.

It is noteworthy that there are lots of related studies in wayfinding domain. This report only picks some representative theories in wayfinding field. Regarding to empirical findings of factors, the results are often contradictory in different articles. Thus, this section simply demonstrates some general accepted or numerous proved findings.

3.3.1 Definitions

The term wayfinding and route choice are often mixed-up in literature. In fact, it is difficult to distinguish them by definition, since they often express same meaning in different articles. In this section, to clarify the meaning of 'wayfinding', the definitions of wayfinding and route choice and the differences between them are discussed in detail, for the purpose of the research presented in this report.

The definitions of wayfinding are varied in different research field. It was first defined by Lynch (1960), as a process of consistent use and organization of sensory cues from the external environment to efficiently move through space. Golledge (1999) defined wayfinding as a process of determining and following a path or route between an origin and a destination. And he stated wayfinding is a purposive, directed and motivated activity. In essence, wayfinding is the process of finding way to a destination in a familiar or unfamiliar place, using environmental cues (Farr et al., 2012).

Route choice or route selection and wayfinding are frequently transferable in literature. Few people define a strict distinction between them. To clarify the distinction, based on the definition of Bovy and Stern (1990), the choice of a route for a particular trip from a set of given route alternatives is called the route choice problem. And they stated route choice is a subset of wayfinding problem. Another subset of wayfinding is route search problem: searching or becoming informed about new routes. The most important feature of route choice problem is that there is a choice set for travellers to choose. The choice set including all alternatives known to the traveller to complete journey (from specific origin to destination). This feature indicates that travellers know the location of destination and possible ways to reach there.

In this research, visitors are more focused on 'finding' and 'searching' aspects. Since they are unfamiliar drivers, who may don't know the exact location of destination. Additionally, visitors are unable to generate alternative routes, based on their spatial knowledge of the city. Therefore, the term 'wayfinding' is used in the report. It has wider range of application and gives emphasis on the process of 'finding'.

3.3.2 General introduction to factors influencing wayfinding

Wayfinding is performed under the interplay between a person's characteristics and the environment characteristics. Factors have an impact on wayfinding can be classified into two major types: internal (personal) factors and external (environmental) factors (Farr et al., 2012; Prestopnik & Roskos-Ewoldsen, 2000). This section provides a brief introduction of these two types of factors.

The personal factors include personal profile attributes (like gender, age, education, driving experience, etc.), culture, familiarity of the environment, spatial abilities, preferred wayfinding strategies and psychological condition, etc. It is noteworthy that these personal factors are not independent. There are interactive influences between each other. For instance, the gender can affect one's spatial abilities, preferred wayfinding strategy and psychological condition. Another example is that longer driving experience must result in relative older age (but not necessary true vice versa). Four categories of personal factors are listed in Table 3.1, namely personal profile, spatial abilities, wayfinding strategy and psychological condition. Only these four categories are investigated in the research, due to their importance in wayfinding. Culture is not discussed here, since the interaction between visitors and others is beyond the scope of this research. And the familiarity of the environment is not included, because the research topic is wayfinding in unfamiliar environment.

The personal profile represents demographic characteristics, including gender, age, education level and driving experience. The spatial abilities consist of two different ones: map reading skill and spatial orientation (sense of orientation). Actually, there are more profile attributes and spatial abilities can influence wayfinding. But due to time limitation, this report only discusses these six factors.

Table 3.1 Overview of influential factors on wayfinding

Human (internal) factors	Environmental (external) factors
<u>Personal profile:</u> Gender Age Education level Driving experience Culture * Familiarity of the environment * <u>Spatial Abilities:</u> Map reading skill Spatial orientation (sense of orientation) <u>Wayfinding strategy</u> <u>Psychological condition</u>	<u>Spatial layout:</u> Density of building * Geometric layout * Landmarks Signage * <u>Navigational aids:</u> Map Verbal instructions

Factors with * are not discussed in the report.

Environmental factors involve density of buildings, availability of landmarks, signage and geometric layout of paths and intersections, etc. They can influence individual's ability to find ways (Boumenir et al., 2010). In spite of various environmental factors, this research simply focuses on landmarks. As one of the research question is to examine the impact of landmarks during evacuation wayfinding.

Furthermore, the navigational aid is also discussed and it is classified as an external factor. But it is not an environmental factor, since it is not an element in the environment. Travellers learn spatial knowledge via different information sources. And it can lead to difference in individual's cognitive map.

The overview of wayfinding factors is presented in Table 3.1. Factors with * are not discussed in the report. The environmental learning and cognitive map are introduced before the discussion of spatial abilities. The description of psychological condition is combined with evacuation in section 3.4.

3.3.3 Personal profile

Personal profile includes gender, age, education level and driving experience. All of them were investigated in the research. This section presents empirical findings related to these factors. Their effects on wayfinding and influences on other personal factors are elaborated here. It is noticeable that the discussion of education level is missed here. Since few empirical evidences can prove its significance in wayfinding.

Gender

Researchers found differences exist in male and female spatial performance. Male averagely perform better than female in wayfinding (C. A. Lawton, 2010). The gender differences in spatial abilities largely contribute to the differences in their wayfinding performance. The spatial abilities also have an impact on preferred wayfinding strategies. Additionally, the strategies affect wayfinding performance as well (Farr et al., 2012). Last but not least, men and women experience different spatial anxiety during wayfinding (Schmitz, 1997). Table 3.2 shows a summary of empirical findings revealed how gender differences affect other personal factors.

Age

As stated in many studies, elderly drivers experience difficulties in wayfinding, due to declines in vision, spatial abilities and information processing ability associated with aging (Bryden, Charlton, Oxley, & Lowndes, 2013; Burns, 1998). Head and Isom (2010) confirmed this through experiment in virtual reality. They found that age has an impact on landmark and environmental scene recognition. In addition, elders are less accurate at identifying directional information of landmarks.

Moreover, some older drivers show a tendency of avoiding drive in unfamiliar areas. The possibility of getting lost and lack of traffic condition knowledge make them stressful, when they are driving in an unfamiliar area (Bryden et al., 2013).

Driving experience

Drivers who actively involved in decision making of navigation have a better oriented and more accurate cognitive map of routes traversed than passengers (P. Jackson, 1996; Pearce, 1981). A possible explanation is stated as the difference in environmental experience. Drivers have more urgent need to know the ways

(Walmsley & Jenkins, 1992). According to Jackson's (1998) experiment, drivers who had been driving for one year or less, have less accuracy in wayfinding tasks compared to more experienced drivers.

Table 3.2 The effects of gender differences on other personal factors

Affected factors	Findings	Reference
Spatial Abilities	Male perform better than female in map reading tasks.	Boardman (1990), C. Lawton (1994), Coluccia and Louse (2004)
	Male tend to give higher self-rating in spatial orientation ability.	
	Men show better orientation performance in high-VSWM-load tasks. *	
Cognitive Map	Male have better knowledge of streets and paths.	Pearce (1981)
	Female demonstrate a better use of landmarks and districts.	
Wayfinding Strategies	Men are more likely to apply survey strategy, relying on cardinal directions in wayfinding.	Boumenir et al. (2010), C. Lawton (1994)
	Women prefer route strategy, depending on representations of spatial layout.	
Psychological Condition	Women have higher level of spatial anxiety in wayfinding than men.	C. Lawton (1994) Schmitz (1997)

* VSWM stands for Visuo-Spatial Working Memory

3.3.4 Environmental learning and cognitive map

Environmental learning and cognitive map are always mentioned together in literatures. To be more specific, the formation of cognitive map is based on environmental learning (Guy, Curtis, & Crofts, 1990). Therefore, the concept of environmental learning is transferable to cognitive mapping in some extent. Within this report, there is no strict difference between them.

Downs and Stea (1974) defined cognitive mapping as "a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment". Cognitive map is the product of cognitive mapping process. In essence, cognitive map is a source of environmental information (internal information) used by traveller to solve spatial problems (Passini, 1981). All human spatial behaviour is based on his cognitive map of the environment.

This report tends to use the phrase environmental learning, instead of cognitive mapping. For visitors in a novel environment, learning is more suitable and accurate to describe the process of spatial knowledge acquisition. In order to explain this process in detail, the sources of environmental information and the theory of spatial knowledge development are illustrated below.

People can learn spatial knowledge quickly in an unfamiliar environment. However, the learning process will slow down at some point, reported two days in Pearce's (1977) experiment. As mentioned above, drivers develop cognitive map faster than non-drivers, and more detailed and accurate, in respect to landmarks and routes (Pearce, 1981). Later, Walmsley and Jenkins (1992) confirmed his findings in an experiment related to tourists.

There are three types of information sources identified in environmental learning, namely direct, indirect and inferential information sources. The last one rarely occurs, so it is omitted here. The first information source involves interaction with elements in environment and actual navigation experience. It has the largest influence. The indirect information sources commonly refer to maps (Guy et al., 1990).

With increased navigation experience, individual's spatial knowledge is developed by three stages. They are sequenced as landmark knowledge, route knowledge and survey knowledge (Stern & Leiser, 1988). The theory is visualized in Figure 3.3.

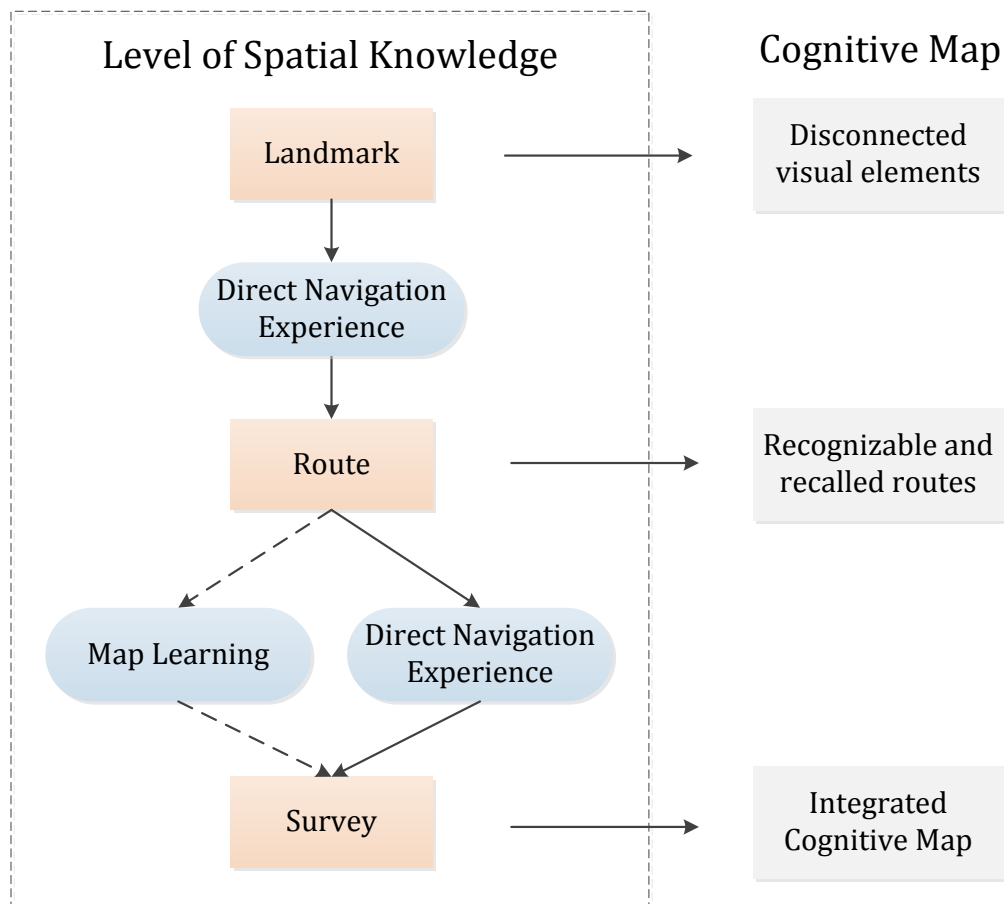


Figure 3.3 Levels of spatial knowledge (Stern & Leiser, 1988)

Landmark is the first acquired knowledge. It is the foundation of further spatial knowledge (Cenani, Arentze, & Timmermans, 2013). At this level, locations of certain objects are known, but the traveller cannot spatially relate one to another. At the second stage route knowledge, traveller knows the sequences of landmarks and

associated decisions and actions. But they lack an overall understanding of spatial layout. Travellers at survey knowledge level view routes as links between locations. They have a proper spatial understanding and an integrated mental map. The acquisition of survey knowledge usually involves with map study. However, some researchers believed it can be obtained from sufficient navigation experience, without map learning (Stern & Leiser, 1988).

3.3.5 Spatial abilities

Spatial abilities involve locating destination in space, perceiving distance and directional relationships, and mentally transforming objects in terms of their position or orientation in space (C. A. Lawton, 2010). All these abilities are related to cognitive processes. Good spatial abilities will result in good cognitive maps. The spatial ability is a major determinant of cognitive mapping ability (Thorndyke & Goldin, 1981).

The utilization of map can enhance the formation of cognitive map, however, the effectiveness of learning can be moderated by personal map reading skill (Guy et al., 1990). The map reading skill is closely associated with traveller's cognitive mapping process. A good map reader performs better in encoding environmental information, evaluating the learning process and focusing attention on unlearned information (Chen & Stanney, 1999). In summary, a better map reader tends to have more detailed and accurate cognitive map.

Spatial orientation is the ability of maintaining orientation to certain location in space and situating in space regardless of the deviation in orientation or learned route (Chen & Stanney, 1999; Farr et al., 2012). It is important to cognitive mapping process. People with good sense of orientation are better in integrating spatial information and more proficient at developing accurate cognitive maps (Chen & Stanney, 1999). And above all, it is clear that a good sense of orientation is an advantage in wayfinding (C. Lawton, 1994).

3.3.6 Navigational aids

Many researchers have investigated the use of navigational aids that assist individuals in wayfinding tasks. These tools can provide position information, display orientation, demonstrate surrounding environment and guide the direction (Chen & Stanney, 1999). However, this research concerns their effect on environmental learning, instead of their assistance in wayfinding.

Maps are most commonly used by city visitors. The map study can enhance the formation of cognitive map. But the effectiveness of this learning process depends on individual's map reading skill. If the map study is combined with other information sources, such as guide information, oral assistance and written assistance, the performance on map will be improved (Guy et al., 1990).

It is found that drivers who only listened to verbal instructions were more accurate and faster to reach destinations, compared to map users. This indicates verbal direction is more effective in assisting wayfinding tasks. Drivers with both map and

voice directions were in between of map only and voice only users (Chen & Stanney, 1999). However, one disadvantage of verbal instruction is that traveller is unable to develop an overall cognitive map.

It is notable that if different information sources provided simultaneously while navigating, it can be detrimental to cognitive mapping. Since it may be too much to process, leading to more attention focused on following instructions instead of learning spatial knowledge (Streeter, Vitello, & Wonsiewicz, 1985).

3.3.7 Landmarks

Lynch (1960) classified five types of elements of city contents, namely paths, edges, district, nodes and landmarks. Paths are channels people move along, which can be streets and walkways, etc. Edges are linear elements set boundaries between two phases, such as shores and walls. And the districts are sections having recognizable, common character. The forth element nodes are strategic points, which people can enter. Nodes may be junctions, convergence of paths and crossings, etc. Last element landmarks are external reference points, which play an important role in spatial tasks like wayfinding. Since one of the research questions is investigating the impact of landmarks during evacuation wayfinding, the report only focuses on landmarks, while other factors are beyond research scope.

In Lynch's (1960) definition, landmarks are simple physical elements, which can vary widely in size. According to Golledge (1999), the concept of landmark has two distinct components. The first one stated that landmark is something attracting attention and being commonly recognized by people. Another defines landmarks as some places or features accrue salience for an individual at a level equivalent to the salience attached to the most widely known and recognized landmark in an area. This definition views landmarks from functional perspective. In this research, the first concept is applied. Landmarks are noticed and remembered by city visitors, due to its dominance of visible form or peculiarity of shape. The second definition is mainly applied by residents.

Lynch (1960) stated that visitor would initially rely on landmarks as direct source for orientation when they arrive in a new place. In addition, landmarks help to identify origin and destination and organize space as reference points or choice points, where decisions are made.

According to the functions and locations of landmarks, he classified landmarks into two groups: trigger cues and reassuring cues. The former one indicates a turning decision must be made and the latter one helps travellers to confirm decisions already made. Based on Lynch's classification, Cenani et al. (2013) define three landmarks types: en-route (located on the route taken), off-route (visible but not located on the route taken) and decision point landmarks. To simplify the problem, the locations of landmarks are not differentiated in this research. The concept of trigger cues (located at intersection) and reassuring cues (located in the middle of path) is applied in the experimental design of landmark placement.

3.3.8 Wayfinding strategies

Wayfinding strategies used by travellers can be largely varied. According to applied spatial knowledge, they are usually generalised into two groups, route strategy and survey strategy (also called orientation strategy) (C. Lawton, 1994).

The route strategy uses a sequence of instructions that facilitate traveller to move from one location to another. The wayfinding process guided by this strategy is often involved with (local) landmarks. For instance, travellers remember turn left or turn right when they see particular landmarks (Prestopnik & Roskos-Ewoldsen, 2000). Travellers who rely on route strategy are easier to get lost once they deviated from a learned route (Boumenir et al., 2010). This strategy is preferred by female, as mentioned previously.

The survey strategy uses an overall cognitive map to integrate information of locations and the relations between locations. The survey strategy gives more focus on global spatial knowledge, which will not change with the orientation change. Thus, the survey strategy is more flexible than route strategy (Prestopnik & Roskos-Ewoldsen, 2000). Travellers who depend on survey strategy usually use cardinal directions (North, South, East and West) as reference points (Boumenir et al., 2010). Males are more likely to apply survey strategy.

3.4 Psychological conditions of visitors relevant for evacuation wayfinding

The psychological condition of visitors in evacuation wayfinding is a mixed feeling resulted from fear of disaster, evacuation (time pressure) and wayfinding process. This section concentrates on time pressure and spatial anxiety, caused by evacuation and wayfinding respectively. The effects of time pressure and spatial anxiety are generalised as stress, which is easier to measure in the experiment.

After receiving the evacuation warning, people will try to evacuate to a safe place as soon as possible. Since the disaster is coming, people need to evacuate within certain time. Otherwise, their lives are in danger. This time limitation gives people a lot of pressure. As described in section 3.1, the perceived time pressure makes people anxious and stressful.

The individual's anxiety about performing spatial tasks usually refers to spatial anxiety (Ramirez, Gunderson, Levine, & Beilock, 2012). It is frequently experienced by travellers. When drivers cannot find the ways, they are likely to feel frustration and irritation (Burns, 1998). And females usually report higher spatial anxiety level than males (C. Lawton, 1994). Schmitz (1997) found that higher spatial anxiety level leads to more time to complete wayfinding task.

Human as information processing entities, apply environmental cues during evacuation wayfinding. The stress can affect how they process environmental information. The range of cues will be narrowed under stress. Furthermore, the cue recognition can be more difficult in complex environment, like a city, due to the overload of environmental information (Ozel, 2001).

Additionally, the stress will lead to an increased priority for processing negative information (Maule, Hockey, & Bdzola, 2000). Alternatives with negative experience are less likely to be selected. It has been observed in reality that residents tend to choose familiar route for evacuation (Murray-Tuite & Wolshon, 2013).

However, the stress is not only resulted in negative effects. Some degree of stress can boost the efficiency of information processing. But beyond certain level, the stress will limit individual's ability to process environmental information (Kerstholt, 1994; Ozel, 2001).

3.5 Conclusion

This chapter builds the theoretical foundation of research. According to Leach's Dynamic Disaster Model, one dominant emotion during evacuation is anxiety, due to perceived time pressure and inability. Their information processing ability and decision making capability can be affected because of that. Then the evacuation responses of city visitors are investigated. It can be concluded that visitors are early evacuees and they have difficulties in finding ways.

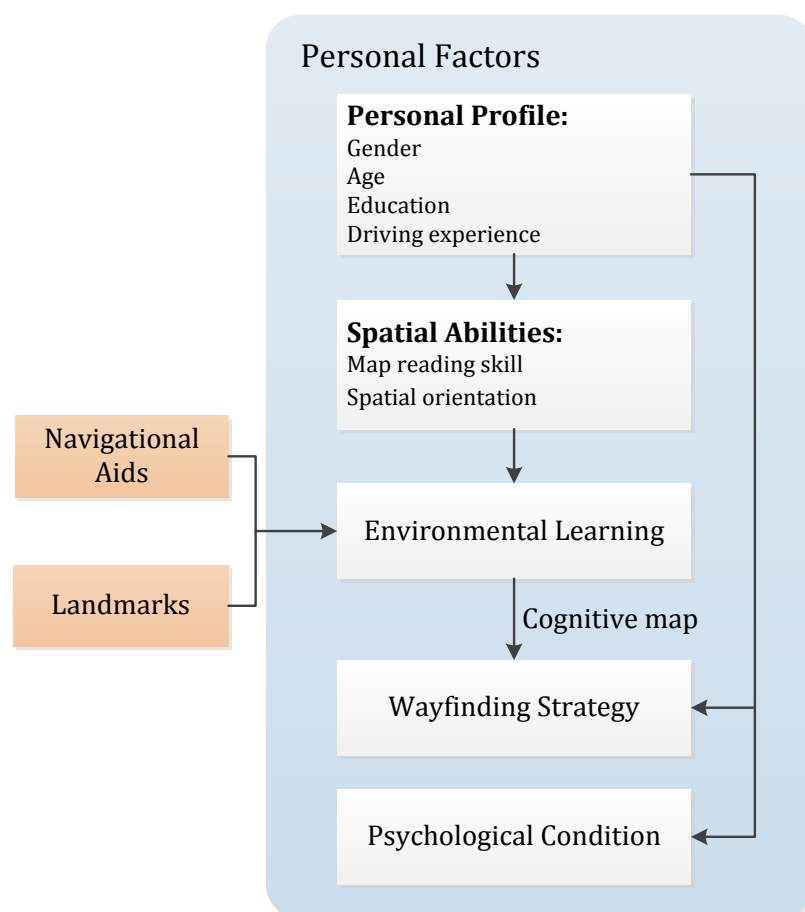


Figure 3.4 Interactions between wayfinding factors

Next, important wayfinding factors are illustrated, in terms of personal factors and environmental factors. All discussed factors and the interactions between them are visualized in Figure 3.4.

The personal profile attributes can affect individuals' spatial abilities. For instance, the gender difference in spatial orientation has been proved in many studies. Another example is the map reading skill, which can be improved with the increased driving experience.

Cognitive map is the product of environmental learning or cognitive mapping process. The spatial knowledge is acquired from direct navigation experience and indirect information sources (different navigational aids, like map and verbal instructions). Landmark as element in environment are learned through direct navigation or map study. It plays an important role in wayfinding, helping to organize space as reference point or choice point.

The spatial abilities have large impact on environmental learning and the formation of cognitive map. A good map reader tends to have more detailed and accurate cognitive map. Similarly, a good spatial orientation is an advantage in wayfinding.

According to cognitive maps and personal preferences, travellers apply different strategies for wayfinding. Two major types of wayfinding strategies are route strategy and survey strategy. The route strategy relies on representatives in the environment. On the contrary, survey strategy users depend on cardinal directions.

Finally, the psychological conditions in evacuation wayfinding mainly consist of time pressure and spatial anxiety. These two emotions are generalised as stress. It can positively or negatively influence wayfinding performance depending on the stress level. Adequate stress may increase information processing efficiency. But beyond certain range, the stress can limit information processing ability, hindering recognition of environmental cues.

4. Evacuation wayfinding framework

As presented in previous chapter, wayfinding involves many contributing factors. But last chapter illustrates different wayfinding factors and their effects separately. An integrated description of wayfinding process is still missing. This chapter first introduces Passini's concept of wayfinding process as a fundamental theory. According to his concept, a theoretical framework of evacuation wayfinding process is built. Next, based on previous literature study, hypotheses of city visitors' evacuation wayfinding behaviour are proposed, in terms of important wayfinding factors.

4.1 Wayfinding framework

Wayfinding is a dynamic process, involving consistently evolved cognition and adapted behaviour and choices. Based on this process-oriented perspective, Passini (1981) proposed three processes in wayfinding: information processing, decision making and decision execution.

Information processing is the basis of other two decision-related processes. The information refers to all information available to traveller when completing a wayfinding task. It includes cognitive map (internal) and sensory information (external).

The decision making process is the development of plans according to environmental information. It is a flexible process. Travellers may devise a new sub-plan to complete the task or change the task, when they meet failure. However, in this case, the change of task means change of evacuation destination. Thus task change will not be considered here. The development of decision plan is based on reoccurring strategies. While the wayfinding strategies are largely determined by the nature of available environmental information.

The last process decision execution is transforming the plan into behavioural actions. It is a matching-feedback process. If the traveller arrives at a location with perceived image as expectation, he will execute the decision. Otherwise, decision execution turns into a new wayfinding problem.

Based on Passini's theory and factors discussed in literature study, a framework of evacuation wayfinding process is finalized in Figure 4.1. It defines evacuation wayfinding as three processes as Passini. Personal characteristics and psychological condition are personal factors. The personal characteristics illustrated here include personal profile and spatial abilities.

Decision making

As a start, visitors receive an evacuation warning and information about the shelter's location. Then they decide whether to evacuate to the shelter. The evacuation decision and the destination choice consist of the phase of goal formation.

Since the shelter may be located at an unknown place to visitor, he must determine a wayfinding strategy (such as a route strategy or a survey strategy) before make a move. The applied strategies are largely determined by personal preference and available environmental information. The information includes cognitive map (internal) and external information, such as shelter description in this case.

Some visitors, who prefer route strategy or have a better understanding of the network, may try to plan the evacuation route as well. The route planning is supported by cognitive map.

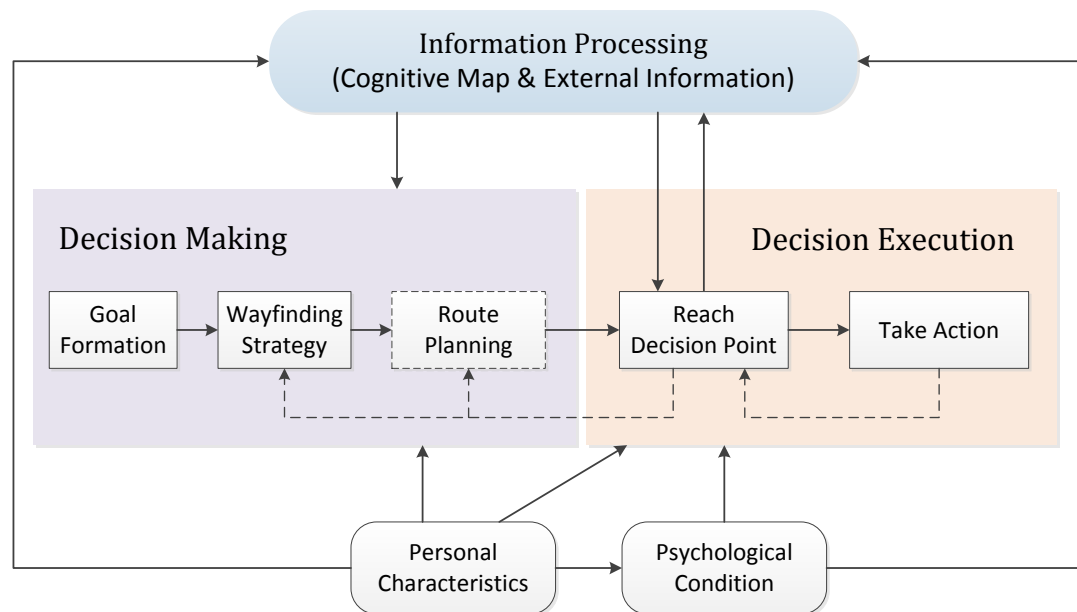


Figure 4.1 Framework of city visitors' evacuation wayfinding process

Decision execution

The visitor searches for environmental cues, when a decision point is reached. If the image (scene or landmarks) is perceived as expectation, he will take action as planned. If not as expected, visitor may find himself lost. This situation could lead to change of route planning and wayfinding strategy. The decision execution is influenced by personal characteristics as well. For instance, traveller with a bad spatial orientation may not be able to follow planned route or maintain his direction towards destination during wayfinding. Additionally, the stress has an impact on the recognition of environmental cues.

Action mainly represents movements, like forwarding and tuning. However, it also refers to speed and other driving related behaviours. Clearly, this behaviour will also be affected by psychological condition.

Information processing

As shown in Figure 4.1, the processed information consists of cognitive map and external information. The cognitive map is internal environmental information. It is determined by environmental learning, which is influenced by individual's personal characteristics. The external information includes environmental cues and assistant

information. In this case, the assistant information means evacuation guidance from hotel manager, official warning and local residents, etc. The effects of psychological condition on information processing have been discussed in section 3.4. The efficiency of information processing can be improved or decreased under different level of stress.

4.2 Hypotheses of evacuation wayfinding

On the basis of literature study and theoretical framework, some hypotheses of visitors' evacuation wayfinding can be proposed. This section presents all hypotheses, in terms of discussed wayfinding factors. The supported evidence behind each hypothesis is also illustrated.

4.2.1 Personal profile

The personal profile attributes have large impact on wayfinding performance. Yet, there is no empirical study of vehicular based evacuation wayfinding. Therefore, it is assumed the effects of these factors correspond to wayfinding findings under normal condition. Hypotheses related to gender, age, education level and driving experience are listed in Table 4.1.

Gender

Based on many wayfinding studies involved with gender differences, the male generally outperforms female in spatial tasks. Therefore, it is assumed in evacuation wayfinding task, the males have higher evacuation success rate. Since it is difficult to measure spatial orientation ability in this experiment, the self-rated sense of orientation is used. According to previous findings, men tend to give higher score on this ability. The rest hypotheses, from G3 to G8, are all concluded from related literatures (see Table 3.2). There is no need to discuss them again.

Age

Because of the declines in cognition, elderly drivers reported difficulties in wayfinding in unfamiliar environment. Based on this finding, the ***hypothesis A1*** assumes a lower evacuation success rate of elders. Due to same reason, ***hypothesis A2*** states the elders cannot match younger drivers in landmark knowledge. In the end, according to self-report, elderly drivers tend to avoid unfamiliar areas. So the ***hypothesis A3*** is proposed.

Education level

There is no evidence in literature proved the significance of education in wayfinding. However, as a basic personal attribute, its effect is investigated in the experiment. Thus, it is assumed by the author in ***hypothesis E1*** that no influence will resulted from different education level.

Driving experience

Jackson (1998) found that newly qualified drivers have poor performance in wayfinding tasks, compared to more experienced drivers. He claimed the reason for that may be inexperienced drivers need to pay more attention on driving, which leaves little spare mental capacity to develop wayfinding abilities. Based on his finding, ***hypothesis D1*** is brought up. Additionally, too much effort in driving can also affect environmental learning and the formation of cognitive map. As a result, it is reasonable to assume inexperienced drivers have less spatial knowledge. Since only landmark knowledge is examined in the experiment, ***hypothesis D2*** is proposed.

Table 4.1 Evacuation wayfinding hypotheses of personal profile factors

Number	Hypotheses	References
G1	Males have higher success rate than females in evacuation wayfinding task.	C. A. Lawton (2010)
G2	Males have better spatial orientation ability than females, in respect of self-rating.	C. Lawton (1994)
G3	Males have better map reading skill than females, in respect of self-rating.	Boardman (1990)
G4	Females have better landmark knowledge than males.	Pearce (1981)
G5	Males prefer survey strategy in evacuation wayfinding.	C. Lawton (1994)
G6	Females prefer route strategy in evacuation wayfinding.	
G7	Female have higher stress level than males in evacuation wayfinding.	Schmitz (1997)
G8	Female are more likely to feel anxious than males during evacuation wayfinding (in proportion).	C. Lawton (1994)
A1	Elderly drivers have lower success rate than younger drivers in evacuation wayfinding task.	Bryden et al. (2013)
A2	Younger drivers have better landmark knowledge than elders.	Head and Isom (2010)
A3	Elderly drivers tend to choose familiar route as route choice strategy during evacuation wayfinding.	Bryden et al. (2013)
E1	Different education levels have no influence on evacuation wayfinding performance.	Assumed by author
D1	Experienced drivers have higher success rate than inexperienced drivers in evacuation wayfinding task.	P. G. Jackson (1998)
D2	Experienced drivers have better spatial knowledge than inexperienced drivers, with respect to landmark knowledge.	

4.2.2 Spatial abilities

The literature study describes the importance of spatial abilities in cognitive mapping and wayfinding. But it is difficult to directly measure individuals' spatial abilities and quality of their cognitive maps. In the experiment, only self-rated scores and landmark recognition are available. Thus, the hypotheses of spatial abilities are related to these measures.

Map reading skill

No direct statement indicates people with better map reading skills will perform better in wayfinding tasks. **Hypothesis M1** and **M2** are deduced from literatures. People with better cognitive maps are supposed to have better performance in wayfinding. **Hypothesis M3** reflects the formation of cognitive map is influenced by personal map reading skill.

Spatial orientation

The hypotheses of spatial orientation are similar to the map reading skill. They are simply based on one statement, that good sense of orientation gives advantage in both cognitive mapping and wayfinding.

Table 4.2 Evacuation wayfinding hypotheses of spatial abilities

Number	Hypotheses	References
M1	Good map reading skill will result in higher success rate in evacuation wayfinding.	Chen and Stanney (1999)
M2	Good map reading skill will result in shorter evacuation time.	
M3	Good map reading skill will result in better landmark knowledge.	Guy et al. (1990)
O1	Good spatial orientation will result in higher success rate in evacuation wayfinding.	C. Lawton (1994)
O2	Good spatial orientation will result in shorter evacuation time.	
O3	Good spatial orientation will result in better landmark knowledge.	Chen and Stanney (1999)

4.2.3 Navigational aids

This research concerns about the influence of navigational aids on the formation of cognitive maps. But the effects are not stated clearly in literatures. To examine whether different navigational aids will affect individuals' spatial knowledge and evacuation wayfinding performance, four hypotheses are proposed here.

Table 4.3 Evacuation wayfinding hypotheses of navigational aids

Number	Hypotheses	References
N1	Participants only with verbal instructions have the shortest evacuation time.	Chen and Stanney (1999)
N2	The evacuation time of participants with both aids is in between of map only and verbal only participants.	
N3	Participants only with map have the best spatial knowledge, in respect of landmark knowledge.	Guy et al. (1990)
N4	Participants only with verbal instructions have the least spatial knowledge, in respect of landmark knowledge.	

4.2.4 Landmarks

One of the research goals is to examine the role of landmarks in evacuation wayfinding. Based on previous research, city visitors tend to rely on landmarks to orientate themselves. Therefore, ***hypothesis L1*** is proposed here:

L1: Participants tend to use landmarks to orientate themselves in evacuation wayfinding (Lynch, 1960).

4.2.5 Wayfinding strategy

Individuals have different preferences to wayfinding strategies in daily life. Route strategy relies on sequence of instructions (environmental cues), which makes travellers easier to get lost. While, survey strategy is more flexible, using cardinal directions as reference points. Based these findings, three hypotheses are listed below.

Table 4.4 Evacuation wayfinding hypotheses of wayfinding strategy

Number	Hypotheses	References
S1	Participants who applied route strategy are easier to get lost than survey strategy users during evacuation wayfinding.	Boumenir et al. (2010)
S2	Participants who applied survey strategy tend to use sense of direction as reference point to orientate.	
S3	Participants who applied route strategy tend to use landmarks as reference point to orientate.	Prestopnik and Roskos-Ewoldsen (2000)

4.2.6 Psychological condition

The psychological condition can be complicated in evacuation wayfinding, since it is a mixed feeling. To simplify the problem, only two hypotheses are brought up here. The first one is deduced from literatures, investigating emotional feelings of participants. The ***hypothesis P2*** examines the influence of experienced stress level

on evacuation performance. It is notable that the stress level investigated in the experiment is not a dynamic one. But one participant only reports one stress level in the evacuation. The test of *hypotheses P2* is based on discrete samples.

Table 4.5 Evacuation wayfinding hypotheses of psychological condition

Number	Hypotheses	References
P1	Most participants feel anxious during evacuation wayfinding.	Leach (1994), Burns (1998)
P2	The evacuation performance shows a fluctuation pattern along with the increase of stress levels experienced by different participants.	Ozel (2001)

4.2.7 Route choice

In fact, this report has not discussed route choice in literature study, because the focus of research is wayfinding instead of route choice. Section 3.4 mentioned that evacuees tend to choose familiar route for evacuation. The underlying reason is people generally have a risk aversion tendency when they are under stress. Thus, *hypothesis R1* is assumed:

R1: Participants tend to choose learned route during evacuation wayfinding (Murray-Tuite & Wolshon, 2013).

4.3 Conclusion

This chapter proposes a theoretical framework of evacuation wayfinding process. It is based on Passini's theory and wayfinding factors identified in chapter 3. The framework divides the wayfinding process into three interrelated sub-processes, namely decision making, decision execution and information processing. In decision making process, travellers make evacuation choice and destination choice, select wayfinding strategy and plan evacuation route. Then when travellers reach a decision point, they need to take action based on the situation he perceived. The information processing supports two decision-related processes, by evaluating external information and retrieving internal cognitive maps.

Next, based on the built framework and findings discussed in the literature study, some hypotheses of visitors' evacuation wayfinding behaviour are presented. They are classified by the type of wayfinding factors, including personal profile attributes, spatial abilities, navigational aids, landmarks, wayfinding strategy, psychological condition and route choice. All hypotheses are examined in the evacuation experiment which is discussed in the next chapter.

5. Methodology

In this research, a driving simulator experiment is applied to examine the proposed hypotheses. But there are other possible approaches, like real-life experiment and (stated preference) survey. A brief discussion of advantages and disadvantages of each approach is presented in Table 5.1.

The survey asks a set of questions regarding to evacuation wayfinding in an unfamiliar city. The respondents answer questions with their hypothetical choices. However, the survey is unable to investigate individuals' behaviour while driving. Therefore, it is not suitable to study wayfinding problem.

The driving simulator enables participants actually driving while finding ways in a virtual environment. It has been proved that simulator driving behaviour approximates, but does not exactly replicate, on-road driving behaviour (Mullen, Charlton, Devlin, & Bedard, 2011). For the purpose of this research, its validity is sufficient.

The real-life experiment involves conducting evacuation experiment in a real city and the participants driving on roads. It can simulate real evacuation situation in large extent. Despite its high behavioural validity, a real-life urban evacuation experiment is extremely difficult to conduct. Since the involved money, time, material and related authorities problems are all beyond the researcher's capability.

Table 5.1 Comparison of three possible approaches

Approaches	Advantages	Disadvantages
Survey (stated preference)	Easy to conduct, possible to collect large amount of data	Low validity due to lack of actual driving behaviour and emergency feelings
Driving simulator experiment	Provide vivid city view, full controllability of evacuation environment , automatically collect behavioural data, relatively easy to operate	More difficult to drive than real car, potentially cause motion sickness, hard to create real evacuation feelings
Real-life experiment	High validity, close to actual behaviour	Very difficult to perform, considering the study subject is urban evacuation

Based on above discussion and comparison, driving simulator experiment is the best option in this research. The survey may oversimplify the research problem and performing a real-life experiment is unrealistic.

This chapter describes the experiment setup first. After that, the way measures collected in the experiment and data analysis methods are explained in detail.

5.1 Experiment setup

The evacuation experiment was performed in virtual environment, created and displayed via the driving simulator. Thus the first section introduces the configuration of the driving simulator, followed with the design of city network. Then,

assumptions made in the experiment are discussed. The entire experiment consists of four phases and takes approximately 60 minutes to complete. Participant information is briefly illustrated at the last section.

5.1.1 The driving simulator

The driving simulator used in this experiment is owned by Delft University of Technology, Department of Transport and Planning. The description of the driving simulator presented below are cited from Hoogendoorn (2012):

“The driving simulator consists of three screens that placed at an angle of 120 degrees, a driver’s seat mock-up and hardware and software interfacing of this mock-up to a central computer system. The central computer system consists of two personal computers, one as a controller with a Graphical User Interface and the other is a Traffic personal computer. Two personal computers are connected through a Local Area Network (LAN).

From the driver’s seat, the view of the driving environment consists of a projection of in total 210 degrees horizontally and 45 degrees vertically. The applied software was developed by STSoftware. It has several modules: StRoadDesign, StScenario, StControl, StTraffic and StRender.

The driving environments are designed with StRoadDesign. This tool generates a geometrically correlated graphical and logical database required for the traffic module and the graphical rendering module.

The actual test drives are generated with StScenario, which makes use of a scripting language. This scenario controls the module StControl, which provides control over the simulation module StTraffic. StTraffic finally computes the dynamic traffic system based on intelligent agents based technology. During the test drives, the graphics are rendered through StRender at a 60 fps frame rate. ”

5.1.2 Virtual city network

In order to simulate an urban evacuation in driving simulator, a small virtual city was built (8 km from North to South and 10 km from West to East). The author built it with imagination, trying to create a network close to real life but not too complicated. The city’s road network is fairly simple, which is a closed network (no external connections). Southeast part of the city is next to the sea, as a tourist attraction and risky area in the disaster. The full city map is presented in Figure 5.1. All roads in the city are displayed on the map.



Figure 5.1 Virtual city map with landmarks

Buildings and landmarks

Several landmarks are placed in the city, such as windmills, power plant, tall office buildings, etc. As stated in literature study, a salient landmark must contrast with the environment in its attributes (shape and colour, etc.), status (e.g. tourist attraction) or its spatial location compared to others in the environment (e.g. at the intersection) (Caduff & Timpf, 2006). Based on these principles, the setting of landmarks is designed as Figure 5.1. Most landmarks are placed at the intersections (decision points). Two landmarks (landmark 2 and 9) are located in the middle of the path as reassuring cues. The screenshots of landmarks from driver's view are demonstrated in Appendix A.

Buildings placed in the virtual environment have a medium density level within the city and a low density level outside the city (buildings on ring roads). To mimic real city layout, the building styles are distinctive in different blocks, e.g. apartments in residential districts, offices in commercial districts and warehouses in industrial districts.

Road condition

All roads in the city are two-lane ways, carrying bidirectional traffic. Each lane is 3-metre wide. Overtaking is possible on all roads, but U turn is forbidden under any circumstances, due to operational limitation of driving simulator (U turn will cause simulation breakdown). The speed limits are varied on three different types of roads: 70 km/h on ring roads, 60 km/h on normal roads and 50 km/h on primary roads. The city map with speed limits is demonstrated in Appendix B.

Traffic condition

Random road users are generated from three dead-end roads that not shown in the city map. Generated drivers will strictly follow the speed limits. However, because of program error, sometimes they flash wrong directional signal or hit the participant's car without avoidance.

Generated road users are driving to random directions, in both visiting trip and evacuation scenario. And this is informed to the participants, that it is meaningless to follow other road users.

The traffic volume on roads ranges from low to normal, although some intersections may have waiting queues. It is noteworthy that the generation frequencies of road users in both visiting trip and evacuation scenario are the same, suggesting there is no difference in traffic volume under two conditions.

5.1.3 Experiment assumptions

The evacuation wayfinding experiment was designed within the boundary of research scope. Therefore, several assumptions are made as premises of the experiment. The assumptions and their supporting reasons are discussed below.

Assumption 1: all visitors rent cars in the city and they will drive the car to evacuate

Nowadays, car rental is a common way to visit city, which gives visitors more flexibility and convenience (Anable & Gatersleben, 2005). Based on previous study, most people will choose car as their evacuation transport means, if they have access to it. Thus, it is assumed city visitors all rent a car in the city, and they will drive for visiting and evacuation.

Assumption 2: all travellers are first-time visitors in the city.

To ensure the unfamiliarity, a hypothesised virtual city was built. The city network is not in accordance with any existing city. Thus, all participants have no experience with the tested environment, indicating their spatial knowledge can only obtained from the experiment. This gives full controllability of environmental learning means and the formation of cognitive map.

Assumption 3: all participants decide to evacuate immediately.

As mentioned in literature study, the tourists (who unfamiliar with the environment and the disaster) usually possess a higher risk perception in disasters. In addition, the evacuation likelihood and departure time choice are beyond the research scope. Therefore, it is directly assumed all participants will prepare to evacuate after receiving warning message.

Assumption 4: visitors only receive information about the direction and photo of the public shelter in warning message, without address and distance.

Evacuation information provided to evacuees, especially initial warnings, is often unclear, incomplete and even faulty, partly due to limitation of technology and misunderstanding in communication (Kowalski-Trakofler, Vaught, & Scharf, 2003). In this case, the travellers may receive unclear and incomplete information because of language barrier, culture difference and limited information sources (Cahyanto et al., 2014). Even if they ask residents for help on the way, it is possible that the residents just point out the general direction with brief description of the building.

Therefore, in the experiment, it is assumed participants receive help from a hotel manager. The manager shows them a brief description of the public shelter, including its photo, relative direction to the hotel and the global orientation (see Appendix C).

5.1.4 Experimental design and procedure

The whole evacuation wayfinding experiment lasts about 60 minutes. It was divided into 4 phases. Monetary reward (10-euro coupon) was used as an incentive to stimulate participants, motivating them to try their best in the evacuation. Additionally, time countdown was displayed on the screen to give them tension and stress. All these settings were intended to create a real emergency feeling.

Phase one: preliminary survey

First, the participants were asked to read the informed consent, which described the procedure of experiment and risks of motion sickness. After all conditions agreed, they were required to fill a preliminary survey about some demographic questions, like gender, age and driving year, etc. (see Appendix D).

Phase two: visiting trip (trial trip)

To make participants familiar with driving simulator and the virtual city, they were asked to pretend as a business traveller who was the first time to visit this city. Today they need to visit three destinations, two companies for business and windmills for sightseeing. The route has already planned for them and they just need to follow the route under the guidance of navigational aid.

Before the start of visiting trip, participants have to read instructions about how to drive on the simulator and background story of visiting trip. The instruction ensures that no unexpected problem will happen during the experiment, due to the operational limitations in driving simulator. The instruction and background story are illustrated in Appendix E.

In the visiting trip, the participants were randomly divided into three groups, two experimental groups and one control group. All three groups had exactly the same visiting route and destinations. The traffic condition was simulated as normal.



Figure 5.2 Tourist city map and visiting route (3 circled buildings are destinations)

Tourist map group (experimental group 1)

Participants in this group had tourist map at hand during the whole visiting trip. Planned visiting route and position of destination buildings were marked on the map, which was placed next to the steering wheel. However, no verbal instruction was provided. The tourist map only shows part of the city, and the public shelter is beyond the scope of tourist map (Figure 5.2).

Verbal instruction group (experimental group 2)

In the verbal instruction group, participants were guided by voice about where to turn and where to stop. It is assumed that the addresses of destination buildings were inputted in the navigator. The instructions were only simple phrases like turn left, keep straight and turn right. Actually, the instructions were given by the researcher during the visiting trip. Participants had no access to the map.

Both tourist map and verbal instruction group (control group)

Participants who got both navigational aids were assigned to control group. In this group, it is assumed that the addresses of destination buildings were inputted in the navigator. Participants can follow the voice directional guidance whilst follow the planned route on tourist map during the visiting trip.

Phase three: evacuation scenario

After a short break of visiting trip, the participants were informed that a category 5 hurricane is coming and it will land on this city's coastline in short time. They have 15

minutes to evacuate to the public shelter, which is safe and far away from the sea. A simple description of the public shelter was provided to participants, including a photo of the public shelter, its located direction relative to the hotel (northwest direction). The evacuation background story and shelter description is presented in Appendix C.



Figure 5.3 Screenshot of evacuation time countdown (first 15 minutes)



Figure 5.4 Screenshot of evacuation time countdown and money decreasing (Last 5 minutes)

During the evacuation, participants had no assistant tool. In the first 15 minutes, a time countdown and the value of reward (10 euro) were displayed on the screen. But after 15 minutes, the amount of reward money started to drop from 10 euro with a speed of 2 euro per minute (see Figure 5.3 and Figure 5.4). If participant reach the shelter within 20 minutes, a message will show on screen "Evacuation succeed".

On the other hand, if participant couldn't arrive in time, at the moment of 20 minute, the experiment will be terminated, and the evacuation will be announced as a failure: "Evacuation failed".

Although participants were divided into three groups in the visiting trip, they had the same condition in evacuation, no assistance from map, voice or the researcher. In addition, the behaviour of other road users and the traffic condition were unchanged in both visiting trip and evacuation scenario.

Phase four: questionnaire

After the experiment, participants were asked to fill a questionnaire about their behaviour during evacuation. In the end, all participants received 10-euro reward as a compensation of time.

5.1.5 Participants

Experiment participants were recruited from employees and students of Delft University of Technology as well as residents in Delft. All participants must be licensed drivers, but no limitation to their driving habits (left-hand driving and right-hand driving). The experiment had no requirement for driving simulator experience. When participants indicated symptoms of motion sickness, they were excluded from the experiment immediately.

Additionally, all participants were naive as to the purpose of the experiment. They didn't know what kind of behaviour was observed, but they were aware of the evacuation task in advance.

Table 5.2 Description of participants in terms of groups

Groups	Participant Number	Mean age (SD) (years)
Tourist map	17 (Male 12, Female 5)	29,06 (9,48)
Verbal instruction	17 (Male 12, Female 5)	25,53 (4,89)
Both map and instruction	17 (Male 12, Female 5)	27,53 (6,39)
Total	51 (Male 36, Female 15)	27,37 (7,32)

The experiment was conducted from May 13 to May 23, 2015. In total, there are 51 participants completed the experiment. Each experiment group has same participant number and gender distribution (17 participants consists of 12 male and 5 female participants). The age of participants varied from 18 to 50 years. A detailed description of participants is presented in Table 5.2.

Table 5.3 Description of participants in terms of gender

Gender	Participant number	Mean age (SD) (years)
Male	36	27,75 (7,94)
Female	15	26,47 (5,49)

As stated in Table 5.3, the gender distribution is around 7:3 (70.6% male and 29.4% female). The small sample size of female can be explained by two possible reasons. First, men are naturally more interested in driving simulator (they viewed it as a

video game) compared to women. The second reason is related to the dissemination of recruitment information. It was mainly posted in the faculty of Civil Engineering and Geosciences, which possesses larger share of male students and employees than female.

Additionally, there are 6 participants having prior driving simulator experience and only 2 participants reported a real evacuation experience.

5.2 Data collection

This section gives a description of the way information collected in the experiment. Most personal information, such as map reading skill, sense of orientation and wayfinding strategy, are based on self-report. Only the spatial knowledge is evaluated through landmark recognition questions. Other behavioural information, like speed, time and selected route were recorded by the driving simulator automatically.

General behavioural data

The general behavioural data mainly collected by driving simulator, including the average speed and evacuation time. However, there is one exception that the self-reported speed limit following behaviour is also included here, as a comparison of recorded speed. Since all participants are advised to follow the speed limit under any circumstance.

Personal profile

All personal profile Information is collected from the preliminary survey, including gender, age, education level, licensed driving years and driving frequency.

It is important to mention the factor driving experience is investigated from two aspects, licensed driving years and driving frequency. The reason is that most recruited participants are students, who cannot get access to car in daily life even though they have held a driving license for long time. Especially international students, they may drive daily at home but don't drive at all when they are in the university. Hence, the licensed driving year does not necessarily resulted in more driving experience. Under this consideration, driving frequency was also examined in preliminary survey.

The driving frequency is measured with four degrees: daily (drive every day), frequently (several times per week), occasionally (several times per month) and seldom (several time per year). International students described above selected occasionally in questionnaire.

Spatial abilities

The measurement of spatial abilities is based on self-assessment. Participants gave their self-rated score in questionnaire, in terms of map reading skill and sense of orientation in real life. The rating scale for both abilities is ranging from 1 to 5, in

which 3 stands for normal. Additionally, whether they have lost during the evacuation wayfinding is also examined through self-report.

Landmarks knowledge

The participants' landmark knowledge was tested by landmark recognition question. In the questionnaire, participants viewed 11 landmarks; 6 of these landmarks were identical to the landmarks in the city and 5 landmarks had never been placed in the network. The nonexistence landmarks in the questionnaire are number 1, 4, 8, 9 and 10 (see question 13 in Appendix F). The landmark knowledge is quantified by the number of correctly identified landmarks in questionnaire.

Table 5.4 Overview of data collected in experiment

Measures	Collection ways	Data format
Velocity	Driving simulator	Km/h
Evacuation time	Driving simulator	minutes
Speed limit	Self-reported in questionnaire	Yes/No
Gender	Preliminary survey	Male/Female
Age	Preliminary survey	Years
Education level	Preliminary survey	Four type of degrees
Driving years	Preliminary survey	Four ranges of driving years
Driving frequency	Preliminary survey	Four degrees of frequency
Navigational aids	Given	
Map reading skill	Self-rated in questionnaire	1 – 5 scale
Sense of orientation	Self-rated in questionnaire	1 – 5 scale
Lost in wayfinding	Self-reported in questionnaire	Yes/No
Spatial layout	Self-reported in questionnaire	Descriptions
Landmarks	Identification in questionnaire	No. of landmarks recognized
Wayfinding strategy	Self-reported in questionnaire	Descriptions
Reference point	Self-reported in questionnaire	Descriptions
Stress level	Self-reported in questionnaire	1 – 10 scale
Main source of stress	Self-reported in questionnaire	Descriptions
Emotional feelings	Self-reported in questionnaire	Descriptions
Preferred route choice	Self-reported in questionnaire	Descriptions
Actual route choice	Driving simulator	Path number
Driving simulator experience	Preliminary survey	Yes/No
Real evacuation experience	Self-reported in questionnaire	Yes/No

Wayfinding strategy

The wayfinding strategies were collected by self-report in questionnaire. And the reference points in wayfinding were also asked as a supporting measure to wayfinding strategy.

Psychological condition

The data related to psychological condition was collected from three aspects: the stress level (before and during evacuation), the main source of stress and the emotional feelings during evacuation. The stress level is measured in scale of 10. All these information are collected via questionnaire.

Route choice

The route choice was examined in two ways, the preferred route choice strategy and actual selected route. The former one was asked in questionnaire and the latter one was automatically recorded by driving simulator.

5.3 Data analysis methods

Because various types of data are collected in the experiment, the analysis methods are varied with respect to each specific factor. This section introduces general principle of how data is analysed.

Descriptive analysis

The descriptive analysis is performed on almost all data, including the description of mean, standard deviation, numbers, percentages and coefficient of variance, etc. For descriptive factors, like wayfinding strategy, only descriptive analysis is applied. Additionally, if the sample size is too small, to avoid bias only descriptive analysis is used.

Statistical analysis

Due to small sample size, the statistical analysis can be found weak and even invalid. Thus, only when the sample size is large enough, a statistical analysis is conducted. Since the sample size is relatively small, most groups are not normally distributed. To compare differences and examine correlations, nonparametric tests are widely used in result analysis.

The normality of tested group is examined before analysis. If it is normally distributed, one-way ANOVA is used, regardless sample number. If the tested group is not subject to normal distribution, nonparametric tests are applied. For two independent samples, Mann-Whitney U test is used. For more than two samples, Kruskal-Wallis test is used.

In terms of correlation analysis, only Kendall rank correlation test is used in the report. Since most measures are scores, instead of continuous variables.

It is notable that to simplify the problem, all factors are assumed independent. Several interactions between factors are analysed here, such as gender's influence to spatial abilities. But some underlying relations are neglected, like the driving year and age and education level and age.

5.4 Conclusion

This chapter introduces the methodology applied in this research. An evacuation experiment based on driving simulator is used to investigate the evacuation wayfinding behaviour of city visitors. The experiment design, assumptions and procedures are all discussed in detail. Further, considering the large amount of data involved in the experiment, an overview of data collection ways and data format is presented. The last section illustrates two data analysis methods and their application principles in this research.

The result of the evacuation experiment based on descriptive and statistical analysis is demonstrated in next chapter. According to the result, hypotheses proposed in chapter 4 are examined.

6. Result analysis

This chapter illustrates the experiment result based on the types of wayfinding factors. Both descriptive and statistical analysis is conducted to examine the hypotheses proposed in previous chapter. The judgements of all hypotheses are concluded in the last section of this chapter.

6.1 Participant overview

In total, there are 54 participants joined the experiment, among which 51 participants completed the experiment. 3 participants dropped the experiment due to motion sickness. An overview of participants' profile is given below.

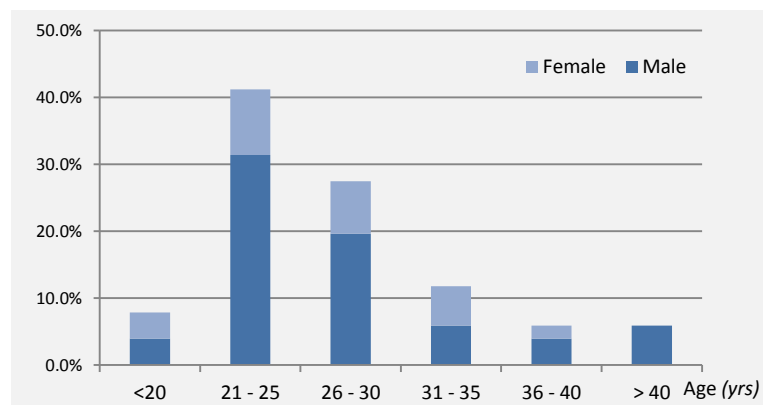


Figure 6.1 Age distribution in terms of gender

The age distribution corresponds to the sources of participants. As discussed before, most participants are students, normally ranging from 21 to 30 years old. In fact, almost 70% participants are between 21 and 30, and males are dominant within this range. Over 40, there is no female participant. The small sample size of female participants makes the results derived from females lacking representatives. Hence, findings related to gender differences are speculative.

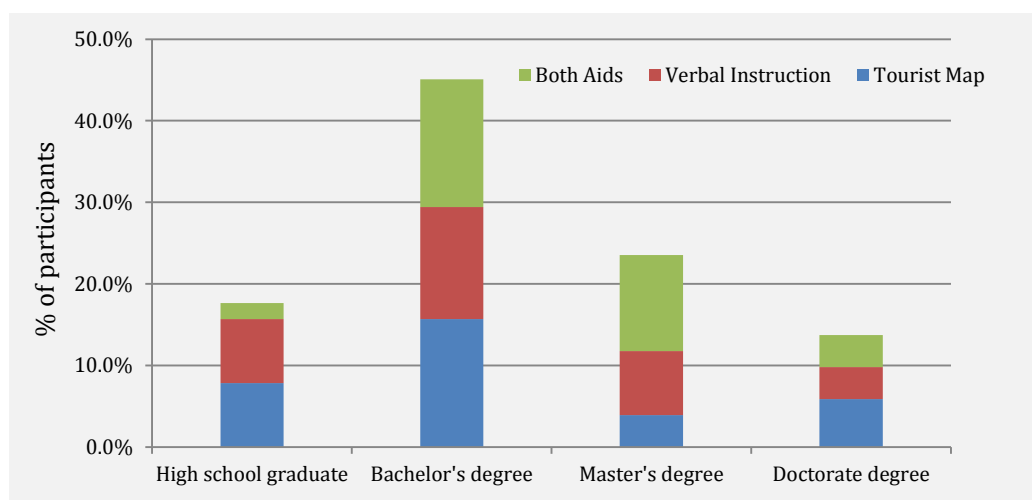


Figure 6.2 Distribution of education level

As illustrated in Figure 6.2, most participants are master students (who possess a bachelor degree). PhD students (with a master degree) rank the second, followed

with employees (with a doctorate degree). And each experimental group (different navigational aids) has generally same distribution in education levels.

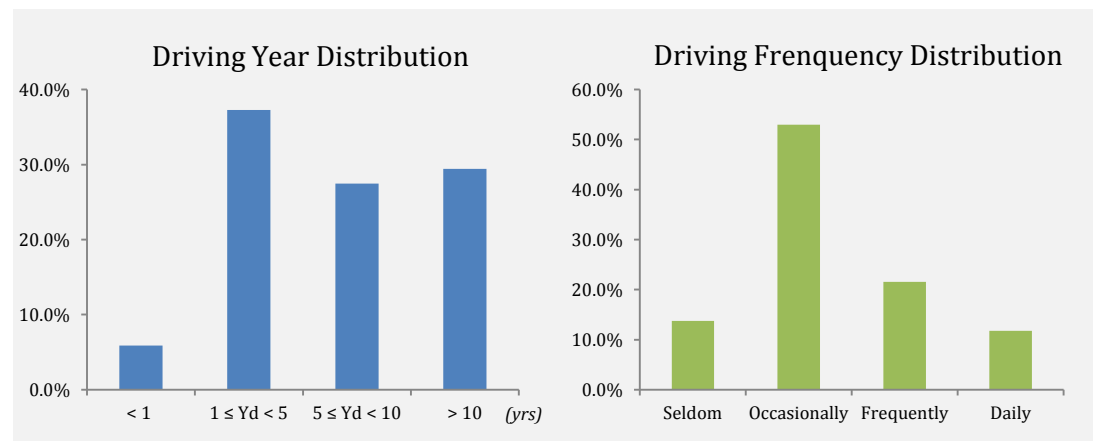


Figure 6.3 Driving experience distribution

As mentioned in data collection, driving experience is measured in two aspects, driving (licensed) year and driving frequency. Participant distribution of these two aspects is presented above (Figure 6.3). From observation, driving year is corresponding to age distribution. Participants who licensed less than five years roughly correspond to participants 21 to 25 years old. In addition, the driving frequency distribution is similar to education level distribution. It confirms that bachelor and master students drive occasionally.

6.2 Experiment result overview

The general result of evacuation experiment is described in Table 6.1, focusing on success rate and average speed. More detailed discussions related to specific factors are presented in following sections.

Table 6.1 Evacuation result and average speed

Evacuation time	Number	Percentage of total	Average speed (km/h)		
			Mean	SD	CV
Within 15 min	22	43.1%	64.46	13.65	0.21
Within 20 min	27	52.9%	62.79	12.97	0.21
Total	51		62.97	12.79	0.20

The evacuation scenario can be viewed as two stages, based on experimental design. First 15 minutes is recommended evacuation time and last 5 minutes is the final rush. If the participant arrived at the shelter within 20 minutes, his evacuation was announced as a success. As shown in Table 6.1, the success rate of evacuation wayfinding task is 52.9%, indicating almost half of the participants failed to reach the safe shelter before the disaster impact. And the ratio of arriving in recommended time is even 10% less. This result confirms the problem statement of research in some extent, that city visitors have difficulties in finding ways during evacuation.

The average evacuation time is 13.59 minutes, only taking successful participants into calculation. The average speed is almost the same for both succeed and failed

participants, in respect of mean average speed, standard deviation and coefficient of variance. This fact suggests that velocity has no influence on the success rate of evacuation task. However, the average speed of participants (62.97 km/h) is slightly beyond the general speed limit on road (60 km/h), which shows the urgency felt by participants during the evacuation.

6.3 Personal profile

The effects of four personal profile attributes on evacuation wayfinding are presented in this section. And the hypotheses associated with these factors are evaluated as well.

6.3.1 Gender

According to literature study, males usually outperform females in wayfinding tasks. It is notable that all percentages presented in bar chart are calculated in terms of total number of males or females.

As presented in Table 6.2, men have significant higher success rate (more than twice) than women in evacuation wayfinding task. But the average evacuation time is almost the same, despite the small number of successful females. Actually, there is no sex difference found in time to complete wayfinding tasks (Prestopnik & Roskos-Ewoldsen, 2000). The experiment result corresponds to that. Based on the differences in success rate, **hypothesis G1** is accepted.

Table 6.2 Descriptive statistics of gender differences in evacuation wayfinding

Measure	Male (n=36)	Female (n=15)	Overall (n=51)
Evacuation results			
Within 15 min (success rate)	19 (52.78%)	3 (20.0%)	22 (43.1%)
Within 20 min (success rate)	23 (63.89%)	4 (26.7%)	27 (52.9%)
Average time (SD) (min)	13.56 (2.35)	13.73 (2.72)	13.59 (2.40)
Average speed (SD) (km/h)	63.90 (12.74)	60.72 (12.64)	62.97 (12.79)
Beyond speed limit	26 (72.2%)	8 (53.3%)	34 (66.7%)
Spatial abilities			
Map reading skill ^a (SD)	4.03 (1.01)	3.27 (1.18)	3.80 (1.12)
Spatial orientation ^a (SD)	4.08 (0.72)	2.93 (1.48)	3.75 (1.13)
Psychological condition			
Initial stress level ^b (SD)	2.64 (1.75)	4.00 (2.22)	3.04 (2.00)
Evacuation stress level ^b (SD)	5.39 (2.00)	6.33 (1.74)	5.67 (1.98)
Change of stress level (SD)	2.75 (2.35)	2.33 (2.24)	2.63 (2.33)
Spatial knowledge			
Landmark recognition (SD) (correct number)	3.42 (1.14)	3.07 (1.12)	3.31 (1.15)
Landmark recognition (accuracy)	77.8%	82.1%	79%

Note: ^a scale ranges from 1 to 5 (3 stand for normal); ^b scale ranges from 1 (low) to 10 (high)

The average speed of female drivers is slightly lower than male drivers, which is in accordance with answers in questionnaire. More than 70% males reported they did not follow the speed limit, while only half of females claimed so. This fact may indicate that female is more careful in driving, even under emergency situation. Another explanation is that male participants viewed the driving simulator experiment as a game, but not a serious driving in real life. Regardless of the minor gender differences in velocity, both male and female drivers were driving slightly beyond speed limit in general.

Based on previous studies, males tend to rate higher score on spatial orientation. They averagely scored 4.08. On the contrary, females are more moderate, that they gave a score of 2.93 in average, which is lower than the normal level 3. The low score of females suggests that most women think they have a bad sense of orientation. According to Mann-Whitney U test, it can be stated that males' spatial orientation ability is significantly better than females' ($p = 0.01 < 0.05$). **Hypothesis G2** is accepted.

As presented in Table 6.2, males averagely scored 1 point higher than females in map reading skill. There is statistically significant difference between males and females in self-rated map reading skill (Mann-Whitney U test, $p = 0.034 < 0.05$). Thus, the **hypothesis G3** is also accepted.

The landmark knowledge is measured by correctly identified landmark numbers. As shown above, the males recognised 3.42 landmarks on average, and the number of females' only slightly smaller (3.07 landmarks). No statistically significant difference can be identified based on Mann-Whitney U test ($p = 0.242 > 0.05$). In addition, the difference in accuracy of landmark recognition is minor as well. In conclusion, **hypothesis G4** is rejected.

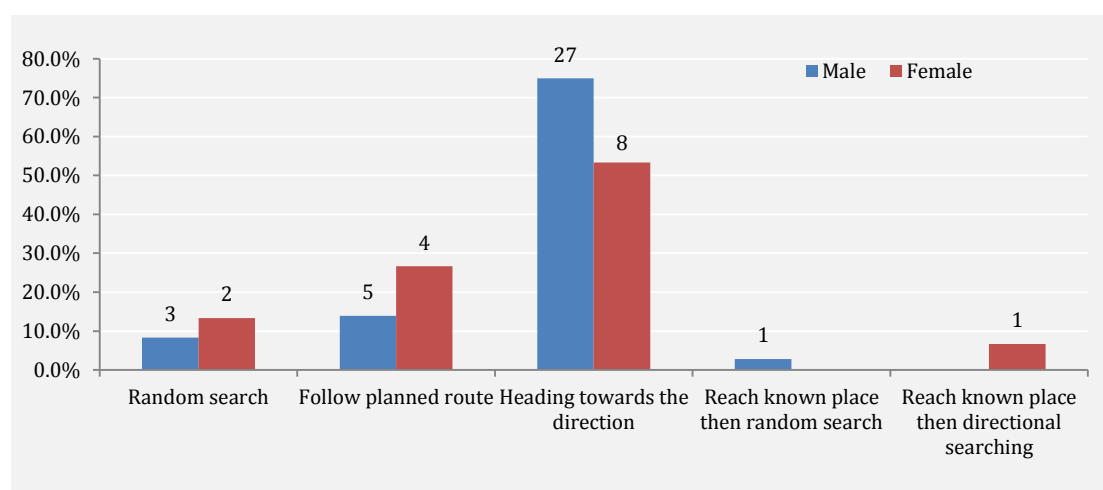


Figure 6.4 Gender differences in self-reported wayfinding strategies
(See question 8 in Appendix F)

The wayfinding strategies applied by male and female during the evacuation are presented in Figure 6.4 (labelled with the number of participants who chose that option). The strategy "heading towards the direction" was mostly used, which is a

pure survey strategy. This may be caused by provided evacuation information (Appendix C), with only direction and photo of the shelter.

However, the result still shows a weak sex difference in wayfinding strategies. Females' choices are more disperse, unlike males' (75% men chose heading towards the direction). Over 25% females planned a certain route to follow before evacuation. But all 4 female participants who applied this strategy got lost and failed the task.

Based on results illustrated in Figure 6.4, the **hypothesis G5** is accepted, because male did show a clear preference to survey strategy in evacuation wayfinding. While, **hypothesis G6** cannot be proved, since female preferred survey strategy as well. It is noticeable that the design of experiment could cause bias on participants' behaviour.

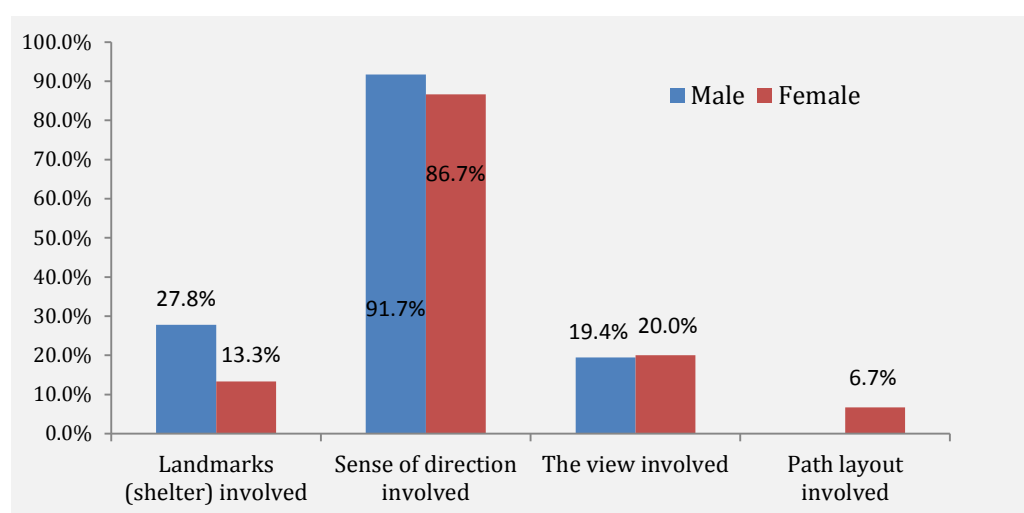


Figure 6.5 Gender differences of self-reported reference points in evacuation wayfinding
(Multi-choice, see question 12 in Appendix F)

As presented in Figure 6.5, the utilization of reference points is roughly corresponding to the application of wayfinding strategies. Majority males and females used sense of direction as their reference point. This may explain why female participants have such high failure rate, since they have bad spatial orientation ability. But surprisingly, larger proportion of males applied landmarks (shelter is also a landmark) to assist wayfinding.

In literature, women are reported more stressful in wayfinding tasks. As the stress level shown in Table 6.2, the female participants have higher stress level (6.33) during evacuation. The males scored one point lower than females (5.39). However, based on the result of Mann-Whitney U test, the stress level of females is not statistically significantly differed from males ($p = 0.183 > 0.05$). The **hypothesis G7** is rejected.

The emotional feelings during evacuation are displayed in Figure 6.6. Most participants felt excited and rushed. One possible reason is that they viewed the evacuation experiment as a game. The difference in anxiety feeling between men and women is minor, only 8% more in females. Considering the small sample size of female participants, affirmative conclusion cannot be drawn on **hypothesis G8**.

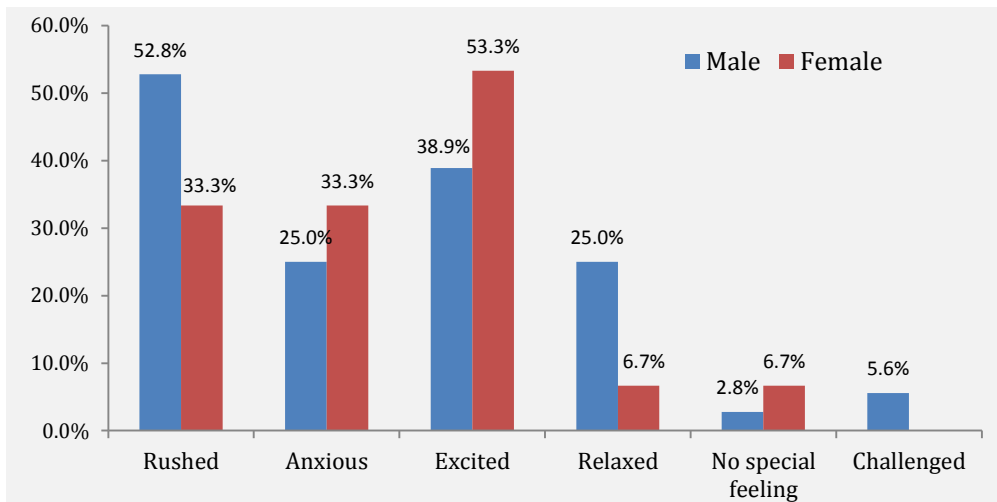


Figure 6.6 Gender differences in self-reported emotional feelings in evacuation wayfinding
(Multi-choice, see question 15 in Appendix F)

6.3.2 Age

Elderly drivers reported difficulties in wayfinding. Thus it is assumed that they tend to perform less well compared to younger drivers. However, in the experiment, the age range of participants is relatively narrow, only from 18 to 50. No real elderly drivers involved. Hence, age related findings in this experiment are unpersuasive. The results of age differences are presented below.

Table 6.3 Description of age differences in evacuation wayfinding

Measures	≤ 30 (n=39)	> 30 (n=12)
Mean Age (SD) (yrs)	24.03 (3.17)	38.25 (6.73)
Within 15 minutes	16 (41.0%)	6 (50.0%)
Within 20 minutes	19 (48.7%)	8 (66.7%)
Landmark recognition (correct number)	3.36 (1.09)	3.17 (1.40)
Landmark recognition (accuracy)	81.3%	71.1%
Most familiar route strategy	8 (20.5%)	2 (16.7%)

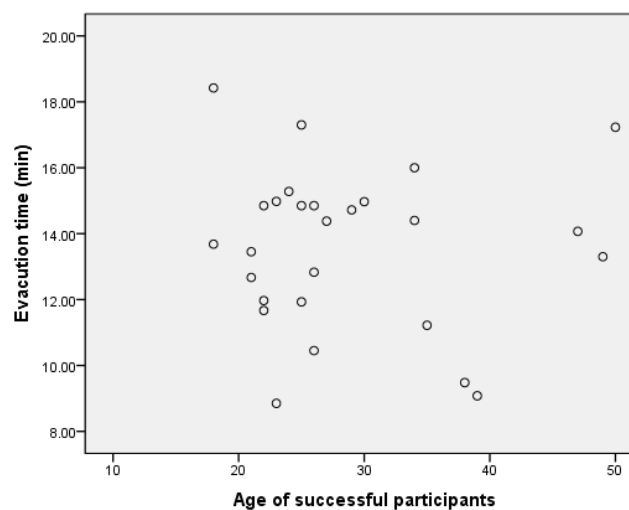


Figure 6.7 Scatter chart of age and evacuation time

To avoid bias caused by small sample number, the participants are divided into two groups for analysis. Based on the results shown in Table 6.3, there is no obvious difference in success rate between drivers younger than 30 and drivers older than 30. In fact, relatively elder drivers performed slightly better than younger drivers, with respect to success rate. This can be caused by differences in driving experience. Figure 6.7 illustrates the relation of age and evacuation time. No correlation can be found on this chart as well. Therefore, **hypothesis A1** cannot be decided here, mainly due to lack of aged drivers.

Hypothesis A2 suggests younger drivers have better landmark knowledge. But the differences demonstrated in Table 6.3 are small, for both correct landmark numbers and recognition accuracy. The statistical analysis shows similar conclusion (Mann-Whitney U test, $p = 0.794 > 0.05$). Thus, no affirmative conclusion can be stated. This is caused by the same reason, that the narrow age range restricts observations.

The presented experiment result seems contrary to the **hypothesis A3**. Younger drivers more prefer taking familiar routes. However, considering the age range of participants, this hypothesis cannot be rejected neither.

6.3.3 Education level

There has no clear evidence proved the education level would influence wayfinding. Thus, **hypothesis E1** assumes no significant difference will be found between different education levels. The experiment results are presented in Table 6.4. Judging from the success rate, no obvious tendency can be generalised. Considering only a few participants succeed in groups other than Master's degree, statistical analysis cannot be performed in respect of evacuation time. Simply based on direct observation of success rate, the **hypothesis E1** is accepted. But due to the unbalance of participant number in different education levels, this judgment is debatable.

Table 6.4 Description of education level differences in evacuation wayfinding

Education level	N	Within 15 min	Within 20 min	Time (SD) (min)
High school	9	3 (33.3%)	5 (55.6%)	15.14 (2.64)
Bachelor's	23	12 (52.2%)	14 (60.9%)	13.33 (2.25)
Master's	12	3 (25%)	4 (33.3%)	14.26 (1.70)
Doctorate	7	4 (57.1%)	4 (57.1%)	11.90 (3.05)

6.3.4 Driving experience

The measurement of driving experience is split into two aspects: driving frequency and driving (licensed) year. Table 6.5 presents general effects of driving experience on evacuation wayfinding. Regarding to driving frequency, the result is unexpected, that participants who drive everyday performed worst. This can be caused by sample bias, or it indicates that driving frequency has little influence on evacuation wayfinding. After all, higher driving frequency does not necessarily lead to more driving experience.

Based on the success rates of four licensed year groups, no clear tendency can be observed. And the average evacuation time seems randomly distributed. Thus, the assumed positive correlation between driving experience and evacuation wayfinding performance cannot be verified. The **hypothesis D1** cannot be judged here. Simply based on observation, the differences of success rate between groups are not significant, thus it cannot be rejected neither.

The **hypothesis D2** suggests experienced drivers have better landmark knowledge. According to the number of correctly recognized landmarks in each licensed year group, this correlation cannot be identified (Kendall rank correlation test, $p = 0.381$). The result of Kruskal-Wallis test proves no significant differences between driving year groups ($p = 0.830$ when < 1 group is included, and $p = 0.981$ when < 1 group is excluded). Therefore, the **hypothesis D2** is rejected.

Table 6.5 Description of driving experience differences in evacuation wayfinding

	N	Within 15 min	Within 20 min	Time (SD) (min)	Correct Landmarks (SD)
Frequency					
Daily	6	0	1 (16.7%)	17.23	2.83 (1.17)
Frequently	11	5 (45.5%)	6 (54.5%)	13.53 (2.76)	3.45 (1.29)
Occasionally	27	16 (59.3%)	17 (63.0%)	13.35 (2.01)	3.33 (1.21)
Seldom	7	1 (14.3)	3 (42.9%)	13.81 (4.41)	3.43 (0.79)
Licensed years (yrs)					
< 1	3	1 (33.3%)	1 (33.3%)	13.68	2.67 (1.53)
$1 \leq Y_d < 5$	19	8 (42.1%)	10 (52.6%)	13.61 (2.85)	3.42 (1.07)
$5 \leq Y_d < 10$	14	5 (35.7%)	6 (42.9%)	13.78 (1.84)	3.21 (1.25)
> 10	15	8 (53.3%)	10 (66.7%)	13.45 (2.71)	3.40 (1.18)

Additionally, it is found the increase of driving year can lead to better map reading skill, based on the result of correlation analysis ($\tau = 0.211$, $p = 0.04 < 0.05$) presented in Table 6.6. However, the personal map reading skill can be affected by other profile attributes, such as age, which is interrelated with licensed year. Therefore, without further investigation, no conclusion can be stated on it.

Table 6.6 Correlation analysis of licensed year

Factor	Measures	Mean	SD	τ	Sig.
Licensed Years	Map reading skill	3.80	1.13	0.211*	0.040
	Sense of orientation	3.75	1.15	0.191	0.057
	Correct landmarks	3.31	1.16	0.037	0.381
	Evacuation stress	5.67	2.00	0.163	0.078

τ . Kendall rank correlation coefficient *. Correlation is significant at the 0.05 level (1-tailed).

6.4 Spatial abilities

This section examines the impact of map reading skill and spatial orientation ability through both descriptive and statistical analysis. Because two abilities are measured in scale of 5 (3 stands for normal), to avoid sample bias, the participants are analysed in two groups, participants who scored higher than 3 and the rest.

Table 6.7 Description of spatial abilities differences in evacuation wayfinding

	N	Within 15 min	Within 20 min	Time (SD) (min)	Correct Landmarks (SD)
Map reading skill (mean = 3.80)					
Score ≤ 3	18	4 (22.2%)	6 (33.3%)	14.44 (3.36)	3.44 (0.98)
Score > 3	33	18 (54.5%)	21 (63.6%)	13.35 (2.17)	3.24 (1.25)
Spatial orientation (mean = 3.75)					
Score ≤ 3	15	3 (20%)	4 (26.7%)	15.05 (2.64)	3.27 (1.28)
Score > 3	36	19 (52.8%)	23 (63.9%)	13.33 (2.39)	3.33 (1.12)

As shown in Table 6.7, the participants who rated higher in map reading skill have almost twice success rate in evacuation task. Due to this significant difference, **hypothesis M1** is accepted. The two spatial orientation groups have similar results. Drivers who scored higher in sense of orientation have much higher success rate. Thus, the **hypothesis O1** is also accepted.

Based on Table 6.7, the differences of evacuation time and landmark knowledge in two spatial abilities are difficult to identify simply based on observation. Therefore, a correlation analysis is conducted, presented in Table 6.8. It is notable that the time of failed evacuation task is also included, to avoid bias in analysis. As the experiment would stop after 20 minutes, the time of failed evacuation task was recorded as a little bit more than 20 minutes.

Table 6.8 Correlation analysis of spatial abilities

Measures	Kendall rank correlation test (rated scores)	
	τ	Sig. (1-tailed)
Map reading skill		
Evacuation time (min)	-0.191*	0.040
Correct landmarks	-0.038	0.375
Spatial orientation		
Evacuation time (min)	-0.262**	0.008
Correct landmarks	0.050	0.339

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

The evacuation time is significantly correlated with two spatial abilities. Two negative coefficients indicate better map reading skill and spatial orientation ability lead to shorter evacuation wayfinding time. Therefore, **hypothesis M2** and **O2** are both accepted.

It is also assumed that better spatial abilities will result in better landmark knowledge. However, according to above analysis, there is no significant correlation can be identified. Hence, **Hypothesis M3** and **O3** are rejected.

6.5 Navigational aids

Three experimental groups had different navigational aids, which were randomly assigned to participants. It is assumed that the navigational aids would affect the formation of cognitive map and thereby influencing wayfinding performance. The

general results of three groups are presented in Table 6.9 and Table 6.10. The evacuation success rates are similar in three experimental groups.

The impact of navigational aids on gender difference has not mentioned in the hypotheses. The gender differences caused by different navigational aids are significant. No verbal aided female participants succeed in evacuation task. Contrary to that, males in verbal instruction group have the highest success rate (75%). Considering only 5 females in each group, no affirmative conclusion can be drawn here. However, this result gives some insights of how navigational aids affect environmental learning and wayfinding performance. One possible explanation to this result is the gender difference in spatial orientation ability.

Table 6.9 General results of navigation aid differences in evacuation wayfinding

Navigational Aids	Within 15 min			Within 20 min		
	N (n=17)	Male (n=12)	Female (n=5)	N (n=17)	Male (n=12)	Female (n=5)
Map	7 (41.2%)	5 (41.7%)	2 (40%)	8 (47.1%)	6 (50%)	2 (40%)
Verbal	8 (47.1%)	8 (66.7%)	0	9 (52.9%)	9 (75%)	0
Both	7 (41.2%)	6 (50%)	1 (20%)	10 (58.8%)	8 (66.7%)	2 (40%)

Hypothesis N1 states that verbal aided group has the shortest evacuation time. Obviously it is not true according to Table 6.10. The average evacuation time of verbal aided group ranks the second, which does not correspond to **hypothesis N2**. The evacuation time in three groups is subject to normal distribution. Thus one-way ANOVA is applied to examine the difference between groups (sig. of variance homogeneity = 0.378). No statistically significant difference is found in evacuation time of three groups ($F = 1.599$, $p = 0.223 > 0.05$). To conclude, **hypothesis N1** and **N2** cannot be judged based on experiment results, due to the insignificant difference. After all, from observation, the differences of evacuation time between three groups are only one minute.

Table 6.10 Descriptive statistics of navigation aid differences in evacuation wayfinding

Navigation Aids	Time (SD) (min)	Lost rate	Correct landmarks (SD)	Landmarks (accuracy)
Map	12.57 (2.73)	11 (64.7%)	3.53 (1.13)	86.3%
Verbal	13.39 (2.73)	10 (58.8%)	3.12 (1.32)	73.5%
Both	14.58 (1.70)	11 (64.7%)	3.29 (1.05)	76.9%

The results of landmark recognition are presented in Table 6.10. As suggested in **hypothesis N3** and **N4**, map aided group identified most correct landmarks and verbal aided group recognized least. Based on Kruskal-Wallis, there is no significant difference between three groups in landmark recognition ($p = 0.616 > 0.05$). Thus, no conclusion can be made regarding to **hypothesis N3** and **N4**.

6.6 Landmarks

Only one hypothesis is proposed on landmarks. Since the recognition of landmarks is used as a measure to evaluate cognitive map and spatial, there is no need to discuss it here. The importance of landmarks has been stated many times in literature.

Hence, it is expected that city visitors will use landmarks to assist wayfinding in evacuation. However, the result displayed in Table 6.11 indicates differently. Only 12 participants (23.5%) used landmarks to orientate themselves in evacuation. On the contrary, over 90% participants applied sense of direction as reference point. No statistical analysis can be performed on this factor. Therefore, simply based on descriptive results, the *hypothesis L1* is rejected.

Table 6.11 Utilization of reference points in evacuation wayfinding

Reference points*	Participant number	Percentage in total
Landmarks (shelter) involved	12	23.5%
Sense of direction involved	46	90.2%
The view involved	10	19.6%
Path layout involved	1	2.0%

*. Multi-choice question, see question 12 in Appendix F.

6.7 Wayfinding strategies

As shown in Table 6.12, it is clear that pure survey strategy “heading towards direction” is dominant, 68.6% in total. It has the highest success rate (62.9%) among all wayfinding strategies. The second rank strategy is route strategy “follow planned path”. It has exceptional high probability of getting lost (88.9%) and very low success rate (22.2%). The third rank strategy “random search” does not belong to either strategy. The remaining two strategies are neglected in discussion, since only two participants used them.

Table 6.12 Description of wayfinding strategies in evacuation

	Participant number	Success rate (within 20 min)	Lost rate
Random search	5 (9.8%)	3 (60%)	4 (80%)
Follow planned path	9 (17.6%)	2 (22.2%)	8 (88.9%)
Heading towards direction	35 (68.6%)	22 (62.9%)	19 (54.3%)
Reach know place then random search	1 (2.0%)	0	0
Reach known place then heading to the direction	1 (2.0%)	0	1 (100%)

Based on *hypothesis S1*, participants who use route strategy are easier to get lost. It can be easily proved by its high lost rate. And as landmarks, wayfinding strategies cannot be analysed statistically. Therefore, the *hypothesis S1* is accepted according to descriptive results.

Table 6.13 Relation of wayfinding strategy and reference point

Reference points	Random search (n = 5)	Follow planned path (n = 9)	Heading towards direction (n = 35)
Landmark involved	2 (40%)	3 (33.3%)	6 (17.1%)
Sense of direction involved	4 (80%)	6 (66.7%)	34 (97.1%)
The view involved	2 (40%)	3 (33.3%)	6 (17.1%)
Path layout involved	0	1 (11.1%)	0

Furthermore, the reference points used by participants are largely determined by their wayfinding strategies. The relations between reference points and wayfinding strategies are demonstrated in Table 6.13. Almost all participants who applied survey strategy “heading towards direction” used sense of direction as their reference point in evacuation. However, for participants who preferred route strategy, the use of landmarks and path layout is not dominant. Instead, most of them used sense of direction to orientate. As mentioned previously, the provided evacuation information may lead to bias on their choices. Despite of the possible bias, the **hypothesis S2** is accepted and the **hypothesis S3** is rejected, simply according to the results of experiment.

6.8 Psychological condition

The overview of participants’ emotional feelings during evacuation wayfinding is illustrated in Figure 6.8. Two major feelings are rushed and excited. Anxious feeling ranks the third. It seems that most participants felt the time pressure due to the countdown on screen. This is supported by the main source of stress (see Figure 6.9). In addition, participants were excited about the evacuation task, viewing it as an interesting game. The proportion of anxious feeling only accounts for 27.5%. Thus, the **hypothesis P1** is rejected based on the experiment result.

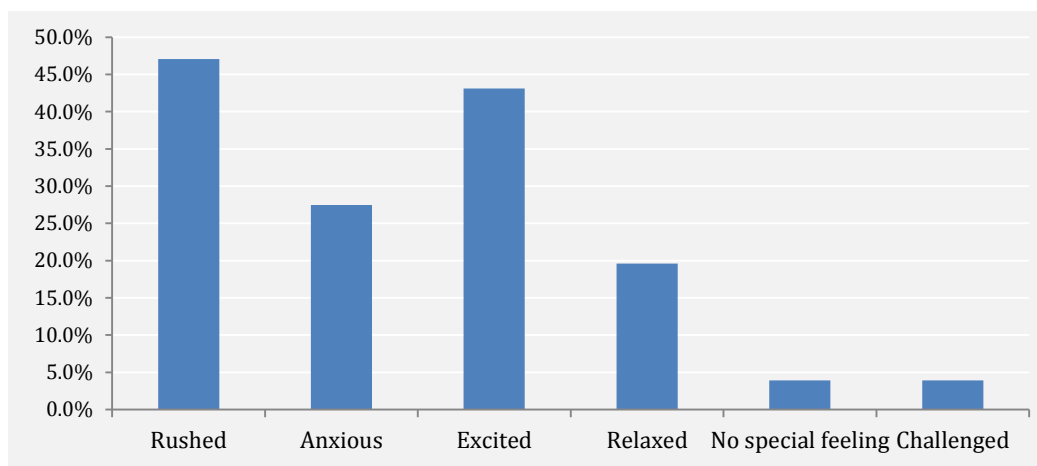


Figure 6.8 Overview of emotional feelings during evacuation wayfinding

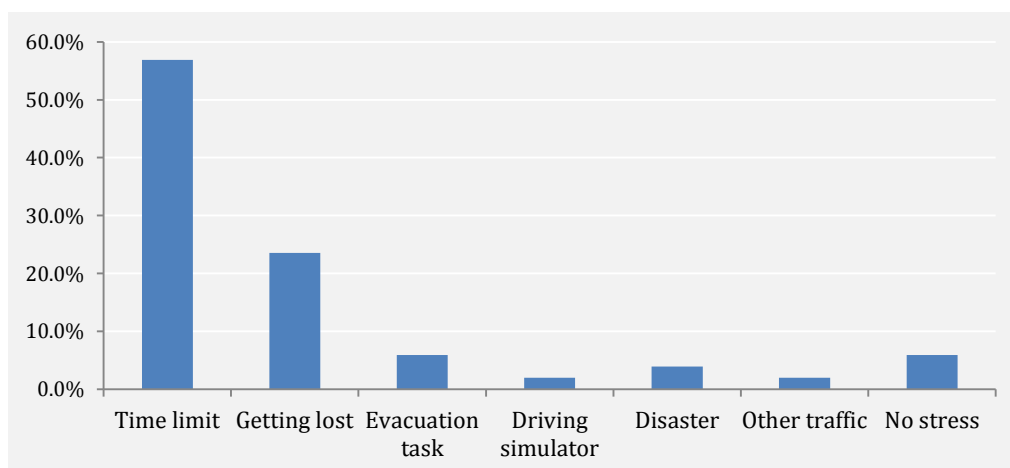


Figure 6.9 Overview of main sources of stress in evacuation wayfinding

The **hypothesis P2** assumes the evacuation performance fluctuates along with the increase of stress levels experienced by different individuals. As presented in Figure 6.10 and Figure 6.11, the evacuation success rate and evacuation time is not linear related to stress. It can be observed that participants whose stress levels are 3 and 6 have high success rate. This corresponds to the evacuation time plot. Within certain range of stress level, the evacuation performance is improved. And when the stress reaches certain points (such as 6), the evacuation performance starts to decrease. Based on these two figures, the **hypothesis P2** can be accepted in some extent. But since this result depends on self-rating, it may be inaccurate and bias. More investigation is required to make a clear statement.

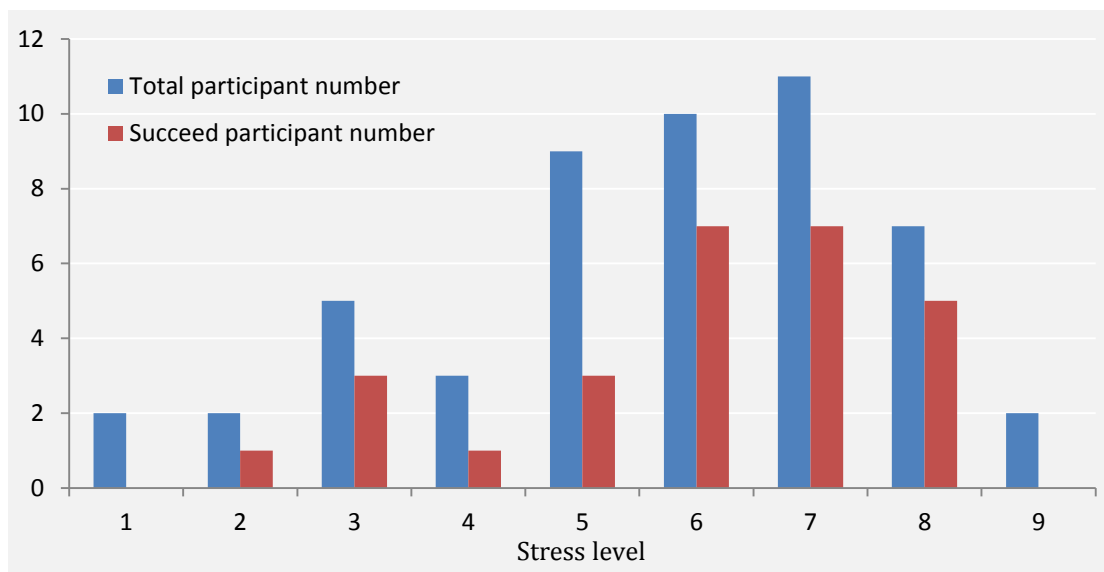


Figure 6.10 Stress level difference in successful participant number

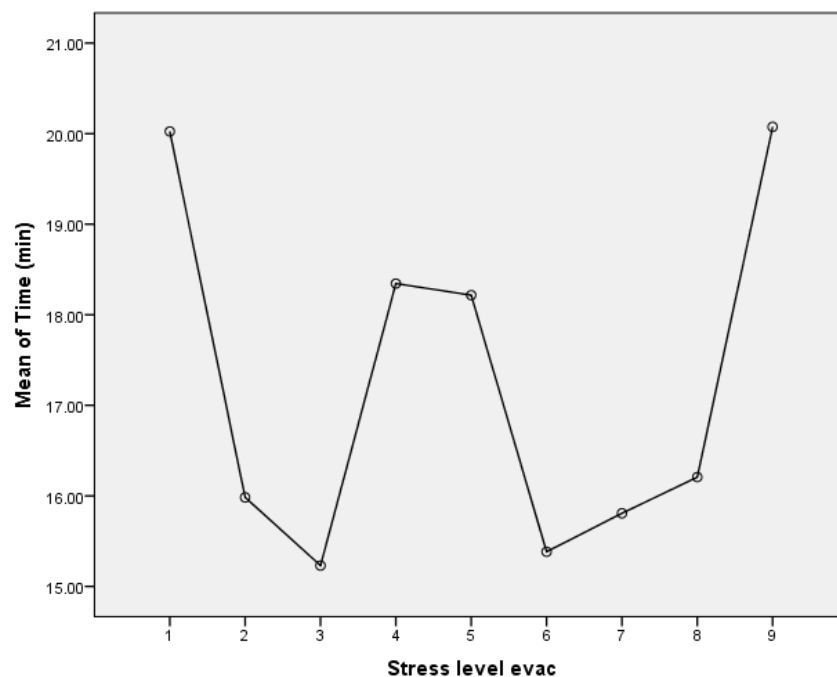


Figure 6.11 Evacuation time plot regarding to evacuation stress level

6.9 Route choice

Since route choice is not the focus of this research, this section just briefly discusses it based on the evacuation route selected (see Appendix G). As presented in the map, the most travelled path is not a learned path. Instead, it is the path (red) next to the origin and pointing to the west direction. In contrast to that, the path (dark green) next to the beach and learned in visiting trip was one of the least travelled route. These two facts are easy to understand. As participants knew the shelter is located at the northwest direction, it is natural to heading towards that direction. It corresponds to the result of wayfinding strategy and reference points.

The ***hypothesis R1*** assumes participants would choose route learned in visiting trip. But the map does not reflect significant preference to learned route. Only paths on the “right direction” were mostly selected. It is impossible to define the choice of certain path is caused by familiarity or “it is on right direction”.

In summary, it is quite difficult to analyse the route choice based on the information collected in this experiment. Besides, it is questionable that whether participants can build up familiarity to certain route within such short time. Any conclusion made on route choice can be biased, since the nature of provided evacuation information may restricted participants’ alternative choices. As a result, the ***hypothesis R1*** cannot be decided here.

6.10 Conclusion

All hypotheses are examined in above sections. To provide an organized overview, the judgments of proposed hypotheses are summarized in this section, with brief descriptions.

6.10.1 Personal profile

Gender

G1: The success rate of males (63.89%) is much higher than females (26.7%) in evacuation wayfinding task. The conclusion is based on descriptive result.

G2: Males’ self-rated score (4.08) of spatial orientation ability is statistically significantly higher than females’ score (2.93).

G3: Males’ self-rated score (4.03) of map reading skill is statistically significantly higher than females’ score (3.27).

G4: No statistically significant difference can be identified based the result of landmark recognition. Males correctly pointed out 3.42 landmarks, and females pointed out 3.07 landmarks on average.

G5: Neglecting bias caused by experiment design, over 70% males applied pure survey strategy in evacuation wayfinding. The conclusion is based on descriptive result.

G6: Neglecting bias caused by experiment design, over 50% females used pure survey strategy in evacuation wayfinding. But only around 25% applied route strategy. The conclusion is based on descriptive result.

G7: No statistically significant gender difference can be identified in stress level during evacuation wayfinding. Females rated slightly higher (6.33) than males (5.39).

G8: Only 8% more females felt anxious than males. And the anxiety is not a dominant feeling during evacuation, accounting for 33.3% and 25% in females and males respectively. Considering the small number of female participants, this hypothesis cannot be proved affirmatively.

Table 6.14 Summary of personal profile hypotheses judgments

Number	Hypotheses	Judgements
G1	Males have higher success rate than females in evacuation wayfinding task.	Accepted
G2	Males have better spatial orientation ability than females, in respect of self-rating.	Accepted (Statistically)
G3	Males have better map reading skill than females, in respect of self-rating.	Accepted (Statistically)
G4	Females have better landmark knowledge than males.	Rejected (Statistically)
G5	Males prefer survey strategy in evacuation wayfinding.	Accepted
G6	Females prefer route strategy in evacuation wayfinding.	Rejected
G7	Female have higher stress level than males in evacuation wayfinding.	Rejected (Statistically)
G8	Female are more likely to feel anxious than males during evacuation wayfinding (in proportion).	Undecided
A1	Elderly drivers have lower success rate than younger drivers in evacuation wayfinding task.	Undecided
A2	Younger drivers have better landmark knowledge than elders.	Undecided
A3	Elderly drivers tend to choose familiar route as route choice strategy during evacuation wayfinding.	Undecided
E1	Different education levels have no influence on evacuation wayfinding performance.	Accepted but debatable
D1	Experienced drivers have higher success rate than inexperienced drivers in evacuation wayfinding task.	Undecided
D2	Experienced drivers have better spatial knowledge than inexperienced drivers, with respect to landmark knowledge.	Rejected (Statistically)

Age

A1: No significant difference found in success rate between drivers younger than 30 and drivers older than 30. The hypothesis cannot be decided due to the lack of aged drivers.

Because of the same reason, **hypothesis A2 and A3** cannot be judged as well, regardless of experiment results.

Education level

E1: Simply judging from the success rate of evacuation task, no obvious tendency can be generalised. But due to the unbalance of participant number in different education levels, this judgment is debatable.

Driving experience

D1: Based on the success rates of four driving year groups, no clear tendency can be generalised. Due to the minor differences between groups, it cannot be rejected neither, according to descriptive result.

D2: No statistically significant differences found between different driving year groups. And based on correlation analysis, no positive correlation of driving year and correct landmark numbers can be identified.

6.10.2 Spatial abilities

With respects of success rate and evacuation time, the map reading skill and spatial orientation have similar results. The participants who rated higher in these two spatial abilities tend to have higher success rate in evacuation task. Based on correlation analysis, two spatial abilities are both negatively related to evacuation time, i.e. the higher score, the shorter evacuation time. But no significant correlations found in spatial abilities and landmark recognition. The conclusions of hypotheses are demonstrated below.

Table 6.15 Summary of spatial ability hypotheses judgments

Number	Hypotheses	Judgments
M1	Good map reading skill will result in higher success rate in evacuation wayfinding.	Accepted
M2	Good map reading skill will result in shorter evacuation time.	Accepted (Statistically)
M3	Good map reading skill will result in better landmark knowledge.	Rejected (Statistically)
O1	Good spatial orientation will result in higher success rate in evacuation wayfinding.	Accepted
O2	Good spatial orientation will result in shorter evacuation time.	Accepted (Statistically)
O3	Good spatial orientation will result in better landmark knowledge.	Rejected (Statistically)

6.10.3 Navigational aids

No affirmative conclusion can be made on all four hypotheses. Because the differences of evacuation time and landmark recognition are not statistically significant in three experimental groups. As a result, all hypotheses regarding to navigational aids cannot be accepted nor rejected.

Table 6.16 Summary of navigational aids hypotheses judgments

Number	Hypotheses	Judgements
N1	Participants only with verbal instructions have the shortest evacuation time.	Undecided
N2	The evacuation time of participants with both aids is in between of map only and verbal only participants.	Undecided
N3	Participants only with map have the best spatial knowledge, in respect of landmark knowledge.	Undecided
N4	Participants only with verbal instructions have the least spatial knowledge, in respect of landmark knowledge.	Undecided

6.10.4 Landmarks

In respect of landmarks, there is only one hypothesis proposed.

L1: Participants tend to use landmarks to orientate themselves in evacuation wayfinding.

According to experiment results, only small number of participants (23.5%) used landmarks as reference points to orientate in evacuation wayfinding. Thus, the **hypothesis L1** is rejected based on descriptive result.

6.10.5 Wayfinding strategies

Most participants (88.9%) who applied route strategy got lost during evacuation. Almost all participants (97.1%) who relied on survey strategy used sense of direction as their reference point. But majority of route strategy users (66.7%) also used sense of direction as reference point, instead of landmarks (33.3%). Based on these descriptive results, the judgments of related hypotheses are demonstrated below.

Table 6.17 Summary of wayfinding strategy hypotheses judgments

Number	Hypotheses	Judgments
S1	Participants who applied route strategy are easier to get lost than survey strategy users during evacuation wayfinding.	Accepted
S2	Participants who applied survey strategy tend to use sense of direction as reference point to orientate.	Accepted
S3	Participants who applied route strategy tend to use landmarks as reference point to orientate.	Rejected

6.10.6 Psychological condition

Only 27.5% participants felt anxious during evacuation wayfinding. The dominant emotional feelings are rushed and excited. Hence, the **hypothesis P1** is rejected. As **hypothesis P2**, it is partially proved by two figures. One of them shows the relation of success rate and stress level. Another figure presents the fluctuation of evacuation time with the increase of stress levels. However, due to the result depending on self-rating, it can be inaccurate and bias. Thus, the **hypothesis P2** is accepted but debatable.

Table 6.18 Summary of psychological condition hypotheses judgments

Number	Hypotheses	Judgments
P1	Most participants felt anxious during evacuation wayfinding.	Rejected
P2	The evacuation performance shows a fluctuation pattern along with the increase of stress levels experienced by different participants.	Accepted but debatable

6.10.7 Route choice

Hypothesis R1 assumed that participants tend to choose learned route during evacuation wayfinding. The route choice is only briefly discussed in the report. According to Appendix G, no significant participants' preference can be identified. Therefore, **hypothesis R1** cannot be decided based on experiment result.

7. Conceptual evacuation wayfinding model

Based on the descriptive and statistical analysis of experiment result, the effects of influential factors in evacuation wayfinding are clarified. On the basis of that, a detailed conceptual evacuation wayfinding model is constructed here. The wayfinding process corresponds to the framework proposed in chapter 4.

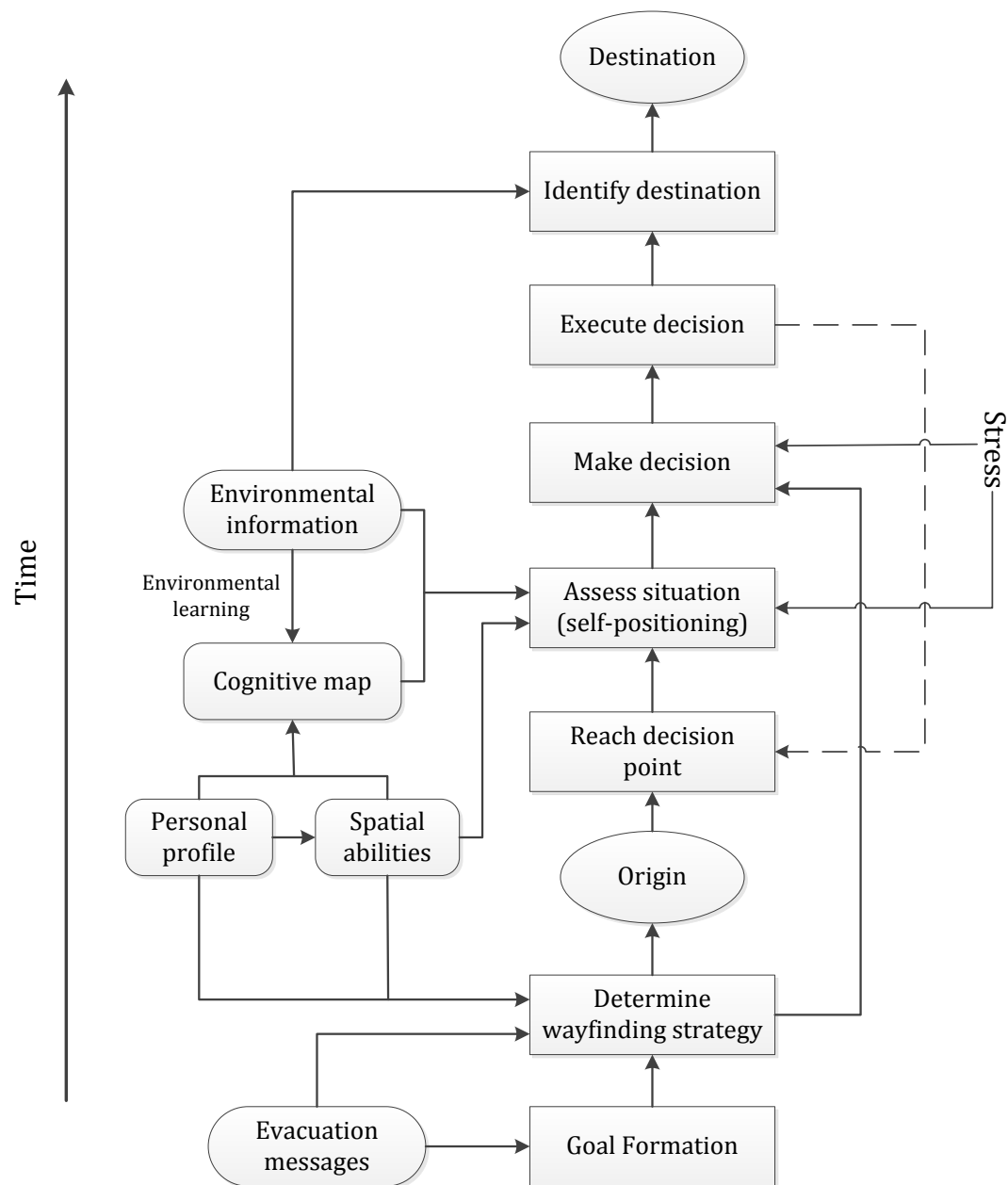


Figure 7.1 Evacuation wayfinding conceptual model of city visitors

Decision making

The wayfinding process starts with receiving evacuation messages. Based on available information, the destination of evacuation is decided. After that, the wayfinding strategy should be determined. As presented above, the determinants of

wayfinding strategies can be personal profile attributes (mainly refers to gender), spatial abilities, and the provided evacuation information. Among these determinants, the provided information is very important. Taking this experiment as an example, with only directional information available, most people directly headed towards the shelter. If detailed evacuation route is provided, people may tend to follow the route instructions.

Decision execution

The moment visitor departs from the origin location, the decision execution begins. Once the visitor arrives at a decision point (an intersection), he need to assess the situation first. This assessment involves orientating his position, based on internal cognitive map and external environmental cues (such as landmarks). The spatial abilities, spatial orientation in particular, will largely influence individual's self-positioning. People with bad sense of orientation would have difficulties in identifying directions, f.i. they have no idea where is the north. In addition, the situation assessment is a cognitive process that affected by psychological condition.

After the visitor recognised his position, he needs to make decision for next move. The decision is mainly determined by planned wayfinding strategy. For example, people who use survey strategy will select path according to its direction. While people apply route strategy may choose path based on presented cues, like turn to the left side of certain building. As shown in figure, the stress can influence individual's decision making capabilities, especially in emergency situation.

From reach decision point to execute decision is a loop process. Until the destination is identified and reached, the evacuation is finished. It is notable that with the elapse of time, the stress level is increasing. Observed from the experiment, people drove faster in last few minutes and the time spent on situation assessment became shorter and shorter. Sometimes they just turned to random direction without think. In contrast with that, participants generally made long stops before intersections to consider their next move, when the time was still adequate.

Information processing

The information processing is illustrated at the left part of figure. As discussed in previous chapter, the formation of cognitive map is affected by many factors. Three major categories are presented in the model, namely the personal profile, spatial abilities and environmental information. It is noteworthy that only part of the interactions is demonstrated in the model. For instance, the spatial abilities and personal profile also have an impact on environmental learning process.

8. Conclusions and recommendations

This chapter gives a synthesis of research findings. In the conclusions, all research questions are answered. Then limitation and problems in the research are discussed in detail. Finally, some recommendations for further research are proposed.

8.1 Conclusions

This research examines the wayfinding behaviour of unfamiliar drivers in urban evacuation. The impact of wayfinding factors is investigated through a driving simulator experiment. This section answers all research questions, and the main findings of research are integrated in the answers.

8.1.1 Answers to research sub-questions

This research brought up three sub-questions. The answers to these questions formulated the answer to the main research question. In this section, answers to the sub-questions are presented.

1. *What is the city visitors' evacuation process in terms of travel behaviour?*

According to literature study, the city visitors' evacuation process is similar to the residents' in general. But they make different choices at decision points. Their travel behaviour is composed of four choices, namely evacuation participation choice, departure time choice, destination choice and route choice or wayfinding. Before the participation choice, their first response to the disaster is also discussed in the report, since it can affect following travel choices.

The city visitors lack information sources in disasters, but they may have shorter forewarning time with the help of hotel staff. After receiving warning messages, they will decide whether to evacuate. Due to the anxiety caused by unfamiliarity, city visitors tend to have higher risk perception and more likely to evacuate. As city visitors need less preparation time, they usually evacuate at early stage under the fear of disasters. In terms of destination choice, city visitors prefer shorter distance and travelling time. As a result, most of them went to shelter in community. The final travel choice of visitors is route choice or wayfinding. However, few studies addressed this problem. Based on literature, it is suggested city visitors have difficulties in finding ways.

The process described above is the general evacuation process of city visitors, in terms of their travel choices.

2. *Which factors have an impact on evacuation wayfinding behaviour in unfamiliar environment?*

In the literature study, there are six major types of wayfinding factors identified. They are personal profile, spatial abilities, wayfinding strategy, psychological condition, spatial layout and navigational aids. The personal profile includes four

factors: gender, age, education level and driving experience. Only two spatial abilities are discussed in the report, namely map reading skill and spatial orientation. In respect of spatial layout, this research simply focuses on the landmarks. The impact of landmarks is answered in next sub-question.

Based on empirical findings, several hypotheses of evacuation wayfinding behaviour are proposed, in terms of these factors. To examine the hypotheses, an evacuation experiment based on driving simulator was performed. According to the result of descriptive and statistical analysis, the effect of each factor in evacuation wayfinding is clarified.

In personal profile attributes, gender has the largest influence on evacuation wayfinding. Men generally perform better in evacuation task, partially due to better spatial abilities than women. But no significant effect can be observed from other three factors in this experiment.

Both map reading skill and spatial orientation has a positive effect on evacuation wayfinding performance. It seems that good spatial abilities can result in higher success rate in evacuation task and shorter evacuation time, based on the experiment results.

Regarding to navigational aids, two common tools are examined in the research, map and verbal instruction. However, no statistical differences can be identified between different navigational aids groups in this experiment.

Most participants used survey strategy to find ways in the experiment, directly heading towards the direction of the shelter and relying on their sense of orientation to locate themselves. People, who tried to follow a planned route, have a low success rate and high lost probability. Perhaps route strategy is not the best option for city visitors in evacuation wayfinding, simply judged from this experiment.

The last factor is psychological condition, which can be complex in evacuation. But the experiment failed to create a realistic emergency situation, that most participants felt rushed and excited, instead of anxious. The evacuation performance did show a fluctuation pattern with the increase of stress levels experience by different individuals. It indicates that the time pressure and anxiety in evacuation not only negatively affect behaviour but also have positive effects within certain stress level.

To conclude, simply based on this experiment, gender, spatial abilities, wayfinding strategies and psychological condition have an impact on evacuation wayfinding behaviour in unfamiliar environment.

3. What is the effect of city landmarks on evacuation wayfinding behaviour in unfamiliar environment?

The importance of landmarks has been mentioned a lot in literature. Hence, it is expected that the city landmarks will play an important role in evacuation wayfinding of city visitors.

However, the result of this experiment proved the opposite. Few city visitors used landmarks as reference point to orientate themselves in evacuation. On the contrary, majority of participants depended on their sense of direction.

This situation can be explained by three reasons. First, the provided evacuation information caused bias on participants' choice. Second, the stress in evacuation can affect individuals' information processing capability and thus the range of environmental cues is narrowed. In addition, the cue recognition can be more difficult in complex environment, like a city, due to the overload of environmental information. The third reason is that the landmarks placed in virtual environment are not outstanding enough to caught attention of participants.

In summary, the effect of city landmarks on evacuation wayfinding behavior is insignificant in this experiment. But considering the bias, its effect in real life remains unclear.

8.1.2 Answers to main research questions

Based on the answers of sub-questions, the main research question can be answered in this section.

How do city visitors find ways in a vehicular-based urban evacuation?

On the basis of literature study and evacuation experiment, a conceptual evacuation wayfinding model is built, which explains how city visitors find ways in a vehicular-based urban evacuation.

After receiving evacuation messages, the visitors first need to determine whether to evacuate and where to evacuate to. Next they determine a wayfinding strategy based on their preference and provided information. This is the decision making process. Then visitors start from the origin (possibly their hotels). Once they reach a decision point, they need to assess the situation first, involving locate their position based on cognitive maps and environmental cues. After that, they can make a move decision according to their wayfinding strategies, like turn left or turn right. This situation assessment and decision making (at intersection) process will repeated until visitors identified and arrived at destination.

During the evacuation wayfinding, the psychological condition (stress level) is changing with the elapse of time, and it affects visitors' information processing capabilities. Additionally, personal factors, such as gender and spatial orientation, also have an impact on visitors' situation assessment and the determination of wayfinding strategies.

8.2 Discussions

As an exploratory study, this research has many problems. A lot of factors are discussed here without intensive and careful examination. This section discusses two major problems existed in research.

8.2.1 Evacuation experiment

The driving simulator provided the opportunity of studying relatively realistic evacuation wayfinding behaviour in a controlled environment. However, the drawbacks of using a driving simulator in experiment are also obvious. They are generalised into three aspects: the limitation of driving simulator, the difficulty in simulator operation and program and equipment restrictions.

The limitations of driving simulator

The richness of virtual environment clearly cannot match the real world. And more importantly, the idiothetic (specific word used in psychology field, can be understand as self-proposition) inputs are missing. The idiothetic inputs are internally generated sensory signals that reflecting the actual body movements. Therefore, the idiothetic information is conflicting with the visual and auditory information, when participants in a fixed driving simulator. This conflict can cause motion sickness, which was happened to some participants. Though the visual sense will override the idiothetic inputs when they conflict, the driving simulator brought unnatural feelings to participants, possibly disturbing their judgment (Aginsky, Harris, Rensink, & Beusmans, 1997).

The difficulty in simulator operation

It has been reported that people encounter difficulties in maintaining knowledge of location and orientation when they are navigating in virtual environment. Considerable attention and effort are devoted to operating driving simulator and adapting virtual street views, which leaves no capability to pay attention to the environment (Chen & Stanney, 1999). This will affect the formation of cognitive maps, resulting in neglect of spatial layout and landmarks on road. And eventually it will influence the evacuation wayfinding performance. Besides, due to the size and angle of screens, participants only have a limited view of the path, which makes landmarks hard to notice.

Program and equipment restrictions

The limited number of available 3D model of buildings in the software database restricted the choice option of landmarks. Therefore, the landmarks lack salience, e.g. no exceptional high or uniquely shaped buildings as landmarks in city. This can also cause the neglect of landmarks during evacuation wayfinding.

Because of the bugs in software, participants are not allowed to make U-turn or steering the wheel aggressively. All these behaviours will cause simulator screen freeze, and the experiment cannot continue under this situation. This fact largely

restricts participants' behaviour in evacuation wayfinding. Many participants expressed a wish to turn around after they found they turned to a wrong direction, which is normally possible in real life.

Due to bugs in simulator software, the behaviour of generated road users is uncontrollable. For example, they flash wrong directional signal before intersections, making participants confused and causing accidents. Sometimes they don't automatically avoid conflict with the tested car, leading to car crash. Although the accident won't cause any damage to the tested car and the experiment can continue, it will affect participants performance (extend evacuation time) and trigger bad emotional feelings.

Additionally, the generated road users can be extremely slow at intersections, creating long waiting queues. Though traffic congestion is normal in real evacuation, it is caused by unreasonable behaviour in the experiment, which will not present in real life. The long unnecessary waiting made participants take aggressive movement, such as drive on pavement to bypass waiting queues.

8.2.2 Data analysis

Due to time limitation, the driving simulator experiment only has 51 participants. This is a quite small sample size, considering the number of investigated factors. Thus, the bias caused by small sample size is relatively large, leading to the results of experiment questionable.

In addition, many results are based on descriptive analysis and observations on figures and charts. Therefore, the statements to tested hypotheses are not trustworthy.

Last but not least, underlying correlations between factors are neglected in analysis. All samples are assumed independent to simplify analysis, but in fact, they are not. For example, the relation between age and driving year, age and education level, etc.

8.3 Recommendations for future research

This research as an exploratory study leaves many questions to answer in future research, in respect of evacuation wayfinding. Some recommendations are proposed as possible direction of future research. Based on the findings in this research, no practical recommendations are proposed here. Since most results are ambiguous and questionable, demanding more research effort.

1. The relation of landmark utilization and stress level in evacuation wayfinding

The importance of landmark in wayfinding cannot be proved in this research. As discussed previously, it can be caused by the decline of information processing capability under stress. The individual's perception range is narrowed, leading to difficulties in recognising environmental cues (Ozel, 2001). However, this correlation could not be observed in current experiment results. Therefore, to verify the impact of landmarks in urban evacuation of city visitors, further research is required.

2. The involvement of other information sources

In this research, all other information sources are excluded. The driver had to evacuate without any external assistance on the way. But in reality, it is not the case. Even though the visitor is in a foreign city with language and culture barriers, he can always find someone to ask for help. Thus, the involvement of interactive information sources can be useful to practical implications.

3. Research on specific factors

The small sample number leads to lots of insignificant differences in factors, like navigational aids. If we narrow down research scope and focus on one or two specific factors, it is possible to clarify the effects of these factors in evacuation wayfinding.

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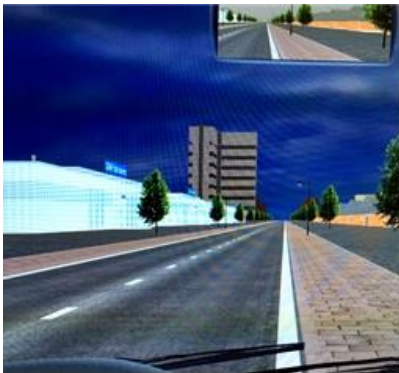
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Appendix

- A. Screenshots of city landmark
- B. City network with speed limits
- C. Shelter description
- D. Preliminary survey
- E. Driving simulator instruction and background story
- F. Evacuation wayfinding questionnaire
- G. Evacuation route selected

A. Screenshots of city landmarks



Landmark 1 - At intersection
(First Destination)



Landmark 2 - Middle of path
(Second Destination)



Landmark 3 - At intersection
(Third Destination)



Landmark 4 - At intersection



Landmark 5 - At intersection



Landmark 6 - At intersection



Landmark 7 - At intersection



Landmark 8 - At intersection



Landmark 9 - Middle of path



Landmark 10 - At intersection



The Hotel



The public shelter

B. City network with speed limits

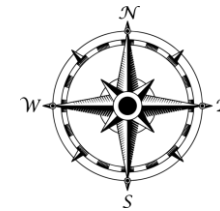


C. Shelter description



Public Shelter

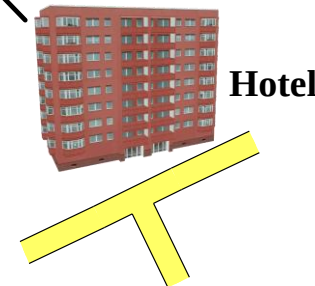
The public shelter is located at the northwest direction of your resided hotel (as shown in map). It is a tall blue building and it can be easily found from far away.



Emergency Evacuation Notification

A category 5 (winds over 155mph) hurricane is approaching towards this city's coastline. An official evacuation warning was issued, recommended that you leave this city or evacuate to public shelter in **15 minutes**. You decided to evacuate to the public shelter right now.

Please imagine you are really under emergency situation, and try your best to arrive at the public shelter in **15 minutes**. If you reach the destination in time, you will get a reward of 10- euro VVV receipt (VVV Cadeaubon). However, **beyond 15 minutes**, your reward will drop 2 €/min. The evacuation will be announced failure at the moment of **20 minute** and the simulation programme will be terminated.



Hotel

D. Preliminary survey

1. What's your subject number?
2. What's your gender?
 - ☐ Male
 - ☐ Female
3. What's your age?
4. What is the highest degree or level of school you have completed?
If currently enrolled, highest degree received.
 - ☐ High school graduate
 - ☐ Bachelor's degree
 - ☐ Master's degree
 - ☐ Doctorate degree
 - ☐ Other:
5. When did you get your driving license?
 - ☐ Less than 1 year
 - ☐ More than 1 year but less than 5 years
 - ☐ More than 5 years but less than 10 years
 - ☐ More than 10 years
6. How often do you drive?
 - ☐ Daily (almost every day)
 - ☐ Frequently (several times per week)
 - ☐ Occasionally (several times per month)
 - ☐ Seldom (several times per year)
 - ☐ Other:
7. Have you participated in any experiment on Driving Simulator before?
 - ☐ Yes
 - ☐ No
8. How much stress do you experience at this moment?

1	2	3	4	5	6	7	8	9	10
Low									High

E. Driving simulator instruction and background story

Instructions

1. Please sit on the simulator and adjust the seat to your comfortable position.
2. Get familiar with the accelerator, brake pedal, the gear and the steering wheel.
3. Rotate the key to start engine.
4. Please switch on the directional signals before you make a turn.
5. Please slow down and look around when you are approaching an intersection. If you are too fast, you may run off the road. The advised turning speed is around 20 km/h.
6. Please follow the speed limit under any circumstances.
7. Please driving very carefully and try to avoid conflict, since other cars won't avoid crash automatically.
8. But if you got hit, don't get panic, stay calm and restart the engine. And remember once you got hit, the car will change to manual driving mode.
9. You should not make a U turn in the experiment, nor steering the wheel hardly. This kind of behaviour may cause the simulator breakdown and freeze. Please be gentle when you steering the wheel.
10. Please try to drive as you drive in real life.
11. Sometimes the screen may suddenly freeze for a moment when you are driving. This is a normal situation. You can just ignore it and continue driving.
12. If any unexpected situation happens during your experiment, please report to researcher immediately.

Background story

Phase one – Trial trip

Please pretend you are a first-time visitor to this city, for some business and sightseeing. This city is an industrial city, which also possesses historic sites, e.g. windmills from 18th century. It has a beautiful beach located at the southeast part of the city. You live in a hotel close to the beach.

Tourist map group

Today, you are going out visit two companies for business and on your way back, you pay a visit to the windmills. Three destinations are already marked with a black circle on your tourist map. When you reach these points, please stop the car on roadside and wait for 15 seconds. The route is planned in advance, red lines and arrows on map. Please just follow the route.

Verbal instruction group

Today, you are going out visit two companies for business and on your way back, you pay a visit to the windmills. The addresses of three destinations are already input in your navigator. A verbal instruction will guide you. When you reach the destinations, please stop the car on roadside and wait for 15 seconds. Please just follow verbal guidance.

Both navigation aids group

Today, you are going out visit two companies for business and on your way back, you pay a visit to the windmills. The addresses of three destinations are already input in your navigator. A verbal instruction will guide you. Meanwhile, a tourist map with marked destinations and planned route is also provided. When you reach the destinations, please stop the car on roadside and wait for 15 seconds. Please follow the planned route and instructions.

F. Evacuation wayfinding questionnaire

1. What's your subject number?
2. Did you ever participate in a real evacuation before?
 - ☐ Yes
 - ☐ No
3. What was your navigation aid during the visiting tour?
Which tool was provided to you?
 - ☐ Tourist city map
 - ☐ Verbal instruction
 - ☐ Both verbal instruction and tourist map
4. What's your map reading skill in real life?
3 stands for normal.

1	2	3	4	5
Weak				Strong
5. Did you successfully evacuated to the shelter in 15 minutes?
 - ☐ Yes
 - ☐ No
6. Did you successfully evacuated to the shelter in 20 minutes?
 - ☐ Yes
 - ☐ No
7. Did you lost your way during the evacuation?
 - ☐ Yes
 - ☐ No
8. What was your wayfinding strategy to the shelter during the evacuation?
No matter if you were lost or not.
 - ☐ Follow the route planned in mind before evacuation
 - ☐ Heading towards the direction of the shelter
 - ☐ Reach a familiar place first, then find the way based on the direction of the shelter
 - ☐ Reach a familiar place first, then choose a random path, drive and search
 - ☐ Choose a random path first, then drive and search
 - ☐ Other:
9. Do you have a strong sense of orientation in real life?
3 stand for normal.

1	2	3	4	5
---	---	---	---	---

Weak

Strong

10. If you could plan the route, what would be your route choice strategy during evacuation?

You plan the route from first-time visitor's point of view.

- ☐ Shortest path
- ☐ Minimal travel time
- ☐ Less traffic (lower congestion level)
- ☐ Minimal number of intersections
- ☐ Minimal turnings
- ☐ Most familiar route
- ☐ Most known landmarks along the route
- ☐ Most outstanding landmark along the route
- ☐ Easiest to drive (less curves, better road condition)
- ☐ Other:

11. What do you remember about the layout of the city network?

You can select more than one option.

- ☐ The general shape of the city (the location of sea, mountains, etc.)
- ☐ The general layout of roads
- ☐ The location of intersections
- ☐ Part of the layout of roads
- ☐ The shape of roads (curves and straight ways)
- ☐ Other:

12. What did you use as a reference point to orientate yourself during the evacuation?

You can select more than one option.

- ☐ The sense of direction
- ☐ The shape/layout of roads
- ☐ The landmarks
- ☐ The view (street view or scene)
- ☐ Other:

13. Please select the landmarks you saw in this city.

Enter the number of landmarks on paper (e.g. 1,2,3).

Please enter the number of landmarks in questionnaire



1



2



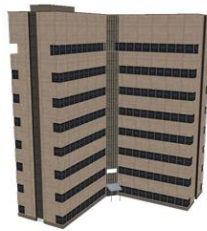
3



4



5



6



7



8



9



10



11

14. Did you follow the speed limits during the evacuation?

- ☐ Yes
- ☐ No
- ☐ Don't know, didn't notice the speed

15. How did you feel when you were evacuating?

You can select more than one option.

- ☐ Rushed
- ☐ Anxious
- ☐ Excited
- ☐ Relaxed

☐ No special feelings

☐ Other:

16. How much stress did you experience during the evacuation?

1 2 3 4 5 6 7 8 9 10

Low

High

17. Please select the sources which were stressful to you.

- ☐ The time limit
- ☐ The disaster (fear of life threat)
- ☐ The evacuation task
- ☐ Getting lost in the city
- ☐ Driving on simulator
- ☐ I didn't experience any amount of stress
- ☐ Other:

G. Evacuation route selected



